MINISTRY OF EDUCATION AND SCIENCE OF THE REPUBLIC OF KAZAKHSTAN

Kazakh National Research Technical University named after K.I. Satbayev

K. Turysov Institute of Geology, Oil and Mining

Department of Oil, Gas, and Ore Geophysics

Alsiyeu Ulan Maratuly

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Topic «Seismic exploration for the search of solid minerals»

DIPLOMA WORK

Specialty 5B070600 – Geology and exploration of mineral deposits

Almaty 2020

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ADMITTED TO DEFENCE
Head of the Department of Geophysics
Doctor of geological-mineralogical sciences, professor
Abetov A.E.
"_____"_______________2020y.

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Done by Alsiyeu U.M.

Ermekbay Z.G.

Turdibayev I.A

Scientific superviser

Lecturer

Sirazhev A.N.

"_____"________2020 y.

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Geophysics Department

APPROVED BY
Head of the Department of Geophysics
Doctor of geological-mineralogical sciences, professor
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THE TASK
to complete the diploma work

Students Alsiyeu U.M., Ermekbay Z.G., Turdibayev I.A.

Topic: «Seismic exploration for the search of solid minerals»

Approved by order of the Rector of the University №762–b from "27" January 2020 y.

Submission deadline of the completed work "15" May 2020 y.

Initial data for the diploma work: were provided by the scientific adviser

Summary of the diploma work:

a) disclosure of characteristics of the object of research;

b) field observation technique;

c) processing and interpretation of 3D seismic data;

List of graphic material: 22 slides of the presentation of work are presented.
Recommended main literature: Smirnov V.I. Geological foundations of prospecting and exploration of ore deposits.

GRAPH
of diploma work preparation

Name of sections, list of issues to be developed	Submission deadline to scientific adviser	Notation
disclosure of characteristics of the object of research	05.03.20y.-04.04.20y.	
field observation technique	05.04.20y.-22.04.20y.	
processing and interpretation of 3D seismic data	23.04.20y.-10.05.20y.	

Signatures
consultants and the standard controller for the finished diploma work indicating the sections of work related to them

Name of sections	Consultants, N.P.F. (academic degree, rank)	Date of signature	Signatures
Disclosure of characteristics of the object of research	A.N. Sirazhev		
Field observation technique	A.N. Sirazhev		
Processing and interpretation of 3D seismic data	A.N. Sirazhev		
Standard controller	M.M.Aliakbar		

Scientific supervisor Sirazhev A.N.

Students fulfilling the task Alsiyeu U.M.

Ermekbay Z.G.

Turdibayev I.A.

Date "_____"______________2020 y.

АҢДАТПА

Дипломдық жұмысқа «Қатты пайдалы қазбаларды сейсмикалық барлаумен іздеу»

Дипломдык жұмыс Қазақстанның кен орындарында 3D сейсмикалық барлау жұмыстарының тиімділігін бағалау мәселелеріне арналған. Жиландин құрылымы кен орындарының бірінің мысалында, Орталық Қазақстанда орналасқан Жезқазған кен ауданы, геологиялық құрылымды зерттеу және мысты құмтас сияқты минералдануды анықтау үшін сейсмикалық барлау мүмкіндігі көрсетілген. Жұмыс кіріспеден, 6 бөлімнен, қорытындыдан, пайдаланылған әдебиеттер мен қосымшалар тізімінен тұрады. Зерттеудің өзектілігі, мақсаты, міндеттері, ғылыми жаңалығы және жұмыстың практикалық маңыздылығы көрсетілген. Мыс құмтас шөгінділерінің контурлы сейсмобарлау әдісі талданып, зерттелді. Зерттеу объектісінің сипаттамалары ашылады. Далалық бақылаудың әдістемесі мен технологиясы жетілдірілген. Кен геологиясының мәселелерін шешуде сейсмикалық мәліметтерді өңдеу және түсіндіру техникасының ерекшеліктері қарастырылған. Қатты пайдалы қазбаларды іздеу мен барлау кезінде 3D сейсмикалық барлау жұмыстарын пайдалану мүмкіндігін бағалау нәтижелері келтірілген.

АННОТАЦИЯ

К дипломному работе «Сейсморазведка при поиске твердых полезных ископаемых»

Дипломная работа посвящена вопросам оценки эффективности применения 3D сейсморазведки на рудных месторождениях Казахстана. На примере одного из месторождений Жиландинской структуры, Жезказганского рудного района, расположенного в центральном Казахстане, показана возможность сейсморазведочных исследований для изучения геологического строения и выявления оруденения типа медистых песчаников. Работа состоит из введения, 6 глав, заключения, списка использованной литературы и приложений. Рассмотрены актуальность исследований, цель, задачи, показаны научная новизна и практическая значимость работы. Проанализирован и изучен метод сейсморазведка для оконтуривания отложений залежей медистых песчаников. Раскрыты характеристики объекта исследований. Уточнены методика и технология полевых наблюдений. Рассмотрены вопросы особенности методики обработки и интерпретация данных сейсморазведки при решении задач рудной геологии. Приведены результаты оценки возможности применения 3D сейсморазведки при поисках и разведки твердых полезных ископаемых.

ABSTRACT

To the diploma work «Seismic exploration for the search of solid minerals»

The diploma work is devoted to the issues of evaluating the effectiveness of 3D seismic exploration in ore deposits of Kazakhstan. The example of one of the deposits of the Zhilandy structure, the Zhezkazgan ore district, located in central Kazakhstan, shows the possibility of seismic exploration to study the geological structure and identify mineralization such as copper sandstones. The work consists of introduction, 6 chapters, conclusion, list of references and applications. The relevance of research, the purpose, tasks, the scientific novelty and practical significance of the work are shown. The seismic exploration method for contouring deposits of copper sandstone deposits was analyzed and studied. The characteristics of the object of research are disclosed. The methodology and technology of field observations are refined. The features of the processing technique and interpretation of seismic data in solving problems of ore geology are considered. The results of evaluating the possibility of using 3D seismic surveys in the search and exploration of solid minerals are presented.

CONTENT

INTRODUCTION

Theme of the diploma work: "Seismic exploration for the search of solid minerals"

The purpose of this work is to study the application of 3D seismic survey for delineation of solid minerals deposits, using the example of work carried out in the Zhezkazgan ore district. On the way to achieving this goal, it seems expedient to solve.

Objective of research: to evaluate the possibility of 3D seismic exploration in the allocation of prospective ore-bearing structures of cuprous sandstones on the example of one of the deposits of Zhilandy structure, Zhezkazgan ore district, in Central Kazakhstan.

The main objectives of the research:

- analysis of the current state of the seismic survey method in solving geological problems,
- refinement of field observation techniques and technologies;
-systematization of seismic data processing;
- analysis of interpretation of field seismic data;
-geological interpretation of seismic data;
- evaluation of the possibility of applying 3D seismic exploration in search and exploration of solid minerals.

The diploma work is based on the materials on the deposit of Zhilandy group, Zhezkazgan ore district, collected in the process of pre-graduate production practice in the company, which is engaged in service work on processing and interpretation of seismic data.

In the process of research for the diploma thesis were widely used literary data: publications of Kazakhstan and foreign authors; generalizing materials of the Central-Kazakhstan Interregional Territorial Department of Geology and Subsoil Use "Center-Kaznedra".

Processing of 3D seismic field data was carried out using SeisSpace-5000.0.3.1 (Landmark) system, Well-Logging interpretation was performed in GeoLog system, and seismic-facial analysis was performed using Stratimagic.

In view of the above, the issues addressed in the diploma work are very relevant.

The diploma work contains 98 pages of text, including 3 tables, 41 figures.

1 Contemporary state of the seismic prospecting method in solving geological problems

Kazakhstan's subsoil contains more than 90 types of minerals, which is due to the exceptionally successful territorial location of the country, which includes a variety of geological structures, rocks with a long period of formation from ancient Archean formations to young Quaternary sediments. All the above mentioned creates a powerful mineral and raw material base of Kazakhstan. And its important component is solid minerals. Solid minerals are a vast group of minerals, which are divided into: combustible minerals: fossil coal, peat, oil shale; metallic minerals: metal ores, native metals; and non-metallic minerals: construction materials (granite, basalt, pumice, etc.) and chemical raw materials (salts, etc.). [1]

The most advanced, modern methods of prospecting and exploration of minerals, including solid minerals, are geophysical methods of exploration. Studies of various physical phenomena occurring on the surface and in the Earth's, crust allow us to judge about the structure of the latter, the presence of deposits of ores, oil, coal and other minerals. Geophysical methods of exploration allow studying natural resources and discovering deposits of valuable industrial raw materials and fuels. In this regard, the role of geophysical methods in geological exploration is continuously increasing. [5]

The main prospects for the growth of mineral reserves and the identification of new industrial deposits are associated with the study of greater depths and in the foreseeable future the trend of increasing the volume of prospecting and exploration work at greater (up to 1-2 km, and sometimes even greater) depths will continue. As the labor intensity and cost of drilling works sharply increase, it is quite natural that in solving the problem of deep prospecting more and more attention is paid to improving geophysical methods of prospecting and exploration. However, as we move to studying deeper and deeper parts of the section, the geological efficiency of the traditional complex of structural geophysical methods is decreasing. This is due to the low resolution and accuracy of the method based on the study of potential fields, in the study of large depths under conditions of intense interference of the upper part of the section.

1.2 Seismic prospecting methods, their advantage over geophysical methods of potential fields

The main information on the geological structure of the region during seismic exploration is obtained as a result of studying the propagation of reflected and refracted waves. There are two main methods of seismic exploration: the method of reflected waves and the method of refracted waves. In addition, the method of transmitted waves is also used, when waves are observed passing through the studied strata, for which the source or receiver of vibrations (or something else) is located in a deep well or in a mine. In particular, when conducting various types of seismic prospecting, transmitted waves are studied to determine the propagation velocity of elastic waves in the thickness being studied and the "reflection time-depth" relationship. [3]

The method of refracted waves is based on the study of elastic waves refracted in the geological layer, where the propagation velocity of the elastic wave is greater than in the overlying layers. As a result, when observing at sufficiently large distances (compared to the depth of the layer) from the source, the wave main part of its path passes in the layer at an increased velocity. Due to secondary refraction, the refracted waves return to the surface of the earth, where they can be observed and recorded. Having determined the travel time of the refracted wave at several points on the surface of the earth, it is possible to calculate the depth and angle of inclination of the layer surface, in which an elastic wave propagates at an increased velocity, and also the magnitude of this velocity. The latter in some cases allows us to judge the lithological composition of the rocks that make up the layer. [2]

Currently, the Common Depth Point method (CDP) is mainly used. The common depth point method is a modification of the method of reflected waves and is based on the summation (accumulation) of reflections from common sections of the boundary at different positions of the sources and receivers of oscillations.

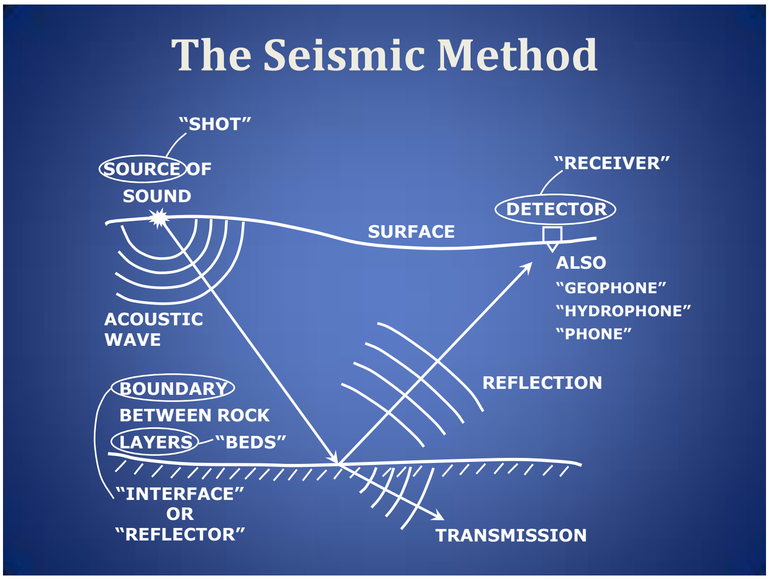

Figure 1.1.1 – The Seismic Method

Seismic methods can also be classified, taking into account other features. So, depending on the type of recorded waves, the longitudinal wave method, the exchange wave method, and the transverse wave method are distinguished. Longitudinal wave method has the greatest practical importance at present time. This is due to the fact that in the explosion mainly longitudinal waves are formed. In some areas where intense exchange waves are observed, they are used to solve geological problems, usually together with longitudinal waves. Monotypic transverse waves are weakly manifested in ordinary explosions. Currently, to develop the transverse wave method, powerful sources of transverse wave generation are being developed. [3] The transverse wave method has advantages over the longitudinal wave method. Transverse waves have a lower propagation velocity and a shorter wavelength than longitudinal waves. This improves the accuracy of measuring the transverse wave travel time. Unfortunately, at present, multiwave seismic exploration, using both longitudinal and transverse waves, is carried out on a limited scale, at the level of experimental and methodical work. [4]

Depending on the frequency of the recorded oscillations, there are low-frequency (less than 25-30 Hz), mid-frequency (30-100 Hz) and high-frequency (over 100 Hz) modifications of seismic exploration. The study of a particular frequency range depends mainly on the depth of the research, the degree of dismemberment of the geological section and the features of its absorbing properties. When using seismic exploration to separate the ore section, it is necessary to apply a high-frequency modification of the method. For example, in the Zhezkazgan ore district, the applied operating frequencies reach 160-180 Hz.

With an increase in the depth of research and, accordingly, the travel time of the waves, in order to attenuate the influence of absorption, it is necessary to register ever lower frequency oscillations. The lowest-frequency vibrations are recorded during the work by the method of deep seismic sounding. This method is used to study the structure of seismic boundaries located in the lowest parts of the earth's crust at depths measured in tens of kilometers (Konrad border, Mohorovichich border, etc.). The deep sounding method uses technical means and methodological techniques similar to those used in the method of reflected waves and the method of refracted waves.

An important method of seismic exploration is controlled directional receiving, which is used mainly for recording reflected diffracted waves. It allows to accurately determine the direction of arrival of seismic waves. The study of seismic waves inside the medium is carried out in deep wells by the method of vertical seismic profiling. With its help, it is possible to identify the waves observed on the surface of the earth.

The bottom of the seas and oceans is becoming one of the main areas of search for mineral exploration. In this regard, marine seismic acquisition has gained great importance. Due to the special conditions for making observations, it differs from ground-based seismic exploration in technical and methodological respects and has some characteristic features.

Each of the listed methods and modifications has certain advantages and disadvantages, correctly taking into account which, it is possible to effectively use all the possibilities of seismic exploration. Widely used is the integration of various seismic methods with each other. [3]

From an economic point of view, seismic exploration is in constant competition with other methods. [1] An indicator of the important role of seismic work in mineral exploration is evidenced by its widespread use. Seismic exploration is mainly used in solving various problems of structural geology. Therefore, at present, seismic exploration is usually widely used in the search and exploration of minerals whose deposits are associated with certain structural features, such as oil and natural gas, coal, rock salt, etc. [2] For example, when choosing places for places almost all oil companies of the company rely on the results of interpretation of seismic data for laying exploratory oil wells. [3]

Other methods of exploration geophysics (electrical exploration of various modifications, gravity exploration, magnetic exploration, analysis of thermal fields), surface gas-chemical studies, remote (aerial photographs, aero-geochemical surveys, etc.) research methods provide additional information about the deep structure of the Earth, geochemical and other fields, supplementing the data CDP seismic surveys. But these methods are only additional, because they do not allow mapping traps and deposits of hydrocarbons in order to prepare them for deep exploration, appraisal and exploration drilling. It is this task that is assigned to the seismic exploration of the CDP, which makes it the leading method of exploration geophysics in oil and gas geology. [4]

1.2 Types of seismic prospecting works

Seismic exploration methods are mainly used in solving various problems of structural geology. Seismic exploration is most widely used in prospecting and exploration of mineral deposits, which are closely related to certain structural forms of the host rocks. Such minerals primarily include oil and natural gas. Therefore, seismic exploration is most widely used in solving various problems of petroleum geology. Seismic methods are also used in the study of regional structural features, for solving engineering and geological problems, etc.

At different stages of research of a particular region, it is required to obtain various information about its geological structure. In the first period, the study of the area is limited to the establishment of general patterns in its geological structure, i.e., dissection, section, clarification of the largest forms of folding, large angular disagreements, etc. Then they proceed to a preliminary study of individual structures and their relationship, to detail the geological section etc. The last stage of exploration consists in a detailed study of individual structures or their parts, the division of structures into separate tectonic blocks, the study of the structure of each of them.

In accordance with the main tasks of exploration at three different stages of geological exploration, there are three main types of seismic exploration: 1) regional (reconnaissance route); 2) search (reconnaissance areal); 3) Detailed. These types of work differ from each other in density and in the way the network of profiles is located on the ground, as well as the observation systems on the profiles. Three-dimensional observations are very often used for detailed work. The choice of the type of work is determined by varying degrees of detail in the research. [3]

1.3 Stages of seismic prospecting works

Seismic exploration work includes the stages of design, field work and desk studies.

The design stage consists in substantiating (based on geological tasks) and designing the methods of field work, data processing and interpretation, performing estimated calculations, scheduling work. The result is a seismic survey project.

Field work consists in obtaining the initial seismic information (seismograms) and, in terms of cost and importance, is the main stage of seismic exploration. Equipment that is used during seismic exploration includes seismic wave sources, geophones, data recording (collection) tools, processing systems. Currently, a variety of sources of seismic and acoustic waves with different energy and frequency characteristics are used for seismic exploration. The choice of source is determined by the conditions of work (land, sea), the nature of the solved geological problems.

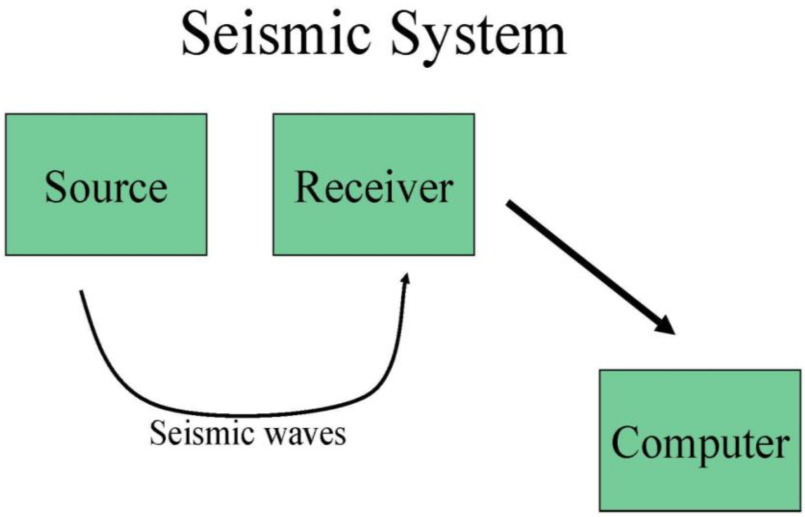

Figure 1.3.1 – Seismic System

As a result of the work of seismic exploration tools, a seismogram is formed - a digital record of the amplitudes of displacements and oscillations as a function of time, i.e. the totality of seismic traces received from one point of the explosion (shot gather). The number of seismograms corresponds to the number of explosions (generations), and for seismic exploration the CDP can exceed tens of thousands. If vibrations are excited in the SP, then at the receiver points various classes of waves will be recorded: direct, surface, refracted, and reflected once. Graphs of the dependence of the arrival times of certain waves on the distance between the source point and the receiver point are called hodographs. Direct and surface waves propagating along the observation surface, respectively, have linear hodographs, and the hodographs of reflected waves have a curved (hyperbolic) shape. That is what they differ from interference waves, which allows them to be identified and tracked on seismograms.

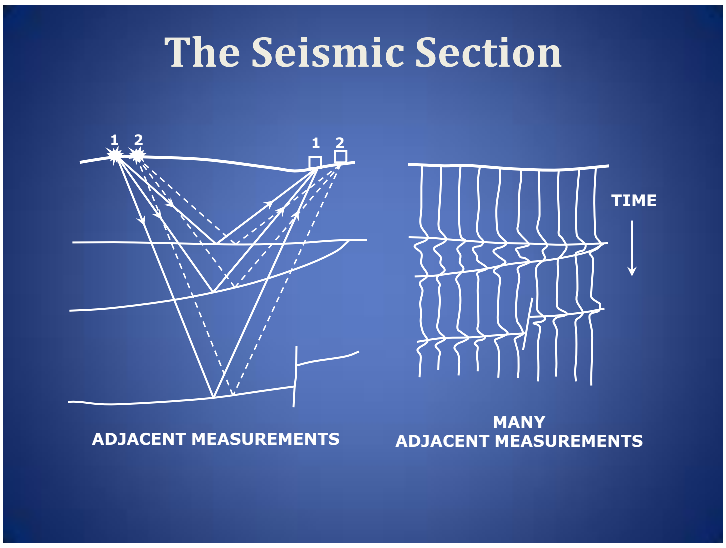

Figure 1.3.2 – The Seismic Section

Desk studies include data processing and interpretation. The processing stage consists in the formation of seismic sections from the field data (CDP 2D) or seismic data cubes (CDP 3D). The general task of digital processing of seismic data in the method of reflected wave is to suppress noise and extract with a minimum distortion from the obtained field records (seismograms, i.e., input data) a useful signal (once reflected waves) or, otherwise, ensuring the maximum signal / noise ratio. This allows to obtain a correspondence (visual similarity) of time sections or cubes of seismic traces, which are output information, with the studied structure of the subsoil.

The interpretation of seismic data is a step using the processing data and its quality is largely determined by the qualification and even intuition of the interpreter. Interpretation is the process of extracting geological information from seismic data in order to study the structural plan of the study area at different stratigraphic levels, determine the lithological composition and formation conditions of oil and gas bearing and prospective deposits, map traps and hydrocarbon deposits. The interpretation of seismic survey data is performed using all available geological information, including drilling and well logging data.

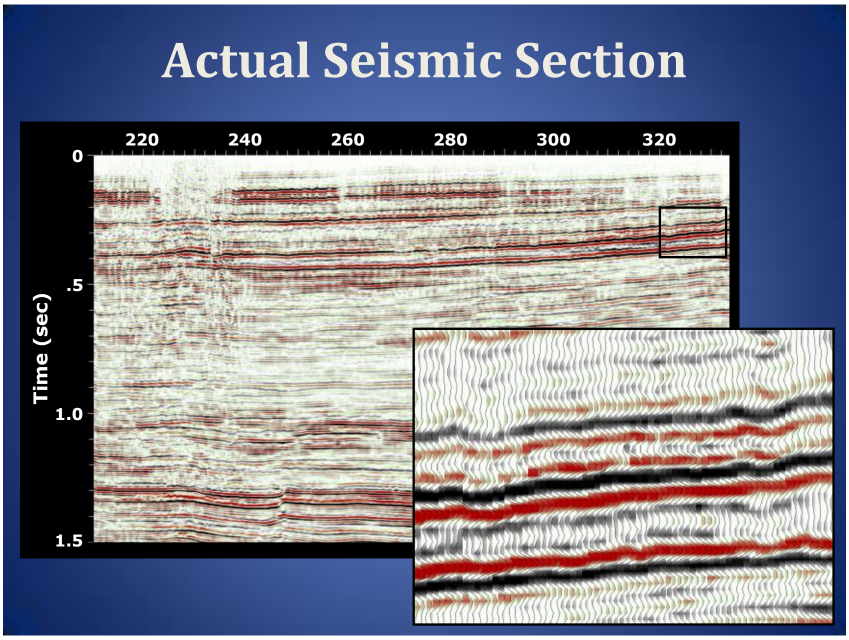

Figure 1.3.3 – Actual Seismic Section

The end product of seismic exploration work is a time or depth seismic section, which is an image of seismic boundaries with the corresponding geological reference. In the vertical axis, the time of the reflected waves is recorded on the seismic time sections as it represents the time it took the energy to pass through the ground, reflect and then return to the surface, it is also called the "two-way time". The vertical time section scale is usually measured in milliseconds (one thousandth of a second is 0.001 seconds). The horizontal axis of seismic sections is the distance on a certain scale. During processing, seismic traces are combined together in various ways, and modified using complex mathematical operations, but they always remain “traces”. The conclusion of a large number of tracks sequentially one after another at their exact spatial location forms the final “seismic section”, which gives the geologist a structural picture of the subsurface structure. [4]

1.4 Physical-geological basics of seismic prospecting

Real geological environments with some approximation can be considered as elastic environments. In them, elastic waves of various types can arise and propagate.

The features and laws of propagation of elastic waves in absolutely elastic media are in many respects similar to the features of the propagation of waves of more complex real media.

Elastic is a body that changes its volume and shape, or, in other words, is deformed if a force is applied to it, and instantly returns to its original state after the termination of its action. Under the action of small forces, many rocks can be considered elastic.

Changes in the size or shape of an elastic body or its parts that occur under the action of applied forces are called deformations. Two main types of deformations can be distinguished. In one case, under the influence of the applied forces, the volume changes, while its shape remains unchanged. Such deformations are called volume deformations. In another case, on the contrary, the volume remains unchanged, but its shape changes. Such deformations are called shape deformations or shifts.

The concept of stress is introduced to determine the magnitude of the force, regardless of the size of the body. By stress is meant an internal force acting on an elementary area in an elastic body, balancing the action of the surrounding elastic medium and referred to a unit area. There is a relationship between stress and strain, established by Hooke's law, according to which the magnitude of the strain is directly proportional to the magnitude of the stress.

The value of E is called the modulus of longitudinal tension (Young's modulus), the value of σ is the transverse compression modulus (Poisson's ratio). The values of E and σ are independent of the size and shape of the body, as well as from each other, they characterize only the elastic properties of the substance. The elastic properties of any isotropic elastic body are completely determined if the values of E and σ are known. Instead of the elastic constants E and σ, other constants are sometimes used, for example, the compression modulus K, Lamé elastic constants, and others. However, all these quantities are interconnected and can be calculated if two of any elastic moduli are known.

Hooke's law is established for absolutely elastic bodies. It is also valid for most rocks, if the strain is not too large. The smaller the magnitude of the observed deformations, the closer the substance is in its properties to an absolutely elastic body. It’s a limitation of Hooke's law. Colossal stresses arise near the explosion region, and here Hooke's law does not apply. Only for areas located at some distance from the place of the explosion, where the deformations turn out to be quite small, can the conclusions arising from this law be used.

A so-called elastic wave travels through the medium, which propagates with a certain finite velocity, depending on the elastic constants and density of the medium. It was mentioned above that any deformation of an elementary volume, an elastic medium can be considered as a result of superposition of two deformations - volume deformation and shape deformation. This separation is of great importance, since it turns out that each of these types of deformations is associated with a special type of elastic wave propagating with a velocity inherent only to it. In an infinite elastic medium, two types of waves can exist: a longitudinal wave and a transverse wave.

The longitudinal wave P carries with it only volume deformations. If in a medium through which a longitudinal wave propagates, a small object is selected and its changes are considered, then it will be noticed that the angles between its faces do not change, while its volume changes over time. As a result, in the region of the elastic medium through which the longitudinal wave passes, alternating zones of tension and compression arise, and the particles oscillate around their initial position in the direction coinciding with the direction of wave propagation.

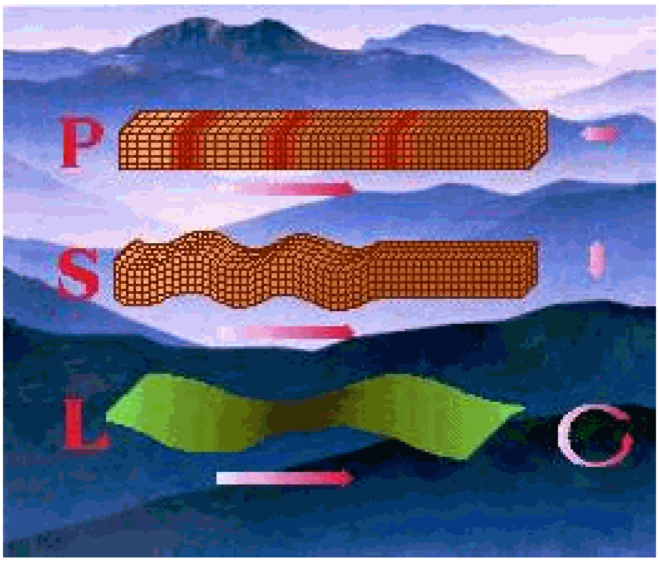

Figure 1.4.1 – The longitudinal P and transverse S waves

The transverse wave S is associated with deformations of the shape, therefore, during its propagation, body do not experience volume changes and only the angles between their faces are distorted. It is as if the layers of the elastic medium are sliding relative to each other, and the particles oscillate in the direction perpendicular to the direction of wave propagation.

When an explosion occurs at some point O of the elastic medium, the resulting volumetric (longitudinal or transverse) wave propagates with a certain finite velocity, depending on the physical properties of the medium and the type of wave. Short-term particle oscillation during the passage of the wave occurs at each moment of time inside a certain region of the medium bounded by two closed surfaces. The external surface at the given moment separates the region of the elastic medium in which the wave has already caused the particles to oscillate from the region of the medium that the disturbances have not yet reached. This surface is called the front (leading edge) of the wave. The inner surface separates the area in which they have already ceased. This surface is called the rear (trailing edge) of the wave.

The laws of fronts in an elastic medium can be derived from the well-known basic principles of Huygens-Fresnel or Fermat geometric optics. These principles are equivalent and can be deduced from one another. The Huygens principle establishes how, in a medium at all points of which the wave propagation velocity is known, it is possible to construct a set of wave fronts if the position of the front at a certain point in time is known. According to the Huygens principle, each point lying on the surface of a given front should be considered as an independent elementary source of oscillations.

The Fermat principle, or the principle of least time, establishes an important property of seismic rays, according to which the travel time of a wave along a beam is less than the travel time of it along another possible path. Based on the Fermat principle, it is possible to determine the shape of a seismic beam in a medium in which the velocity distribution is known.

The principle of superposition of waves has the great importance in studying wave propagation: if two waves propagate simultaneously in a certain region of the medium, then each of them will move as if the other wave does not exist.

When the velocity of propagation of an elastic wave in different regions of space is not the same, then the rays are not linear. Considering the case when there are two layers I and II of high power, touching along the flat boundary of R. By supposing that an elastic wave propagates in layer I, which we call the incident wave. The latter, depending on the type of deformation associated with it, can be a longitudinal or transverse wave. In the case when the incident longitudinal wave P reaches the boundary R, its reflection and refraction occur. Due to the energy of the incident wave, secondary waves are formed. These include reflected waves and transmitted waves

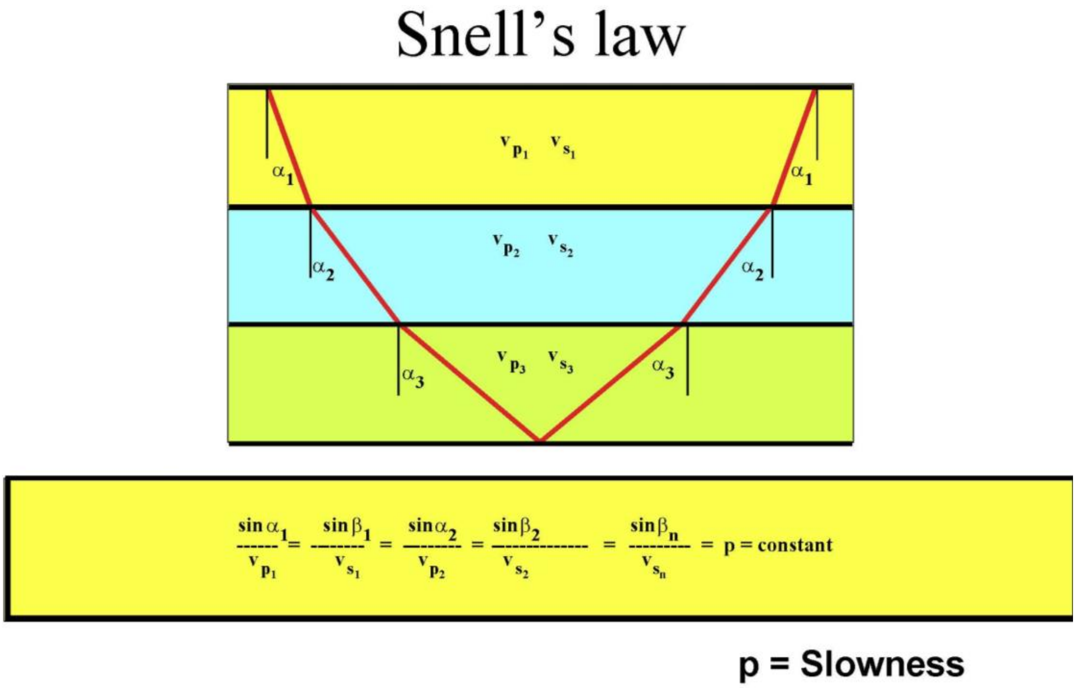

Figure 1.4.2 – Snell's law

The phenomenon of enveloping by an obstacle wave is called diffraction. If an impenetrable obstacle is encountered in the path of the wave, then a regular geometric shadow does not form behind it, but there is some disturbance that goes around the obstacle, called the diffracted wave. All types of elastic waves can diffract.

Longitudinal and transverse waves, excited by external forces acting in a certain limited region of the medium, are observed at more and more remote points from time to time: the strains transmitted by them sequentially capture the entire surrounding volume of the medium. Therefore, longitudinal and transverse waves are combined by the concept of body waves. In an infinite elastic medium, only body waves can exist.

In the presence of boundaries separating the volumes of media with different elastic properties, waves of a different type, called surface waves, can arise near these boundaries. The most important for seismic exploration is the surface Rayleigh wave observed on the surface of the earth. Another type of surface wave observed on the free surface of the earth is the Love wave (transverse surface wave).

To solve various geological problems, elastic waves are of interest, which, having reached the object under study, can then be seen in the area where the observations are made. Since the generation and registration of waves is carried out near the surface of the earth, the reflected and refracted waves are of the greatest importance for seismic exploration.

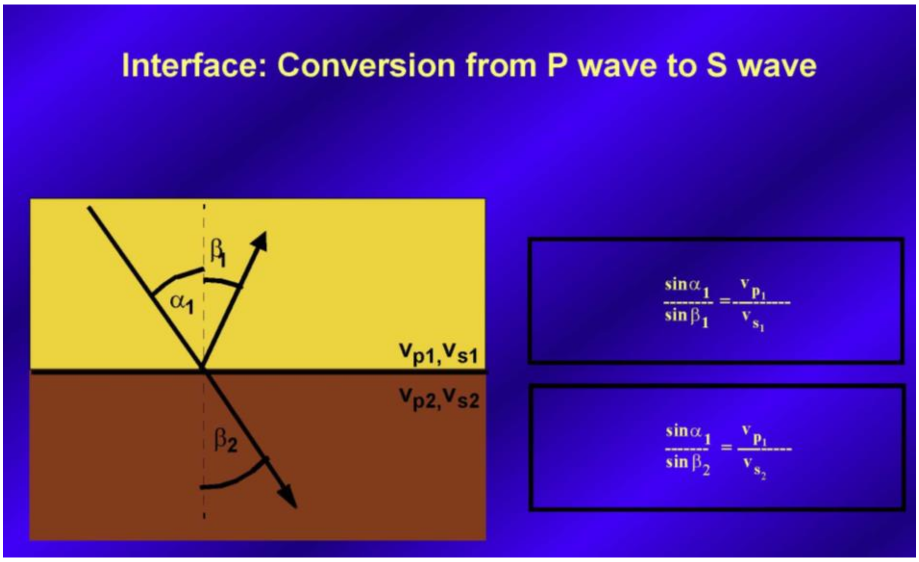

Figure 1.4.3 – Conversion from P wave to S wave

The study of hodographs of reflected and refracted waves allows to draw conclusions about the geological structure of the area: to determine the position of reflecting or refracting boundaries and to study the distribution of velocities in the thickness of the earth's crust. To obtain hodographs, it is necessary to record the motion of the soil surface that occurs during the passage of reflected and refracted waves. The movement of the soil surface is the sum of the oscillations created by all kinds of waves arriving at it.

Rocks composing geological environments have specific features due to their composition, conditions of formation and development and modern conditions of occurrence. When assessing the possibilities of using seismic methods, the correct consideration of these features is of paramount importance.

The possibility of using seismic exploration as a method for studying the geological structure of a given region is based on the fact that the refracting and reflecting boundaries coincide with the geological boundaries, i.e. with the boundaries of stratigraphic horizons. That is why information about the position of reflecting or refracting boundaries allows geologists and geophysicists to judge the structure of underground strata and the features of their structure.

In most areas, loose, weakly cemented deposits occur under the soil layer. Such deposits, unless they are completely saturated with water, are characterized by very low velocity values and form a low velocity layer, which is characterized by a strong absorbing effect, especially with respect to high frequencies. The power of the low velocity layer varies from zero to 80-100 meters. Usually is 8-15 meters. The lower boundary of the low velocity layer often coincides with the level of groundwater, which is explained by a sharp increase in velocity in completely water-saturated loose rocks. In areas of permafrost development, low velocity layer is absent.

The difference in the properties of the low velocity layer along the seismic profile leads to a different delay of the wave as it passes through the low velocity layer. Therefore, this distorting effect must be taken into account when processing of seismic materials. [3]

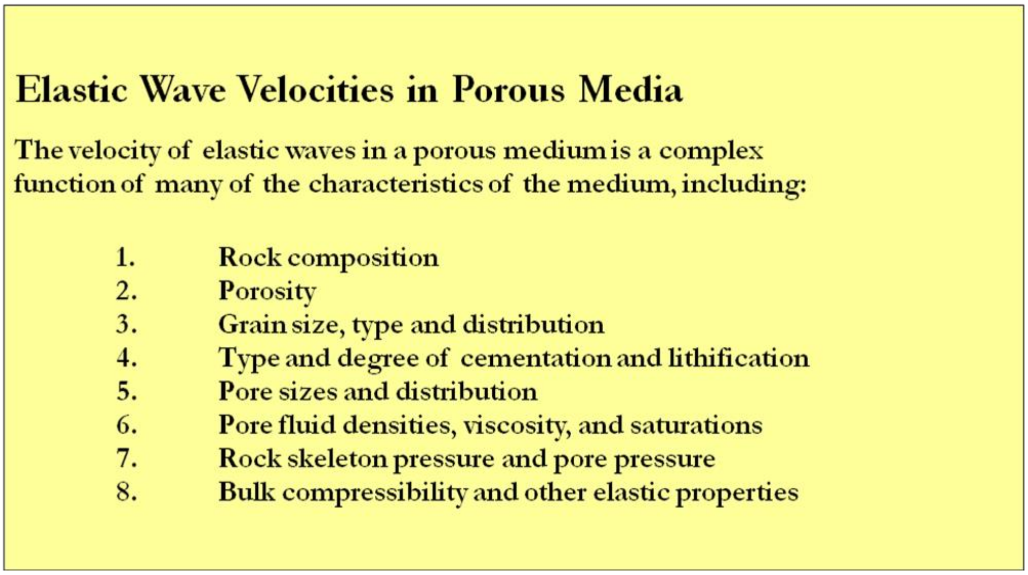

Figure 1.4.4 – Elastic wave velocities in porous medium

1.5 Experience of using seismic prospecting in solving ore geology problems

In recent decades, due to high metal prices and low efficiency of prospecting for ore objects located near the surface, prospecting and exploration of mineral resources have moved to greater depths. Objects with complex geological structure and great depths are increasingly included in development and operation, which requires special conditions for their development. The percentage of "empty" wells drilled does not decrease, which is in no small part due to the complexity of the structure of the investigated prospective ore objects. At the same time, practical experience has proved the presence of ore deposits at great depths, usually characterized by a large concentration of ore bodies and a high content of useful component. Taking into account the increasing cost and complexity of deep well drilling, the technologies that allow increasing the coefficient of reliability of ore deposits forecasting are of great importance. One of such technologies is 3D modeling of geological media [1].

Solving the issues of modeling the structure and formation of complex geological media and ore objects, minimizing the risks of their development is an important task for the rational development of solid minerals deposits. At the same time, the most complex and problematic geological models are characteristic of ore objects located at great depths, complicated by disjunctive tectonics, presence of block structure, variety of lithologic-facial composition of rocks, sharp inhomogeneity of ore body and host medium [2].

Today, methods are being developed in Australia, Europe, Canada, and South Africa to improve the efficiency of exploration for deep-seated solid minerals, and more efficient and safe technologies for the development of ore deposits are being used.

Due to the increased labor intensity and cost of drilling operations, today's tasks are increasingly being solved with the widespread use of cheaper geophysical methods of exploration and prospecting for solid minerals. Traditional geophysical research in mining relies heavily on potential field and electromagnetic methods, both air and ground. Magneto-, gravel- and electro-exploration of various modifications are now effectively used to identify promising targets in depths below 500m and to plan exploration drilling. Seismic methods are generally recognized to provide greater penetration depth and good resolution, but the majority of mining specialists have until recently believed that seismic profiling is economically inefficient to solve problems of ore geology. In addition, the opinion is often voiced about the low informaa tion of insufficiently intense, ambiguous reflections of seismic signals, due to the lack of understanding of how the observed seismic signals correlate with the peculiarities of the deep heterogeneity of the geological environment in the ore areas, as opposed to the well studied, typical for geological complexes of sedimentary (oil) basins [3].

Years of research in Canada have changed this view, pointing to a possible new niche for seismic exploration. Like the oil and gas industry, mining is the cornerstone of Canada's economy, with an estimated $12 billion in solid minerals production. It produces about $12 billion a year. With some notable exceptions (the discovery of the Vuazi Bay nickel-cobalt deposit in Labrador), Canada's mining industry is looking for new ore deposits to increase the dwindling reserves in the deposits currently under development. The requirement to identify deep ore horizons to date has stimulated the search for new technologies to reduce costs and improve drilling efficiency [4].

Since 1990, the State Geological Survey of Canada, in collaboration with industry, has been implementing a program to evaluate the use of seismic exploration methods for the prospecting and exploration of solid minerals. Seismic surveys have been carried out to study both regional crustal structures in the ore regions of Ontario and Quebec as well as experimental detailed profiles through important mining areas in the Abitibi sub-provincial area (Figure 1.5.1).

Figure 1.5.1 – The location of major mining provinces in Central and Eastern Canada. The green zone shows the location of the Abitibi sub-provincial of the Canadian Shield, one of the most important mining areas in the world.

Detailed studies were carried out using high-frequency parameters of seismic signal recording (source-receiver distance 20m, 30140 Hz sweep, 240 channels, 120-fold coverage, sampling interval 2ms, length of the correlated recording 5s with 12s sweep). As a result, it was found that ores dispersing volcanogenic rocks produce stable reflections that are clearly correlated over long distances (Clowes, 1994). These results provided the impetus for further studies to evaluate the use of multichannel seismic (MCS) in studying deep ore horizons (up to 2 km and more) and designing an effective field development technology.

The study of the elastic properties of rocks has shown that the expected dispersion of values in the acoustic impedance between the ores and the host rocks is sufficient to highlight observed reflected and/or scattered waves. However, to extract an ore deposit using MCS, it must meet the following geometric criteria: minimum thicknesses ~5 m and lengths ~100 m. Figure 1.5.2 shows an example of migrated seismic cross-sections of the Matagami and Quebec deposits, which illustrate seismic wave reflections associated with volcanic ore complexes in the Abitibi ore province.

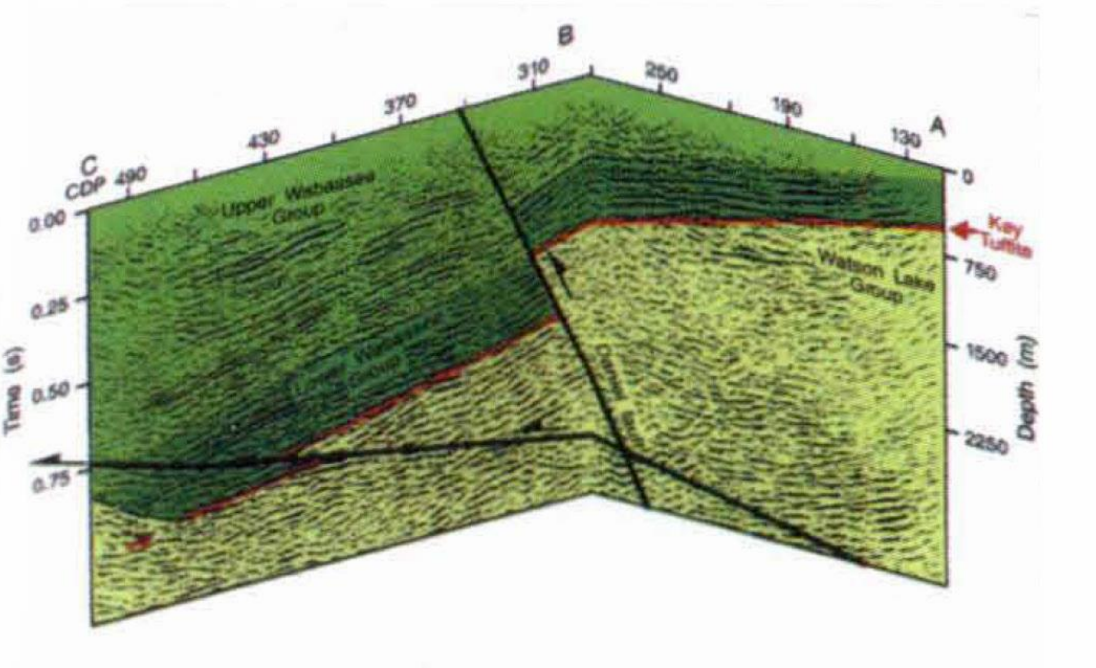

Figure 1.5.2 – A high-resolution seismic section in Matagami District 29-3, North Quebec (Adametal., 1995).

Subsequent seismic studies linked to well data have shown that the lithological contacts between ultramafic and acidic rocks, characterized by good petrophysical differentiation and significant massif lengths, are also favorable for their isolation using the MCS method. However, in some fields, such as Buchany, structural zones (faults, shifts, etc.) are better fixed than lithological contacts. In both cases, these studies have shown that qualitative registration and correctly processed seismic data can serve as a valuable geophysical tool for interpretation of the stratigraphic and structural framework of mineral systems and, less frequently, direct detection of deep ore deposits.

The possibility of using seismic survey for oil field development monitoring (4D seismic survey) is widely known. In this direction, there is also a positive result for ore deposits to identify worked-out blocks of ore deposit and build models of underground workings for further successful development of the deposit. The analysis of the synthetic and observed 2D nonmigratory section at the Creighton Quiver deposit and the massive sulphide deposit of the Gertrude deposit near Sudbury, Canada, shows the possibility of distinguishing the boundary between the intact and developed parts of the ore body in the direction and nature of the seismic signal energy scattering. These and other results of seismic data modeling show that the direct scattering propagates in the direction of the lenticular deposits fall, and in terms of amplitude of seismic waves, the boundary between the depleted area of the ore deposit, characterized by the maximum diffraction response, is distinguished (Fig. 1.5.3).

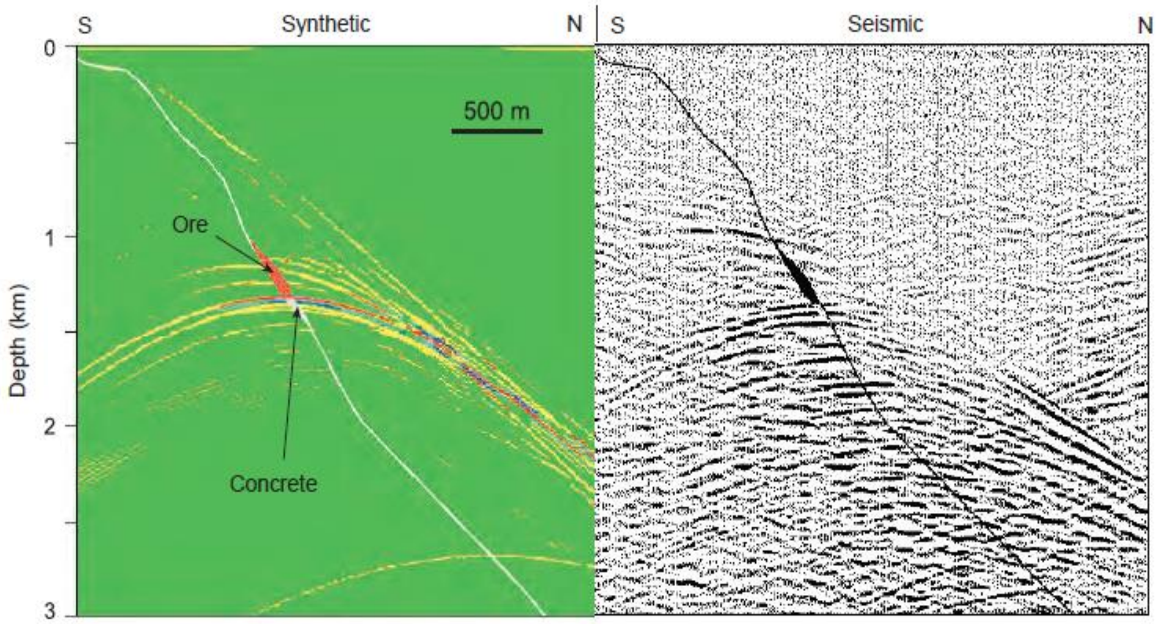

Figure 1.5.3 – Synthetic (left) and observed (right) reflections from massive sulphide deposit of Gertrude in Sudbury. The diffraction of seismic waves at the top of the ore body shows the boundary between the intact and mined-out part of the ore deposit (Milkereitetal. 1996).

A comprehensive analysis of geological and geophysical data was carried out by Australian researchers at the Kumbalda field (Western Australia). Seismic survey was carried out using a series of search profiles (2D) and the area directly above the ore deposit (3D) (Figure 1.5.4). As a result, it is shown that 2D and 3D seismic surveys provide sufficient reliability for solving the following geological problems (Figure 1.5.5-1.5.6):

- differentiation of the geological section by seismic wave propagation velocity velocity and rock density;
- extraction of lithologic-facial inhomogeneities of the geological section, stratigraphic complexes, and mineralization zones at depth;
- extraction of fluid zones and their distribution areas;
- extraction of contrasting (massive) ore deposits in terms of physical parameters, determination of their morphology and geometry.

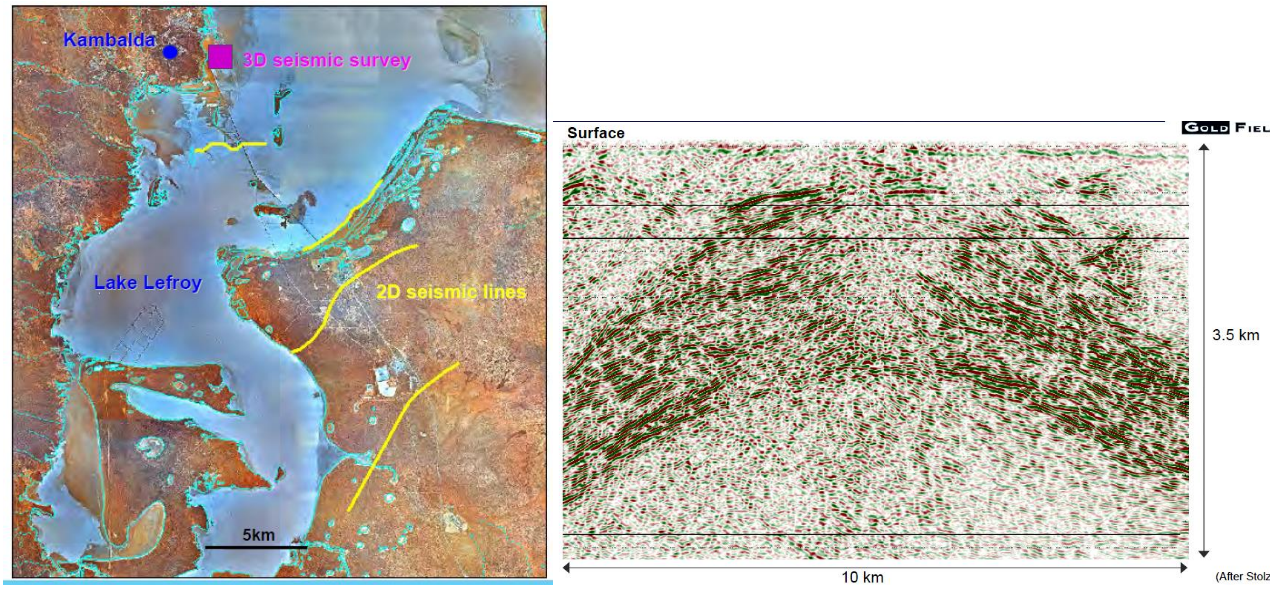

Figure 1.5.4 – Kambalda deposit (Western Australia). Seismic 2 & 3D Studies (StolzandLally, 2006)

Thus, to date, numerous positive results have been obtained in 2D and 3D seismic field work in various fields of solid minerals (Malhmiretal., 2012). Seismic techniques are increasingly being used in ore geology to identify a wide range of minerals, including base metals (Cu, Pb, Zn, Al, etc.), uranium, diamonds, precious metals and provide for the study of deep geological structures containing ore-bearing horizons and in some cases can be used for direct extraction of ore deposits.

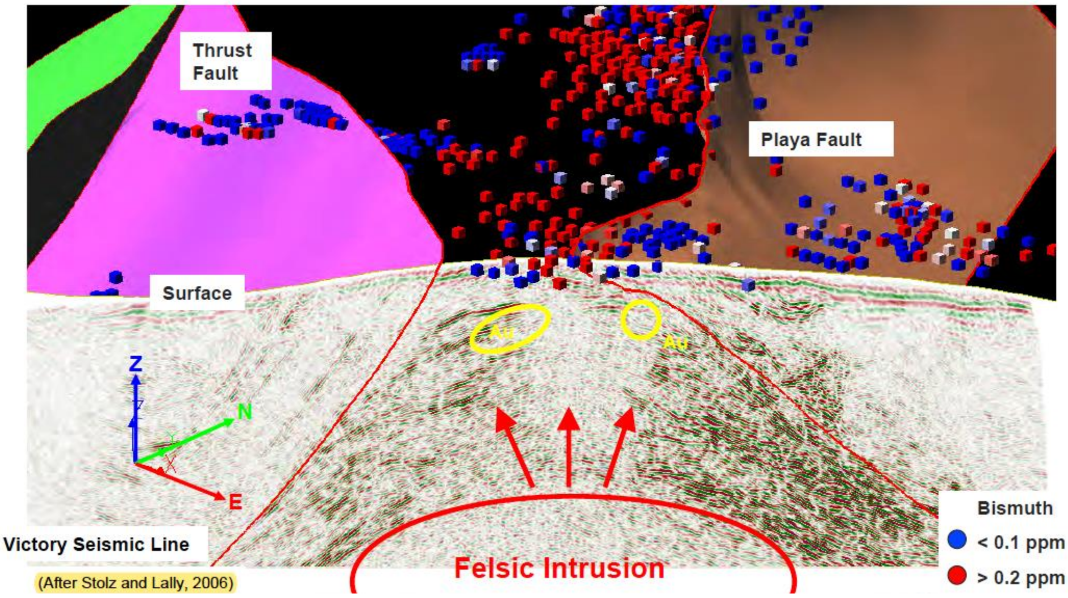

Figure 1.5.5 – Kambalda deposit (Western Australia). Integrated interpretation of geological and geophysical data in studying gold objects (StolzandLally, 2006)

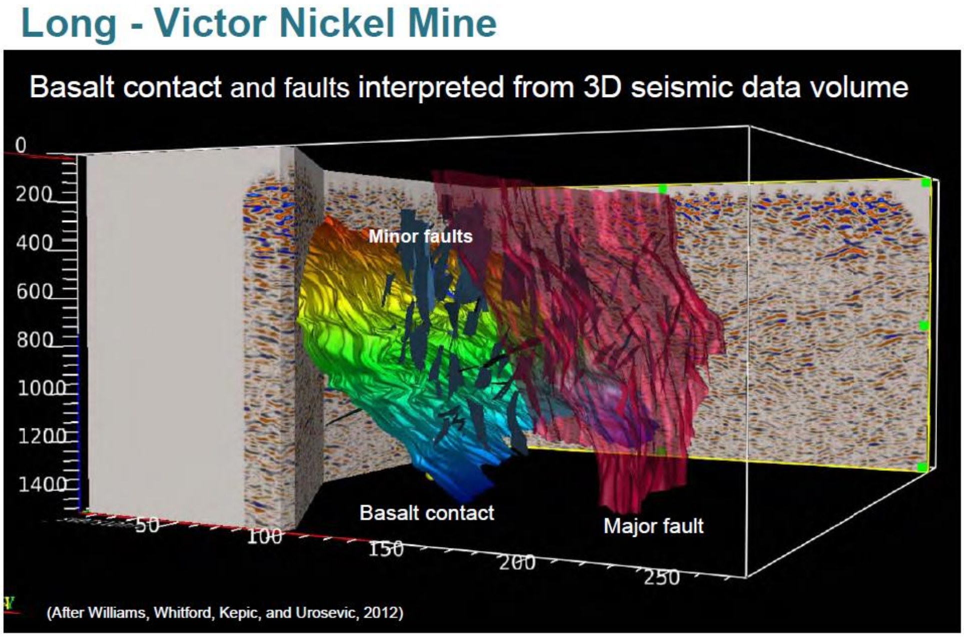

Figure 1.5.6 – Kambalda deposit (Western Australia). 3D seismic model of a nickel ore deposit (Williams, Whitford, Kepic, and Urosevic, 2012).

In addition to field seismic surveys, well seismic surveys are widely used, such as VSP, VSS and interwell seismic transmission. Seismic surveys are carried out for the purpose of prospecting and exploration of mineral deposits at depths above 1km, as well as for planning underground excavations during the development of deep ore facilities.

The increasing use of seismic exploration at various ore sites shows that it is finally becoming recognized and traditional in the mining sector. This opens up new opportunities for geophysicists, but also poses additional challenges for the solution of new problems.

Ore seismic exploration is considered to be a wide range of methods used both for regional studies and for solving various problems of structural control of ore deposits in geological environments more complex than those studied by traditional seismic exploration in oil exploration works. Therefore, there was a need to determine the possibility of using high-density wide azimuth 3D seismic survey for structural mapping of ore areas and detailed study of deep-lying ore-bearing complexes in Kazakhstan.

To date, most ore areas of Kazakhstan have been studied from the surface quite well and the fund of shallow and easily discovered deposits is almost exhausted. In a large part of the region there is a task to search for deposits at depths of 1000-1500 and more meters. In solving such problems, direct methods of searching will be replaced by indirect methods based on studying and applying the peculiarities of volumetric geological structure of ore areas, ore fields and deposits, i.e. on the basis of volumetric geological modeling.

At present, there are no proposals of domestic and foreign companies on application of 3D seismic survey for modeling ore deposits in complex mining and geological conditions that meet international requirements and can fully meet the needs of the industry.

High resolution 3D seismic exploration and modern processing and interpretation complexes can provide high quality materials to solve the following geological problems:

- study of structural and tectonic structure of ore areas;

-selecting and refining ore control structures;

-detection and deep mapping of ore control faults;

-volume mapping of intrusive massifs;

-determination of the spatial position of ore-bearing areas within intrusive zones, etc.

In ore areas the seismic survey solves the following tasks:

a) regional studies of ore provinces and areas;

b) identifying and studying individual ore control structures;

c) study of the structure of ore fields to identify areas promising in terms of ore body content.

In regional studies, areas of several tens or hundreds of square kilometres are studied. The relief of rocks under sediments, boundaries in metamorphic strata and mapping of lithological complexes under covering sediments are studied. In the study of ore areas, the use of MRW allows mapping based on the size of the boundary velocity. In many cases, this allows localization of zones interesting from the point of view of subsequent detailed studies.

When studying and tracking ore-controlling structures, both the method of refracted wave and the method reflected wave are used. Using these methods, it is possible to register waves arising in weakened zones associated with disturbances to which ore fields are confined. The use of the method of reflected wave allows one to study tectonics to depths of 1-2 km, which is important for explaining the processes of ore formation and the direction of prospecting. For instance, such observations within the Magnitogorsk mega-synclinorium allowed to study its deep structure. Three dissonantly occurring rock complexes were identified and their geological interpretation was given. The connection of copper pyrite deposits with anticlinal structures is outlined.

In detailed studies aimed at studying ore fields in igneous and metamorphic sediments, seismic exploration encounters significant difficulties caused by the complexity of their structure, low velocity differentiation of rocks, instability of their velocity characteristics, as well as the relatively small size of the desired objects. To overcome these difficulties, it is important to combine seismic exploration with other geophysical methods and drilling. When exploring alluvial deposits, seismic exploration has been successfully used both for dismembering a section and for searching for promising structural objects. [3]

One of the typical tasks of ore seismic exploration is mapping the foundation roof. The indicated problem is most simply solved under conditions when the foundation is relatively homogeneous in material composition and is covered by the seasoned thickness of loose formations. Comparing the above data, it can be noted that the greatest discrepancies between the results of seismic and electrical exploration when determining the depth of the basement are confined to areas of rugged terrain and a sharp change in the thickness of loose deposits. In such areas, as analysis shows, the error of electrical exploration methods, compared with seismic exploration, is 2-3 times higher. The relative error in determining the depth to the foundation using seismic exploration, determined by comparison with drilling data, does not exceed 10%.

The tasks of studying the internal structure of bedrock are among the most difficult in seismic exploration. As an example of the results obtained in such cases, we briefly consider some of the results of seismic exploration in one of the regions of Western Uzbekistan. The study area is characterized by the development of strongly altered sedimentary-metamorphic rocks of the Paleozoic age, represented by rhythmically alternating sandstones, siltstones, mudstones and their intermediate varieties. The thickness of the formations exceeds 2.5 km. According to the method of refracted waves, taking into account the results of uphole survey performed in the upper part of exploratory wells, the seismic model can be represented by five layers, in which the lowest layer is identified with the bottom of the weathering crust.

2 Characterization of the object of research

2.1 Geographic and economic characteristics of the area

Zhezkazgan ore district is located in central Kazakhstan. Zhezkazgan ore district includes the Zhilandy group of deposits. The group of Zhilandy deposits is located in the Ulytau district of the Karaganda region, 30-35 km northwest of the Zhezkazgan mine. The group includes the Saryobinsk ore field, the Itauz, Kipshakpai and Karakoshak deposits. Studied by K.I. Satpayev, D.L. Wercom, V.P. Stetsenko, V.P. Bakarasov, V.M. Potapochkin, M.K. Satpayeva, F.A. Kurmakaeva, L.N. Lynovoi, E.V. Puchkov and others. The deposits are confined to the Zhezkazgan syncline, complicated by folds of a higher order and discontinuous violations. The deposits of the Taskuduk and underlying Zhilandy horizons represented by gray-colored siltstones, sandstones and conglomerates participate in the structure of the deposits.

2.2 Characteristics of the geological structure of the area

The Zhezkazgan ore region affects adjacent areas of the following three structural zones, at the junction of which it is confined: the Zhezkazgan depression in the south, the Ulytau brachisklad zone in the west and the Kengir brachish structure in the north and east. In a larger structural plan, these zones of brashkladok are located between the Ulytau-Arganat megalanthory in the west, composed of Precambrian rocks, the Sarysu-Teniz zone of block folds in the north and northeast, formed mainly by the rocks of the Middle Paleozoic and Zhezkazgan depression in the south east, within which the Upper Paleozoic is distributed predominantly.

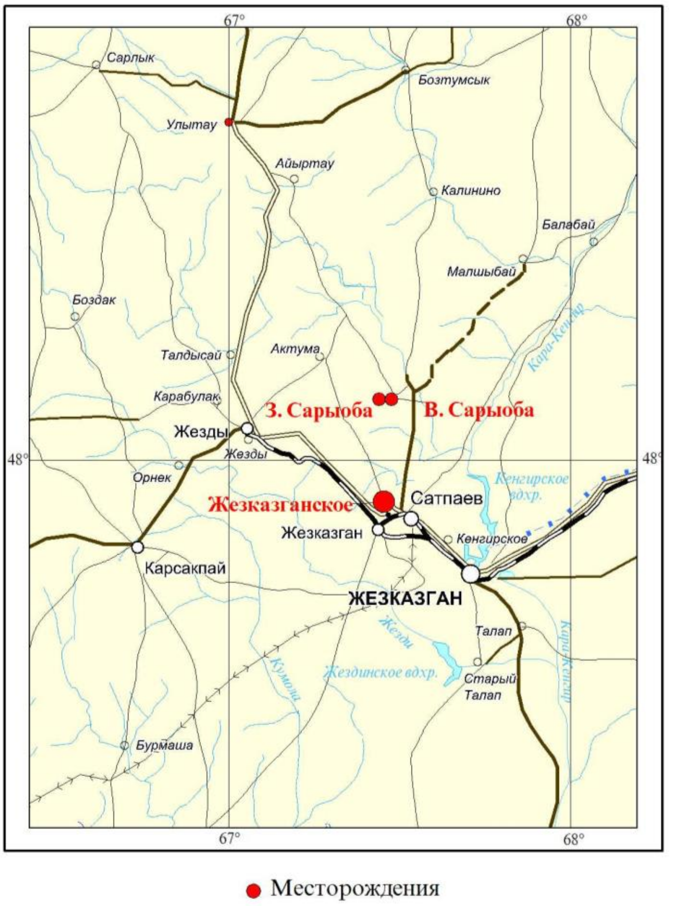

Figure 2.2.1 – Overview map of the research area

2.2.1 Stratigraphy and lithology

The geological structure of the described deposits involves deposits of the Upper Beleutins of the Serpukhov layer of the Lower Carboniferous (C_1sb_l), the Taskuduk Lower-Middle Carboniferous (C_1s2-C_2ts) and the Zhezkazgan Formation of the Middle-Upper Carboniferous (C_2-C_3). Of these, the first two suites at the described deposits are ore-bearing. Mineralization in both of them is confined to layers of gray sandstones and dark gray siltstones. The following is a description of the geological structure of the above stratigraphic units. (Fig. 2.2.1.1- 2.2.1.2)

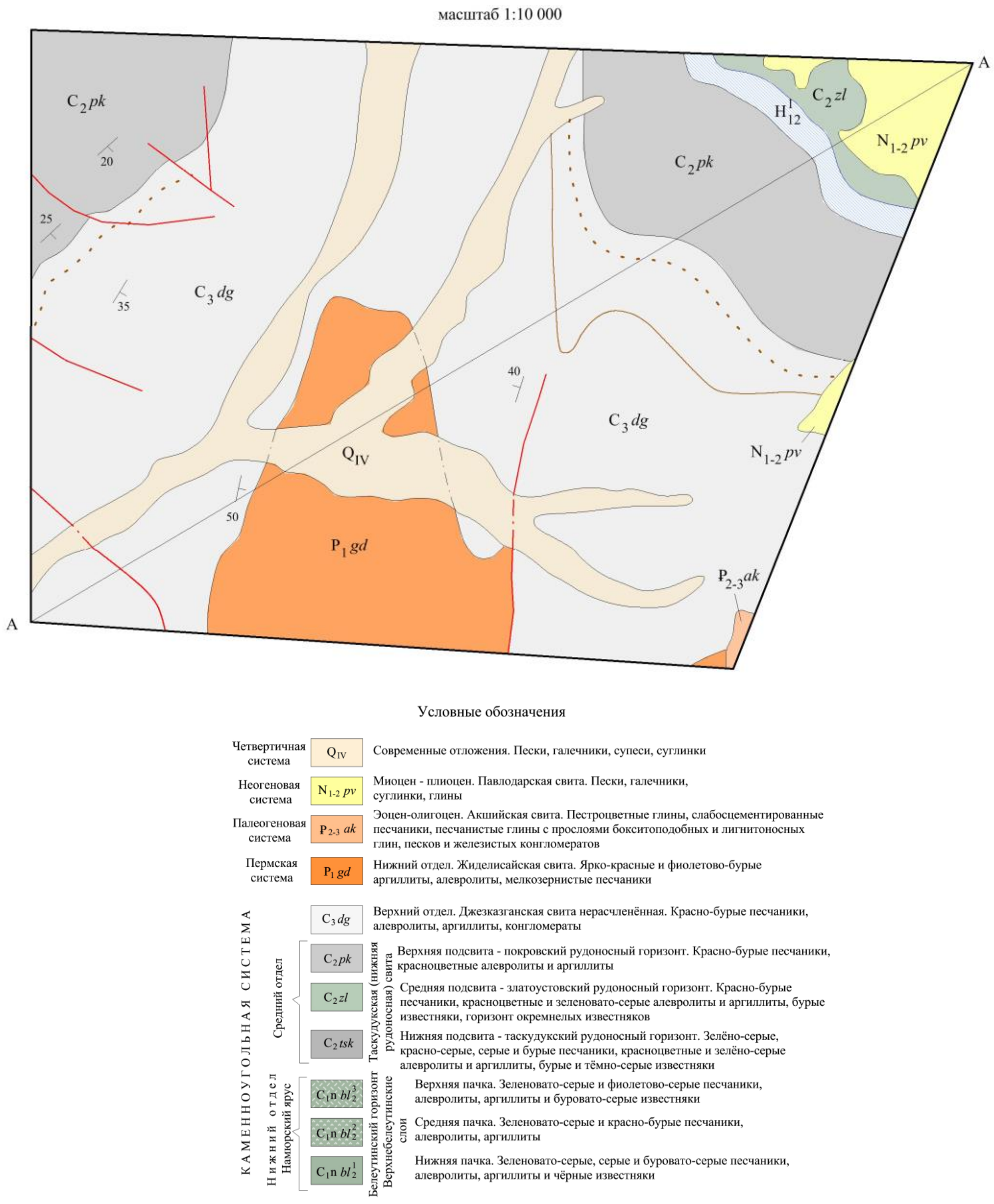

Figure 2.2.1.1 – Geological map of the area of work

In the geological structure of the region, rocks of several geological systems take part - from Precambrian to anthropogenous.

Figure 2.2.1.2 – Stratigraphic column

The Precambrian and Lower Paleozoic formations transgressively, through the basal conglomerates, overlap a thick (up to 3000 m) Middle Paleozoic stratum of terrigenous and carbonate sediments. The Zhezkazgan series of deposits, including from the bottom up, is attributed to the Upper Paleozoic:

A) Zhezkazgan ore-bearing stratum of sandy-clay sediments, subdivided into Taskuduk and Zhezkazgan formations with a total thickness of 650-680 m;

B) the Zhidelisay Formation, consisting of alternating layers of red-colored mudstones and sandstones with a total thickness of 300 m;

C) The red-colored stratum, according to the overlapping Kengir suite, represented by interbedded layers of gray and dark gray marls and dolomitic limestones with a total thickness of 500 m.

The first two suites are ore-bearing, and their study in the area is focused on. They are characterized by frequent intercalation of brown and gray sandstones, siltstones, mudstones with rare interlayers of conglomerates and silicified limestones (hornfelses).

2.2.2 History of geological development

In the geological history of the Zhezkazgan ore district, three stages are distinguished: geosynclinal, covering time from Precambrian to Ordovician inclusive, parageosynclinal (Silurian-Perm) and platform (from the Mesozoic). Rocks from Cambrian to Silurian do not reach the surface in the area of the area of deposits of the Zhilandinsky group, however, the characteristic of the geosynclinal stage of development is given here to understand the general history of the formation of the ore region.

The initial period of geosynclinal development of the region occurs in the early and middle Proterozoic. At this time, under marine conditions, an accumulation of a variety of terrigenous and volcanogenic, less often carbonate rocks, subsequently metamorphosed and turned into gneisses, amphibolites, various schists, porphyroids, and marbles. At that time, ferruginous quartzites formed.

2.2.3 The basic elements of tectonics

As an example, from the Zhezkazgan ore district, the East Saryoba deposit is used. The East Saryoba field, like the other deposits of the Zhilandinksy group, is confined to the western, northwestern, northern, northeastern and eastern wings of the Zhezkazgan syncline (Fig. 2.2.3.1). The manifestation of Hercynian tectogenesis led to the formation of structures of the second and higher orders (domes, troughs) here, complicated in turn by longitudinal flexion zones such as flexures and disjunctive disturbances. In general, the field is characterized by a complex geological structure. The deposit area was the zone of greatest stresses, which led to the formation of not only folded, but also large explosive faults. The Zhezkazgan deposit itself is confined to the same complex tectonic nodes in the southern part of the Zhezkazgan ore field.

In the northern part of the Zhezkazgan syncline, 9 anticlinal and synclinal structures of the second order are currently distinguished: Taldybulak syncline, Kopkuduk syncline, Karashoshak syncline, Kipshakpai uplift, East Saryoba (Kulmanovskaya) synklinal, Saryoba synklinal. Some of these second-order folding structures in cross section have a typical trunk profile. The wings of such folds have angles of incidence of 70-80º. The immersion of the axes of the secondary structures, as a rule, occurs in a southerly direction at an angle of 10-15º. In addition, the northern wing of the Zhezkazgan synclinal is characterized by the presence of small transverse flexures (relative to the strike of rocks).

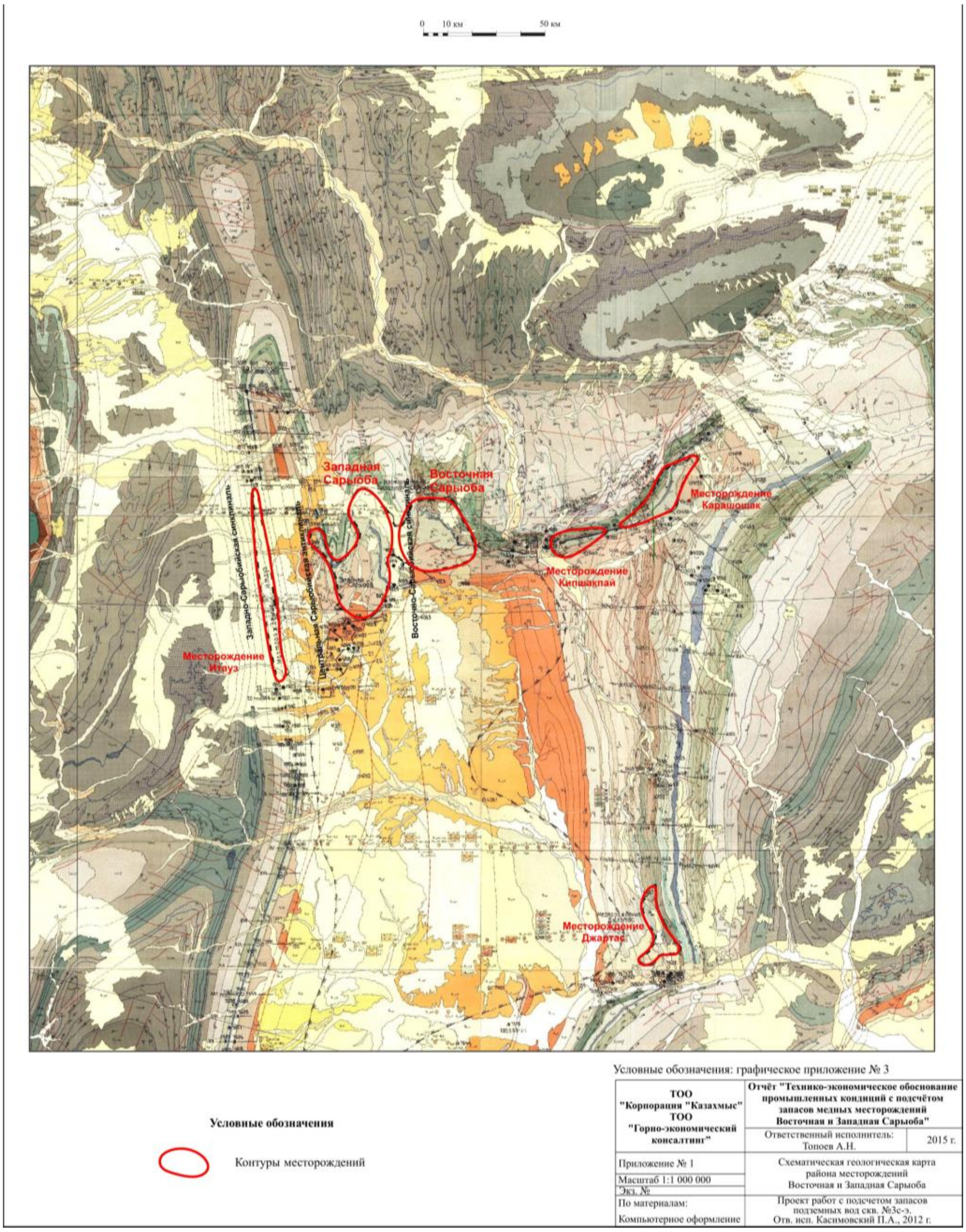

Figure 2.2.3.1 – Schematic geological map of Zhezkazgan ore district

Discontinuous violations in the northern part of the Zhezkazgan syncline are widespread. The largest violation is the Central Saryoba reverse fault, passing between the East and West Saryoba deposits. Violation can be traced along the azimuth of SV-20-25º at a distance of more than 10 km and represents a difficult crushing zone with a thickness of 300-400 m. Apparently, this zone is the eastern branch of the Spassk-Ulytau deep fault.

In the zone of the Central Saryoba reverse fault, there is a section of the planned open-cast mining of reserves not calculated in 1975. due to the extremely complex geological structure of this site. Open mining contours were outlined within latitudinal profiles 46 - 51 to a maximum depth of 110 m. The fault zone consists of numerous discontinuous faults of a thrust-shear nature, dividing the site into separate tectonic blocks. In the general case, tectonic blocks are sequentially pushed one from another from east to west, creating a peculiar structure of “fish scale”. Fragments of rocks and ore deposits in individual tectonic blocks, respectively, are also pushed against each other from east to west with a clockwise rotation, so that they acquire a submeridional strike.

The second major discontinuous violation is a latitudinal fault with a displacement amplitude of up to 500 m in the plan, identified in the zone of the Saryoba and Kipshakpai deposits. This gap is a continuation of the Ayakkagyl discharge and passes through the Kipshakpay deposit and further through the Ayrakbay ore occurrence is traced up to the southern areas of the Saryoba deposits, where it is connected with the main fault-shift. In some areas, it takes on a thrust character. This violation is the northern branch of the Terekti deep fault. Zhezkazgan fault-shear disturbances are very characteristic of the Kipshakpay and Karashoshak deposits. The vertical amplitude of these violations does not exceed 50-100m, and the horizontal - 200m.

Minor discontinuous faults such as faults and faults are especially numerous in the East and West Saryoba deposits. In most cases, they quickly fade over the fall. In addition, on the northern wing of the Zhezkazgan syncline, a series of small crushing zones formed as a result of small rock movements is established. Along with this, it is necessary to note the presence of stratified displacements with the formation of bleached milonitized zones. Small gaps and cracks are very numerous in the fields of the Zhilandy group.

Breaking breaches of host rocks, which are sometimes cemented by vein quartz, calcite, and barite, often with disseminated ore minerals, are usually developed in zones of discontinuous disturbances.

2.2.4 Structural features of deposits

The structural features of the Zhezkazkan ore district are described by the example of two deposits. The East and West Saryoba deposits, as well as other deposits of the Zhilandy group, are confined to the wings of the Zhezkazgan syncline. The manifestation of Hercynian tectogenesis led to the formation of structures here, complicated by longitudinal zones of flexure type flexure and disjunctive disturbances. The field site was the zone of greatest stresses, which led to the formation of both folded and discontinuous faults.

In the northern part of the Zhezkazgan syncline, 9 anticlinal and synclinal structures of the second order are distinguished: Taldybulak synclinal, Kopkudu syncline, Karashoshak synclinal, Kipshakpai uplift, East Saryoba synclinal, Saryoba synclinal, West Saryoba synclinal and Itauyz synclinal. Some of these folded structures in cross section have a typical trunk profile. The listed synclines are associated with the same deposits.

Discontinuous violations in the Zhezkazgan syncline are widespread. The largest violation within the ore field is the Saryoba reverse fault, located between the described deposits of East and West Saryoba. Violation along the azimuth of SV-20-25º was traced at a distance of more than 10 km and represents a difficult crushing zone with a capacity of 300-400 m.

The prenatal age of these violations is unambiguously established by the example of the most studied Saryoba reverse-strike fault. Ore mineralization is located on both sides of this fault, along which the displacement of the rocks is recorded. In addition, ore bodies, as they approach discontinuous disturbances, gradually wedge out and are predominantly chalcopyrite. It is a typical mineral of the peripheral parts of ore deposits.

2.2.5 On the morphology of ore bodies

In the described deposits, ore bodies of three main forms are distinguished: cloak-like, round-elongated and ribbon-like. Cloak-like ore bodies with large sizes are characteristic of those deposits that are located in the middle of the ore-bearing section. Confining to the most dislocated layer of sandstones, they cover anticlinal uplifts, synclinal troughs and their wings. The main reserves of copper ores are associated with cloak-like ore deposits. The highest copper concentration and high ore body thickness are observed in the domed parts of gentle folds and on the wings of flexure zones. At the same time, most of the ore bodies in such structural regions are oriented by the long axis in the direction of incidence of the host rocks.

Round-elongated and ribbon ore bodies are small in size and are usually located closer to the soil and roof of ore-bearing horizons and on the flanks of cloak-like deposits, where the degree of dislocation of the rocks is relatively less pronounced.

2.2.6 Associated Minerals

There are no associated minerals at the East Saryoba field. The host rocks mined from quarries are partially used for the construction of quarry and access roads. As mining quarries, overburden rocks are planned to be used for intra-mine dumping and reclamation of disturbed lands.

2.3 The selection of the site for seismic research, target and geological tasks

The research site is located in the Karaganda region of the Republic of Kazakhstan within the Zhilandinsky group of copper deposits. A series of tectonic faults and minor explosive faults have been mapped at the fields. Ore bodies of deposits occur in accordance with the host rocks and have a stratiform, lenticular and ribbon forms. Their strike is latitudinal. Oxidized ores are emitted in the upper part of the section. Sulphide ores are distributed mainly to a depth of about 1 km.

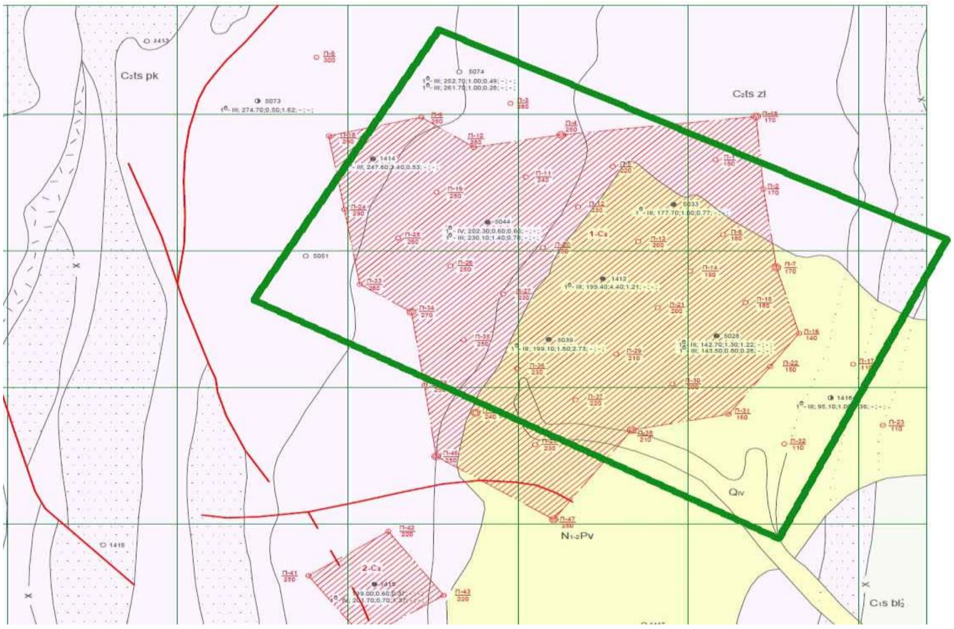

Figure 2.3.1 – Contour of a site for seismic research

The purpose of the work. On the basis of three-dimensional seismic exploration, to clarify the geological structure of the area designated for the study to a depth of 0.8 -1 km, highlighting and tracing the area of low-amplitude plicative (folded) and disjunctive disturbances.

The tasks of the work. Evaluation of the prospects of using high-density wide-azimuthal 3D seismic exploration for a detailed study of the geological structure of the section in order to study the ore-bearing horizons of the Beleutin Formation (C_1), the Zhezkazgan Formation of the Upper Carboniferous (C_2-$_3$dg) with a total thickness of 650-680 m and sand-clay deposits of the Taskuduk Formation of Middle Carboniferous (C_2ts) with a total thickness of 260 m:

- the formation of a seismic geological model of objects for the subsequent design of exploration drilling;

- structural mapping of ore-promising areas and a detailed study of deep-lying ore-bearing complexes.

3 Field observation technique and technology

3.1 Selection of an observing system

Typically, a seismic batch receives a program from the customer in the form of lines on a map that show where to get the data. The seismic party is generally not responsible for compiling the program. This circumstance sometimes leads to research failures, since it can give rise to a mood in which the goal of the work is not to obtain certain information, but only to formally execute a certain program. The lack of a clear understanding of the goals of the program may lead to the selection of an erroneous methodological solution among the possible options. It is good practice to "work out a program on paper" before starting field work. This helps to evaluate what kind of data it is desirable to print, to think over the problems that you may have to face, to discuss possible alternative solutions and how to obtain such data that will allow to avoid ambiguous interpretation.

Before starting reconnaissance, one should ask the question: "Is it possible to obtain the required information using the intended observation scheme?" For migration data transformation, it may be necessary that the profiles are located in a different way than directly through the vertices of the structures in order to correctly evaluate the true dimensions of the structure. Vaulted sections can be so badly broken that profiles through them will not give certain information. Search structures sometimes fall outside the resolution of the seismic method. The variability of the upper part of the section along the intended profile can be very large, which complicates the interpretation of the data, while moving the profile line even by a small distance will lead to a significant improvement in the quality of the data. Obstacles to blasting on a given profile can increase difficulties, which are easy to avoid if you slightly shift the profile line, which will achieve the same goals at a lower cost. Where the angle of incidence of the layers is significant, laying a profile through the wellhead will not provide the necessary alignment of ground seismic data and well observations. It may turn out that seismic profiles do not extend a sufficient distance beyond faults or other structures in order to confidently establish the presence of such structures in the section or to determine the magnitude of displacements for the fault case, the network of profiles should be planned so that it extends beyond the exploration area at a distance equal to depth target object. Profile lines can cross structures such as faults at such an angle that the presence of these structures on the record will be indistinguishable. Inadequate control over the intersections of the profiles can lead to the fact that recordings from structures lying under the profile line will be complicated by reflections from side structures located away from the profile.

3.1.1 The choice of the location of the points of generation and reception. Observing system design

After the preliminary operations are completed, the field batch breaks down into a breakdown of the profiles for which observations will be conducted.

For geodetic observations, a laser device is used. Using its upper part, measure the distance to the rail at distances up to 3 km with an accuracy of 6 mm. The coordinates and elevation of the points of explosion and the centers of the groups of receivers are usually determined using theodolite and measuring tape. A measuring tape is often a wire equal in length to the interval between groups of receivers. With the help of this wire, the centers of consecutive groups are marked along the profile and each center is marked with a symbol, most often a brightly colored plastic tape, called a flag. Theodolite helps to maintain the straightness of the profile and to exceed the center of each group of receivers due to the sight on the rail, which carries the worker in front with a measuring tape.

Currently, the use of electronic measuring equipment for seismic studies is expanding, which is based on measuring the travel time of a light beam (laser beam) from a theodolite to a rail and vice versa. This equipment is characterized by high velocity and high accuracy. The digital scale gives the distance, the difference in elevations and the direction, essentially reducing the probability of reading errors. Such equipment can be used to lay the reference network and to bind to triangulation marks and wellheads, even if it is not planned to use it to determine the position of all points of the explosion and the centers of groups of geophones.

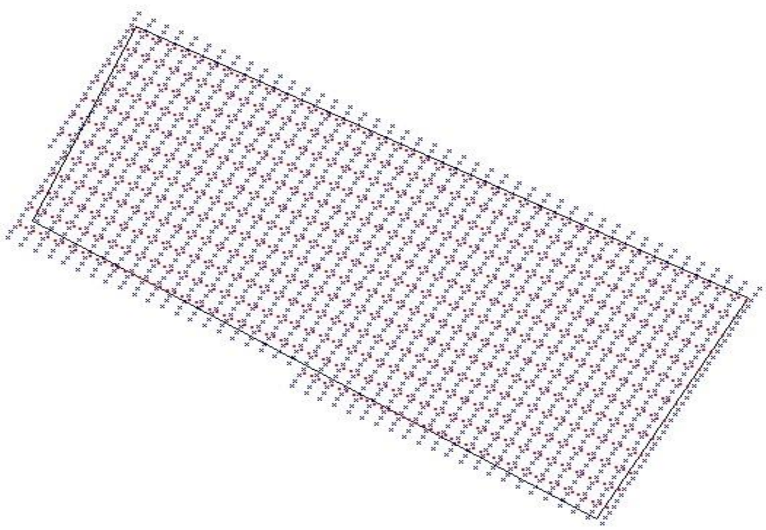

Fig 3.1.1.1 – 3D shooting design

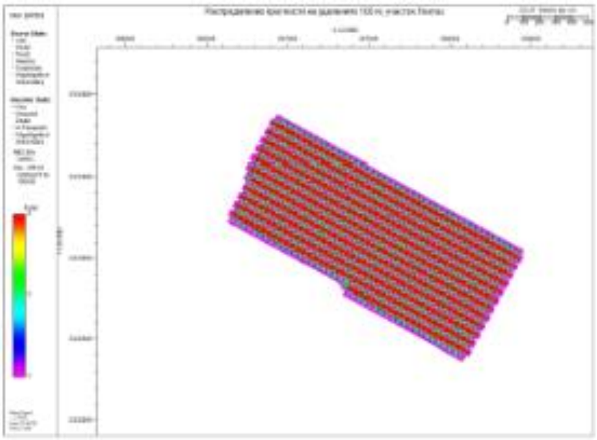

Fig 3.1.1.2 **–** Distribution of CDP fold coverage at distances of 100 m

Fig 3.1.1.3 – Distribution of CDP fold coverage at distances of 200 m

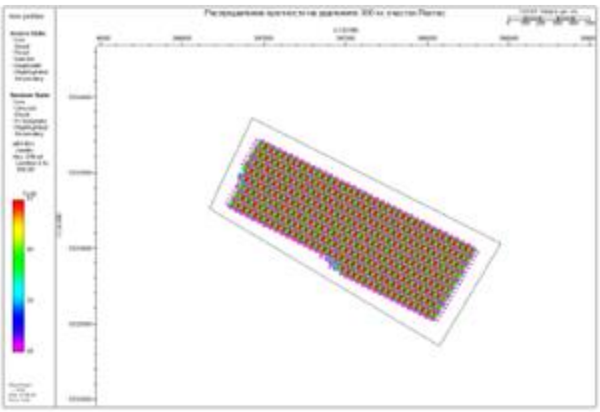

Fig 3.1.1.4 – Distribution of CDP fold coverage at distances of 300 m

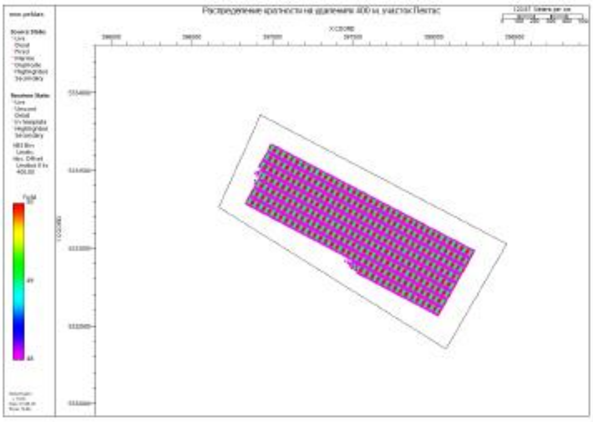

Fig 3.1.1.5 – Distribution of CDP fold coverage at distances of 400 m

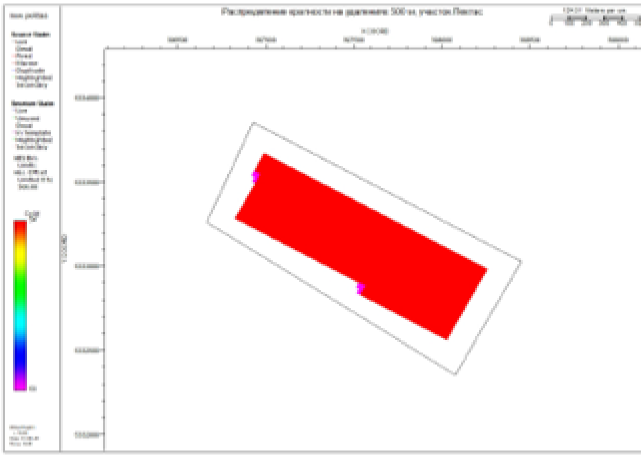

Fig 3.1.1.6 – Distribution of CDP fold coverage at distances of 500 m

Sometimes radio systems are used to control horizontal coordinates, especially in swamps and in shallow areas, where elevation can be controlled from the water surface level.

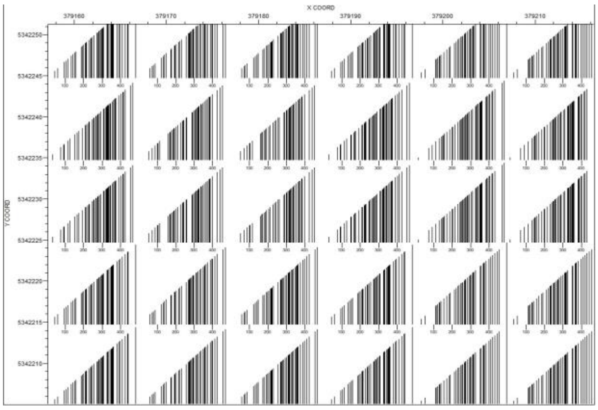

Fig 3.1.1.7 – Offset Histograms

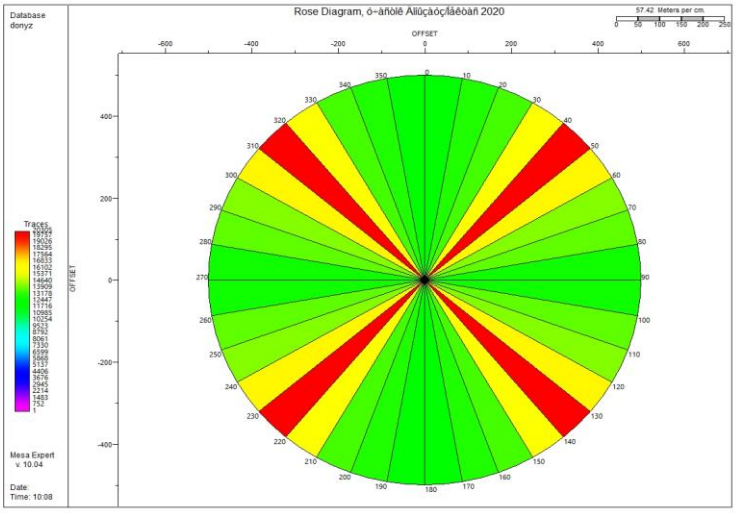

Fig 3.1.1.8 – Rose Diagram

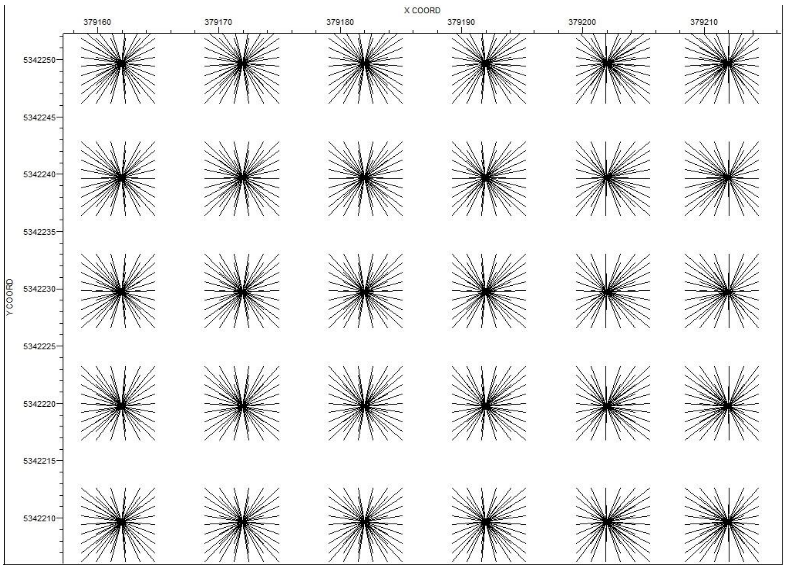

Fig 3.1.1.9 – Spider Diagrams

The topographer is obliged to indicate in his data and on the map the position of the most important objects, such as, for example, ravines, buildings, roads, fences, etc. In addition, he notes the available paths along which drilling equipment, seismic stations, etc. You can deliver the set points in the fastest way.

In impassable areas or in the case of dense vegetation, a team of road builders may be required. Such a team prepares the conditions for the work of the research party, and its activities are usually directly supervised by a topographer, who, therefore, is responsible for preparing straight-line glades in given directions.

3.1.2 Seismic sources and source parameters

The traditional way to generate seismic vibrations is to explode. For these purposes, seismic blast holes are drilled to a depth of 60 m (usually 10-15 m), where the explosive charge is laid. An explosive station is equipped with an generation synchronization system designed to synchronously launch a seismic station, produce an explosion and mark the moment of the explosion (generation of vibrations). Explosion is a relatively cheap and highly efficient source of seismic vibrations. The main disadvantages are its impossibility of repeated accurate reproduction of the source pulse, as well as the preservation of accurate time intervals between repeated explosive pulses. In addition, a special permit is required for the storage, transportation of explosives and the production of explosions. To some extent, non-explosive sources of oscillation are free from these drawbacks and have other advantages. When conducting seismic surveys on land, vibration sources (vibroseis) are widely used, which create pressure pulses in the rocks using a special metal plate with a frequency of 7-8 to 100-120 Hz. Due to the fact that the vibration source is mounted on a car, it is efficient, easy to use and allows you to get a well-known and reproducible signal. Typically, this source is used in conditions where explosions are impossible due to environmental conditions or safety requirements (the presence of pipelines, power lines, settlements, etc.). Less commonly used are pulsed generation sources. They generate acoustic impulses as a result of the discharge of a capacitor bank through an electrode system or a metal plate. In marine seismic exploration, air and water guns are used, which throw an air bubble or stream of water into the sea under high pressure (respectively, sparkers and boomers).

3.1.3 Seismic receivers and receiver array parameters

On the profile, in advance of the arrival of the seismic station, a streamer is pulled out and seismic receivers are installed. When working with single devices, they are installed in special pits with a depth of 20 cm to 1 m. The bottom of the pits is leveled to make good contact with the soil, when working with groups of receivers, each device is installed in a pit or inserted into the soil with a pin.

If the profile point where the seismic receiver (group) is to be installed is near trees, buildings, or other possible sources of interference, then the geophones are shifted to the side relative to the profile by a distance of 10-20 m. Each case of a pit offset from the profile line is more than 5 m should be noted in the field log of the operator. If there is any narrow obstacle on the profile line (swamp, lake, river bend, settlement, etc.), within which it is impossible to install geophones, pits are placed, bypassing the obstacle, along its border. The location of the pits should be depicted on the outline, which is attached to the field log of the operator.

The cables connecting the geophones to the station (streamers) are laid along the parking lot. Their unwinding and winding are usually carried out when the station or the winding machine moves along the profile.

Scythes should be placed somewhat away from the communication cable (at a distance of 10-15 m) in order to avoid creating interference on the line of geophones. To avoid communication between these circuits, it is necessary to carefully monitor the integrity of the insulation of the communication cable, streamer and the electrical circuit of the geophones. At the same time, with the unwinding of the streamers during the movement of the station or the winding machine, seismometers are unloaded from it. If it is impossible to drive along the profile, unwinding and winding the braids are done manually.

When unwinding the braids while driving the car, you must follow the safety rules. Simultaneously with the unwinding of the braid, the workers of the seismic team carefully install the seismic receivers. All devices must stand vertically and be equally oriented along the profile. After installing the receiver, it is attached to a cable or braid. Seismic sensors should be numbered: the same channel of the station is always recommended to attach a single geophone or a group.

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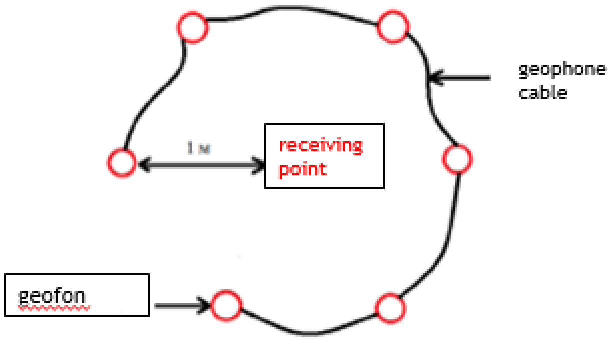
When grouping geophones, the work proceeds in a similar manner. The center of the group is located near each dig, and the pits for the geophones are symmetrical about it, at equal distances between each other. The seismic receivers are connected to the cable with special additional wires.

3.1.4 Seismic recording systems and recording parameters

Drilling operations are followed by registration of explosions. The participants are divided into three groups depending on the main functions: the explosive team is responsible for loading explosives into the borehole (if it was not loaded by drillers) and blasting dynamite; auxiliary workers unwind the streamers, install geophones at the rear points and connect them to the seismic streamers; The seismic team directly records the signals.

Ancillary workers lay out the streamers and connect the seismic sensors to them, the operator checks and adjusts the amplifiers and other blocks of the recording system and checks the correct operation of the streamer to make sure that all the geophones are connected. Then he gives the detonator a signal by phone or radio to undermine the charge (the device used to detonate explosive charge) by turning it off for safety and informing the operator of its readiness for work. Then the operator presses the battle button, as a result of which the buzzer is turned on and the recording system is started. A series of encoded signals sent by recording equipment undermines the charge. The blasting machine transmits back to the recording equipment a signal about the moment of the explosion (time stamp). The data is recorded, and the operator views the record to make sure that it is free of visible defects, after which the equipment moves to the next point of the explosion.



3.1.4.1 – Placing a group of geophones

In the case of registration using the common depth point method, the explosion points are located close to each other - with an interval of 100 to 400-500 m in the usual symmetrical arrangement. The high productivity and work efficiency necessary to achieve a low cost per kilometer profile left their mark on field procedures. At the same time, the overlap redundancy reduced the significance of each individual record, so the random skipping of individual records became acceptable. In addition, the wide dynamic range of digital recording from the part eliminated the need for filtering in the field and adjusting the equipment to the local conditions.

Cost considerations dictate the requirement that the registration process not impede other procedures. Field experimental work is carried out in the shortest possible time, and it is not possible to spend time on repeated explosions to improve recording quality or on frequent physical movements of seismic recording equipment. Blast holes can be drilled along the entire profile before the registration of vibrations begins, so that the operator never waits for drillers. Members of the seismic team lay out and check the spare streamers and geophones. Due to the channel switch, the recording unit may not physically be in the place where it is connected to the electric power supply. The registration unit is connected to the seismic streamer in any convenient place.

The channel switch allows you to connect the necessary geophones, after which the explosives are instructed to cock the explosive machine. After the explosion, the detonators move to the next blast hole (which is not too far away), and the operator sets the channel switch so that the next arrangement of geophones is connected. The interval between explosions can be only a few minutes, and the seismic station remains in place for the whole day. The wells in which the failure occurred are not loaded again with explosives, and the explosions are not repeated. The recording unit does not move along the profile and, therefore, is least exposed to possible damage. Due to the fact that less equipment is transferred along the profile, the damage to the surrounding area is reduced. Thus, in addition to increasing the efficiency of registration, additional savings are achieved. If surface sources of vibrations are used during seismic operations, they are installed at a given point and at a certain time, by the signal of the operator, begin to radiate energy to the earth. Despite the fact that the explosive is not always used, the terms “explosion” and “explosion point” continue to be used. The energy emitted by each surface source is usually small compared with the energy from the explosion of an explosive charge, therefore, many records are made at each point of the explosion and then they are summed in phase to obtain one record.

3.2 Technical means. Apparatus and equipment

SCOUT's cordless geophysical information gathering system is based on the use of standalone zero modules with built-in solid-state memory. It consists of an autonomous field recorder of seismic signals, a data acquisition and generation system, as well as auxiliary equipment (chargers, network equipment).

When discussing cableless telemetry seismic recording systems in well-known publications, the main attention is paid to the opening possibilities of studying hard-to-reach areas, territories of settlements, and gaining financial, technological, and environmental areas. The implementation of the potential methodological advantages over cable systems is of no less practical importance. First of all, this refers to the possibility of expanding the range of technical and methodological techniques used by seismic scouts. Let us dwell on the discussion of some of them. The use of cordless systems involves recording vibrograms using vibration sources of seismic vibrations. The procedure for the correlation conversion of vibrograms is transferred from the field to the cameral stage. This is of particular importance in the development of fundamentally new seismic technologies based on the principles of multi-level, adaptive and non-linear seismic exploration, which allows you to save the maximum possible amount of information for analysis. As a result, a more complete information base is provided for solving methodological problems aimed at expanding the dynamic range, the resolution of seismic records, the depth and geological information content of studies.

3.2.1 Recording equipment parameters

Cordless technology provides the ability to layout arbitrarily complex interference systems, laying both straight and curved lines of profiles in any direction, and much more. Working with an unlimited number of channels while ensuring high-precision time synchronization can give impetus to the large-scale introduction into practice of geological exploration of the long-discussed highly promising “total” seismic exploration when it is required to cover large, including hard-to-reach areas with a dense network of receivers.

The recorder contains a channel with 24-bit digitization, an integrated highly sensitive GPS receiver, a clock generator, an integrated test signal generator, non-volatile memory with a capacity of up to 32 GB and a high-speed ETHERNET port for data transfer. If the GPS signal is lost, the clock can keep accurate time for 2 hours.

The decrease in the level of interference when registering by cableless systems is also of great practical importance, since seismic streamers create the effect of a "cable wave" and increase the level of microseisms, and the radio channel increases the level of electromagnetic interference. Wireless systems can also play a significant role in solving very urgent problems at present - conducting seismic work in water areas and matching the received data with the observational data on land. In order to increase the efficiency of solving these problems, the developers of the SCOUT system provided the possibility of its work with both geophones and hydrophones. Moreover, the type of seismic sensor is taken into account automatically upon agreement with the input of the recording device.

Almost unlimited recording length, this provides the possibility of a detailed study of the stationarity and dynamic characteristics of the random wave field in order to optimize the parameters of field interference systems, as well as the implementation of passive seismic acquisition techniques, including those with direct search tasks.

The immediate prospects for the widespread introduction of cableless registration systems in the practice of seismic surveys are likely to be related to obtaining more accurate information about the upper part of the section (UPS). For example, a detailed study of the UPS can be provided by supplementing the basic observation system of the General Deep Point Method by arranging autonomous field recorders of seismic signals with small (from 1 to 5 m) variable distances between channels. With only 16 three-channel modules, it is possible to implement full-fledged shallow observations of the Method of Refracted Waves to obtain systems of catch-up and counter hodographs. The small distances between the channels will allow the processing and interpretation of the records of the first entries traditionally used in shallow seismic exploration methods with the construction of a detailed velocity model necessary for calculating static corrections.

The composition of the cordless system:

- The on-board complex consists of a data management system including: a control computer with software, a synchronization unit and auxiliary channels, an inverter of a supply voltage of 12V / 220V.
- The ground complex consists of a wireless standalone recorder.
- A field data collection control module that includes a tablet.
- Battery charge module with charger unit.

3.2.2 Sources

Before the falling load began to be used around 1954, explosives were the only source of energy for seismic surveys. Although explosives are a more dominant source, they continue to be a widespread method of exciting seismic energy when working on land.

Two types of explosives are mainly used: gelatin dynamite and ammonium nitrate. The first is a mixture of nitroglycerin and nitro cotton (which forms explosive gelatin) and an inert material that binds the mixture and with which you can change the "strength" of the explosive. Ammonium nitrate is cheaper and less dangerous because it is harder to detonate than gelatin dynamites. Ammonium nitrate and nitrocarbonitrite are the most common explosives that are currently used (in the form of Nitramon). Other types of explosives are sometimes used.

Explosives are packed in briquettes or cardboard or plastic tubes with a diameter of about 5 cm, which usually contain 0.5-5 kg of explosives. Tubes or briquettes are designed so that they are easy to connect with the ends, thus obtaining explosive charges of various sizes.

The detonation velocity (i.e., the velocity with which an explosion propagates from the point of generation throughout the volume of explosives) of explosives used in seismic exploration is high and amounts to 6-7 km / s: therefore, the excited seismic pulses have a very steep front along compared to other energy sources. Such a high concentration of energy is desirable from the point of view of seismic wave analysis, but at the same time it is harmful from the point of view of damage to surrounding rocks.

To initiate an explosion, electric detonators are used. They are small metal sleeves having a diameter of approximately 0.6 cm and a length of about 4 cm. They contain a wire with high resistance, immersed in a explosive charge that is crushed into powder, which quickly ignites. Using two wires extending at the end of the sleeve, a strong current is passed through the wire with high resistance, and the heat generated in this case causes the powder to ignite, which leads to an explosion of explosives in the detonator capsule. Previously, the detonator capsule is placed inside one of the explosive charges, so that undermining it leads to the explosion of the entire charge.

To initiate an explosion in a charge of ammonium nitrate, initiating militant charges are usually required. These are briquettes of a more powerful explosive, which are used as elements in compiling a full charge. The detonator is placed in an opening at the end of an action movie to excite it.

The current that causes the detonator capsule to explode comes from an explosive machine. The latter is essentially a device for charging a capacitor to a high voltage using either battery batteries or a hand-held generator and then discharging it at the required moment through a detonator capsule. An explosive machine is connected to a device that generates an electrical impulse at the moment the explosion occurs. This impulse captures the moment of the explosion f - 0. The moment of the explosion is transmitted by telephone line or by radio recording equipment, where it is recorded along with seismic data.

A number of methods are used to concentrate the energy propagating down from the explosion. The detonation front in an explosive propagates, as a rule, much faster than a seismic wave in a rock. Therefore, the seismic wave formed in the upper part of the long charge lags behind the wave generated at its lower boundary, even when the explosive charge is detonated from above (which is usually done). Sometimes explosives with a low effective detonation velocity are used; such explosives are usually placed in flexible long tubes that are difficult to load into wells. In some cases, delay blocks are placed between a set of concentrated explosive charges to enable the wave in the rock to catch up with the explosive front. They may contain delayed detonators (which introduce a fixed delay between the moment of detonator capsule explosion and the main charge explosion) or they can use a spiral detonating cord (so that the detonation front goes a longer distance). Single-shot impact fuses are also used; they detonate when they are activated by a shock wave from another explosion.

Although explosives are compact sources of high energy, they have many disadvantages that often impede their use: high cost; time and costs associated with drilling wells.

Currently, many diverse sources of energy have been created for work on land and at sea. Consideration of those that are mainly used at sea and quite rarely on land.

All, without exception, surface energy sources have less power than explosive ones, and their widespread use has become possible thanks to accumulation methods that allow you to add up the effects of a large number of weak pulses in order to obtain the desired result. There is a possible technique for grouping surface sources.

The very first non-explosive source to be widely used was the shock source, tamper, or falling load. This method was developed primarily by McCollum Geophysical. A rectangular steel plate weighing about 3,000 kg was dumped from a height of about 3 m. The moment of impact was recorded by a sensitive element on the plate. Usually the load was dropped every few meters and the results of 50 or more strokes were combined into one field record. The time interval between the release of the load and the impact of it on the ground is not constant enough to be able to use several drum sets at the same time. Currently, the use of impact sources is limited to areas of deserts or semi-deserts where massive trucks can move relatively easily.

Unlike other energy sources that are designed to release energy into the earth in the shortest possible time, the vibroseis source emits energy to the earth within a few seconds.

A geophone converts seismic energy inputs (or vibrations) into electrical voltage which can be accurately measured.

A vibrator – track generates seismic vibrations which are received by geophones. Usually used several vibrators, it depends on parameters of acquisition.

Fig 3.2.2.1 – Equipments

The control signal causes the vibrator (usually hydraulic) to transmit alternating pressure to the steel plate, pressed against the ground by the weight of the truck. vibroseis sources give low energy density; as a result, they can be used in cities and other places where the use of explosives or other sources would cause serious damage. Currently, vibroseis is used in almost one third of land seismic surveys.

3.2.3 Seismic Receivers

Seismic receivers are designed to convert mechanical vibrations of the soil into electrical vibrations. In ground seismic exploration, receivers with induction converters are used; in marine seismic exploration, mainly piezoelectric receivers are used.

The first electromechanical seismic receiver was designed by B. B. Golitsyn in 1906. The main parts of his device are preserved in modern designs. Each induction seismic receiver has the following main parts: body, inert mass, spring, attenuation device, and electromechanical converter.

An inert mass is connected to the body of the seismic receiver using one or more springs and can move relative to the body. Therefore, when the body of the seismic receiver, mounted on the surface of the earth, vibrates with the soil, the inert mass due to inertia moves relative to the body. These relative movements of the inertial masks are used to create a varying voltage.

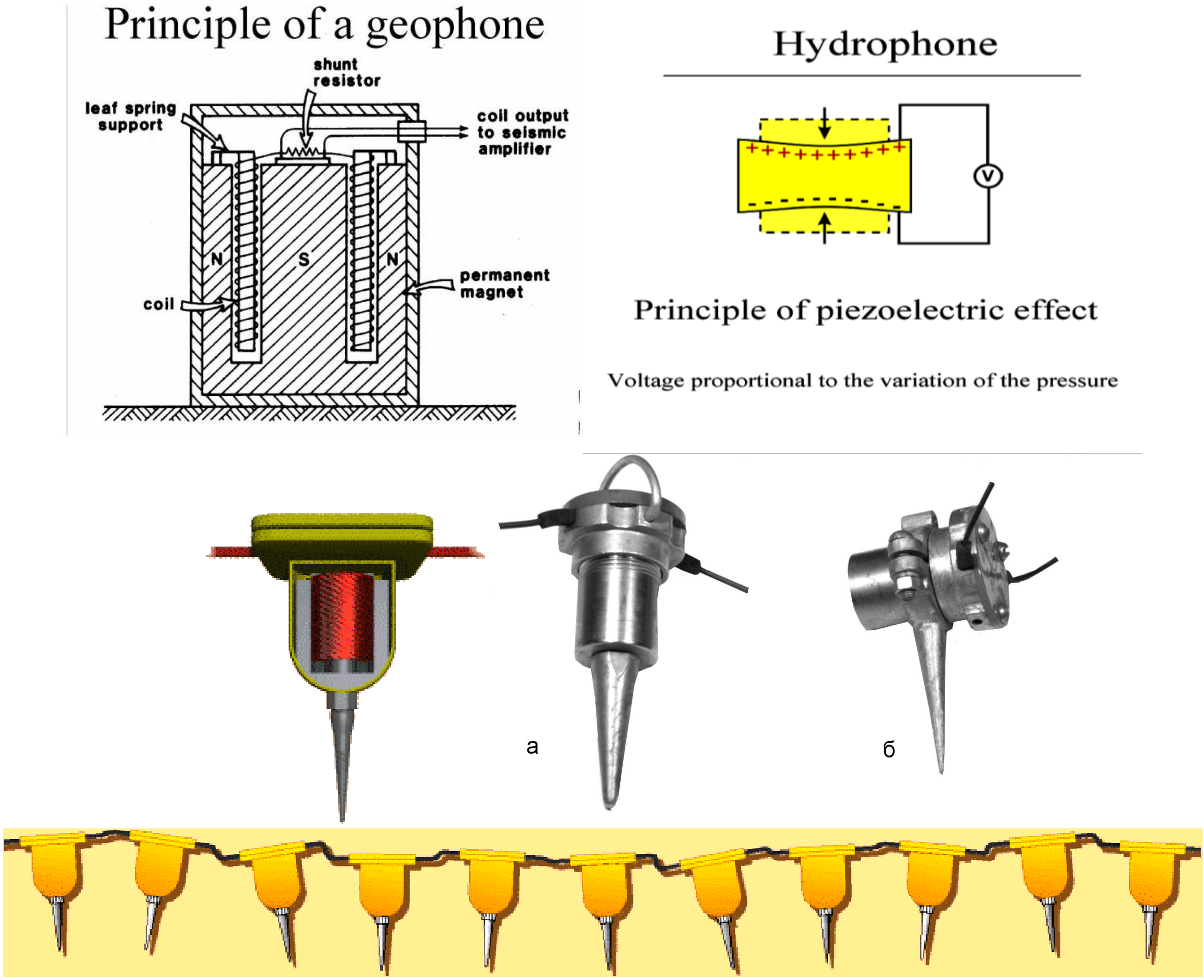


Fig 3.2.3.1 – Geophones

If the inert mass suspended on springs from the body of the geophone is removed from the equilibrium position and left to itself, then for some time it will oscillate around its equilibrium position. These are free (or intrinsic) vibrations of an inert mass. Thus, the inertial mass displacements relative to the body are made up of two components: 1) forced vibrations caused by soil movement; 2) free vibrations. The latter depend only on the properties of the seismic receiver. Since seismic exploration examines the movement of the soil, the free vibrations that are superimposed on the forced vibrations are an obstacle that should be eliminated as far as possible. To reduce the duration of free oscillations, the seismic receiver is equipped with a device that causes attenuation. Such a device is called a damper.

To convert mechanical vibrations into electrical vibrations in most domestic geophones, the phenomenon of electromagnetic induction is used, and geophones are equipped with electromechanical transducers of various designs. The converter is connected to the receiver in such a way that its moving part (for example, a coil) is. part of the inertial mass of the seismic receiver, and a fixed one (for example, a permanent magnet) is rigidly connected to the body. With such a device, the inertial mass relative to the housing will inevitably cause an alternating voltage to appear at the poles (coil) of the converter.

In modern geophones, two main types of induction transducers — electromagnetic and electrodynamic — are used. The former are characterized by a significantly greater weight of inert mass and somewhat greater sensitivity than the latter. In addition, in marine exploration and for some types of observations in wells, seismic receivers with piezoelectric transducers are used. In geophones with electrodynamic transducers, electromagnetic damping is used to create attenuation. When the coil oscillates, induction currents form in it, which, by the Lenz rule, interacting with an external magnetic field, tend to slow down these oscillations. Since an inertial mass can be made small with an electrodynamic transducer, the effect of weak induction currents is sufficient to create the proper attenuation.

The seismic receivers are installed on the profile at equal distances from each other. Distances are chosen at which one can confidently trace the same phases of the useful waves on adjacent tracks on the tape. The possibility of phase tracking depends on: 1) the difference in the arrival time of the reflected (or refracted) wave to two adjacent geophones; 2) the visible period of the recorded reflections or refractions; 3) the ratio on the record of the amplitudes of the useful waves and interference recorded simultaneously; 4) the degree of repeatability of the recording form of useful waves on adjacent tracks.

3.2.4 Accessories

Amplifiers

Excluding the reaction to shortly after the moment of the explosion, the output signal of the geophone is too weak to register it without amplification. In addition, the amplitude range of the useful signals at the output of the seismic receiver extends from a few tenths of a volt at the beginning of registration to about 1 μV at the end of registration several seconds after the explosion (signals weaker than 1 μV are lost in the instrument noise). Thus, the relative change, or dynamic range, is about 105 (100 dB). Therefore, in addition to the task of amplifying weak signals, the amplifier still usually has the goal of compressing the range of recorded signals. In addition to this, amplifiers are used to filter the output signals of the geophone in order to amplify the signal relative to noise.

In seismic amplifiers semiconductor devices are usually used, which makes it possible to make them very compact. Usually they are mounted in a seismic station or on some other vehicle, but if necessary, they can be transferred manually.

The gain of the amplifier changes during the recording interval, starting with a low value in the initial part of the recording, where very strong signals are suitable for the receivers, and ending with a high value fixed by the switch position. A time-variable gain (dynamic range compression) can be achieved using automatic gain control (AGC). It is performed using negative feedback in a circuit that measures the average level of the output signal within a short time interval and selects a gain that keeps the amplitude of the output signal more or less constant regardless of the level of the input signal. If the time delay between the change in the amplitude of the signal and the subsequent change in gain is too small, the amplitude of the oscillations at the output will be almost constant and the reflected waves will not appear on the record; if this time interval is too long, subsequent reflected waves will not be detected at a long recording time. Information about the amplitudes of the oscillations will be lost in both cases. The use of AGC was widespread until the 60s, and it still continues to be used, especially when printing information.

To calculate the amendments for LWL, it is important to be able to correctly register first arrivals, i.e. times of the first energy approach to geophones. (To the receivers located near the point of explosion, the first waves are approximately along straight-line paths connecting the point of explosion and the receiver; the head wave refracted at the bottom of the LWL is the first to approach the remote receivers. If you turn on the AGC to adjust the gain before the first arrivals, the input signal is low (which is entirely determined by noise) will lead to a very large gain; then the output will record noise amplified to such an extent that it will become difficult to accurately determine the moment of approach of the first arrivals. and the problem is solved by using the initial attenuation of the gain level (or suppression). A high-frequency signal (about 3 kHz) is introduced into the AGC circuit, which leads to a decrease in the gain so that the noise becomes hardly distinguishable. In the future, the high-frequency signal is eliminated by filtering, and, therefore, in the output signal it does not appear.

3.3 Field methodology

According to the field methodology, the following types of work were carried out on the site:

1) Topographic and geodetic knowledge
2) Installation of geophones on (SP and RP)
3) Drilling and blasting
4) Experimental seismic work
5) Uphole survey of wells

3.3.1 Topographic and geodetic works

The implementation of topographic and geodetic work to create a survey justification with the laying of geodetic signs and benchmarks using GPS Leica SR 530 (5 receivers) on the site includes:

1. Collection and systematization of materials
2. Conducting reconnaissance work
3. Carrying out in kind and fixing on the ground corners of the site.
4. Creation, condensation (observation) of the reference geodetic network.
5. Computer processing of observation results.
6. Breakdown of profiles (RP and SP).
7. Transfer of materials and a report on the work performed.

The methodology and accuracy of topographic and geodetic works are determined in accordance with the requirements of the "Instructions for topographic and geodetic support of geological exploration" -1984 and the "Instructions for topographic surveying on a scale of 1: 500 - 1: 5000 and CN and R of RK 1.02 - 18 - 2004 ., conventional signs for topographic plans on a scale of 1: 500 - 1: 5000 of the 1989 edition

The conventional coordinate system and the Baltic altitude system were used.

Creating a reference geodetic network

At the site, the topographic and geodetic contractor designed and surveyed the geodetic reference network to include the two nearest SGN sites and two ground crossings.

The resulting support network is presented in the form of triangles with the inclusion of points: (452.1; 433.9; 396.3; 407.6)

The core network was observed using four Leica SR 530 receivers (s / n 0037545, 0037598, 0037504, 0037583), in Static mode with post-processing. The observation period at each designated point was at least one hour.

When performing GPS observations, each ground-based data collection system consisted of an antenna on a support, a receiver (recording device), and a field log. Each of the available GPS receivers is designed for the recording velocity of one observation every fifteen seconds.

Arriving at the reference sign (the point of the survey justification) for the purpose of conducting observations, the team consisting of a surveyor (surveyor technician), worker (measurer), driver, unloaded the equipment. Further above the point, the point of the survey justification, a GPS antenna was installed, which was brought to the “working state” (centered, brought to the horizon). When installing the antenna, its height was measured at least twice, the average result with rounding to a millimeter was recorded in the log.

GPS Profile Breakdown (RTK / OTF)

Using the GPS complex Leica SR530 for the breakdown of profiles - a team (taking into account the personnel of the base station) consisting of two topographers, three workers (gauges), two drivers, arriving at the reference point, unloads the equipment, launches the base GPS station. Then, using a mobile GPS receiver, the surveyor, as he walks along the profile line, carries out the removal of points with a specified interval (picket) from the calculated coordinates of the outgoing pickets with saving the observation results to the drive controller. Every 0.2 seconds, the mobile receiver determines its location relative to the base station and displays it on the screen of the drive controller.

The surveyor, visually assessing his position on the screen relative to the true location of the picket (the center of the circle on the screen), aligns the center point of the screen with the displayed location of the antenna. The future position of the picket on the ground is corrected by moving the milestones with the GPS satellite antenna in one direction or another.

The surveyor at the moment of aligning the center of the circle on the screen with the position of the satellite antenna displayed by the point gives the workers a command to fix the location of the stake to be taken out with a wooden stake, then fixes (writes) the coordinates of the location of the stake point to the controller.

The maximum distance of mobile receivers operating in the “RTK / OTF” mode from the base station is 5-8 km.

Computer processing of breakdown results

Processing of data obtained in the process of GPS observations was carried out in software products TGO (Trimble Geomatics Office) TBC (TRIMBLE Business Centre), GPS survey 2.2, 2.35. To calculate and equalize the reference network, we used the coordinates of the triangulation points (from previously performed work in the field) available on the site.

In the same software products, the coordinates obtained as a result of GPS observations were recalculated into the WGS 84 system.

3.3.2 Arrangement of receivers. Grouping of geophones

The seismic receivers are mounted vertically and buried for tight connection with the ground. Previously, at each picket, the snow in the places of installation of geophones is cleared.

Figure 3.3.2.1 – Installation process of geophones in SP

Table 1 − Reception Group Options

	Name of parameters	Value
	Number of devices in group	6
	Number of devices in section	3
	Number of sections in group	2
	Type of geophones SG-10 10Hz	SG-10 10Hz
	Base group reception	6
	Distance between neighboring	1m
	Reception group center	At the picket
	Polarity of SEG normal geophones	SEG normal

3.3.3 Generation of seismic vibrations. Drilling work. Imploding works

Table 2 - Registration options

№	Parameter name	Value
Registration options		
1	Recording length	2 sec
2	Sampling interval	0.001 sec
3	Bass filter	Off
4	HF filter	0.8 Nyquist frequency
5	Amplification factor	12 dB

6	Correlator/summer	
7	Media type	RAID recording drive 2TB array
8	Recording format	SEGD 8058

Table 3 − Generation Parameters

Explosive source:		
	Charge Depth	От 5 to16m
	Charge weight	0,125кg
	Electric detonator	EMF-1
	Explosive	Petrogen

Drilling works

Blast holes are drilled by URB-2KGK-100 and URB-2A2 machines using a pneumatic shock method of drilling.

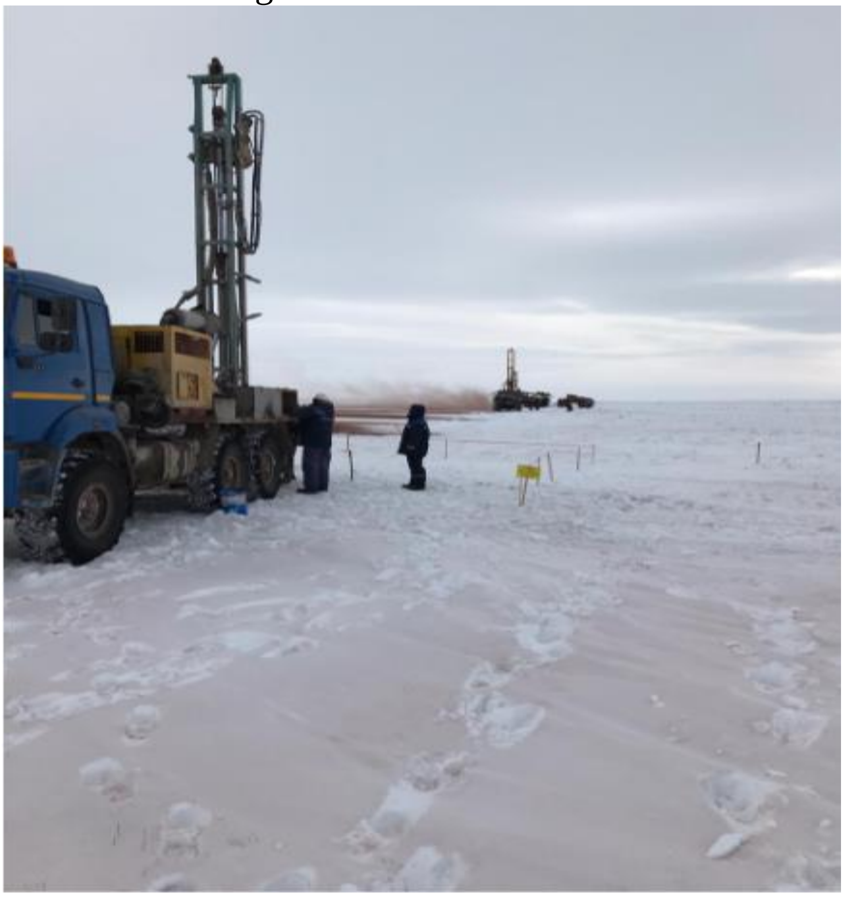


Figure 3.3.3.1 – Drilling of a well under an explosion at a SP

Imploding works

Blasting operations are carried out by a specialized detachment under the leadership of the Person responsible for explosive blasting in full compliance with the rules adopted in the Republic of Kazakhstan, Industrial Safety Rules for blasting operations.

Charges are placed at the approved optimum depth. Immediately before immersion of the charge, the depth of the well is checked by a template, the charge is lowered only after the correspondence to the required depth is established. Blast holes are sealed with drill cuttings.

When registering seismic data, a vertical time device must be used, installed near the wellhead in undisturbed soil.

Below are illustrations of the importance of the correct charge depth. Amplitude-frequency spectra show RF energy gain.

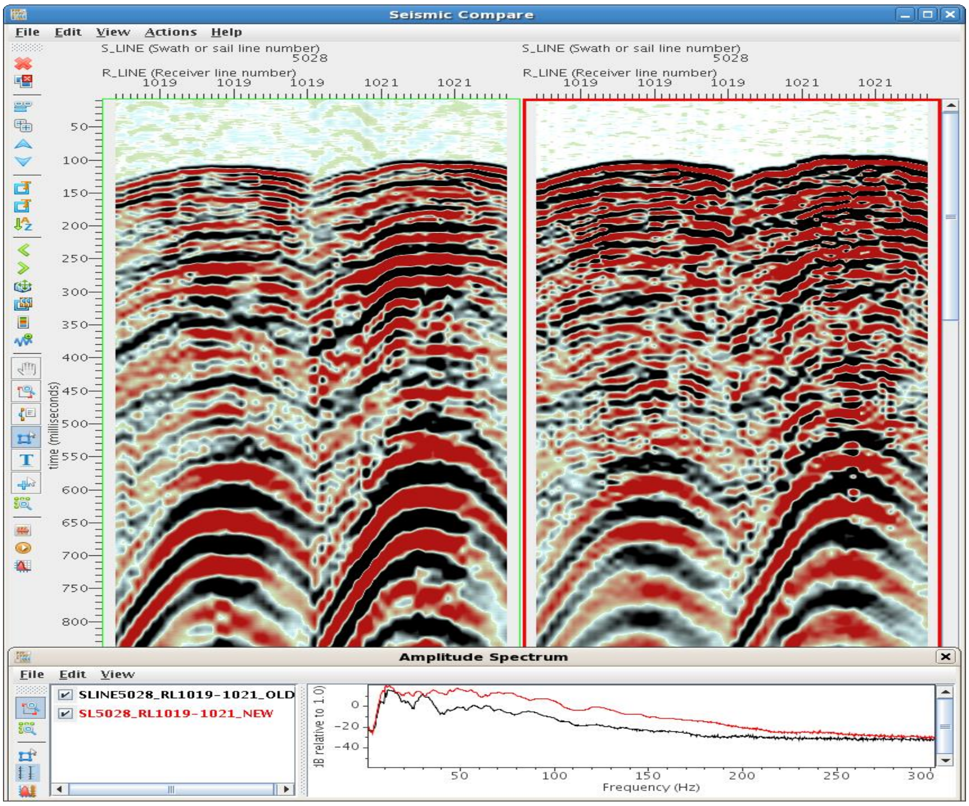


Figure 3.3.3.2 – Optimal and non-optimal burial charge in the well

Liquidation work is carried out in the course of work, after the well is shot by filling the wellhead with drill cuttings and collecting the ends of the end wires.

3.3.4 Experimental seismic work

The experimental work program provides for testing at shot points (SP) of various depths of the charge and various charge weights. Considering significant changes in the geological structure of the upper part of the section, experimental work was carried out from two points of generation with different geology in the upper part of the section.

During the experimental work, we used data on three uphole surveys obtained by the inverse method (detonators in the borehole, receivers on the surface). Two detonator arrangements were tested:

• Uphole survey-01 (depth 32 m.) - step of the detonators in the garland = 2 m (32-30-28, etc.)

• Uphole survey-02 (35 m.) and Uphole survey -03 (23 m.) - to a depth of 11 m. The step of the detonators in the garland = 2 m (35-33-31, etc.), then 1 m. (11 -10-9 etc.)

Analysis of the recording spectra at different depths, as well as comparison with the lithological description data, made it possible to determine the optimal response at depths of 15-17 m. It was taken into account that at uphole survey -01 the boundary between the weathering crust and bedrock was at 15 m. This interval was taken as minimum and reference for further tests on the depth of the charge.

Then at uphole survey -02 (the center of the square) two series of control shootings were carried out. The first series was the choice of the optimal depth of production blast holes. The second by definition of the mass of explosives.

For this purpose, LP 1001-1035 were spread out and worked out in the vicinity of the uphole survey position for 2 groups of wells - to a depth of 10-15-20-27m and to a mass of explosive charge of 62.5-125-250-500g. The mass of the charge was determined from the parameters of the mass of the whole piece = 250 g in order to conveniently divide into equal masses of charge.

According to the results of experimental work and uphole survey data, a charge mass of at least 0.125 kg is taken. The depth of well drilling during the opening of bedrock, penetration through bedrock is 1-1.5 m. If the bedrock is not opened, at the entrance to the clay weathering crust along the bedrock, a penetration of 5-8 m.

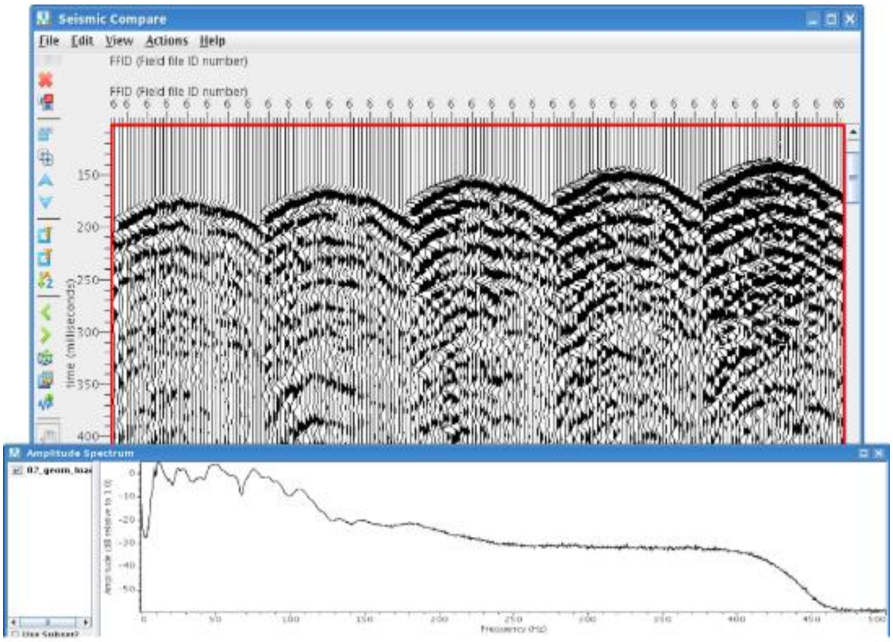


Figure 3.3.4.1 – Well depth tests. Depth 10m

3.3.5 Methodology for studying the upper part of the section. Uphole survey of wells

Studying the top of the section

The study of the velocity characteristics of the upper part of the section (low-velocity zone - LWL) for calculating the state corrections was carried out using well uphole survey. Uphole survey data was also used to determine the optimal depths of the charges, in connection with which reverse uphole survey was used. Drilling operations were carried out by a drilling rig URB-2A2 with a description and construction of geological columns for wells uphole survey. The SCOUT seismic station was based in an UAZ car.

Discretion - 1 ms, open channel. Generation step - 2 meters, starting from the bottom of the well. Signals will be recorded on one channel from three paralleled and previously tested for the identity of geophones installed by a triangle with a side of 10 cm in 1 meter from the wellhead.

Explosions in the well will be carried out using a garland of EMF detonators with a distance of 2 meters between them. Before lowering the garland of detonators, the depth of the well is measured with an accuracy of 10 centimeters and the length of the garland is adjusted. After the garland is lowered into the well, the well becomes clogged with fine dry sand. After that, a consecutive shooting of the shotgun in the well starting from the bottom will be made.

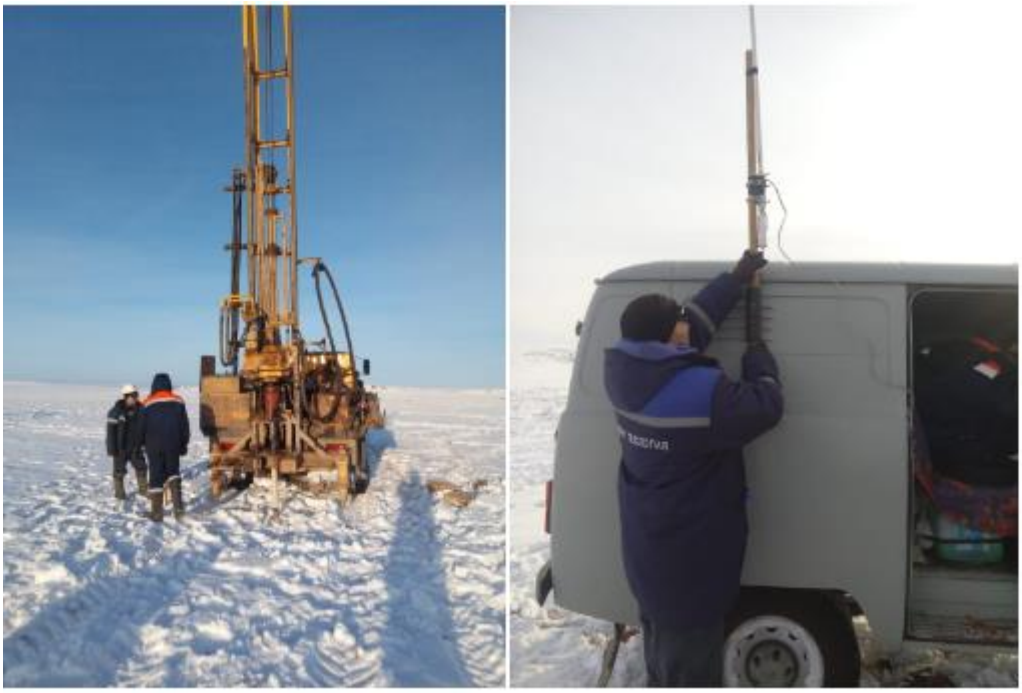


Figure 3.3.5.1 – URB-2A2 Drilling rig and uphole survey station

When drilling uphole survey wells, a leading geologist was located at the site of work, who provided geological documentation for the well. Based on the results of well drilling, passports were compiled.

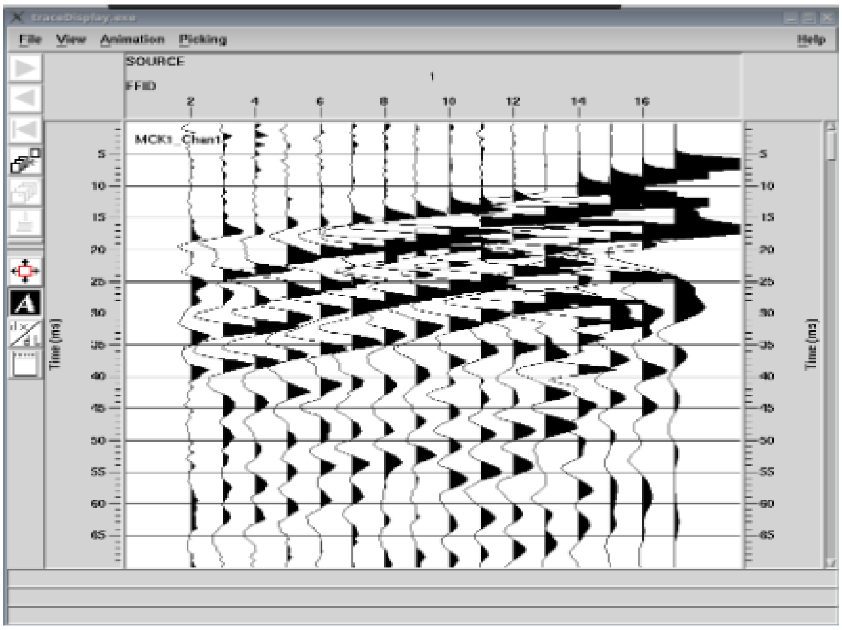


Figure 3.3.5.2 – Uphole survey seismogram

4 Seismic data processing

Time area of the data processing is performed on the processing complex of SeisSpace-5000.0.3.1 (Landmark) system.

3D seismic survey was performed for the purpose:

– study of geological structure in Zhezkazgan ore district of the horizons with total capacity of 650-680 m;

– forecasting of ore spreading zones based on the analysis of seismic attribute calculation results;

– extraction and mapping of ore-containing structural objects.

4.1 Source data analysis

The data received for processing were converted from the SEGD -8058 format to the internal SeisSpace format, and the project database was created using SPS files and trace headers were assigned geometry. Fig. 4.1.1 shows the area map.

The obtained field material is complicated by various interferences: regular low-frequency and irregular, and high-frequency. Almost on all seismograms there is a "courg" of low-frequency waves - interferences. Amplitude overload in the zone of channels close to the point of explosion is observed at all points. At most of the points of explosion the presence of low-frequency interferences (10-20 Hz) is observed. A multiplicity map of the area is shown in Figure 4.1.2.

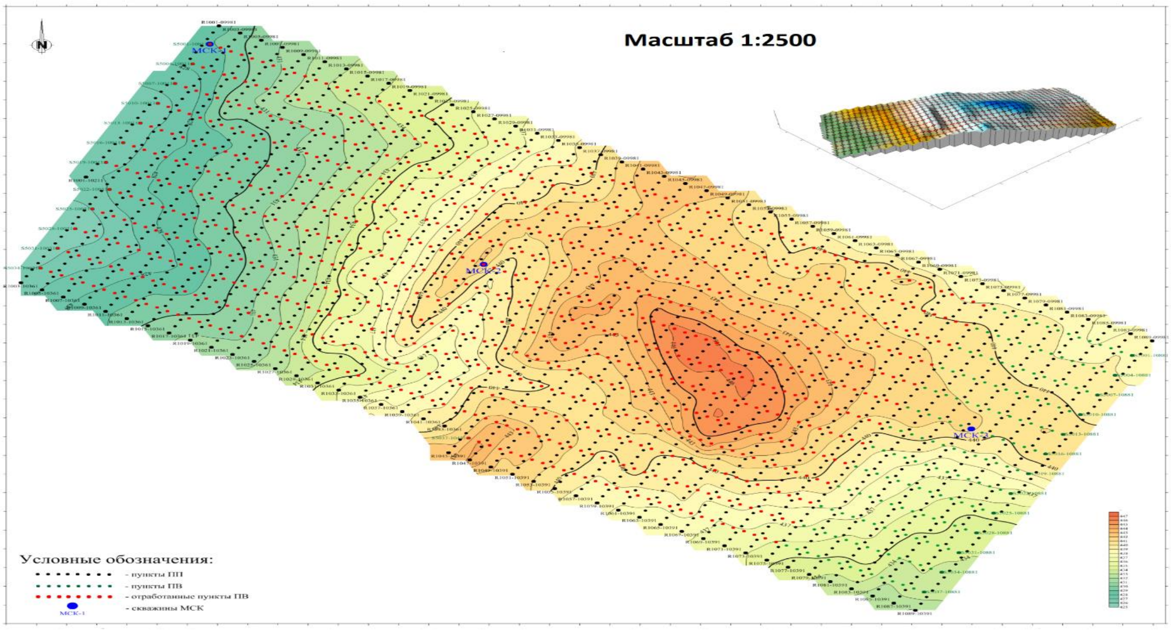


Figure 4.1.1 – Area map

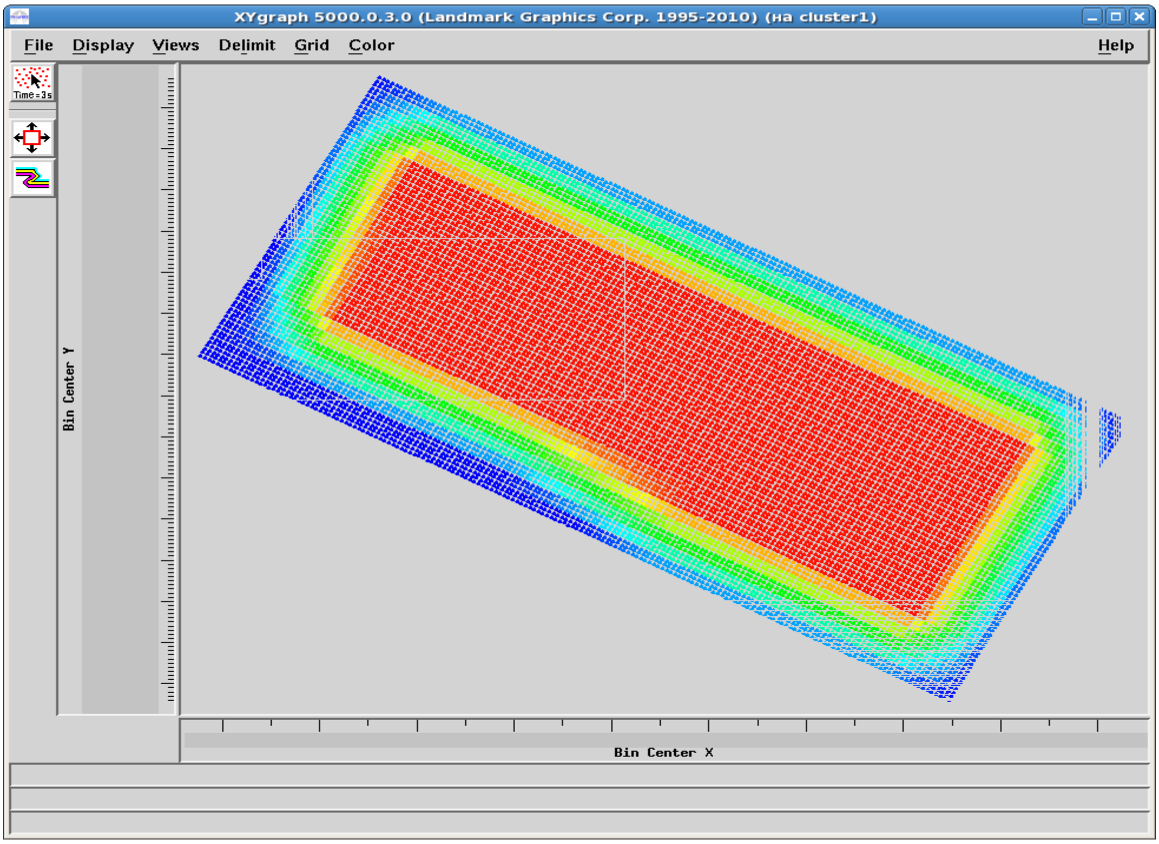


Figure 4.1.2 – Area multiplicity map

4.2 Testing of processing procedures and parameters

During the processing of materials, the procedures and their parameters were tested. To select the standard processing column, testing was performed on the basis of source data and summary traces.

4.2.1 Amplitude recovery for spherical difference

Amplitude recovery was tested by the following formulas

$$A=A(i)*T N(i) \quad (1)$$

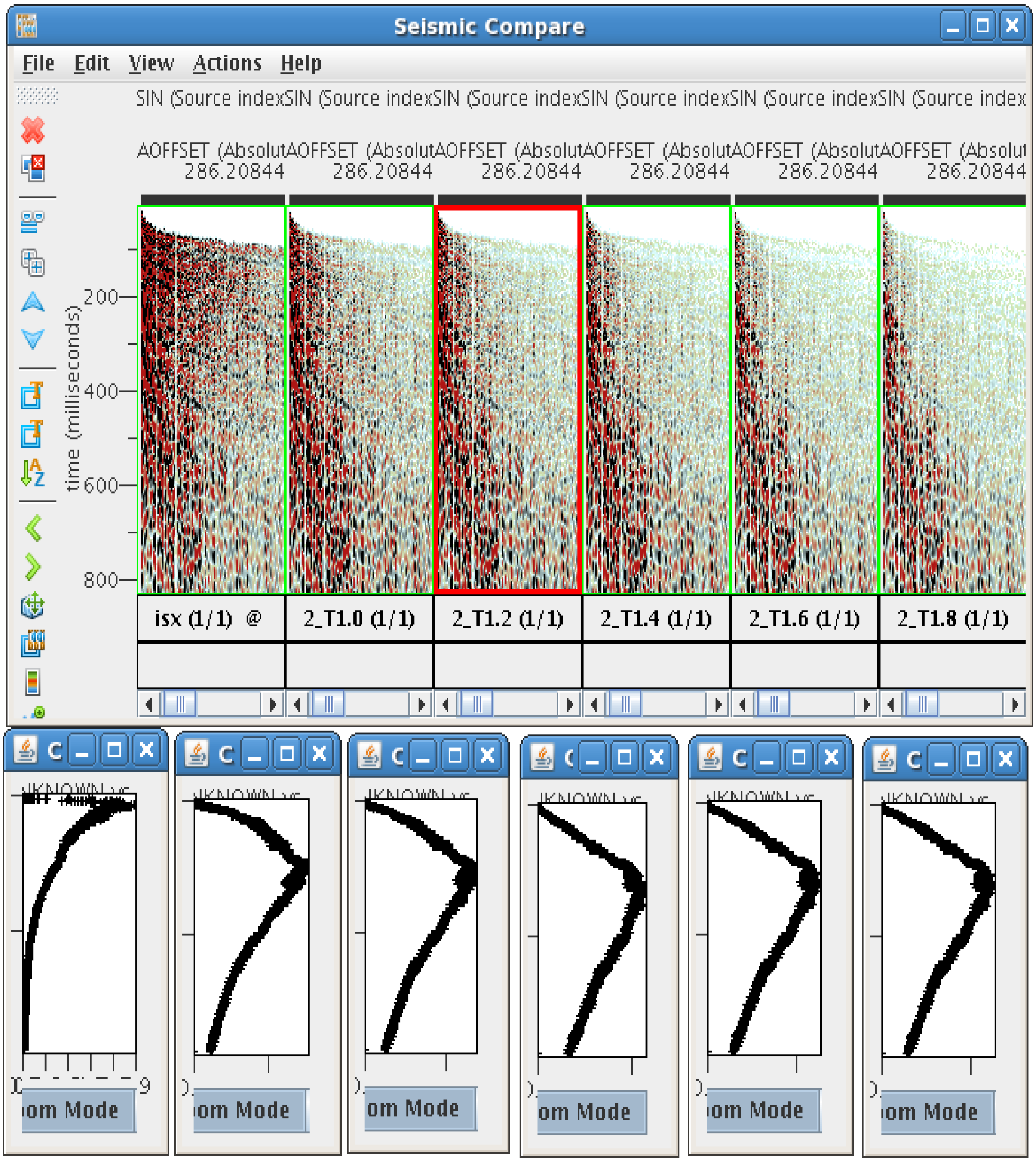
or the "i" discrete after recovery;

T(i) - discrete time "i";

N - amplification function indicator;

To compensate the amplitude attenuation of the seismic wave, which occurs during its propagation in the medium, the values N=1.0.1.2.1.4.1.6.1.8 were tested.

Based on the analysis of test results and graphs of the signal amplitude dependence on time the function of gain-T, N=1.4 was selected.



a b c d e f

Figure 4.2.1.1 – Compensation for spherical difference. Fragment of initial seismogram. Testing of T(i)**N function and corresponding graphs of signal amplitude dependence on registration time: a - before compensation, b - function T(i)**1.0-, c - function T(i)**1.2, d - function T(i)**1.4, e - function T(i)**1.6, f - function T(i)**1.8.

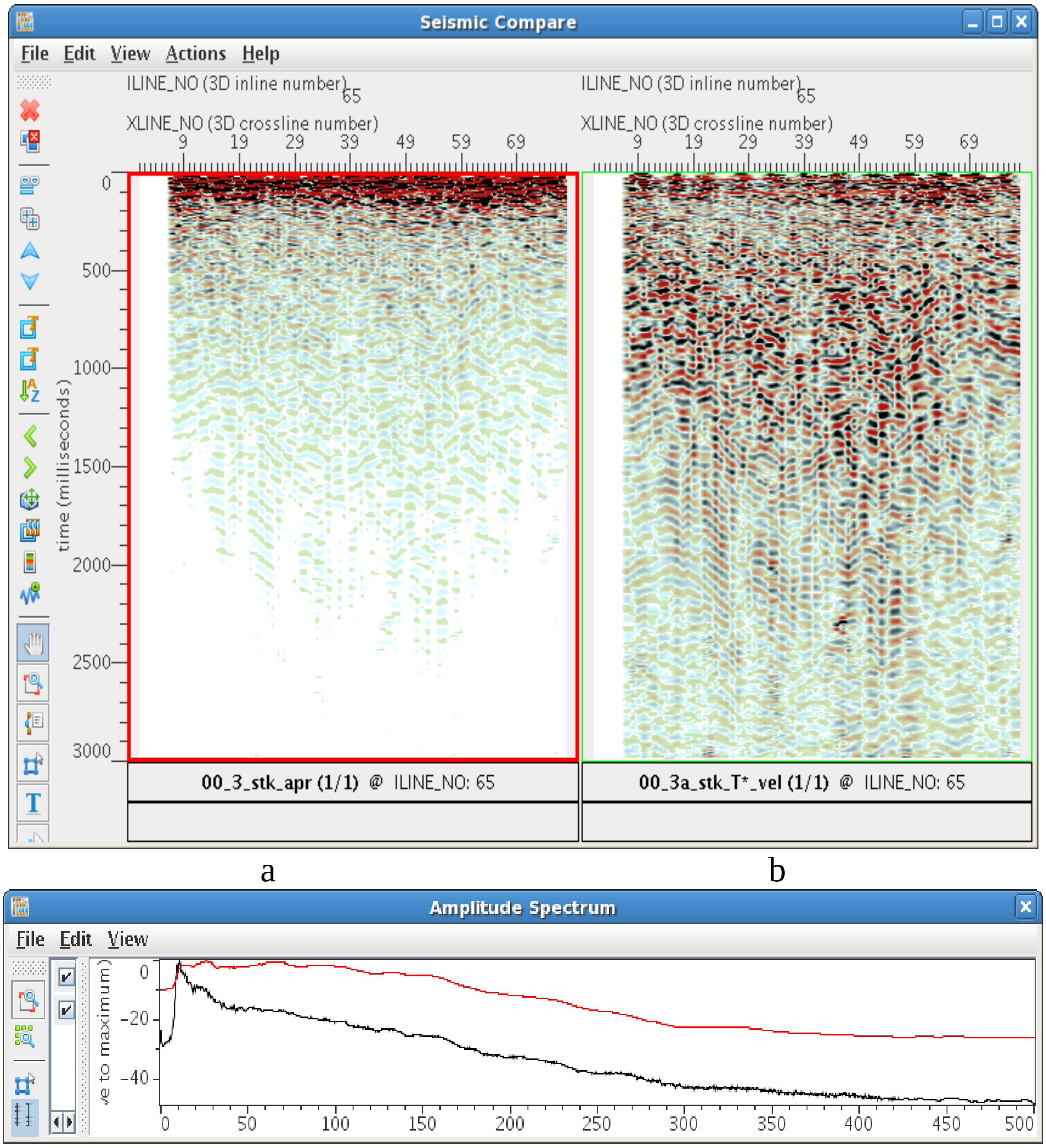


Figure 4.2.1.2 – Compensation for spherical difference. Time slice fragment and corresponding time dependency plots of signal amplitude: a - before compensation, b - after compensation (function T (i)**1.4)

4.3 Surface wave suppression

To suppress the energy of interference caused by the surface wave, according to the initial data, the application of 3D-FK filtration procedure in the cutting mode was tested.

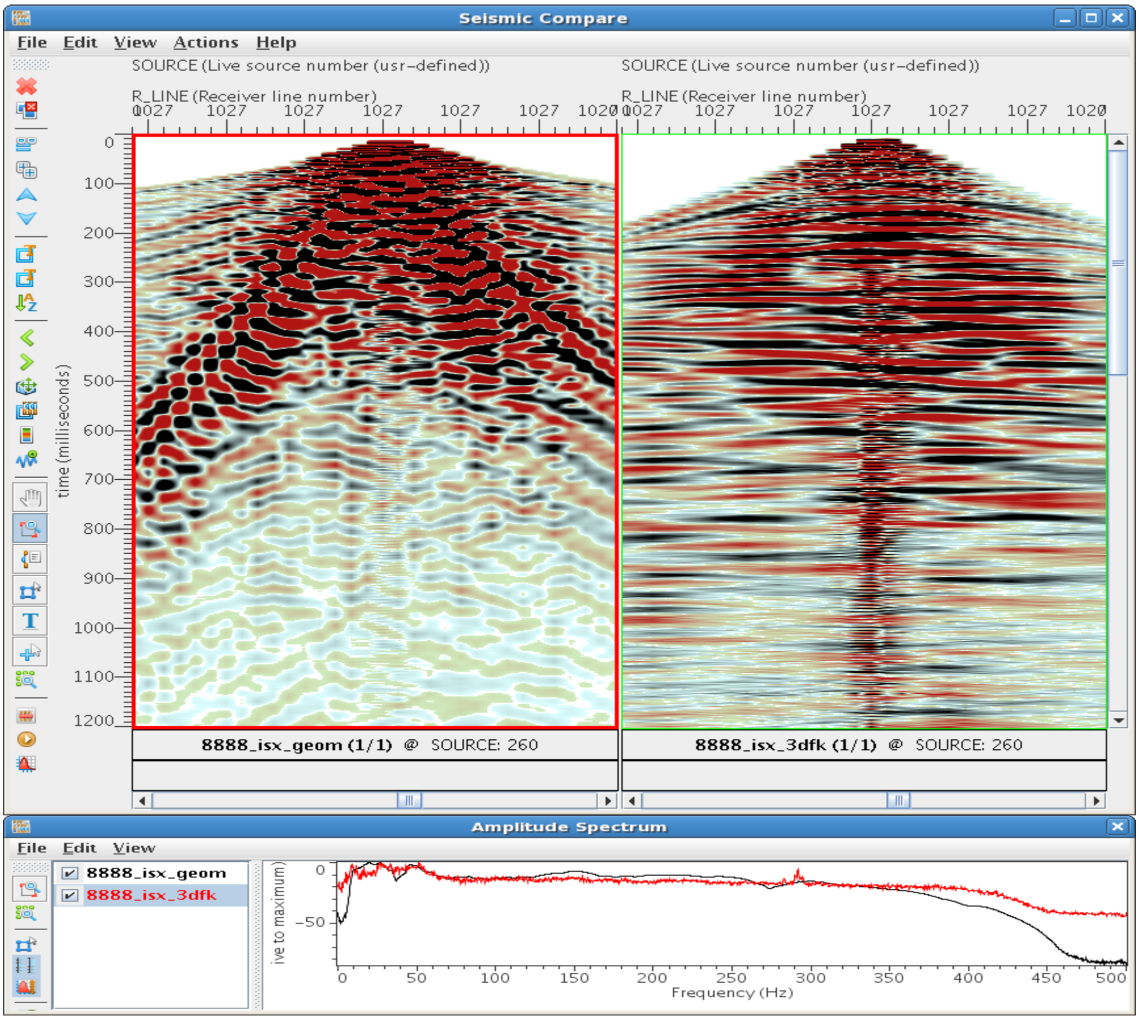


Figure 4.3.1 – 3D-Fk - filtration in cutting mode. SP 360. Receiving lines 1027. Input data fragments before and after 3D-Fk - filtration.

4.4 Deconvolution

To obtain the maximum vertical resolution of the signal and preserve the spectrum in the range of useful frequencies, deconvolution algorithms were tested: single-channel deconvolution, surface-consistent deconvolution.

When testing the deconvolution parameters, the following were tested:

– the size and number of Windows for configuring the deconvolution operator (one or 2 windows).

– the length operator;

– the level of the added white noise;

– prediction interval (GAP)

Figures 4.4.1 and 4.4.2 show the results of testing the prediction interval length and testing the window for calculating and applying the deconvolution operator.

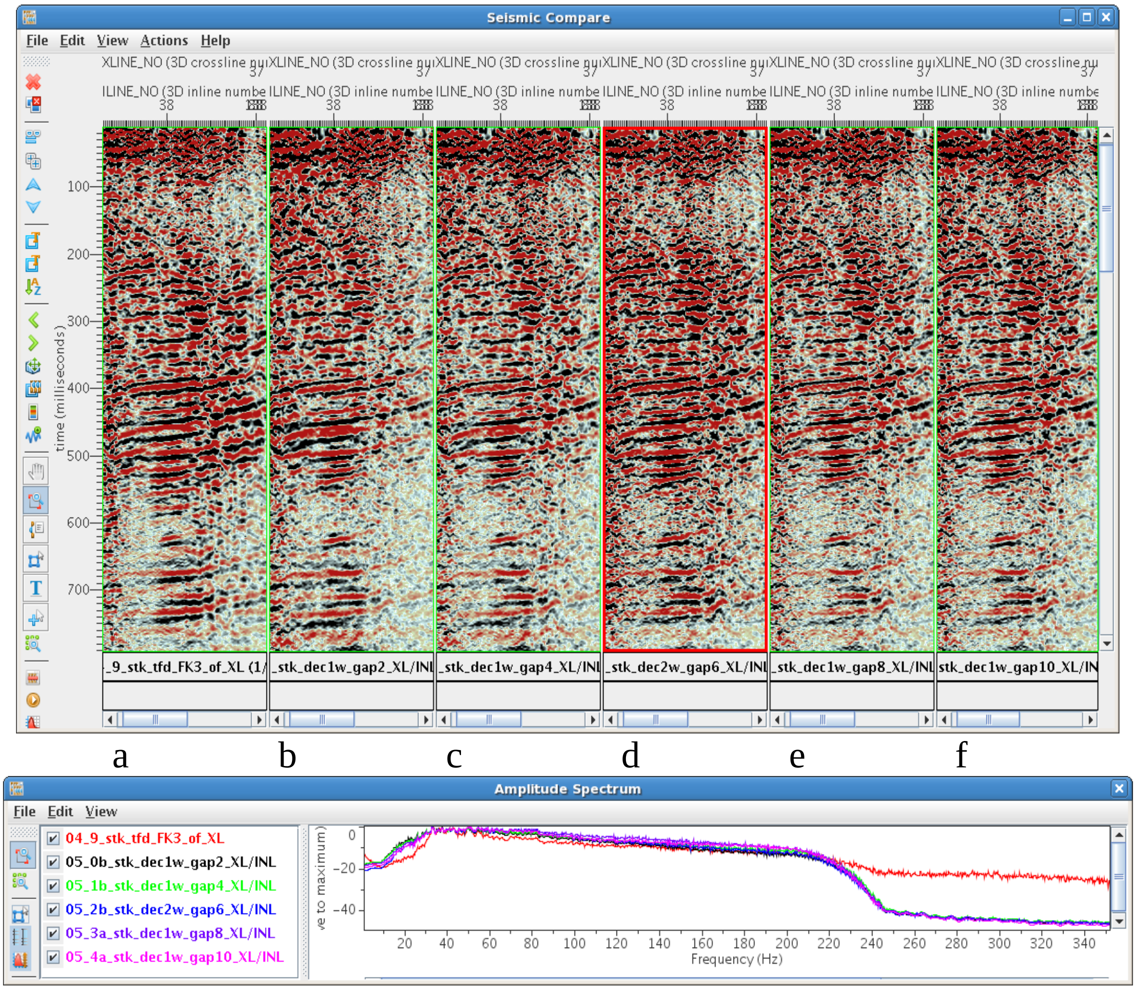


Figure 4.4.1 – Single-channel deconvolution. Prediction interval length testing: a - before deconvolution; b, c, d, e, f - deconvolution and corresponding frequency characteristics: b - GAP=2 ms, c - GAP=4 ms, d - GAP=6 ms, e - GAP=8 ms, f - GAP=10 ms.

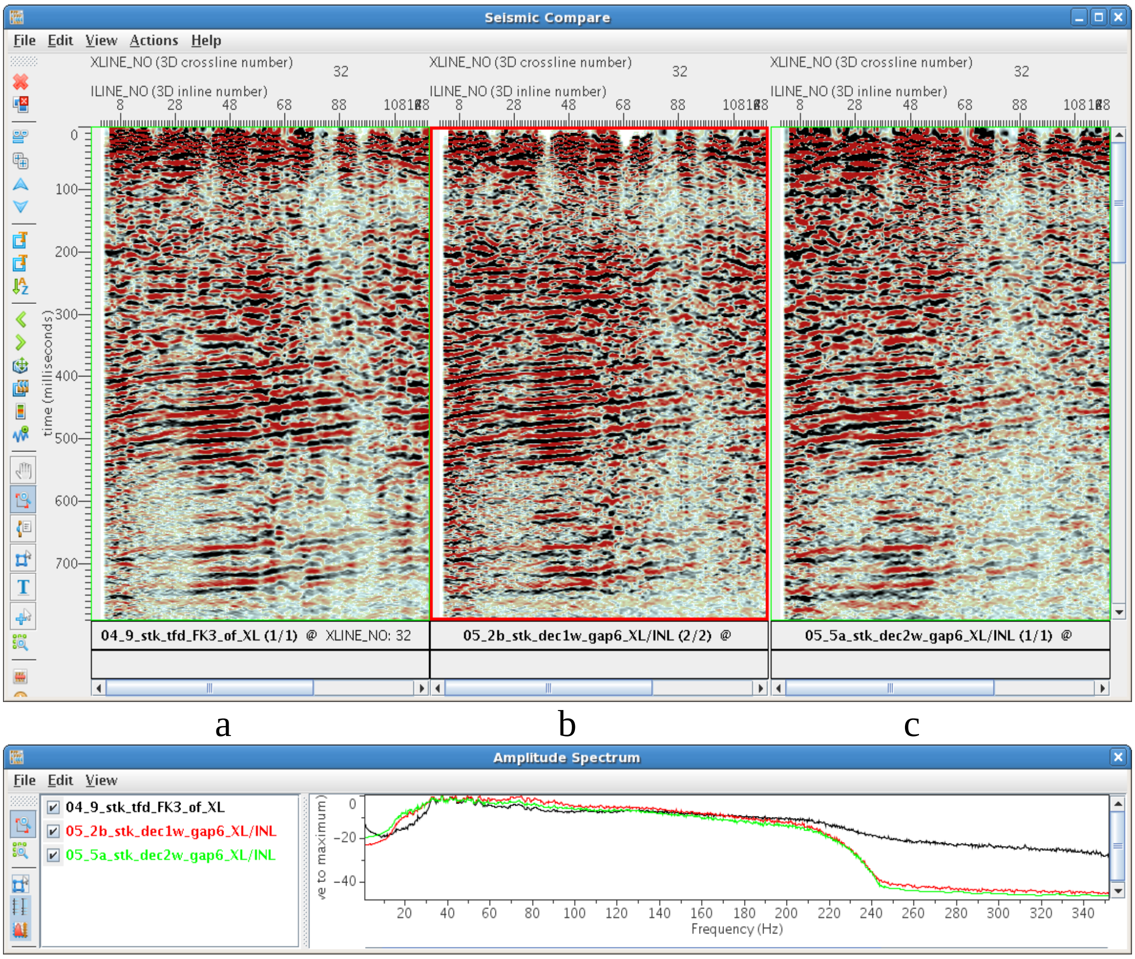


Figure 4.4.2 – Single-channel deconvolution. Testing the window for calculation and application of the operator. Time section fragments: a - before deconvolution; b, c - deconvolution - windows for FAK application: b - W1(0-3000) ms, c - W1(0-800) ms, W2(900-3000) ms

4.5 Residual noise attenuation

For the residual suppression of interference, another iteration of the adaptive Signal-to-Interference Ratio (SNAP) processing was tested. In Fig. 4.5.1 shows the results of the residual attenuation.

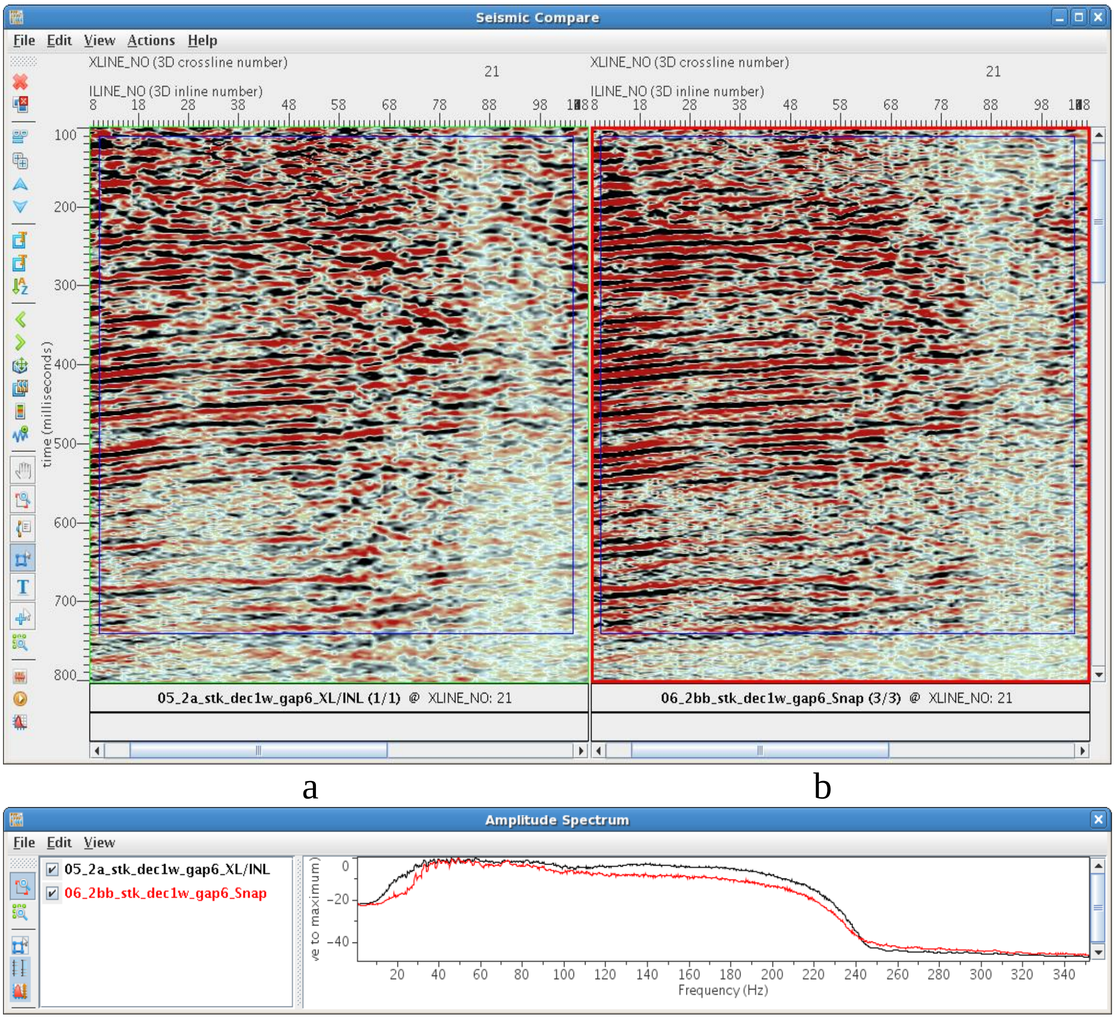


Figure 4.5.1 – Interference suppression. Adaptive noise attenuation. Time slice: a - before the adaptive suppression, b - after the SNAP filter has been applied.

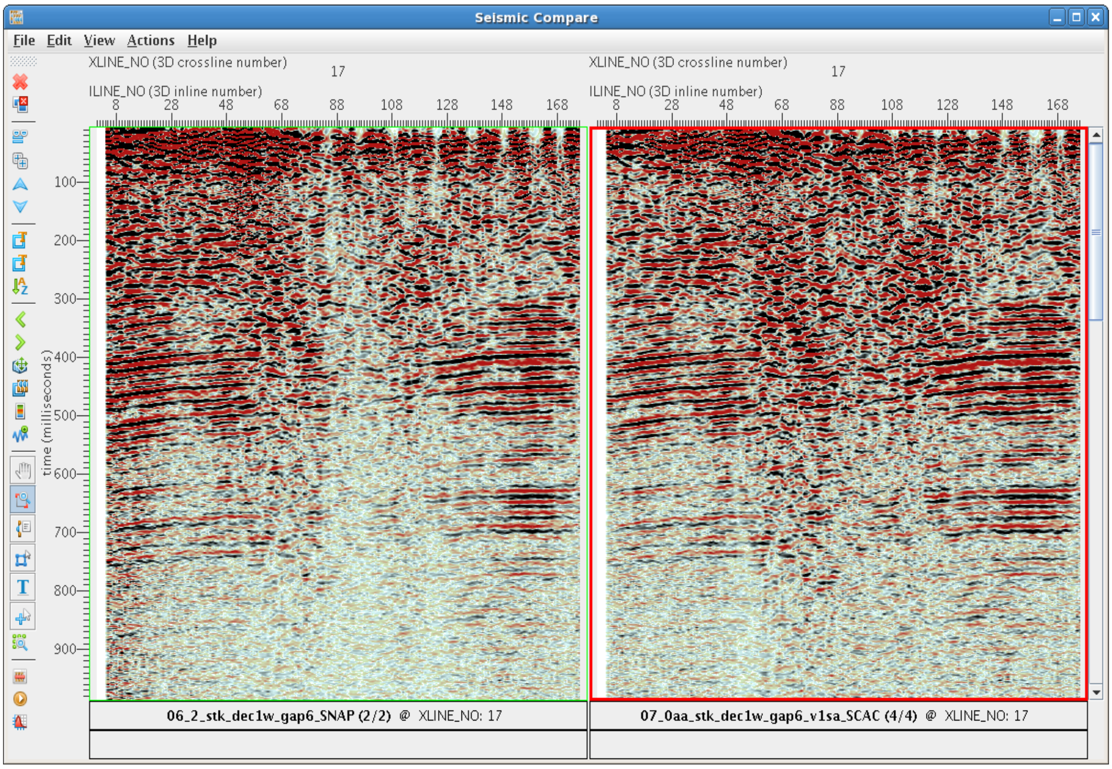
4.6 Surface-consistent amplitude correction

To compensate for the effect of surface-geological conditions on the amplitudes of individual SP, RP and removals, a surface-consistent amplitude equalization procedure was tested and applied. Factors for calculation and application of amplitude coefficients in the time interval (200-2800) ms were tested:

– Amplitude adjustment at the explosion and reception points.

– Amplitude adjustment at blast points, receiving and removal points.

Based on the test results, surface-consistent compensation of amplitudes in the tuning window (200-2800) ms by factors (explosion points, receiving and removal points) was selected to equalize amplitude coefficients. Figure 4.6.1 shows the results of surface-consistent amplitude compensation application.



a b

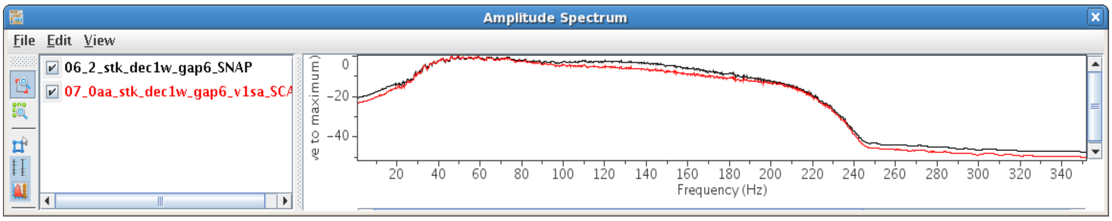


Figure 4.6.1 – Surface coordinated amplitude correction. Time section fragment: a - before amplitude alignment, b - after amplitude alignment (SP, RP and removal factors).

4.7 Static correction

For optimal correction of static corrections, the first analysis of velocites in the network of 120m*120m, the second analysis of velocites in the network of 240m*240m was made beforehand.

The correction of static corrections was tested on windows:

1) 0 - 1000 ms

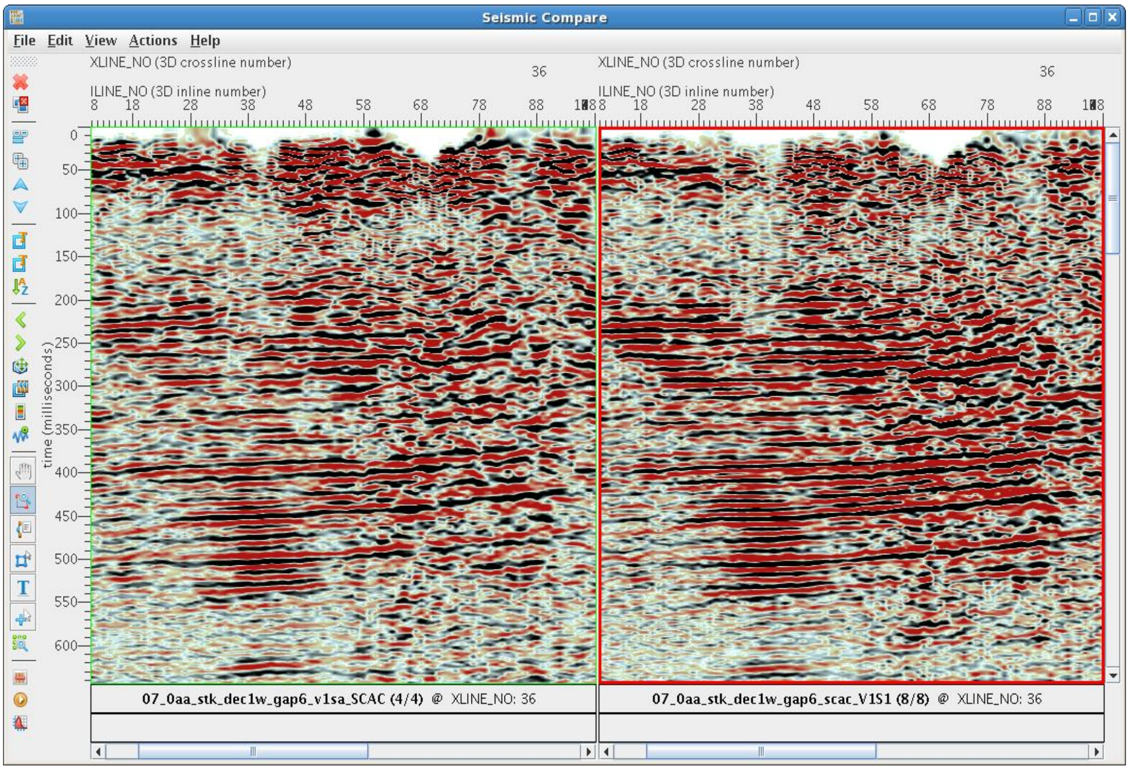
2) 0 - 2000 ms

3) 200 - 800 ms

The model track was formed from the super packs of 3*3, 7*7, 9*9 bins CDP. The maximum allowable static shift was 12 ms. The variants with internal model (where the model trace is formed from the super packages) and external model were tested.

Selected: 1 iteration - (internal model); window FVK=0-1000 ms. Pilot cube of the model 9*9 tr. maximum allowable shift=12 ms. 2 iteration - with external model. maximum allowable shift=12 ms.

Fig. 4.7.1 shows a fragment of the cross-line 36 section after correction of static corrections.



a b

Figure 4.7.1 – Cross-line 36. Correction of static corrections (1st iteration). Time section fragment: a - before static correction, b - static correction.

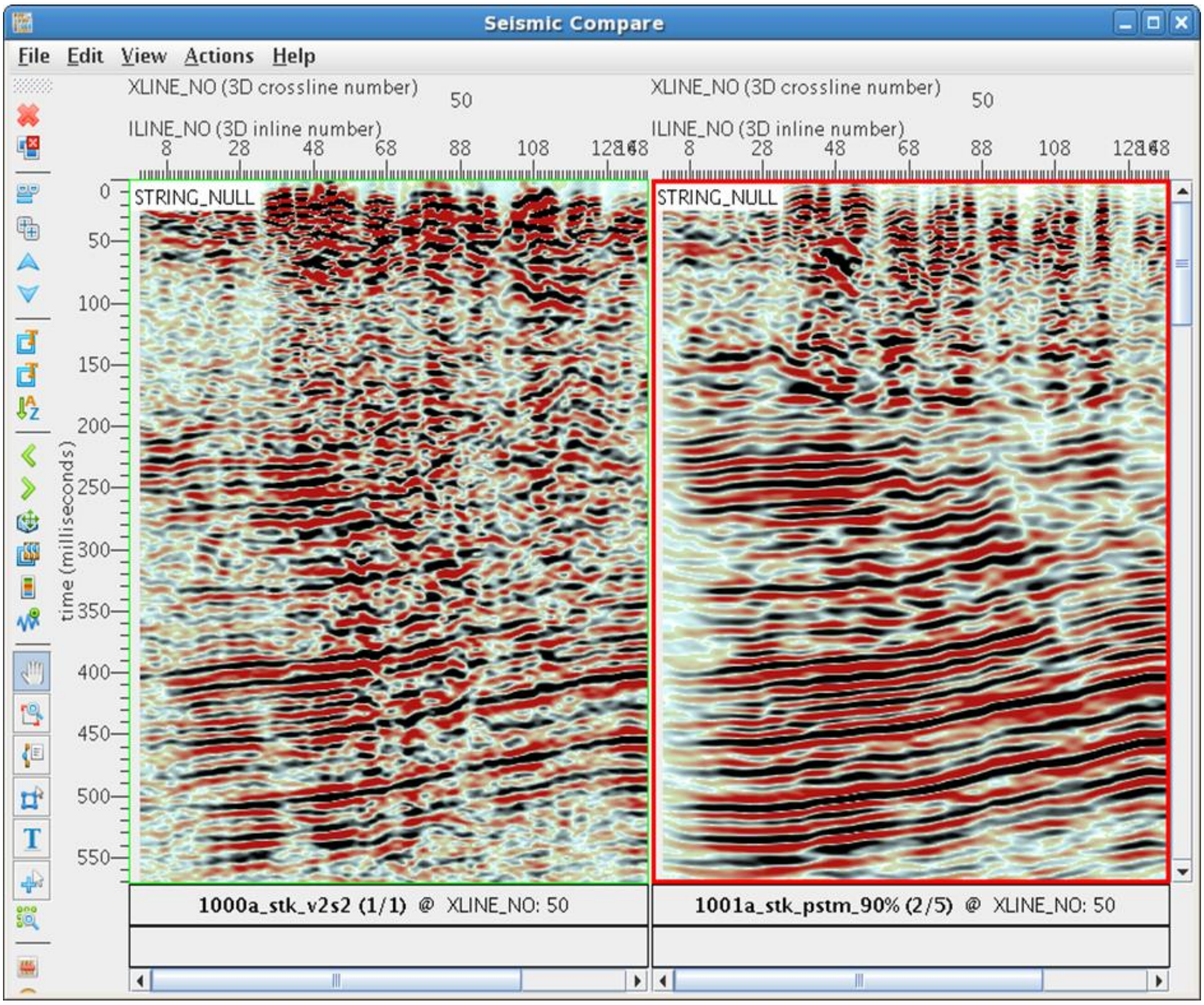
4.8 Time migration of initial sources by the Kirchhoff algorithm

In order to clarify the structural structure of the work area, a migration transformation of the results obtained from the initial data was carried out.

The following parameters were tested: size ½ of aperture - 385m, 495m; percentage of smoothed velocites - 90%, 100%, 110%; 120%.

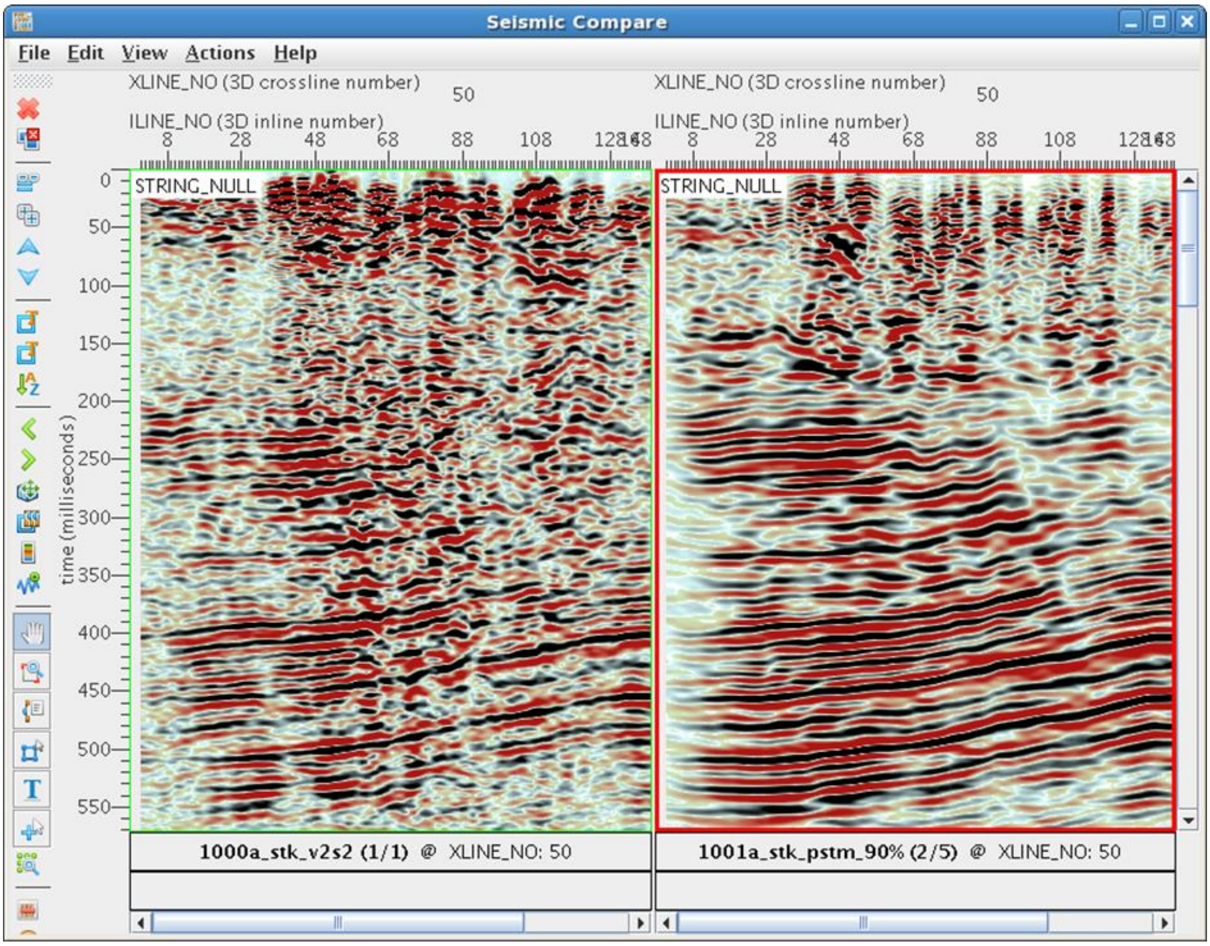
Selected: size ½ aperture - 495 m; Migration velocites - 100%.

In Fig. 4.8.1 - 4.8.4 presents fragments of time sections of the sum and migration.



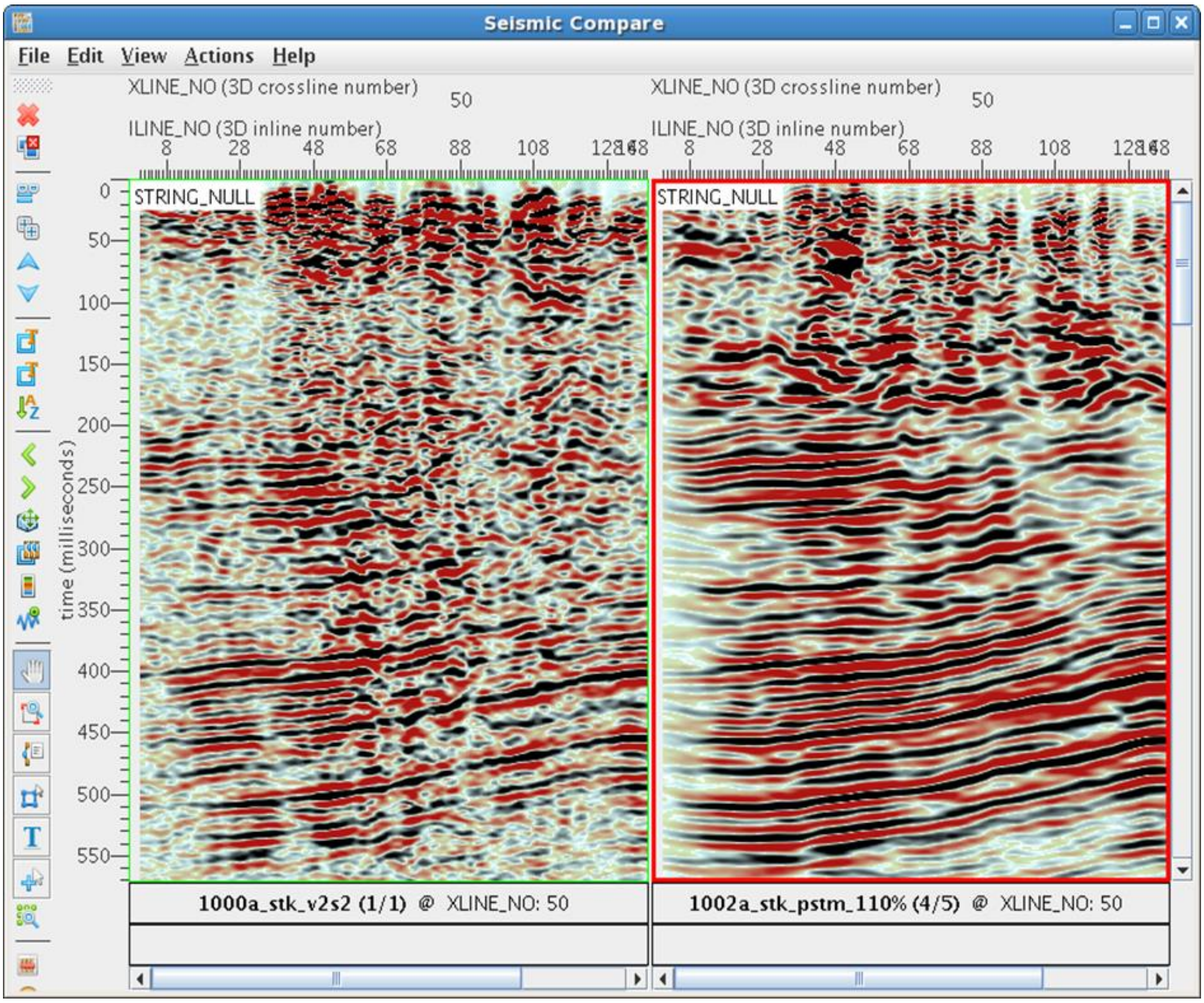
a b

Figure 4.8.1 – Migration (PSTM) percentage of smoothed velocites 100%. Time section fragment. Crossline 50: a - section before migration, b - migration



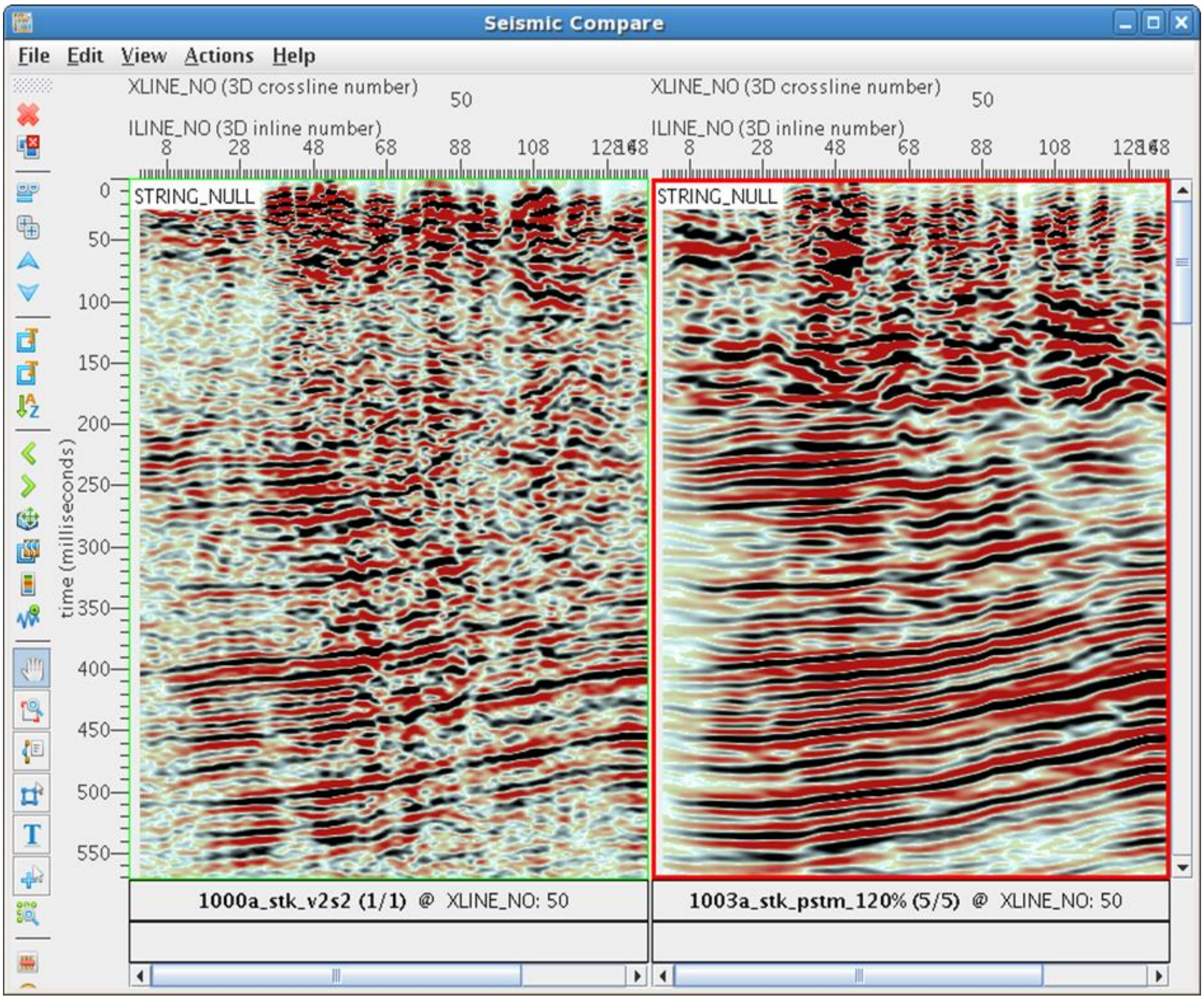
a b

Figure 4.8.2 – Migration (PSTM) Smoothed velocity percentage 90%. Time section fragment. Crossline 50: a - cut before migration, b – migration



a b

Figure 4.8.3 – Migration (PSTM) 110% smoothed velocity percentage. Time section fragment. Crossline 50: a - section before migration, b – migration



a b

Figure 4.8.4 – Migration (PSTM) Smoothed velocity percentage 120%. Time section fragment. Crossline 50: a - cut before migration, b – migration

4.9 Noise suppression by sumatrack. Bandpass filtration

FXY deconvolution procedure was tested to suppress irregular interference and increase signal-to-interference ratio. Bandpass filtering parameters were selected based on frequency spectrum analysis and narrowbandpass filtering. In Figure 4.9.1 presents fragments of migration with post-stacking procedures.

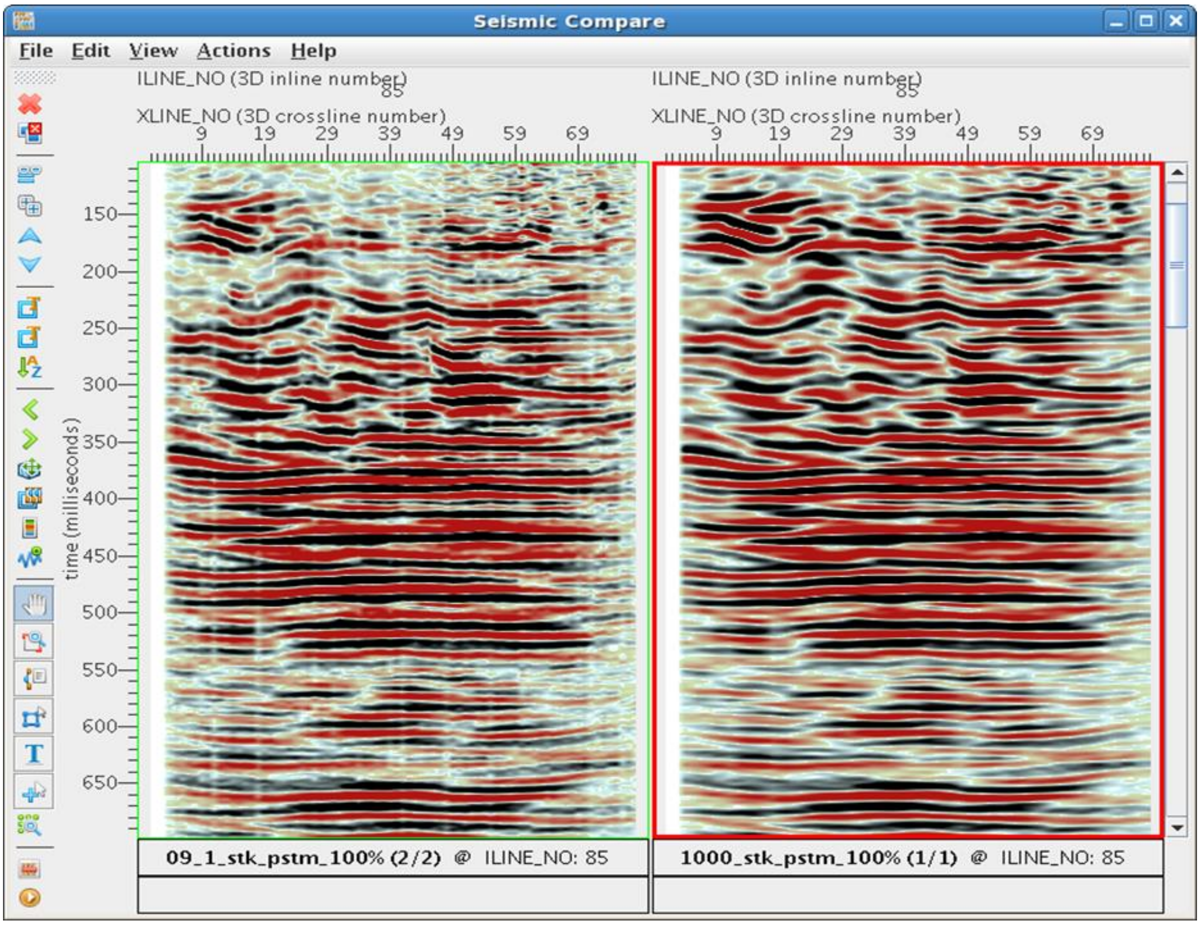


Figure 4.9.1 – Migration (PSTM). Noise suppression by track. A fragment of the time section.

5 Interpretation of field seismic results

Interpretation of materials is made by a set of programs Geographix (Halliburton) and Petrel (Schlumberger) on the basis of the Dell workstation.

A quantitative interpretation of hodographs and time sections begins with a study of the velocity section and determination of the average velocities of the rock strata over each of the revealed reflecting and refracting boundaries. Further, time sections are transformed into deep ones, i.e. the geometry of the section (depth, inclination angles) and the distribution of reservoir, average, and boundary velocities along the profile and depth are determined. The final stage is the geological interpretation of the results, for which all geological information, data from drilling and well logging are used. It ends with the construction of seismic-geological sections, so-called because they are actually structural and geological sections, but constructed according to seismic data and well logging. In addition, structural maps are being built.

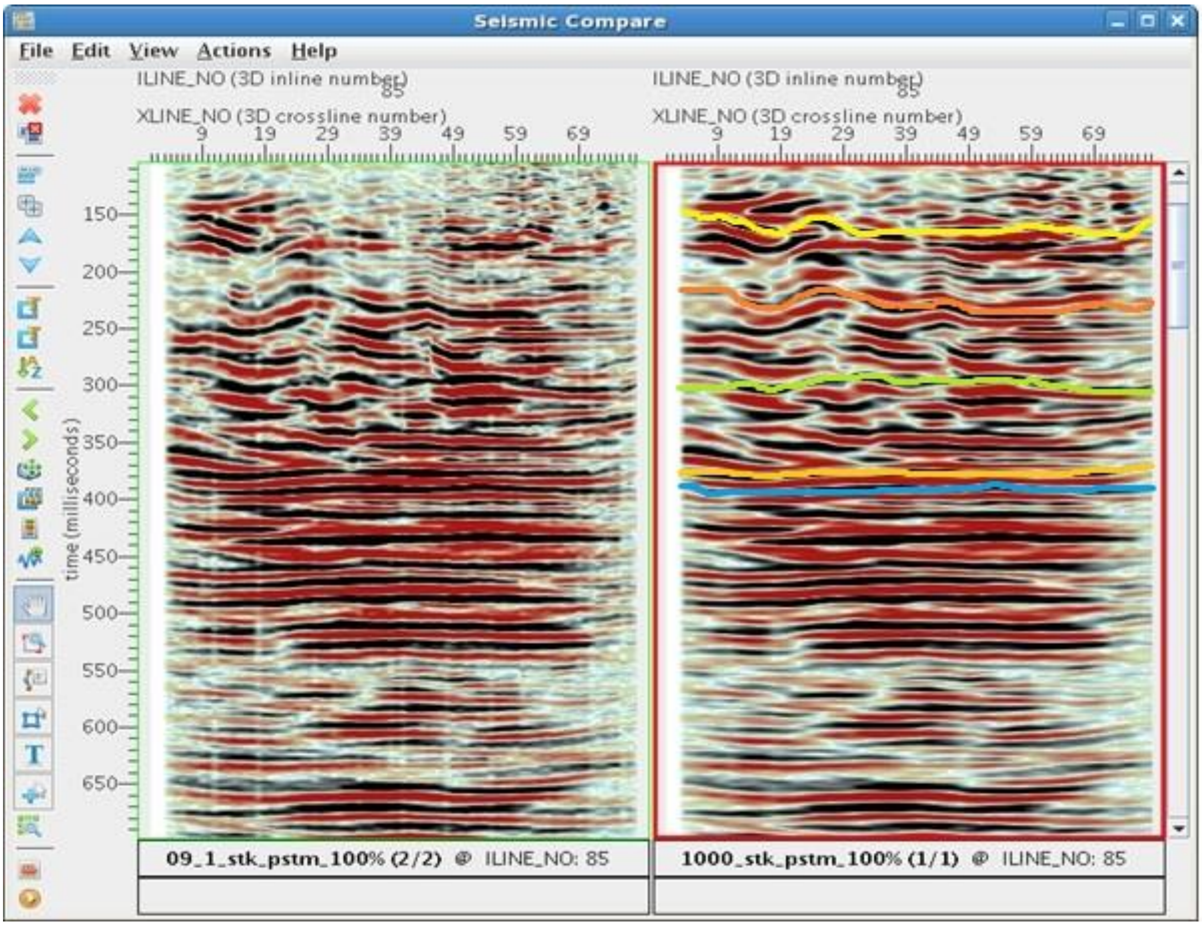
5.1 Correlation of borders by time sections

To convert a time section into a deep one, one should apply the law of velocity distribution in the overburden, and also correct some distortions that occur at steep angles of inclination of seismic boundaries. Such conversion can be carried out on automatically or manually. In the latter case, the waves are correlated in advance and in-phase axes are carried out. The lines obtained in this way are then converted to seismic boundaries. [3]

Correlation of reflected waves is picking and tracking in-phase oscillations over the survey area is the basis of all further constructions based on seismic data.

A seismic reflecting horizon is a reflected wave that is stable in terms of dynamics and propagation area, which corresponds to a certain geological boundary, which is established by linking the seismic exploration CDP and borehole data. Linking is performed using all necessary procedures.

The reference and target reflecting horizons are distinguished. Reference reflecting horizons have regional or subregional distribution. Target reflecting horizons are usually confined to productive strata, for the mapping of which the CDP seismic survey is performed.



Picture 5.1.1 – Seismic section with correlated horizons

For correlation, the most dynamically expressed and stability over the area are selected according to the amplitude-frequency characteristics of the phase, regardless of their polarity. Correlation of reflected waves is carried out either by their extrema, or by "0 transitions" between phases. In most cases, the correlation of the reflected waves should be in-phase, with the exception of reflections in wedge-shaped and lenticular strata, where in-phase correlation is impossible, because layers and packs that control individual reflections wedge out. In such strata, it is necessary to correlate not seismic, but seismogeological horizons, i.e. take into account the position and behavior according to the borehole data of geological boundaries in the studied section interval. [4]

5.2 Isolation and tracing of discontinuous faults

Discontinuous or disjunctive dislocations (dislocations) are manifested in seismic sections by gaps in reflecting horizons, their vertical displacements, the presence of crushing zones and other distortions of the wave pattern. Typically, these violations flock in a significant time interval; on this basis, vertical or inclined planes of displacement fault dislocators (faults, reverse faults) can be distinguished. First, the planes of the displacer fault displacers are selected at time sections, then their position in the plan is mapped. When mapping disjunctives, it is necessary to mark the lowered and raised blocks. Often there are complex, shear dislocations associated with the horizontal movement of the foundation blocks, which transforms in the sedimentary cover into vertical movements with discontinuities in the rock continuity. Often low-amplitude discontinuous faults in individual sections of the section look like small structural complications (kinks) of the in-phase axes. If such inflections line up in vertical lines, then we can safely consider them tectonic dislocations.

CDP 3D seismic exploration makes it possible to map disjunctive dislocations confidently, using, in addition to vertical, horizontal and horizontal sections of seismic data cubes and special cubes of coherence, instantaneous amplitudes and phases, quality factors, etc., on which disjunctive dislocations are clearly visible.

Seismic sections are visualized in an easy-to-interpret form; therefore, the ratios of the vertical and horizontal scales are greatly distorted. If we bring this relationship to its natural appearance, then many tectonic disturbances that look subvertical will turn out to be strongly inclined. This also indicates the widespread occurrence of shear (horizontal) tectonic movements. [4]

5.3 Linking seismic data to drilling and well logging data

For linking borehole and seismic data, data from borehole seismic and well logging are used, first of all, sonic log and density gamma gamma ray log, on the basis of which one-dimensional seismogeological modeling is performed. Two-dimensional seismic-geological modeling is used to solve the direct problem of seismic exploration for complex seismic-geological conditions for the purpose of georeferencing and recognition of geological objects, as well as in attribute analysis. [4]

5.4 Construction of structural maps and sections in depth scale

On the seismic section, the position of the pickets on the profile, the alignment line, the sea level line, and the depth scale should be indicated. It should indicate the points of intersection of the profile with other profiles, as well as the position of deep wells located on or near the profile.

Seismic boundaries with manual processing methods are applied in the form of solid lines corresponding to those areas where the corresponding wave is traced continuously. In areas where the position of a certain horizon is determined presumably, it is depicted by a dashed line. The lines of the alleged faults are applied in the form of a double solid or dashed line.

The section should indicate the operations that were used in the processing of the source records. Each seismic section must contain the name of the organization that carried out the work, the name of the area of work, the profile number and the year of the work. All sections must be signed by the responsible executors. [3]

6 Geological interpretation of seismic data

6.1 Structural interpretation

The total spatial distribution of deposits in the Zhezkazgan region, according to K.I. Satpaev, is determined by their confinement to the junction of deep faults. This idea of K.I. Satpaev was subsequently confirmed by Y.A. Zaitsev (1961), who studied in detail the features of the Hercynian structure in the Zhezkazgan ore district. An analysis of the data of detailed geological survey and exploration work carried out in the northern part of the Zhezkazgan syncline shows that all deposits and ore occurrences of the Zhilandy group are located on the interface between the Zhezkazgan and Itauz synclines, the Akshagyl (in the north) and the Kengir brahiantikinal (in the east), limited to branch of the Terekti regional and from the west - Spassky (East Ulutau) deep faults. The latter is associated with the formation of numerous second-order folding structures and discontinuous disturbances. Based on the results of detailed exploration, it was established that each field of the Zhilandy group is confined to those elements of folding structures of the second order that are associated with zones of deep or regional faults and are complicated by various fracture faults (including those operating in deep or regional faults), smaller folds and flexures. The main ore-controlling structures for deposits of the Zhilandy group are second-order folds complicated by minor explosive disturbances.

A study of the features of mineralization showed that disjunctive disturbances were laid before the formation of ore bodies. The prenatal age of these violations is definitely proved by the example of the most studied Saryoba reverse fault, which is, apparently, the eastern branch of the Spassky deep fault. Ore mineralization is located on both sides of the fault, along which rocks are displaced vertically from 0.3 to 1 km and horizontally by 3 km. However, in terms of mineralization, both in the hanging side and in the lying side, it does not experience such a displacement. The vertical displacement of the ore-bearing horizons also does not have any effect on the vertical distribution interval of ore mineralization in them. The maximum depth of distribution at the West and East Saryoba deposits is almost the same and amounts to 750-800m from the day surface. It should also be noted that all ore bodies, as they approach explosive disturbances, gradually wedge out and are represented mainly by chalcopyrite, which is a characteristic mineral of the peripheral sections of deposits.

Ore-controlling discontinuities that occurred during the initial period of folding formed further played the role of peculiar barriers, near which the host rocks crumpled most intensely into small folds and step flexures, as indicated by their orientation, mainly parallel to the strike of large faults.

An important condition for the formation of interstratal faults and fractured zones is the frequent intercalation of rocks with various degrees of plasticity, therefore, in the geological conditions of the Zhilandy group deposits, the formation of small folded structures was accompanied by the intensive formation of these disturbances (and the associated schistose zones and open contact joints) in gray-colored sandstones, which are favorable for the circulation of solutions and deposits of ore minerals.

Frequent intercalation of different-grained rocks inside the ore-bearing bundle, which have various plastic properties, favored the formation of interstratic weakened zones, delamination planes, and open contact seams during repeated folded deformations. These disturbances in the rocks were the paths of movement of hydrothermal solutions.

Relatively fragile gray-colored sandstones in the deposits of the Zhilandy group are found in only two stratigraphic horizons: Taskuduk and Zhilandy, overlain by a thick layer of red-colored mudstones, siltstones and heterogeneous sandstones. The selective confinement of ore mineralization to these stratigraphic horizons creates an external impression of the existence of a lithological control of mineralization. However, the study of the features of the location of deposits and the nature of the distribution of mineralization in them showed that tectonic deformation of ore-bearing rocks before or at the time of introduction played the main role in the localization of ore mineralization, which created favorable conditions for the supply of ore-bearing solutions.

The thickness of the gray-colored rocks, characterized by the constancy of lithologic-petrographic composition, is not mineralized over the entire area and thickness of its distribution. Mineralization in it is noted in local areas controlled by folded and discontinuous structures, in particular, folds of the second and higher orders, flexures, inter-layer fractures, and fractured zones. At the same time, ore minerals are concentrated along layer-by-layer tectonic faults, which acted as ore supply and ore distribution channels. Further distribution of ore-bearing solutions into the side rocks was determined not so much by their primary porosity as by fracture. The proof is the fact that in the deposits of the Zhilandy group the ore-bearing rocks are not only medium-grained sandstones, but also their dark-gray banded fine-grained differences, and sometimes even siltstones with very limited porosity. These rocks are characterized by the development of a predominantly fine-grained type of mineralization, which indicates the leading importance of ore ore fracturing of rocks. The primary porosity of ore-bearing rocks, including medium-grained sandstones, was apparently insufficient for intensive circulation of ore-bearing solutions. The facts show that in the absence of rock fracturing in the strata of layered faults, the concentration of mineralization (as they move away from them) quickly decays at a distance of several centimeters, and undiluted rocks are practically devoid of ore minerals. Consequently, the primary porosity of the rocks in the localization of ore mineralization played the role of a secondary factor contributing to an increase in the total permeability of solutions and an improvement in the conditions of accumulation of ore substance. The combination of sufficient brittleness with higher primary porosity is undoubtedly a prerequisite for the localization of rich mineralization.

Thus, interstratal disturbances and fracture interlayers of larger rocks associated with their formation were the leading factors that predetermined the stratiform nature of the distribution of ore mineralization.

Of great importance in the localization of mineralization were the physical-chemical, lithological properties of rocks and the carbonate composition of cement.

Barren interbeds separating ore-bearing horizons are usually represented by plastic siltstones and fine-grained sandstones. The absence of mineralization in such sandstones is due to the insignificant supply of ore-bearing solutions due to the weak degree of crushing, due to the influence of contacting layers of plastic rocks. In the process of folding, a relatively strong layer of mudstones, limiting individual ore-bearing horizons along the section, had a special influence on the crushing intensity of gray-colored sandstones.

The study of the core of exploratory wells showed that with the removal of plastic mudstones from the strata, the intensity of crushing of interlayers of brittle rocks noticeably increases. The most dislocated rocks are usually found in the middle part of the section of ore-bearing horizons, where large deposits are located. Interlayers of relatively brittle rocks located near the roof and soil of ore-bearing horizons, with slight bends (on the wings of folds and flexures), underwent plastic deformation in the same way as mudstones and crushed only in arches of small folds. However, these same rocks located in the middle part of ore-bearing horizons, i.e. under conditions of their greatest distance from layers of plastic mudstones, they were deformed with the formation of a large number of small cracks and became easily permeable to ore-bearing solutions.

Based on the plans drawn up for all the deposits identified by the exploration, the ore bodies of three main forms are distinguished: cloak-like, round-elongated and ribbon-like.

Cloaky ore bodies, which are large in size and have a complex external plan, are characteristic of those deposits that are located in the middle of the ore-bearing section. Confining to the most dislocated layer of sandstones, they cover anticlinal uplifts, synclinal troughs and their wings. Copper ore reserves are associated with cloak-like ore deposits. The highest metal concentration and ore body thickness are observed in the domed parts of gentle folds and on the wings of flexure zones. Moreover, most of the ore bodies in such structural regions are oriented by the long axis in the direction of incidence of the host rocks.

Round-elongated and ribbon ore bodies are small and usually located closer to the soil and the roof of ore-bearing horizons and on the flanks of cloak-like deposits, where the degree of dislocation of the rocks is relatively less pronounced. The shape of these ore bodies is determined by their placement in the arched parts of small anticlinal folds and on the wings of stepped flexures.

All ore bodies are elongated, as a rule, across or at some angle to the general strike of the host rock formations. Ore bodies located in close proximity to ore-controlling faults are oriented parallel to their strike.

6.2 Seismostratigraphic interpretation

Reference reflecting horizons R_{III} (the bottom of the C_1 deposits), R_{II} (the bottom of the C_2 ts sediments), R_{II} (the bottoms of the C_1v_2 bottom), the Terekti fault zone and other faults were traced. Estimated depth of the base of the Taskuduk formation.

Picture 6.2.1 – Geological-geophysical section

In stratigraphic terms, mineralization in the deposits of the Zhilandy ore field moves down the section by 800-1000 m, because ore bodies of these deposits are confined to the lower reaches of the Taskuduk Formation and partially lie in the sandstones of the Beleuti horizon. Moreover, unlike Central Zhezkazgan mineralization here already extends beyond the known ore-bearing horizons of the Zhezkazgan series and is found in the underlying sandstones of Namur.

6.3 Highlighting productive horizons and ore

A study of the ores of the Zhilandy group deposits showed that they are characterized by the following features:

a) ore bodies everywhere have almost the same character of localization and are confined to the same rocks;

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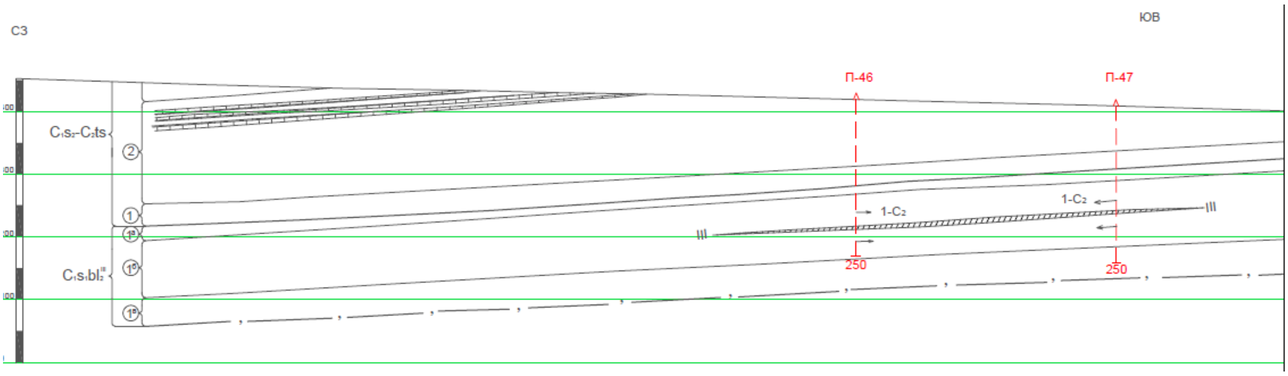

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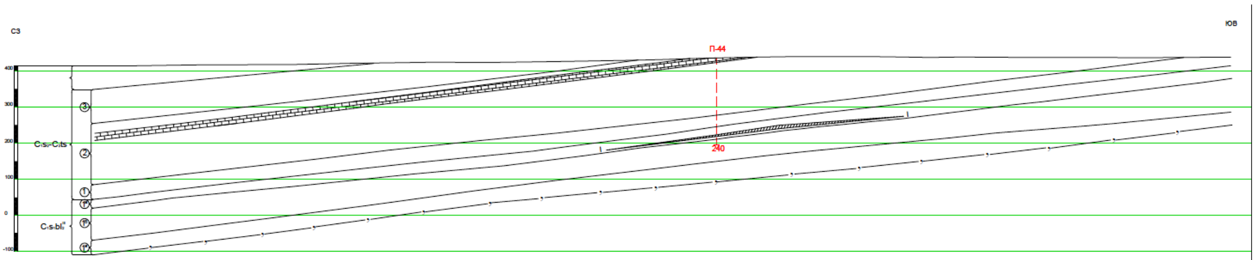

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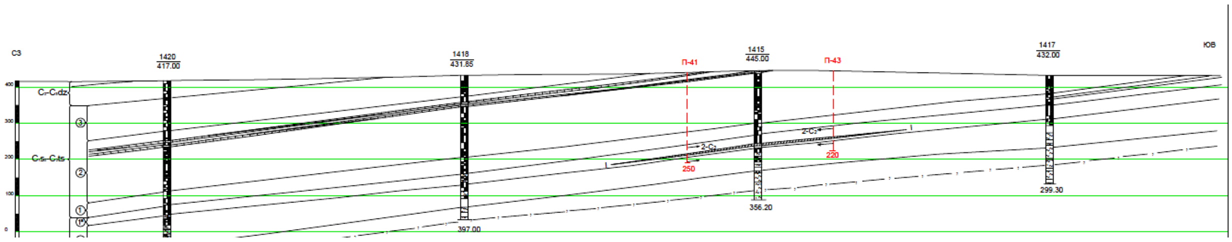

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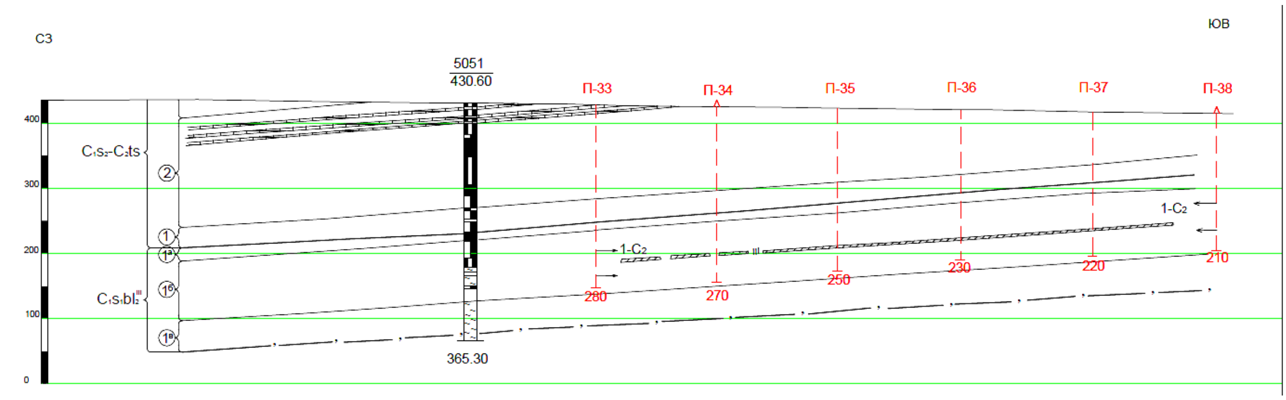

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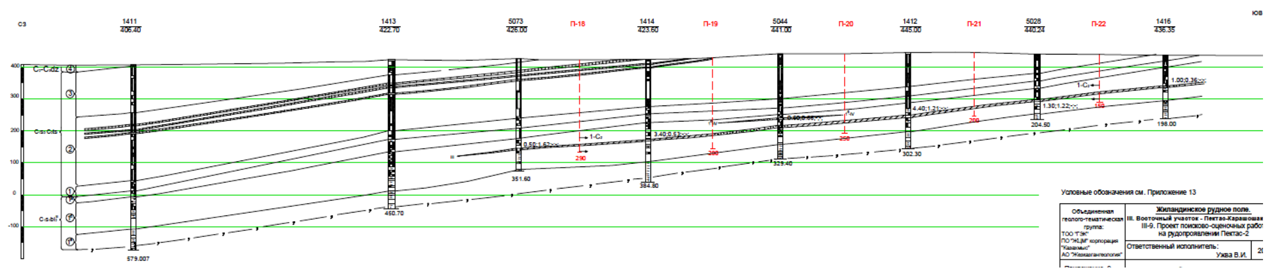
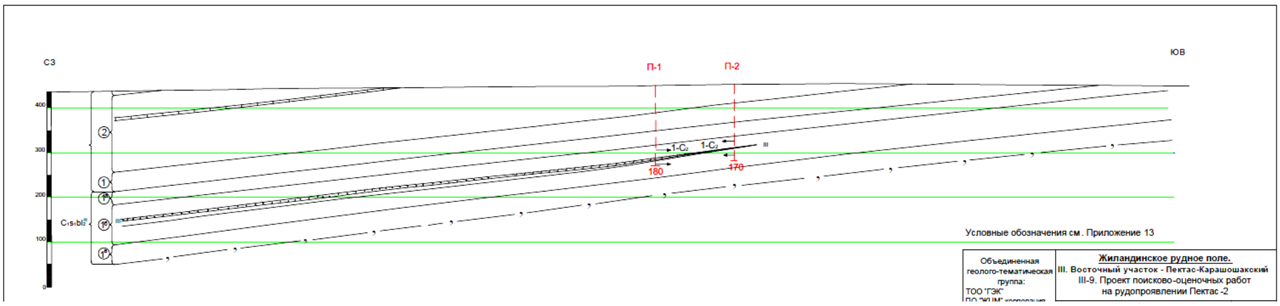


Profile 34



Picture 6.3.1 – Geological-geophysical sections

b) ore mineralization gravitates to medium-grained sandstones of gray and dark gray color (often enriched with carbonized organics) mainly on calcareous cement and is epigenetic in nature;

c) within each ore-bearing horizon, the most mature deposits are confined to their middle part. Ore deposits located at the top or bottom of the ore-bearing horizon are characterized by extreme incontinence and disintegrate in plan into separate ore bodies of different morphology. The maturity or fragmentation of ore deposits into separate bodies among the same enclosing rocks is due solely to the degree of manifestation of the folded and explosive tectonics;

d) a characteristic feature of the localization of mineralization in the deposits of the Zhilandinsky group, as well as in the Zhezkazgan deposits, is the multi-tiered arrangement of predominantly consonant stratiform ore deposits. Visual examination and data of chemical testing of the core show that ore deposits along strike and especially along the section are characterized by an extremely uneven distribution of ore minerals. Interlayers with rich copper contents are interbedded with poor or barren layers. The stratiform and very uneven nature of the distribution of ore mineralization is due to the entry of ore-bearing solutions into readily permeable interstratal and interstratal disturbances and their further distribution to lateral brittle rocks, and the multi-tiered arrangement of deposits is due to the selective formation of these disturbances and fracture zones under conditions of frequent intercalation of rocks with different physical and mechanical properties;

e) within the ore-containing horizons, the deposits are separated from each other along the section by interlayers of empty rocks, the thickness of which varies from 3 to 30 m. Barren interlayers are usually represented by plastic siltstones and fine-grained sandstones, including aged layers of brittle medium-grained sandstones, which often form flanks or are located in the hanging and lying sides of ore bodies. The absence of mineralization in them is due to a weak degree of crushing due to the influence of contacting layers of plastic rocks. This explains the confinement of the main ore reserves to gray-colored medium-grained sandstones, which, in comparison with other ore-bearing rocks, have sufficient brittleness and higher primary porosity;

f) ore-bearing horizons bearing disseminated mineralization at different deposits are mineralized to varying degrees. Moreover, as a rule, ore-bearing horizons do not bear ore mineralization over the entire thickness and area of their development. Mineralization in the form of bands enriched in ore minerals is confined to certain parts of ore-bearing horizons, united both in the section and at a certain lithological-stratigraphic level in ore deposits;

g) the number of ore deposits in individual ore-bearing horizons ranges from 1 to 6. The intensity of industrial mineralization depends on the degree of development of local structures of disjunctive disturbances in ore areas and on the lithological features of ore-bearing rocks. In the arrangement of ore bodies, usually occurring in accordance with the host rocks, as well as in the Zhezkazgan deposit, there is a noticeable movement of them up the section, in the direction of the uprising of gray sandstone strata;

i) the depth of occurrence of industrial mineralization in the deposits of the Zhilandy ore field is different and to some extent is determined by the conditions of occurrence of the host rocks. At the Karashoshak deposit, Taldybulak, Kopkuduk ore occurrences, where ore-bearing rocks have a gentle fall (10-30 °), the industrial mineralization boundary does not fall below 250 m from the day surface. At the Itauz deposit, where mineralization is confined to the steeply dipping wing of the Zhezkazgan syncline tilted to the west, it can be traced to a depth of 1000 m. At

Kipshakpai, East and West Saryoba deposits, characterized by average angles of incidence of host rocks from 30 to 80 °, ore bodies occur to a depth of 700-800 m and occupy an intermediate position between the Karashoshak and Itauz deposits.

The question of the genesis of copper ores of the Zhilandy group of deposits is debatable, and currently there is no single point of view on the nature of their formation, due to the complex and often contradictory features of their geological structure. There are two different views on the genesis of ores of Zhezkazgan, which, due to the common geological positions, extend to the deposits of the Zhilandy group. It is well known that some researchers consider the ores of the Zhezkazgan region to be sedimentary, while others consider it to be endogenous, hydrothermal. Different opinions among geologists who have studied copper deposits of Zhezkazgan with varying degrees of detail have existed for a long time.

In the Soviet period, for the first time, questions of the genesis of Zhezkazgan mineralization from a hydrothermal point of view were highlighted in the works of I.S. Yagovkin and P.M. Nikitin (1934).

The most complete and detailed geological conditions for the formation of the Zhezkazgan deposit were analyzed by academician K.I. Satpayev and Ph.D. T.A. Satpayeva. Based on the vast amount of factual material, they considered the ores of this deposit to be endogenous. The same point of view was actively developed by academician of the Academy of Sciences of Kaz. SSR M.P. Rusakov (1956). The hypothesis of hydrothermal genesis of deposits such as “copper sandstones” was supported by Professor F.I. Wolfson, a Swedish scientist, Professor Davidson and other geologists. An endogenous point of view on the formation of ores of deposits of the Zhezkazgan region was held by the doctor of medical sciences Sh.E. Yesenov, Ph.D. Seifullin, previously directly involved in field exploration, production geologists V.I. Shtifanov, A.V. Strutinsky, N. B. Golodnova and others.

The main evidence, in their opinion, of the hydrothermal character of mineralization of copper deposits in the Zhezkazgan region, is:

- Mineralization is confined to almost all horizons of gray sandstones of the Zhezkazgan and Taskuduk formations;
- Layers of gray polymictic sandstones do not bear mineralization over the entire area of their distribution. Ore-bearing areas are of limited size and narrowly local in nature;
- Mineralization is localized mainly within the folds of the second and third order, having a section-shaped box profile and complicated on the wings by stepped zones of flexures and faults;
- Mineralization is epigenetic in nature and is the result of metasomatic replacement of carbonate cement and grains with sandstone;
- The structural control of mineralization is pronounced: more intense mineralization is confined to the zones of crushing of rocks on the wings of folds, to the zones of gentle intra- and inter-layer disturbances. The wings of box-shaped folds

and flexures are accompanied by intense zones of crushing of rocks, which apparently have a connection with deep-seated disturbances;

- The rocks of the Zhezkazgan and Taskuduk formations, as well as the Namurian sediments underlying them, do not bear traces of regional metamorphism. At the same time, hydrothermal changes in existing rocks are observed in ore horizons: carbonation and silicification of rocks, serialization, albitization and kaolinization of feldspars.

- The regular and consecutive movement of ore mineralization from the lower stratigraphic horizons to the upper ones as the structures are completely submerged. The movement of mineralization is not sharp, but gradual. When ore bodies are submerged, mineralization in the composition of this stratigraphic horizon is dispersed, while the overlying horizon becomes ore-bearing with a tendency to a gradual increase in mineralization. The contours of the depths of intense mineralization form a surface that slant obliquely at an acute angle to the corresponding layers of the Zhezkazgan and Taskuduk formations, the slopes of which are close to the in-situ zones of disturbances;

- The presence of a powerful Zhidelisay Formation, which is a screen for the further rise of metallized hydrothermals. Having reached the lower horizons of this stratum, the solutions were delayed, and their active force was directed toward horizontal migration within the lithologically and tectonically most favorable layers of the Taskuduk and Zhezkazgan formations;

- The confinement of the main ore nodes of the Zhezkazgan and Zhilandy group of deposits to the areas of intersection of large faults. The epigenetic nature of mineralization is associated with these faults, which were the routes of penetration of ore solutions from magma chambers.

A slight increase in the amount of copper in fine-grained rocks is associated with an increase in the content of organic carbon. In this regard, A.A. Arustamov identified two types of copper mineralization - syngenetic and epigenetic. The syngenetic type of mineralization associated with organic carbon saturates pelitic rocks in amounts well below clarke rocks. The epigenetic type of mineralization sharply prevails in sandstones, as the most permeable rocks, and forms industrial concentrations. This type of mineralization owes its origin to hydrothermal processes.

Thus, the formation of copper mineralization in the deposits of the Zhilandy group is due to the manifestation of epigenetic superimposed processes that are caused by the action of hydrothermal solutions emerging from the depths. In light of the above, it is possible to consider the copper deposits of the Zhilandy group to be classified as hydrothermal metasomatic ones more justified.

CONCLUSION

Ore seismic exploration is classified as a wide-range method used both in regional studies of the earth's crust and in solving multidimensional problems of structural control of ore deposits in geological environments that are immeasurably more complex than those studied by traditional seismic exploration in oil exploration. The objects of ore seismic exploration are various geological structures: intrusive formations, structural folded elements, contact zones, articulated-thrust zones, discontinuous faults, kimberlite pipes, weathering crusts, etc.

As part of the geophysical complex, seismic exploration began to be used in searches for various deposits of solid minerals: polymetals, copper, nickel, iron, chromium, diamonds, bauxite, gold, etc.

As a result of the analysis of the current state of the seismic survey method in solving geological problems, disclosing the characteristics of the object of study, clarifying the methods and technologies of field observations, systematizing the processing of seismic data and analyzing the interpretation of the results of field seismic and geological interpretation of seismic data, an assessment was made of the applicability of 3D seismic surveys in prospecting and exploration solid minerals by the example of work in the Zhezkazgan ore district.

According to the results of the work, the possibility of using high-density wide-azimuth 3D seismic exploration for structural mapping of ore-promising areas and a detailed study of ore-controlling complexes in a selected area is shown.

- Based on the use of modern means of recording, receiving and exciting elastic vibrations for seismic surveys, the assessment and capabilities of modern processing and interpretation systems at ore objects are given to obtain materials of high quality and efficiency of ore seismic exploration in solving the following geological problems:

- study of the structural and tectonic structure of ore regions,
- allocation and refinement of ore-controlling structures in sedimentary and effusive-sedimentary folded rock complexes,
- detection and deep mapping of ore-controlling faults,
- localization and study of the morphology of differentiated intrusions and other deep objects

We can conclude that due to the resolution and depth, seismic exploration is the most accurate method after the well logging methods, however, seismic exploration must be based on linking data recorded in time to depth and lithology. Therefore, for a thin dissection of lithology and the construction of a geological model, we recommend drilling and a well logging complex for target intervals.

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