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Geoecological Problems During Oil And Gas Recover

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Abstract

In this article the authors assessed geo-ecological problems during oil and gas recovery along with accounting for anthropogenic impact on the natural environment of geodynamic processes in the upper layers of lithosphere, where active oil and gas recovery is conducted on the basis of the computer-based systems and facilities of new generation, developed by the experts of the leading scientific centers of the world. In order to do this the scientists used both field and experimental studies of subterranean waters physical and chemical characteristics alterations, alteration of collecting properties of blocks and layers of sedimentary, igneous and metamorphic rocks by standard and new methods. As a result the authors of this publication determined that monitoring of seismic events on the seismic stations network will allow to take into account the seismicity during choosing the process conditions of mining works, planning of construction and operation of engineering structures, cut the likelihood of emergencies and timely inform the people about seismic activity in the area. So the scientists, the authors of this article classified the geologic development data, structure and tectonic regime within Ural region along with considering type and degree of the anthropogenic loads on geologic structures, pumping of associated interstitial waters and toxic industrial effluents into deep absorption layers carbonate rocks. So it has been proved that there is a probability to assess the further change of geological terrain within the area being studied, in the light of the current status of anthropogenic and geodynamic mutual influence. This allows to implement the seismic monitoring in oil and gas bearing Orenburg region, which in its turn, allows to study and analyze the level of alterations of strain-stress state of the geological terrain of the area in real time.

Key words: deposits, oil, gas, geological terrain, anthropogenic load, anthropogenic earthquakes, seismic monitoring.

1. Introduction

No observations and experiments can be absolutely irrespective of the man, in other words, absolutely objective and true. Along with the observed and recorded manifestations of anthropologic alterations in the geological terrain being formed, methodologically rigorous theoretical opening up of the lithospheric plane is necessary as it changes according to natural tendencies of evolution changes is necessary. As there is no one-to-one relation between validity and practical efficiency of the knowledge, on which everyone – physicists, philosophers and experts on fundamental problem of geology point out, there is a necessity of further classification of data on interaction of the geological terrain and near surface layers of lithosphere, which were exposed to anthropogenic impact [1-6]. For this reason evaluation of the geo-ecological problems during oil and gas recovery along with considering the anthropogenic impact on natural environment of geodynamic processes in upper layers of the lithospheric plane, in which there active oil and gas recovery on the basis of computer-based systems and sampling equipment of new generation, developed by the experts of the leading research centers of the world, – is an important scientific, real-world and social problem, which requires urgent solution [7–12].

2. Theory, research methods and applied terms

During the work to assess the importance anthropogenic impact on natural character of geodynamic processes in near surface layers of lithosphere, where active oil and gas recovery is conducted, we used both field and experimental studies of causes and consequences of the unusual, frequently unpredictable events, as the alterations of physical and chemical description of subterranean waters, alteration of collecting properties of blocks and layers of sedimentary, igneous and metamorphic rocks by standard and new methods.

Permissible speed of ground vibrations is a speed, which allows to preserve the buildings and the structures, and probable local strains do not exceed the predicted (guideline) values.

3. Subjects of research

The geological terrain started generating on the territory of Southern Cisurals when the man started using the natural stone, natural waters, ore materials of metals and hydrocarbons practical purposes. While tools and methods of recovery and processing of mineral resources advance, and raw materials treatment technology advance as well, then using of subsurface resources as subterranean storage and for pipeline laying also advance, and construction of terrestrial main line on dislocation of huge amounts of subsurface resources substance, along with water-storage ponds construction. In view of this the subsurface rocks blocks of Earth crust of Southern Cisurals become the sphere of anthropogenic and natural anomalous alterations, which lead to changing of quality of surface and subterranean fresh waters, atmospheric air, living environment of plants, animals, microfauna and microflora, cause epidemics, mental illnesses and so on, including such catastrophic phenomena as anthropogenic earthquakes.

It should be noted that the prediction evaluation of seismic potential capacity of seismoactive areas, provided with current seismologic information and highly researched in tectonic and geodynamic approach, remain unpredictable concerning intensity and time of manifestation [9]. The anthropogenic load, enhanced on near surface layers of lithosphere in areas of oil and gas containing geologic structures of Orenburg Cisurals, may cause anthropogenic and natural seismic events with low level of predictability. The examples of it as follows: the earthquakes in Tatarstan, in Western Siberia, in the North Caucasus and their environmental impact [3]. All of this conditions necessity of conducting assessment of geo-anthropogenic hazard during engineering and operation of oil and gas rock masses in large-sized blocks of fractured sedimentary rocks and tectonic subduction zones. These changes are surely fractal and cannot generally influence the zone water exchange and tectonic regime. Considering the fact that fractality describes the system regime generally, we cannot ignore geo-ecologic changes in the active water exchange zone, dynamics of heat and gas emissions of subsurface resources, penetration of the edge formation waters by means of formation pressure decrease. Also reductions of volumes of porous-fractured field are possible during compaction of fractures in the rocks masses, or transelastic deformations of containers rocks frame. Ultimately the anthropogenic activity on earth surface, such as explosions in mines, wells, on processing installations can weaken or strengthen stress state anthropogenic deformed blocks, and also – most significantly, repetitions of strong and catastrophic earthquakes in Alpine–Himalayan rock folded land.

4. Results and discussion

According to contemporary concepts of tectonophysics mostly shearing deformations develop in earthquake focuses [11]. Here importance of the pore liquids can manifest itself in two ways. During high pressure of porous-fractured waters friction is reduced on shear plane, just like for cover overthrust faults. During high porous pressures the shearing deformations may occur through action of relatively small tectonic stresses. For this reason changes in geological terrain may serve as "trigger" for seismic break.

The anthropogenic earthquakes observed in the countries of Europe and the USA, are the proof of it, especially earthquakes, conditioned by waste water injection into absorbing stratums in states of Kansas

and Oklahoma [15,16], microearthquakes, associated with development of shale gas and shale oil deposits as a result of widespread use of fracking method in states of Alabama, Arkansas, Colorado, Kansas, Miami, New Mexico, Ohio, Oklahoma and Texas [14,17]. Certain decrease of anthropogenic seismic activity is achieved by means of reduction of waste water injection volume into the rocks beds or reduction of non-conventional oil and gas recovery [18].

In most of the cases the caused earthquakes take place in the spheres more or less higher own seismicity. However, the experience of oil and gas deposits on the territory of Tatarstan, Bashkortostan, Orenburg region and Western Siberia, where the seismic events are observed already with alarming frequency, highlights on generation of geo-ecologic hazard focuses [2]. The above mentioned earthquakes took place rather lately, that is why the remote seismic outcomes of porous-fractured rocks blocks stress-deformation states changes are not found yet. Therefore the structure blocks of Earth crust with earthquakes focuses found in them, and also the repeating earthquakes with any frequency can be classified as geo-ecologically hazardous ones.

In order to explain geodynamic interactions in the area the most natural thing is to use lithosphere plates tectonics and deep geodynamics theory. Ural-Mongolian segment of global mobile belt separates the European part of Eurasian Plate from Asian one, and rock folded Ural is a border zone between southeastern margin of East European Platform and southern end of Western Siberian Plate.

The southeastern margin of East European Platform occupies the major part of Southern Cisurals and is heterogeneous complex of Archean-Proterozoic rocks in crystalline basement, overlapped with posterior rock masses of sedimentary formations with competency from 1,6 km on north to 15 km on south. Mantle is located under consolidated crust at depth approximately 30 km (Fig.1).

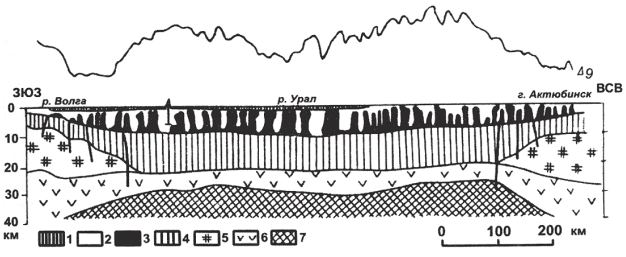


Fig. 1. Geological cross-section through Cis-Caspian syneclise, by V. L. Sokolov, 1970. Southeast of East European Platform [6]: 1 — sediments of Early Pliocene; 2 — sediments of Paleogene, Mesozoic and Permotrias; 3 — salt subjacent intrusives and kettle back; 4 — sub-salt sedimentary sequence; 5-6 — consolidated crust (5 — crystalline granular, 6 — basaltic layers); 7 — upper mantle.

The considered territory of Orenburg Cisurals is a part of Volga-Ural Oil and Gas Province. This territory is exposed to high anthropogenic impact on subsurface resources in the context of large amounts of the taken hydrocarbon crude. Till now gas recovery is on the level of 20 billion cubic meters of oil, which is more than 12,0 mln. of tons, condensate – approximately 0,7 mln of tons. Out of over 200 oil deposits, more than 80% are classified as category of fine ones with reserves less than 1 mln of tons. Almost 95% of the natural gas reserves are concentrated in productive series of Orenburg Oil and Gas Condensate Field, upon that degree of the productive series development exceeds 60% [7]. We tried to analyze and arrange geo-ecologic alterations complicatedly evolving natural systems, processes, which are characterized by wide range of linked natural anthropogenic elements.

Southeastern block of Volga-Ural anticlise is typical for high anthropogenic load on subsurface resources. Several thousands of wells of different purpose were drilled here, provided that during drilling of salt-bearing (rock masses) sections seizure and crumpling of drill strings are being registered, and also circulation loss of drill fluids during drilling carbonate-bearing sections (rock masses). Such units as Gas Processing Facility, Oil Processing Facility, Gas Recovery Stimulation Boosting Compressor Stations work on the field, a dense oil lines and gas lines network was run. Oil and gas recovery on the deposits is followed by taking out of associated formation waters and generation of on hardly purifying industrial wastewaters on Gas Processing Facility and Oil Processing Facility – the wastewaters which contain toxic inputs in concentrations, which are of serious hazard for natural aquifer systems waters quality. These industrial wastewaters on some deposits are loaded back to the productive (rock masses) sections and into deep water-bearing formations under oil and gas accumulations to maintain reservoir pressure. Therefore, soil cover, suprasalt, salt and subsalt sequences of rocks are involved into technogenesis [2]:

– associated formation waters and industrial wastewaters are loaded into в subsalt Paleokarst-fractured intervals of lower Carboniferous Period limestones;

– gas, condensate and oil are recovered from Devonian Period, Carboniferous Period and Lower Permian Period sections;

– saltair section is used for technological purposes (to construct underground gas and liquids storage facilities, and also of low temperature gas separation volumes), rock salt recovery;

– suprasalt section is a reservoir of industrial and mineral fresh drinking waters, construction materials (sands, debris, limestone, clay and so on);

– near surface layers are subject to intense alteration by construction of buildings and industrial facilities, auto-roads, pipelines, open-cut minings, the ground and underground explosions of different power are being performed and so on.

The blocks of the Earth crust which we are considering, have more than billion years geologic evolution history, and during the last 40–70 years the local and large-scale geo-anthropogenic alterations of Paleokarst porous-fractured rocks took place and exogenous geological processes activated in both productive sections, generated for the last hundreds millions of years and on earth surface. Geostatic (formation) pressures, chemical composition of stratified aqueous solutions and the structure of porous-fractured plane – changed in separate blocks of sedimentation (rock mass) sections with a capacity to 12000 km^3, the processes of erosion and of silting-up of waters and nature of seismic events accelerated [9]. Tectonic blocks of Southeastern Volga-Ural anticlise hang within Orenburg Cisurals traveled a long way of geologic evolution. In different geological epochs mostly humid and aridic types of latitudinal and zonal lithogenesis manifested here, and this led to generation of terrigene-carbonate and sulphate–halogenic sequences. The present day lithogenesis is widely represented in aridic and less in humid types [10].

The basement within southeastern margin of Volga-Ural anticlise is a collage of Pre-Cambrian sequences, separated by different age faults, mostly of Late Archean, as differently directed movements of these sequences in combination with latitudinal climatic zonation determined types and distinguishing characteristics of the sedimentary cover structures tectonic regime during Phanerozoe.

The overall picture of Fluid Geodynamics ancient sedimentary basins tell us that artesian basins have a long-term and complex geologic history, they are generating and exist during the stages of tectonic stabilizing during isostatic compensation of lithosphere. In such basins we can see a certain type of physical and chemical (temperature, mineralization, ionic and salt and gas composition) and hydrodynamic (provenance area, formation pressures, directivity of depth flow) zonations on both the area and the open-pit mine [1].

At the present time importance of geological time factor, in the scale of which anthropogenic intervention of the last two centuries – it's almost instantaneous and rigid disturbance of rock and formation pressures, physicochemical equilibrium, stresses in hard rock matrixes, phase states, anomalies of gravitational fields, electromagnetic and other energy fields in near wellbore are, remains poorly known. When we talk about the geological processes extended in time, we also deal with huge steady masses (blocks) of Earth crust.

The outcomes of energy intensive and large scale anthropogenic activity remain poorly known, which reflects on quality of Geologic Information fund and leads to errors in engineering, in forecasting, obtaining scientifically substantiated conclusions. The biggest changes in complex multiphase systems are expected in development of oil and huge gas deposits of hydrocarbon. In such deposits certain researchers observe violent rock bumps, earthquakes, wellbore deviations, fissures of combination and service casing, cross flows of gas and liquid hydrocarbons and formation brines on annular and tubular breakdowns of wells in upper aquifer areas, gas breakthroughs from productive rock mass (section) into atmosphere, which is qualified as geo-anthropogenic crashes and catastrophes.

Anthropogenic activity on developed and industrialized requires integrated study of natural and anthropogenic factors of the geological terrain and life environment of living organisms. Upon that leadership is still with directivity of evolution of more stable inert blocks of lithosphere, and here we should say about environmental functions of lithosphere. The blocks of Earth crust of lower hydrogeodynamic stage, involved into technogenesis, generate natural and anthropogenic systems, subject to general hydrogeodynamic and hydrogeochemical objective laws. And in case if the natural systems had in undisturbed state a balance temperature, gas and chemical regime of lithosphere, hydrosphere and biota, then technogenesis changes them, and so anthropogenic component occurs, which can occur also due to anthropogenic seismic events [3].

On certain deposits, like, for example, on Orenburg Oil and Gas Condensate Deposit, the amounts of the extracted substance become consistent with amounts water drive system in deposit supply contour. As a result the zones of stress-strained sections of rock masses are generated by means of strains of volumes and solidification of porous-fractured plane. Implementation of seismic monitoring on Southeastern slope of Volga-Ural anticlise upon the initiative and under the supervision of Geo-Ecology Department of Ural branch of the Russian Academy of Sciences allows to study and analyze degree of changes of stress-strain state of geological terrain on territory of Orenburg Cisurals live [7,8].

Geographic demarcation of South Cisurals is the first and main phase in assessment of ecological hazard and seismic in the area. Analysis of the published materials on anthropogenic seismic events shows that development of the deposits in stress-strained solid

masses of Earth crust is followed by seismic events, associated with inner energy of layers and blocks of enclosing rocks, exceeding of horizontal stresses over vertical ones, availability of zones of ultimate change of speeds of modern movements of Earth crust, non-uniform distribution on the field and depth of maximum-slope tectonic stresses [2].

Besides that it was determined that the seismic events manifest non-uniformly in time and spacев, the number of the events increases in certain time planes of different duration, and it is conditioned by the impact on stress state of the rock masses by solar activity variations, lunisolar tides, precessions and nutations of Earth's axis rotation and so on. The problem of earthquake prediction is not only a scientific or technical, but social. The third circumstance is likely to stimulate the researches on studying earthquakes precursors.

In Orenburg Cisurals, where more than 200 oil and gas deposits are being used, they made more than thousand of kilometers of the pipelines, they also constructed big objects on reparation and processing of gas and condensate, so the complex physicochemical, geological and geophysical and also seismologic study of Earth crust are currently central. During studying of anthropogenic systems, associated with development of such deposits as Orenburg one, it is necessary to use: achievements of Earth sciences, the obtained data on geomagnetic interactions of rock masses, about structure and mechanics of anthropogenic systems in Earth crust and on Earth surface. All these data are in certain эти links, established, probably, according to the will of the man, but remain absolutely independent of him. Here we are talking about natural and anthropogenic systems, interaction of which is being studied with intent to prevent the possible environmental risks and provision of reasonably safe and efficient exploitation of near surface layers.

Based on registration of seismic events of low magnitude, gravitating towards the tectonic subductions and strain-stress zones, according to distribution of permeability fields and moisture and gas capacity of the rocks the fields and the blocks of possible ultimate stresses segregate and delimit. Provided that we monitor the seismic events and positions of seismic focuses of natural and anthropogenic origin, we will be able to predict flexible precaution measures on prevention of possible seismic events with significant magnitude.

The methods of researching the present-day tectonic processes complement conventional means of studying geological structure and contributes to better understanding of the processes, happening in Earth's Interior. When we use the remote sensing in conjunction with geoinformational technologies on the researched territory it will be possible for us to study the modern tectonic processes in the most efficient way. The obtained data will help us to decrypt the newest ruptures, segregate morphostructures, find the modern geodynamic processes [4].

As is well known, in response to engineering in topmost slices of the Earth's crust and the natural equilibrium of stress-strained state of the blocks of the rock masses, going through anthropogenic impact is disturbed on Earth's surface, and their subduction becomes possible leading to the earthquake. The focuses of the caused earthquakes are likely to be generated in the zones of gravitational field disturbances under impact of hydrostatic loads, or during increase of pressure of porous-fractured waters.

The mechanism of the porous-fractured waters impact on the rock masses blocks in the focuses of the anthropogenic earthquakes, broadly speaking, is little different from the impact in the natural focuses. However, the impact of the subsurface waters on generation of stress-strained compressions, caused by the natural or anthropogenic forces, is still understudied. For the depth zones of the Earth's crust, where the porous pressure of the subsurface waters comes closer to the value of the geostatic load, friction on the surface of the fault plane may go down to zero. At such pressures the water becomes a powerful factor of tectonic movements and earthquakes. The rock masses with heightened porosity and water saturation in consequence of their low density under impact of convective forces acquire the force moment and tend to rise to the shallow horizons of the Earth's crust. However, sometimes the enclosed volumes of the water saturated rocks may plunge into the great depth and to create the focuses of the high tectonic energies in the sphere of high temperatures.

The crystalline basement of East European Platform is special due to its complex inner structure and split-level block structure. On its surface we can see the shown intermediate complex of Riphean, Vendian, Ordovician, Silurian and Lower Devonian buildups, on which the sedimentary rocks of Middle and Upper Paleozoic and Mesozoic and Cainozoic Eras underlay with stratigraphic discordance. In the process of continuous evolution 1600 millions of years ago the generation of the crystalline basement of the platform ended [11]. The modern structure of the basement was created y the following tectonic change. In Karelian, Caledonian and Hercynian tectonic cycle the Earth's crust disjoined by the subductions on separate blocks with individual evolution. Mesozoic, Alpine and neotectonic cycle inheritedly complicated the structure of the region, and the tectonically active depth subductions, flexures, salt tectonic complex of the sedimentations were input.

The blocks of geological terrain of the lower hydrogeodynamic stage are involved into technogenesis and generate natural-anthropogenic systems, subject to general physicochemical objective laws, such as hydrogeodynamic, hydrogeochemical, gravitational ones along the whole section. In undisturbed state they controlled temperature, gas, chemical regime of biota, atmosphere, hydrosphere, the mechanical elastic stress of the upper layers of the Earth crust. In the excited state this process does not stop, although its dynamics changes. The natural component of the lower hydrogeodynamic stage changes as well, but here also anthropogenic component shows itself, as it is connected with distribution of physicochemical parameters. The observed link of the oil and gas bearing structures with subductions and disjunctive deep-laid dislocations indicate evolution of these disjunctive dislocations in both sedimentary cover and crystalline basement. Some part of them belongs to the conventional network of disturbances and generates the "structural lattice" on the research territory [5]. In the platform part of Orenburg region the sublatitudinal subductions, the arcuate subductions and subductons belts and inclined faultings are spread, among them the subductions of north-north-east continuation prevail (fig.2).

The flexures of Cis-Caspian Lowland surround are divided into the line segments by inclined disturbances. The same zone of the inclined disturbances is observed between Orenburg Swell and Karachaganak Rise. In the considered region we also identified the subjacent transit structural zones, which are going between the blocks or the basement highs are often of disjunctive nature. Such zones Ashkadar, Ik-Irtek, Samara are considered as trans-regional ones [8]. In flank of Pre-Urals basin also subduction sublatitudinal zones are noted. Inclined subductions feather the northern lip of Cis-Caspian depression as well. Neotectonic activity during Neogene and Quaternary period revives and generates new fractured zones, which may cause the local seismic events. The anthropogenic earthquakes investigation results analysis showed that the strain accumulated in the rock masses, occurs in form of movements in already existing subductions. According to the results of the conducted experiments, transition of the part of subduction into metastable state is followed by decrease of its dynamic shear rigidity. The arc subduction systems generate three-four belts and correspond to positive narrow magnetic anomalies of the basement on segregation of southeastern depression of Zhygulev-Orenburg anticline.

The mechanical properties change process of the contact starts long before registration of macrodisplacement of the subduction shores. This effect can be found by using tools and used as the basis of the new developed approach to monitoring the anthropogenic and tectonic earthquakes [14]. In the seismic hazard prediction work package we can use the results of restudies of thermal properties of the rocks in the wells. On the well logs of temperature surveys in the well Ordovik–1 in the intervals of depths 0–4976 m it was determined that the geothermic degree on the wellbore changes from 0,7–0,93^0 C to 2,7–2,9^0 C. Along with this increase of geothermic degree is observed in intervals of depths from 1800–1900м to 3000–3100m. On deeper level the geothermic degrees decrease again to 0,43–1,00^0 C [2].

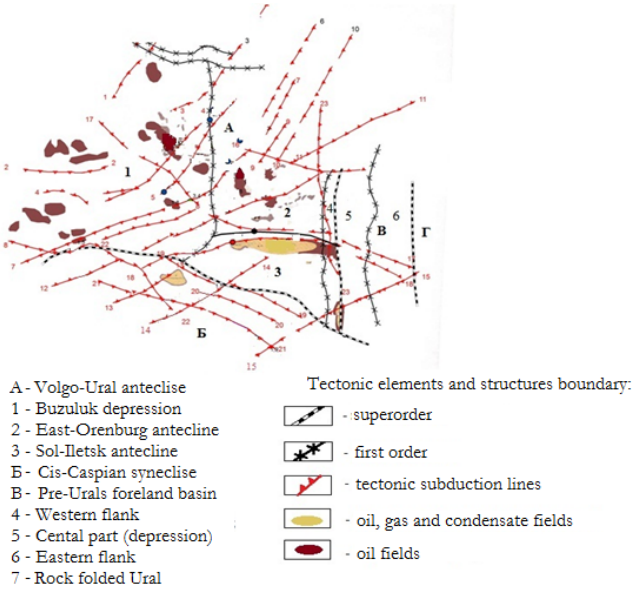


Fig. 2. The map of structure and tectonic elements of Orenburg Pre-Urals [5].

The arcuate systems of the subductions three or four belts and correspond to positive flat magnetic anomalies of basement on the outline of southeastern plunge of Zhyguliov–Orenburg arch.

5. Technology seismic safety

Among the equipment supplied by the manufacturers of the developed mining countries of the world, the device of type ***BlastMate Series III*** (fig. 3) manufactured by the company Instantel, Canada, represents the biggest scientific and practical importance [13–15]. By virtue of on device we can register the vibrations, environment conditions and movements of fractures in the buildings. Such details as human factor effect, errors during processing and presentation of information in form of report, printed by the computer right after the end of explosion, are excluded. Main features of the device Blast Mate Series III:

– the temperature printer with high-resolution and printing speed allows to issue the event reports on-site of works without necessity of connecting to the computer;

– full-sized keyboard simplifies input of comments and other information;

–the key buttons with the only function and menu allow to perform the necessary tasks quickly and adjust the form of signal at the same time with recording the histogram;

–the sampling frequency from 1,024 to 16,384 values per second for a channel and to 65,536 during using only one channel;

– two standard three axes (x,y,z) of a seismic pick-up and two telephone transmitters.

6. Themes for future research

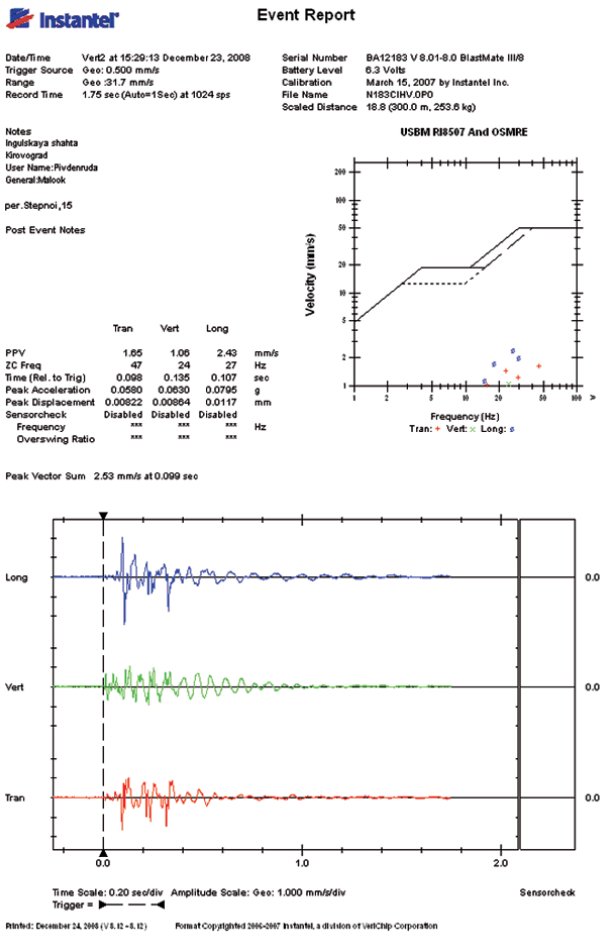
The conducted discussion allows to evaluate the importance of anthropogenic impact on natural character of geodynamic processes in the upper layers of lithosphere, where active oil and gas recovery is conducted [16–18]. So it is necessary to continue the researches on developing the method, based on arrangement of complex characters of seismic hazard on the basis of the new devices and computer-based systems of geomechanical and seismic software developed mining countries of the world, in this context the device of type ***BlastMate Series III*** (fig. 3) manufactured by the company Instantel, Canada, represents the biggest scientific and practical importance [19–21]. When we implement the seismic monitoring in oil and gas bearing Orenburg region allows to study and analyze degree of geological terrain stress-strain state changes in the region, and also impact of these changes on nature and degree of geological terrain alterations.

7. Conclusions

1. ***It was determined,*** that the geothermic degree on the wellbore and well logs of temperature surveys in intervals of depths 0–4976 m changes from 0,7–0,93^0 C to 2,7–2,9^0 C.

2. ***It was shown*** that increase of geothermic degree is observed in intervals of depths from 1800–1900m to 3000–3100m, and on deeper level the geothermic degrees decrease again to 0,43–1,00^0 C.

a)



б)

Fig. 3. Seismograph BlastMate Series III: ***a***– overall view; ***b***– example of the final measurements report3. ***It was noted,*** that seismic events monitoring on the seismic stations network will allow to take into account the seismicity during choosing the process conditions of mining works, planning of construction and operation of engineering structures, cut the likelihood of emergencies and timely inform the people, who live in the zone of the well influence, about anthropogenic seismic activity in the area.

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