NEOGEODYNAMICS PHENOMENA INVESTIGATION AND COMPUTERIZED MAPPING IN BELARUS

Alexander Karabanov* Radim Garetsky*, Roman Aizberg*, Tatyana Aronova**, Dmitry Kurlovich**
*Institute of Geological Sciences, Acad. Kuprevlch str. 7, Minsk, Belarus
**Center of Geophysics Monitoring, Acad. Kuprevich str. 7, Minsk, Belarus

Abstract: The solution of the several problems of neogeodynamics phenomena investigation and mapping was one of the main tasks of the IGCP project No 346 "Neogeodynamics of Baltic Sea Depression and adjacent areas". Investigations performed for the project resulted in a series of international geodynamic maps showing vertical movements at the neotectonic stage, bottom part of Quaternary deposits, recent vertical movements, tectonic stress, epicenters of earthquakes, Moho discontinuity, neotectonic zoning and so on (Aizberg et.al., 2001; Garetsky et. al., 2003). Hence, the water surfaces of the Baltic Sea and the east part of the North Sea, the southern part of Scandinavia, the German-Polish Depression, the Central European block mountains and depressions, western part of the Russian Plain and, partly the Carpathians, were mapped. Despite of, that was done in traditional manner without any digitization, the set of maps showing structure and its dynamics from the Quaternary capping down to the Moho surface fulfils requirements of the modern Information Technology, thus it may and can be computerized in follows of the GIS rules. That will enable authors to supplement project with the newest data, and restructure its visual appearance, in the attached presentation, authors review some problems of geodynamic researches in Belarus.

Keywords: Neogeodynamics, structural pattern, stress field, geological mapping, seismicity

INTRODUCTION

Among the main problems of neogeodynamics phenomena investigation and mapping were the issues pertinent to the geological and computer models explaining the nature of recent tectonic features, correlation between the recent geodynamics and deep structure of the lithosphere, tectonic stress field, seismicity and the active faults which are responsible for the distribution of earthquakes, definition of the most important factors controlling over the geodynamic processes.

S. Ostaficzuk (ed.), The Current Role of Geological Mapping in Geosciences, 157–168.

First of all are to analyse the problems concerning the nature of recent tectonic features and its correlation with the deep structure of the lithosphere. The East European Craton differs essentially from the young West European Platform in the depth to the Moho discontinuity (thickness of the Earth's crust). If the former is described by a rather thick crust (up to 40-60 km), then the latter - by the thinner crust (25-35 km). A regular increase of the crustal thickness is observed in both platforms within the positive tectonic features, and a decrease - within the negative ones. The same is true for the lithosphere thickness. If within the young platform this tendency increased due to recent movements, then within the craton their effect was not so pronounced. Exceptions were the areas of the Fennoscandian Shield and the graben systems in the East Baltic region. Despite scarse evidences about the crustal thickness, its decreasing was noted in the regions of the West and East Gotland, Bothnian and Finnish Grabens showing different depth to the Moho ranging from 10-15 km.

The inquiry into the nature of neotectonic movements revealed the most recent tectonic features (Aizberg et.al., 2003): Baltic-Belarussian Syneclise involving the East Baltic and Finnish Graben Systems (within the East European Craton), North Sea Depression, Central European Zone of subsidences, Central European Zone of uplifts, etc. (within the young West European Platform). The features of the first group demonstrate a superimposed structural pattern against the older platform tectonic units. Those of the second group - are of posthumous character. In general, positive structures show the thicker crust and the negative ones-the thinner crust.

Still one of the debatable problems in geology of Europe is the genesis of the Baltic Sea Depression; This problem solution will provide the key to understanding the geological evolution history of territories of many countries situated in the Baltic Sea basin during the Late Cenozoic. At present there are two different ideas of the Baltic basin genesis. Some geologists associate the origin of the Baltic Sea Depression with glacial erosion, but lately we have many signs acknowledged the tectonic factor as the dominant cause of the Baltic Sea basin formation allowing for a new rifting system that was possibly initiated there. Hence, the most important factors controlling over geodynamic processes that occurred in Central Europe are the Alpine-Carpathian Orogen, downwarping of the North Sea Depression and Central European Zone of subsidences, as well as the development of the recent (embryonic phase) East Baltic Rift System of triple junction. The origination of the Baltic Sea Depression which dates back to Post-Holsteinian time (less than 0.4 mln.yrs.) is associated with it.

The analysis of distribution of the Quaternary strata thickness and composition and the calculation of proportions of materials removed from the central and eastern parts of the basin and redeposited rocks show that only about 40% of the total basin volume can be attributed to exaration. The tectonic genesis of the most part of the Baltic Depression is confirmed by some unconformities revealed in the pattern of glacial sheets and the sea water area, gradual subsiding of the Estonian glint below the sea level, which lower Paleozoic rocks occurred in the Early Pleistocene within an uplifted source area, and a lowered block of Upper-Proterozoic and Early-Paleozoic deposits pre served from erosion which exists in the Gulf of Bothnia.

The Baltic Sea depression had been mainly formed during the last 0.4 mln. yrs (Figure 2). Until the Early Pleistocene there was no evidences of the Baltic Sea existence. At that time, the surface runoff occurred across the territory of the future depression from Fennoscandia toward large freshwater bodies of Central Europe. Inversion movements are associated with the beginning of the Holsteinian. The water transgression occurred from the North Sea in the eastward direction, the Holsteinian Sea crossed Northern Germany and reached the territory of Lithuania and Latvia in the east, while the drainage develop centripetally crossing the territory of the western part of the modern basin from north to south. The sea basin appearance in the Holsteinian in the eastern part of the Baltic Depression was accompanied by the drainage network reconstruction and changes of the river courses within the adjacent regions west of the East European Craton. The Gulf of Bothnia and the Gulf of Finland formed after the Holsteinian. All the above evidences suggest a young age of the depressions of the East Baltic Sea, Gulfs of Bothnia and Finland that possibly form parts of an embryonic riftogeneous triple-arm system.

The last conclusion is supported by a number of various evidences. Firstly, these are deep depressions in the sea bottom relief, which maximum amplitudes of neotectonic downwarping are associated with. These are shaped as narrow linearly extended graben-type structures. The only Likhvin-Holsteinian downwarping shows there maximum values (150-200 m). The most recent fault system bounds and clearly delineates the graben-type structures. A number of block linear horst-type (Central Gotland Uplift) and graben-type (West and East Gotland Uplifts) structures are outlined by faults within the bottom of Gulfs and the East Baltic area. High seismicity values are confined to the bounding zones of Grabens. Local positive heat flow anomalies were determined in the inner sea parts (regions of the Gotland island, Gulfs of Kursh and Finland, etc.). The Earth's crust thickness was noted to decrease within the East-Baltic Graben System, a difference in the Moho depth being as great as 10-15 km.

The evolution of the East-Baltic Graben System and the deep North Sea Depression in the west margin of the Eurasian lithospheric plate was probably due to submeridional tension belts that occurred subparallel to the Mid-Atlantic spreading zone (Figure 1).

As the main reference horizons Lower Oligocene marine deposits (rupelian layers) were selected. In places where the above deposits were absent, the structural features of the bottoms of Miocene marine and Quaternary deposits were taken into account.

Within the territory of Belarus and the neighboring Recent strata are mainly formed by deposits of four formations (Figure 2). The oldest is brown coal formation accumulated during the Late Oligocene, Early and Middle Miocene and widespread on the south of the Baltic region, in Belarus and the Ukrainian Polyessie area (sand, brown coal, clay). The overlying formation of montmorillonite clays (included in the Upper Miocene and Lower Pliocene strata) is found mostly in the southeastern and central parts of the Pripyat Trough and adjacent areas of the Dnieper Trough, to a smaller extent - on the southeast of the Brest Depression, and as spots - within the Belarussian Anteclise territory. Within the Brest Depression, west and south of the Pripyat Trough there is a formation of Pliocene silts and diatomaceous clays. All of Late Oligocene-Pliocene formations are situated in the Early Oligocene sea area. As opposed to old formations the thickness of Mid- and Late Pleistocene glacial formation in general is concordant to the recent tectonic features of the region and the surface of Pre-Quaternary deposits presents a monocline gently inclined from southeast to northwest toward the Baltic Sea basin, is being known that linear marginal glacial landforms, as well as systems of glacial hollows occur above fault zones. It also testifies to the very young age of the Baltic-Belarussian Syneclise, which was formed in the Quaternary time. The important part of investigation are the reconstructions of the tectonic stress field and the active faults. The investigation of recent tectonic stresses have shown that the mechanism governing the development of recent structures west of the East European Craton was largely dependent on shear stresses that have submeridional compression and sublatitudinal exterisional axis. In such a stress field faults of NW strike are right shifts, and those of NE strike - left shifts.

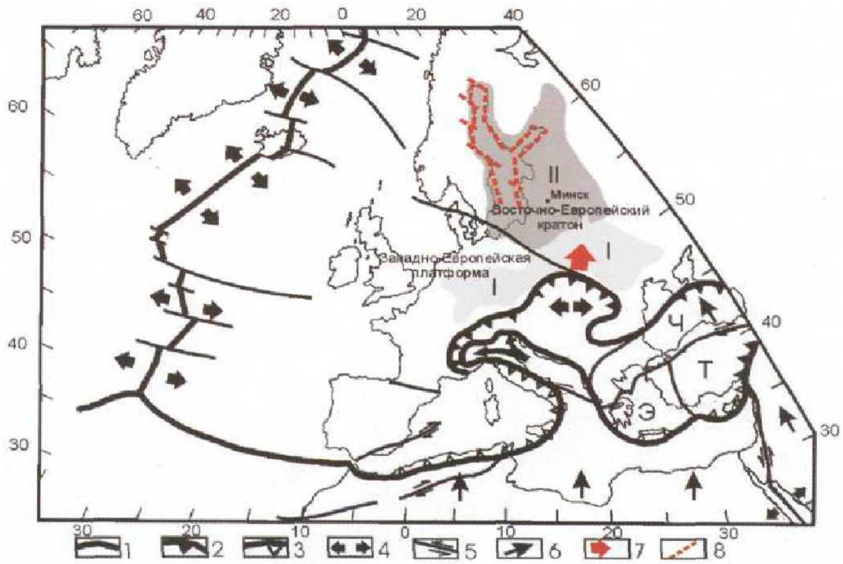


Figure 1. Recent tectonic features and factors controlling over neogeodynamic processes in Central Europe: I-II – neotectonic structures: I - Central European Zone of uplifts, II - Baltic-Belarussian Syneclise; 1-3 – the boundaryes of lithosphe plates: spreading and transform (1), collision (2), subduction (3), 4 – tension, 5 – shear, 6 – direction of plate moving, 7 – direction of the dynamic impact of Carpathian orogen on the East European Craton, 8 – faults of the East Baltic and Finnish Graben Systems

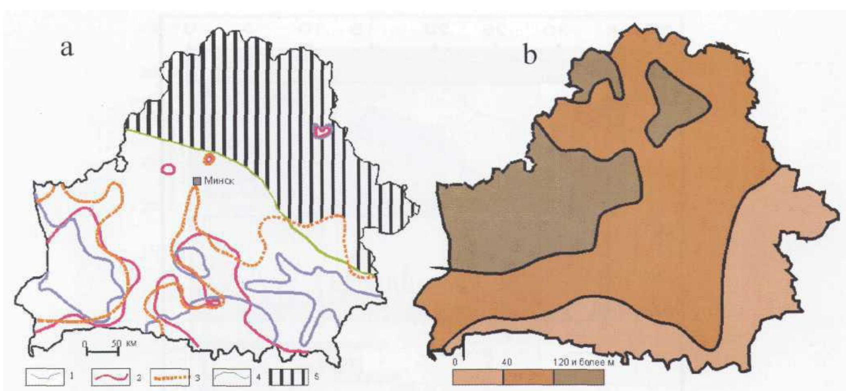


Figure2. Recent formations within the territory of Belarus: a - formations of Late Oligocene-Pliocene: 1-2 – distribution area of browncoal formation, Late Oligocene-Mid Miocene (1 – sand-clayey subformation, 2 - browncoal subformation); 3-4 - distribution area of silt and clays formation Miocene-Pliocene (3 - montmorillonite and diatomaceous clays subformation, Upper Miocene, 4 - silt and hydromicaceous clay subformation, Pliocene); b – average thickness of Pleistocene glacial formation

The orientation of compressive stresses changes appreciably, sometimes to the reverse in the area adjacent to the Baltic Sea basin. Orthogonal faults most often show evidences of faults or shear-faults. This conclusion is confirmed by geological data and investigation of ruptures (Figs. 3,4) in the potassium-mine (Soligorsk).

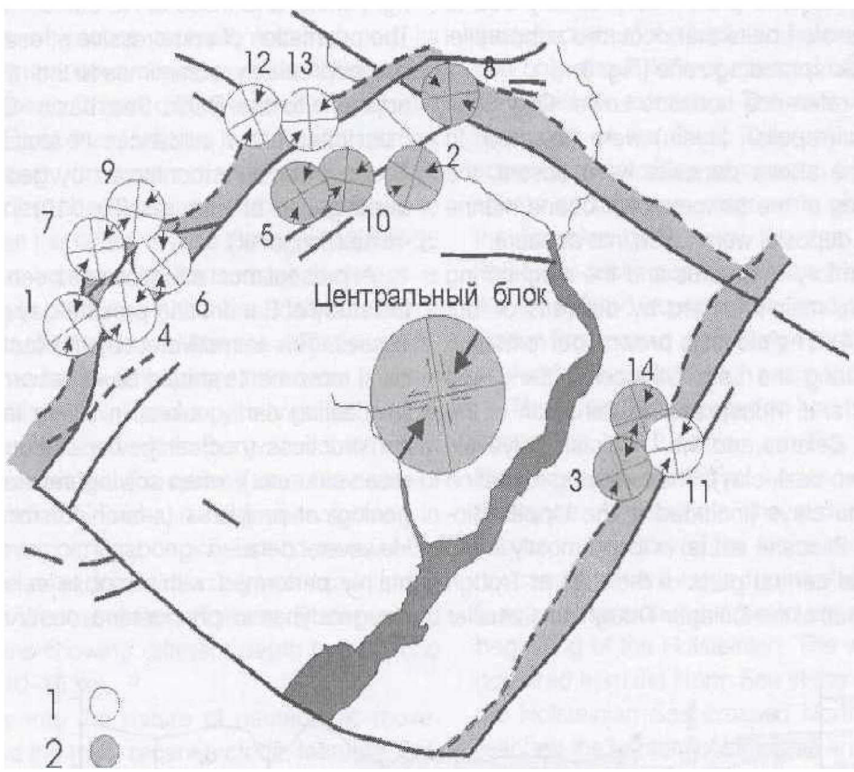


Figure3. The example of reconstruction of the stress field in the potassium-mine (Soligorsk): the full and dotted lines shows the fault zones on different depth (in the south-east runs the zone of Central fault), the numbers show various domains; 1–2 - measuring points in the second (1) and third (2) potassium layer (horizon)

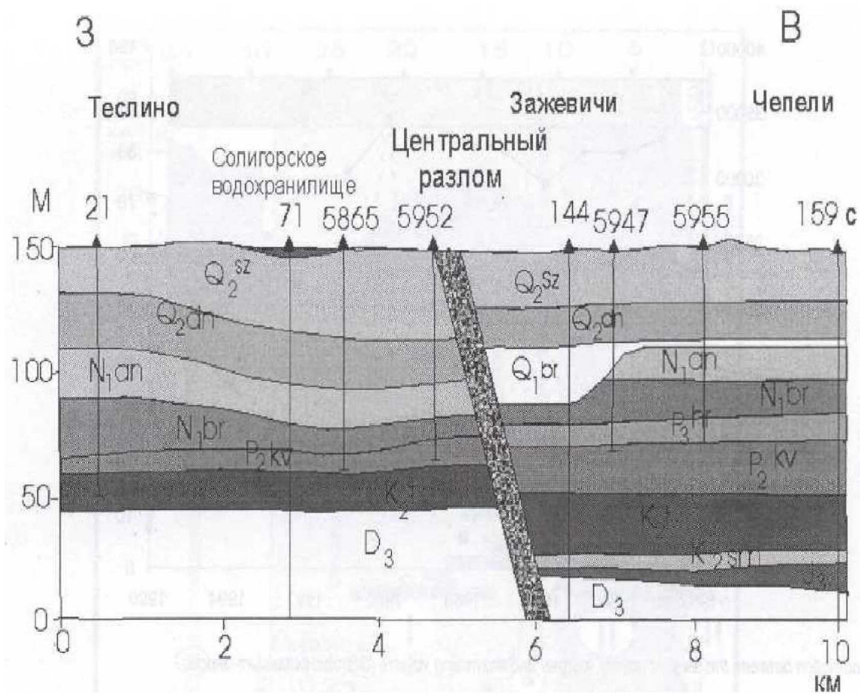


Figure 4. Geological profile across the Central fault near Soligorsk (drawing: looking north)

At present most attention has been concentrated on the study of Recent and present-day geodynamic pro-cesses. This is motivated by the fact that the Earth's crust movements should be necessarily considered in forecasting earthquakes, in sitting large engineering constructions (nuclear power stations, water-storage reservoirs, etc.), when solving several ecological and geological problems (search for minerals included). However, detailed geodynamic investigations were mainly performed within mobile seismoactive areas.

Neogeodynamic phenomena observed within rather stable intra-plate regions have not yet been adequately studied. The seismological data demonstrate that within the territory of Belarus active faults are responsible for the distribution of the earthquakes.

Arc View GIS 3.2a software was used as a tool to design the GIS project entitled ″Earthquakes & Faults of EEP + Soligorsk area″, that involves the digital layers as follow: border, geogrid, territorial waters, rivers, settlements, countries, open sea, faults, EEP earthquakes, Soligorsk earthquakes (Figure5).

At the first stage of the GIS implementation a topographical basis was created by automatic vectoring of image graphics on a recording surface ″Vertical movements since the beginning of Rupelian stage (Oligocene)″ involving digital layers as follow: border, geogrid, territorial waters, rivers, settlements, countries, open sea. A bit map was processed with Adobe Photoshop 6.0, and automatic vertoring was made in a vectorizer R2V (R2V Group, Russia). Each digital object was supplied with an information entered line-by-line in attribute tables.

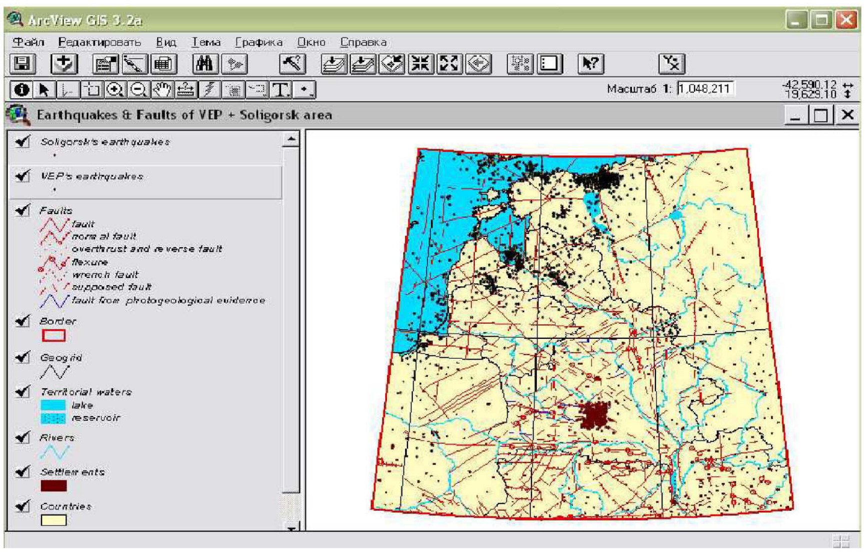


Figure 5. General view of the GIS project ″Earthquakes & Faults of EEP + Soligorsk area″

The second stage expected the creation of digital topics as follow: faults, EEP earthquakes, Soligorsk earthquakes (Figure 6). The faults topic including 523 faults was created with the map ″ Vertical movements since the beginning of the Rupelian stage (Oligocene)″ used as a basis by image graphics digitizing. Dot patterns of EEP earthquakes (1, 673 earthquakes) and Soligorsk earthquakes (729 earth-quakes) were obtained from the database geographical coordinates using Arc View 3.2a Enter Point by Coordinates.

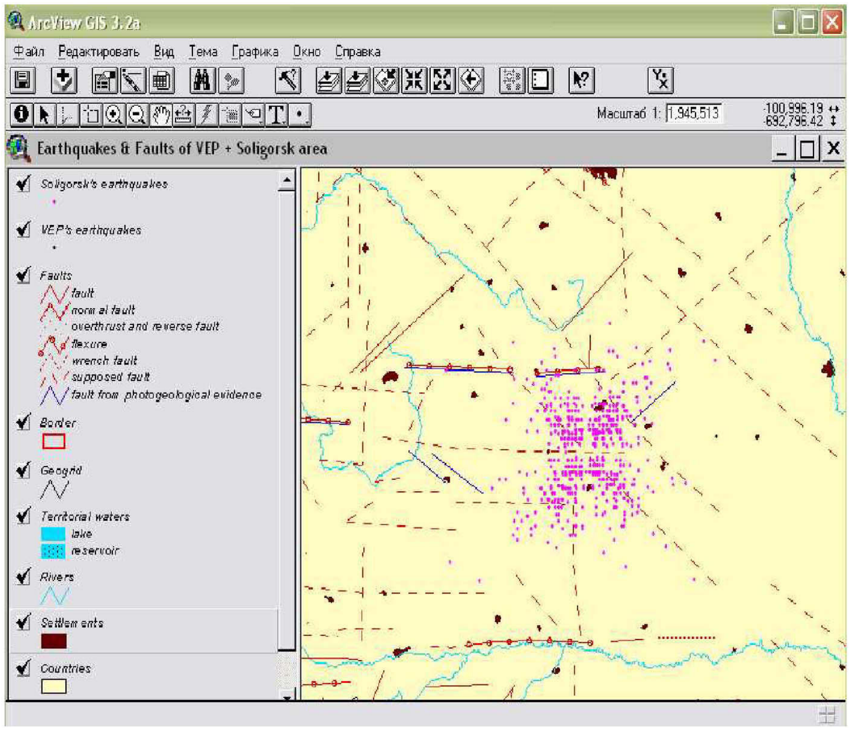
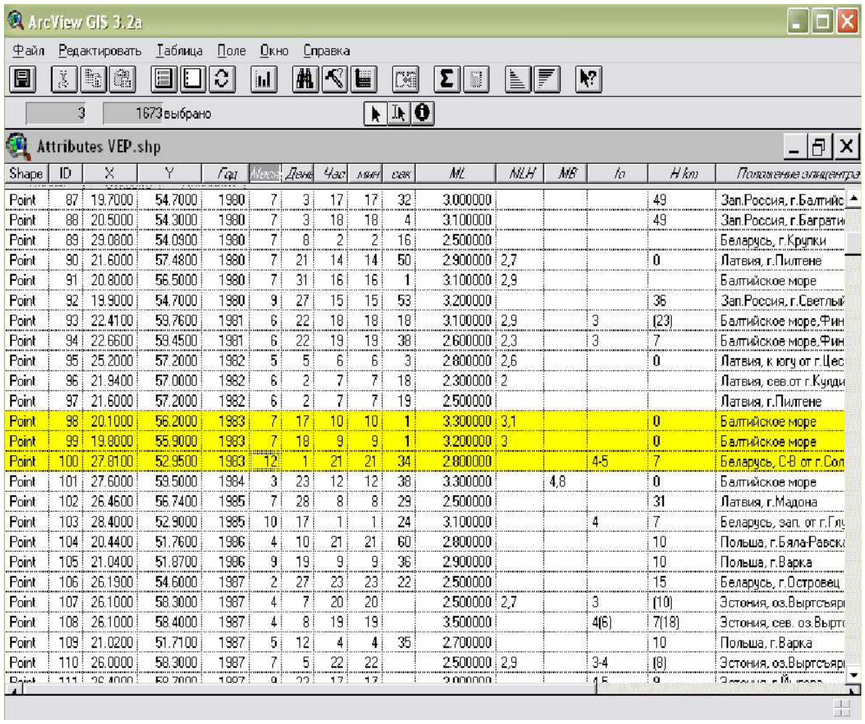


Figure 6. GIS project fragment (Soligorsk geodynamic testing ground)

The final third stage consists in matching graphic objects from EEP earthquakes and Soligorsk earthquakes with the EEP database available at the Centre of Geophysical Monitoring of the National Academy of Sciences of the Republic of Belarus. For this purpose, SQL was connected with the database, and attribute tables were combined with Arc View GIS 3.2a (Figure 7).

So, at the present-day stage of the GIS implementation in the seismic information display system, a topographical basis for the East European Platform western part, as well as the following actual layers: faults, EEP earthquakes, Soligorsk earthquakes were developed. Digital models of the relief, structural horizons, basement surface and some other geological and geophysical parameters are expected to be created later on.

At the same time there are observed the positive connection between the seismic activity and some man-caused factors (Figures 8, 9).



ArcView GIS 3.2a

Файл Редактировать Таблица Поле Окно Справка

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Attributes VEP.shp

Shape	ID	X	Y	Год	Меся	День	Час	мин	сек	ML	MLH	MB	Io	H km	Положение эпицентра
Point	87	19.7000	54.7000	1980	7	3	17	17	32	3.000000				49	Зап.Россия, г.Балтийс
Point	88	20.5000	54.3000	1980	7	3	18	18	4	3.100000				49	Зап.Россия, г.Баграти
Point	89	29.0800	54.0900	1980	7	8	2	2	16	2.500000					Беларусь, г.Крупки
Point	90	21.6000	57.4800	1980	7	21	14	14	50	2.900000	2,7			0	Латвия, г.Пилтене
Point	91	20.8000	56.5000	1980	7	31	16	16	1	3.100000	2,9				Балтийское море
Point	92	19.9000	54.7000	1980	9	27	15	15	53	3.200000				36	Зап.Россия, г.Светлый
Point	93	22.4100	59.7600	1981	6	22	18	18	18	3.100000	2,9		3	(23)	Балтийское море,Фин
Point	94	22.6600	59.4500	1981	6	22	19	19	38	2.600000	2,3		3	7	Балтийское море,Фин
Point	95	25.2000	57.2000	1982	5	5	6	6	3	2.800000	2,6			0	Латвия, к югу от г.Цес
Point	96	21.9400	57.0000	1982	6	2	7	7	18	2.300000	2				Латвия, сев.от г.Кулди
Point	97	21.6000	57.2000	1982	6	2	7	7	19	2.500000					Латвия, г.Пилтене
Point	98	20.1000	56.2000	1983	7	17	10	10	1	3.300000	3,1			0	Балтийское море
Point	99	19.8000	55.9000	1983	7	18	9	9	1	3.200000	3			0	Балтийское море
Point	100	27.8100	52.9500	1983	12	1	21	21	34	2.800000			4-5	7	Беларусь, С-В от г.Сол
Point	101	27.6000	59.5000	1984	3	23	12	12	38	3.300000		4,8		0	Балтийское море
Point	102	26.4600	56.7400	1985	7	28	8	8	29	2.500000				31	Латвия, г.Мадона
Point	103	28.4000	52.9000	1985	10	17	1	1	24	3.100000			4	7	Беларусь, зап. от г.Глу
Point	104	20.4400	51.7600	1986	4	10	21	21	60	2.800000				10	Польша, г.Бяла-Равска
Point	105	21.0400	51.8700	1986	9	19	9	9	36	2.900000				10	Польша, г.Варка
Point	106	26.1900	54.6000	1987	2	27	23	23	22	2.500000				15	Беларусь, г.Островец
Point	107	26.1000	58.3000	1987	4	7	20	20		2.500000	2,7		3	(10)	Эстония, оз.Выртсъяр
Point	108	26.1000	58.4000	1987	4	8	19	19		3.500000			4(6)	7(18)	Эстония, сев. оз.Вырт
Point	109	21.0200	51.7100	1987	5	12	4	4	35	2.700000				10	Польша, г.Варка
Point	110	26.0000	58.3000	1987	7	5	22	22		2.500000	2,9		3-4	(8)	Эстония, оз.Выртсъяр

Figure 7. Attribute Table of the EEP earthquakes topic combined with the Database

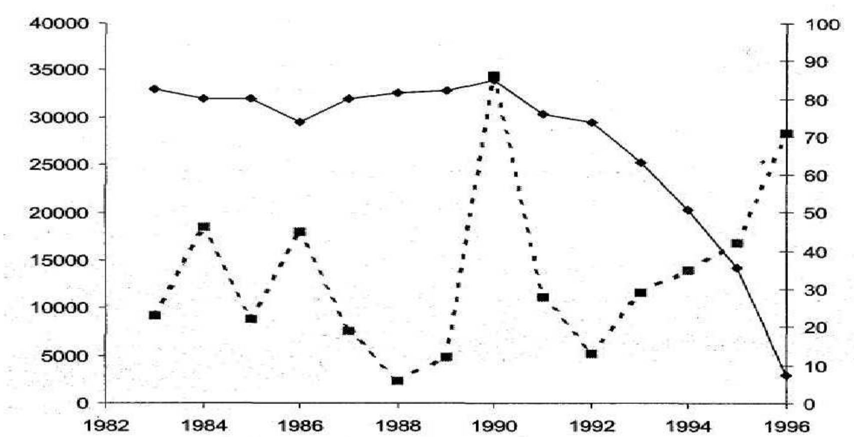

Figure 8. The correlation between the seismic activity (purple) and the mining volume (Starobin potassium deposit)

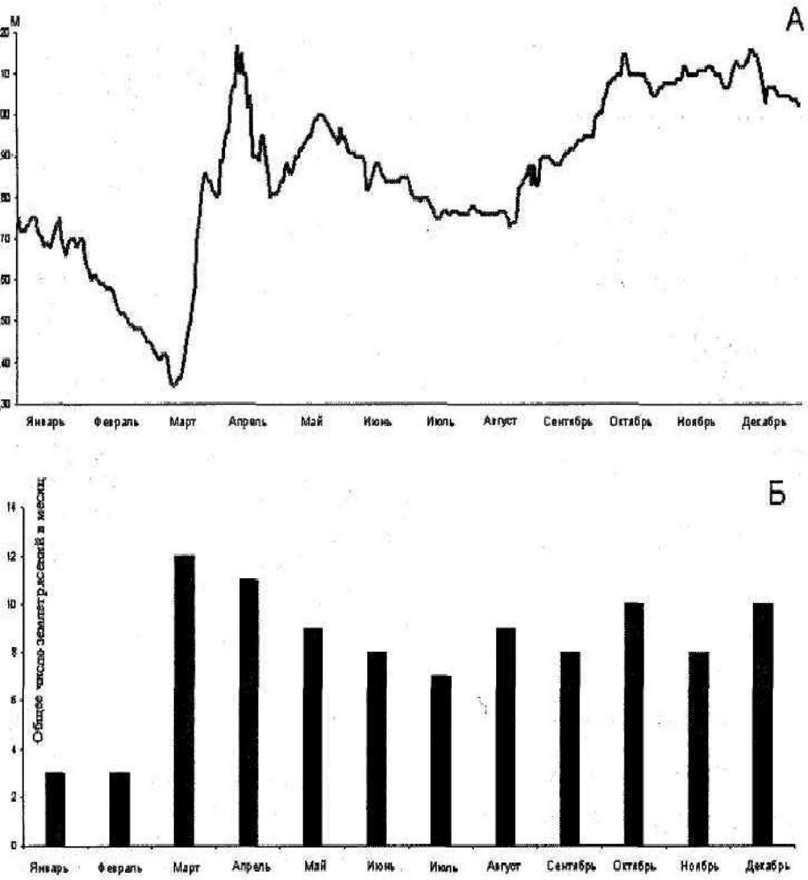

Figure 9. The correlation between the frequency of the earthquakes (red) and oscillations of the water level in Soligorsk reservoir

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