Geospatial analysis of lineaments and local structures using geographic information system

Michail Vakhnin[1]

[1]Institute of Geology of Komi SC UB RAS, Pervomajskaya 54, 167000, Syktyvkar, Komi Republic, Russia

oilkominc@mail.ru

Abstract. Landsat-7 satellite pictures have been used. By means of manual and automatic decoding the lineaments of different extension have been determined and included in the geoinformation system of Northeastern European Russia for the further processing and analysis.

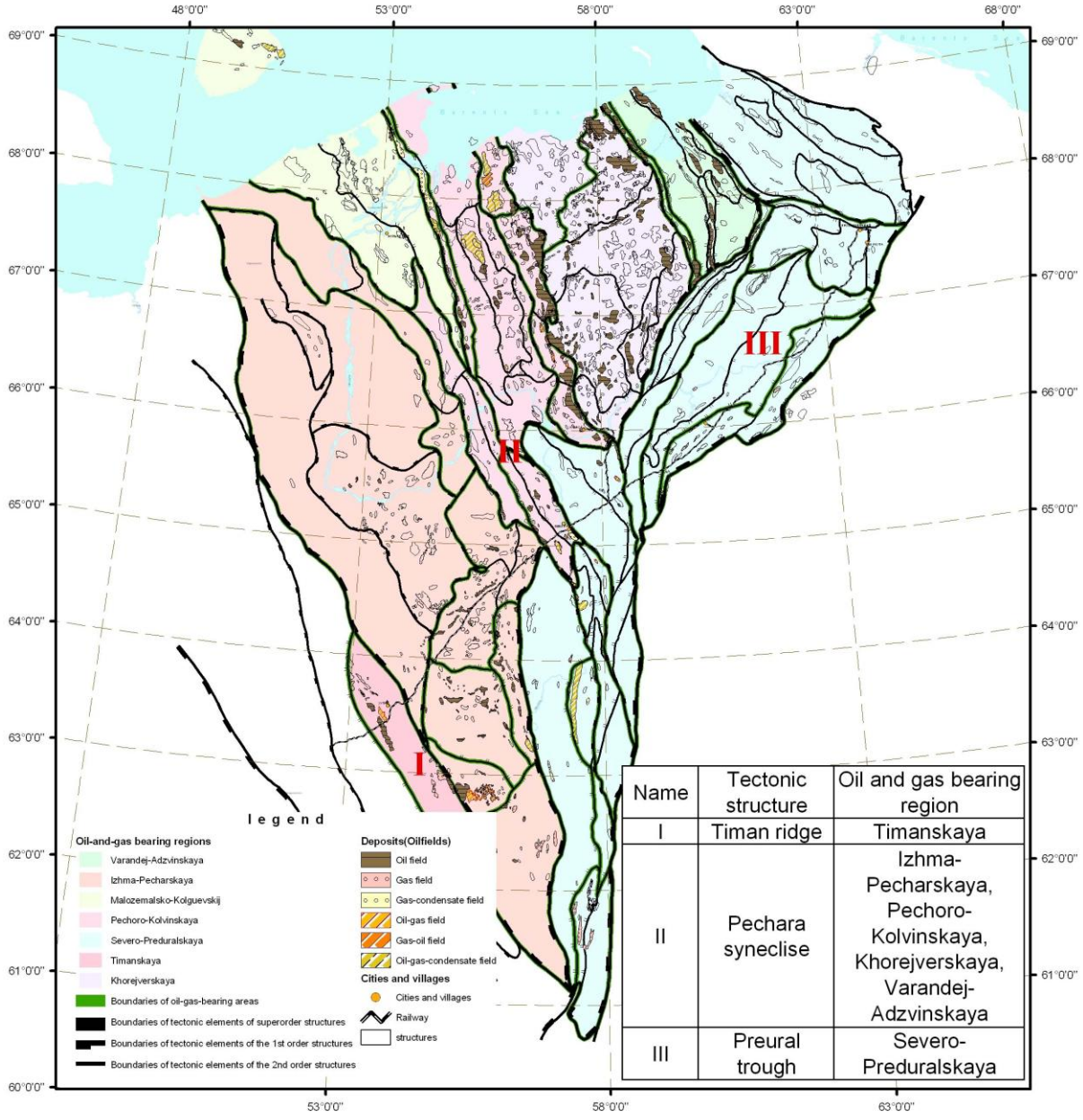
The geoinformation system is realized with ArcGIS 9.2 and contains the following data: a survey map, chronostratigraphic sections, stratigraphic map, tectonic and petrogeological zonation, structural maps, maps of deposits, local structures and data of remote sounding. GIS contains also developed tools for the data processing and analysis. By means of the geoinformation system the analysis of determined lineaments for various tectonic elements, their connection with local structures and deposits of hydrocarbons has been conducted. After lineament digitization, calculation of extension and strikes, the tables of extensions and strikes of the lineaments and rose-diagrams for definite tectonic elements and the whole territory have been made. For a quantitative estimation at the analysis of rose-diagrams the contrast parameter of rose-diagrams has been chosen, and it was defined as the long-to-short axis ratio. This parameter gives information on modern geodynamic activity of the fault system. With the help of the given analysis the zones with mobile and stable basement have been confirmed. The connection between the spatial distribution of local structures and submeridional lines of the global fault network is most precisely tracked. Proceeding from the above-stated it can be concluded that many oil-gas-bearing structures are spatially connected with lines of the global fault network (lineaments) and revealing of these laws gives additional tools for hydrocarbon prospecting.

Keywords: GIS, lineament, Timan-Pechora, local structure, geoinformatics,

1 Introduction

With the use of remote sounding data the lineaments have been determined for the Timan-Pechora province. The obtained data have been incorporated with the geologic-geophysical information into the geoinformation system for the further processing and analysis.
GIS technologies allows integrating all the variety of available data on the structures into a uniform system and enables carrying out of researches in the view of all possible data [1].
The work used space pictures taken by means of satellites Landsat-7, which provide shooting of the earth's surface with application of six channels with resolution 30 meters, and in one IR-channel with the resolution 60 meters with simultaneous panochromatic shooting with the resolution 15 m. The width of the review for all channels makes 185 km.
The data were geopositioned in Gauss-Kruger projection on Krasovsky ellipsoid in the system of coordinates SK-42, the tenth zone. Then by the elements of landscape rectilinear sites (lineaments) were determined. Lineaments are generally understood as linear heterogeneities of the earth's crust and lithosphere. They can be of a various rank, extent and depth. They can develop on surface directly or in the form of geological and landscape anomalies. Lineaments are caused by latent breaks of basement, fracture zones in sediments, etc.
Lineaments and lineament zones are zones (channels) of the raised permeability of the earth's crust. They serve as transiting ways of solutions and gases, which generally possess higher temperature in comparison to the surface of the Earth [2]. Also in fracture zones, especially sedimentary basins, the fluid system is constantly present and redistributed. It results in intensive deformations in fracture zones, and, hence, in their expression in the landscape attributes reflected on space images in the form of lineaments [3]. Therefore, the shape of lineaments on space images is a generalized reflection on the surface of both deformations, and fluid mode of near-surface areas of the earth's crust.
The form of the lineaments, their pattern can help to define kinematic and geodynamic conditions of formations of faults and conditions of their formation.

The intensity and width of lineaments depend on the depth of occurrence of a fault and its activity. The account of all these data by the form, sizes, intensity allows considering faults and geodynamic conditions of the studied area.
The extensions of upper layers of the sedimentary cover occur in the area of structural highs in the presence of vertical neotectonic raises. This results in the removal of overlying rocks and decrease of rock load above. The consequence is a vast number of small fractures and increasing permeability of the sedimentary cover in this area. This circumstance supports migration of fluids, hydrocarbons and water toward the surface of the earth. Rock decompression results in retraction of fluids and increase of rock and surface humidity in the area of structural highs [5].



Name	Tectonic structure	Oil and gas bearing region
I	Timan ridge	Timanskaya
II	Pechara syneclise	Izhma-Pecharskaya, Pechoro-Kolvinskaya, Khorejverskaya, Varandej-Adzvinskaya
III	Preural trough	Severo-Preduralskaya

Fig. 1. Map of tectonic and petrogeological zoning with hydrocarbon deposits and local structures.

It might be noted that the newest and modern tectonic activity of the earth's crust and its raises affect fracturing of the sedimentary cover. The raise of permeability level of the earth's crust in the areas of highs and extension contributes to increasing circulation of underground waters. This results in increased humidity of rocks in the areas of the newest highs and active faults, which allows determining those areas by means of remote sensing.

2 Data analysis

Lineaments are possible to express by a set of quantitative characteristics: orientation, length, density. In the given work lineaments were visually determined from several kilometers to several tens kilometers, which can be related to local category, comparable to the size of local structures. Digitalizing was carried out using the geoinformation system ArcGIS 9.2. In total in the investigated territory about 5000 lineaments of various orders have been determined.
For the analysis GIS has been used, which was realized on the basis of ArcGIS 9.2 and including the following maps: maps of local structures, seismic and drilling maps, maps of deposits, structural maps. The map of structures incorporates digitized contours of structures with data about the depth, horizon (supposed age), morphological characteristics, condition of structures (revealed, prepared for drilling, explored by drilling). The map contains major tectonic boundaries and oil-gas-bearing areas and regions and deposits (Fig.1).
After digitizing of lineaments, calculation of lengths and strikes the tables of lengths and strikes of the lineaments for various tectonic elements and the whole territory of the Timan-Pechora oil-gas-bearing province have been made. Additionally the value of anisotropy has been calculated, where the criterion of anisotropism of lineament distribution is their vector sum. In the case of isotropic (disordered) distribution of lineaments, their vector sum is equal or close to zero, whereas the vector sum of anisotropic (ordered) distribution significantly deviates from zero [8].
The revealed lineaments have been compared to the faults established by seismic prospecting and other geophysical methods
Regularities between the presence of structures with deposits of hydrocarbons, deep faults and density of lineaments have been established. The significant amount of deposits is located in immediate proximity to deep faults.
Lineaments have generally a dominating southwestern and northeastern direction, well conformable to planetary fracturing caused by rotational stress of the upper cover of the Earth(Fig.2).

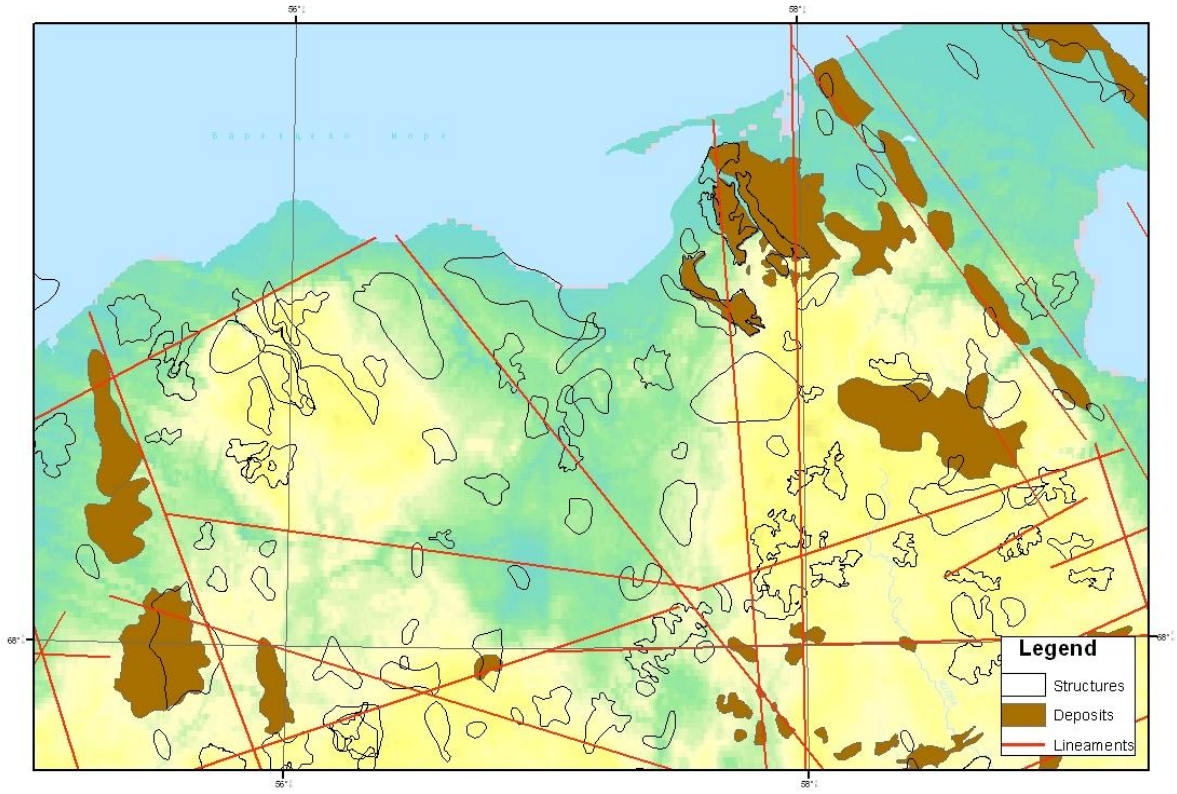


Fig. 2. Map of lengthy lineaments with hydrocarbon deposits and local structures.

Stability of this lineament network is connected, probably, to the fact, that the reanimation of already existing faults is more favorable energetically. The greatest density is observed along such deep faults, as East-Timan, Peri-pechora, East-Kolva, Ilych-Chiksha, Varandey Shapkinsky deep faults,

which are considered as discontinuous-continuous faults. Also the increase of lineament density is confined to the places of crossing of deep faults.
Gaps occur in extension conditions, which results in opening of large number of fractures and occurrence of permeable areas open for vertical fluid migration.
Thus, lineaments (megafractures), resulting from tectonic gaps on space images, reflect the character of dynamic stresses and are connected to the intensity and direction of the newest structural deformations.
The given lineaments, distinct on the space images, are indefinitely recognized during geological mapping and gravimagnetic survey, which better reflect faults caused by compression and considerable relative displacement of the fragments of the earth's crust [5].
At geological decoding in different spectrum ranges the elements of a natural object are recognized variously, therefore the influence of landscape component decreases. We observe vegetation in bright hues in red and near infrared bands, therefore the influence of vegetation decreases and the newest tectonics are well recognized. On the images more damped soils are notable, which can characterize the newest highs. These areas will be characterized by increased density of lineament fields.
At that on the space images larger elements are better recognized because masking role of landscape components decreases [6].
The northern part of Kolva megaswell can be one of the examples – this is an inversion structure over Ordovician-Devonian paleodepression, which is a part of a large Pechora-Kolva aulacogene with rift inherent subparallel faults forming transfer zones of various types [4]. In this area the faults were defined by means of Landsat 7 space images, additionally structural maps from seismic crews were used. The studies aimed at the activity of faults in the newest time. The analysis of lineament fields showed increasing density of megafracturing for number of faults of north-north-western (sublatitudinal) and north-eastern (submeridional) strikes. At that the formation settings of the given faults in the sedimentary cover is very important. Faults of north-western strikes are found in compression settings, and ones of north-eastern strike – in various geodynamic settings including extension settings [7].
At that the fact of abrupt turn of fault zones from meridional direction north-eastward was observed for the fault zone confining the Kolva megaswell in transition to shallow zone of the Pechora Sea. This fact is supported by the change of direction of rose-diagrams of lineaments closer to shelf and in the shallow-water part of the Pechora Sea westward (Fig 3).

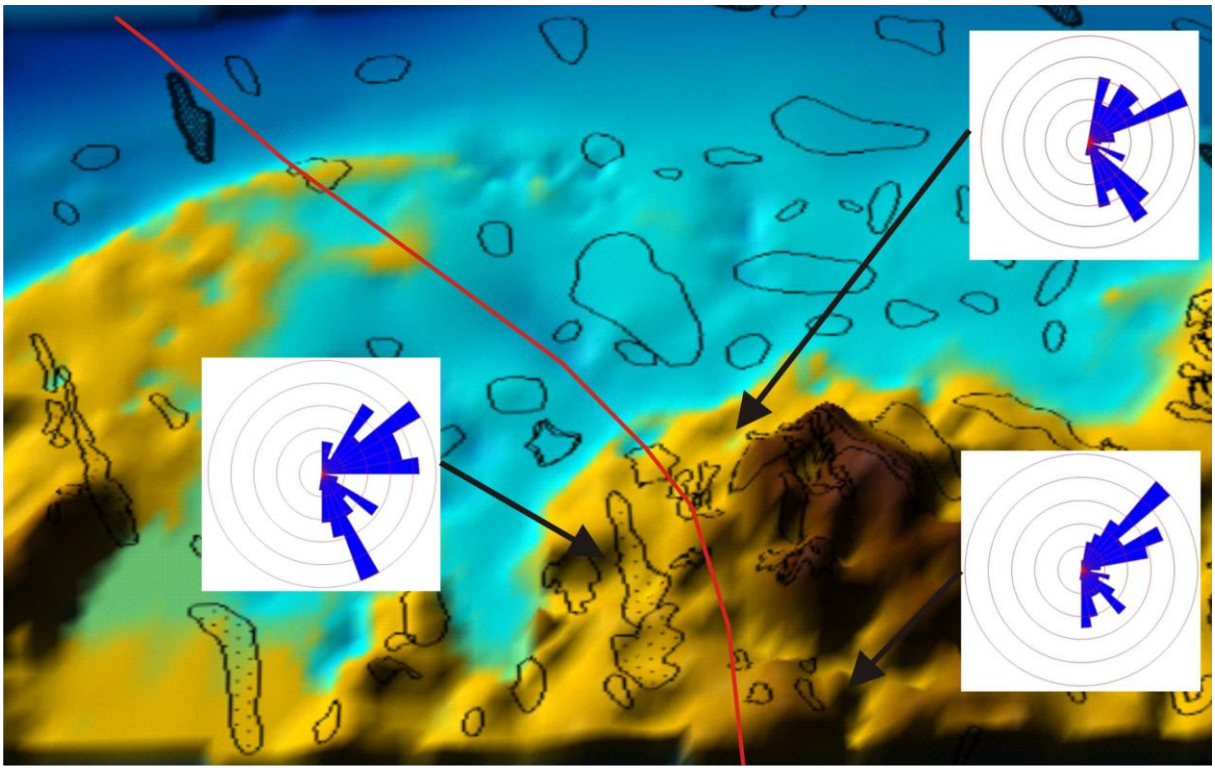


Fig. 3. Relief map of Kolva megaswell with East Kolva fault and lineament rose-diagrams.

This results in complication of structural plan and change of orientation of local structures in the fault area northwestward within 5-10 degrees. One of possible reasons of the changing structural plan in this area can be the influence of shift and overthrust forces at the boundary of the Pechora plate and pre-Paykhoy foredeep in the northern part of the Kolva megaswell.

3 Conclusions

Comparison of structures of all orders shows that fine elements reveal features of structure of larger structures. So, local forms can serve as parameters of tectonic activity of the largest structures and structures of the first and second order; at that the lineaments, built according to remote sounding, correlate well by direction with the local structures located in immediate proximity.
Built rose-diagrams of parameters of specific density and anisotropy of the chosen lineaments on the unit of area in the territory of the Timan-Pechora oil-gas-bearing provinces allowed revealing area of the earth's crust differing by block divisibility, more dislocated and, hence, more permeable. The given areas coincide with the most perspective oil-gas-bearing areas of the province.
Proceeding from the above-stated, it is possible to conclude that many oil-gas-bearing structures are reflected in modern neotectonics and spatially connected with lines of the global fault network (lineaments). Taking the given regularities into consideration in regional and exploration works will allow a more effective investigation of hydrocarbon deposits.

Reference

1. DeMers Michael N. Fundamentals of Geographic Information Systems. - M.: Data +, 1999. - p. 3-8.
2. Kats Ya.G., Poletaev A.I., Rumyantseva E.F. Basics of Lineament Tectonics. - M.: Nedra, 1986. - 144 p. (In Russian)
3. Kuzmin Yu.O. Modern Geodynamics of Fault Zones // Physics of the Earth. - 2004. – No. 10 - p. 95-111.
4. Malyshev N.A. Paleozoic rift zone in Pechora basin and oil-and-gas bearing basin // Construction and dynamicsk lithospheric Eastern Europe. M., GEORART, GEOS, 2006. p.502-508.
5. Rozanov L.N. About geological information the fototon on . space picture - Sov. geology, 1980, № 7, p. 100-106.
6. Sadov A.B., Revzon A.L. Aerospace methods in hydrogeology and engineering geology. M., Nedga, 1979.
7. Sim L.A. Influence global tectogenesis on modern mode of deformation platforms Europe.// M.B. Gzovskij and development tectonophysics. M.: Nauka. 2000. p. 326-350.
8. Ul’masvai F.S., Nalimova N.A., Dobrynina S.A. Local Geodynamics of Northern Sakhalin Based on Results of the Analysis of Lineaments // Doklady Akademii Nauk, 2006. Vol. 409, No. 6, p. 793-794.