P-191 STRUCTURAL EVOLUTION OF THE MID-RUSSIAN AULACOGEN USING ORIGIN METHOD OF SEISMIC INVERSION

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Summary

Reinterpretaion of regional refraction seismic data of past years in the central part of the Moscow Syneclise suggests that the two-layer Archean–Lower Proterozoic basement exists in the area and that the structural evolution of the Mid-Russian aulacogen occurred in two successive regimes. Extensional tectonic regime at Archean-Early Proterozoic was followed predominantly compressive tectonic regime from Early Proterozoic into Late Proterozoic. Tectonic movements were controlled by direction and inclination of the faults and relative location of bocks of basements.

Introduction

Depth structure of Mid-Russian aulacogen was unknown in many respects up present time in spite of it central location and nonindustrial oil and gas shows at some wells of the area from Vendian deposits. CDP seismics produced here in the 1990s gave information mainly about sedimentary layers including Riphean ones (Fedorov, 1997). Reinterpretation of the refracted waves data of past years allowed to establish structure of basement up to depth of 10 km and structural relations of Riphean and Vendian deposits with the basement without significant expensive.

Database and methodology

The location of the profiles is given in a fig. 1. The data of gravitational and magnetic survey were used also. The seismic works were fulfilled in 60-70 years by company "«Spetsgeofizika". The technique included spacing of receivers with interval 100 m and sources of waves with interval of 20-50 km. The maximal distance the source – receiver was made 50-70 km. In result of interpretation at past years the cross sections up to depth of 3-4 km were obtained with only seismic boundary considered as top of crystalline basement. Now method of homogeneous functions of the 2-D inversion is applied for seismic interpretation (Piip, 1991). This technique allows automatically to inverse a time field of the first waves into a continuous velocity cross section, which includes the information on boundaries, faults and velocity anomalies. The method is based on local approximation of real velocity distribution by homogeneous functions

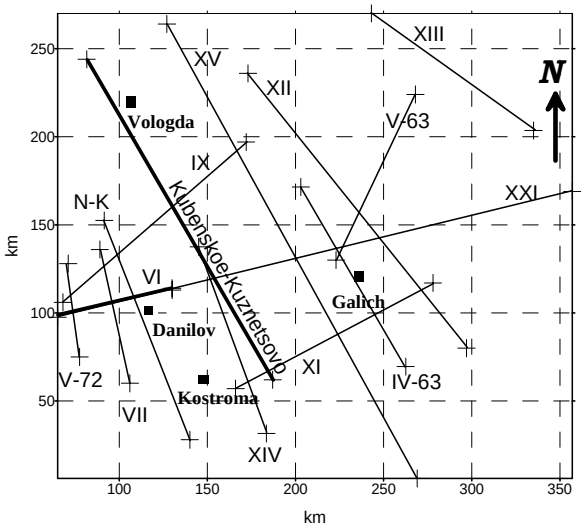

Fig. 1. Map of disposition of profiles. The area is located at the distance about 300 km toward north-east from Moscow.

of two coordinates. New seismic cross sections up to depths of 10-15 km were calculated. The cross sections are checked up by the decision of a forward problem. The results have verified the constructions with accuracy satisfying to modern world criteria. In the cross sections the boundaries, blocks and faults, steeply deeping and gentle were traced. The cross sections are tied at the points of their crossing and to the data of 22 deep wells. Most upper parts of the cross sections are not informative as the registration of waves was produced beginning from some distance from sources. The density and magnetic modelling has allowed to estimate material composition of layers.

Results

In a fig. 2 the section along profile VI located in western part of the area is given. This profile characterizes the main features of a geological structure of the area in the whole. The important feature of the structure is two-layer basement that includes sedimentary layer of Early Proterozoic age by thickness of 2-3 km and crystalline layer supposedly of Archean - Early Proterozoic age. The similar structure of crust was revealed in the Kola superdeep well.
In the cross section ductile and brittle layers alternate. The following layers from below upwards were traced. The bottom layer is crystalline basement. It is characterized by the velocity of waves more than 5.7 km/s, by block structure and by set of listric faults. The all faults decay or change sign at top of the layer. Inside the layer the structures with the increased values of velocity and gradient of velocity are traced, possible intrusions. Disposition of the faults withdraws about extensional regime in that time. Using density modelling it is established that crystalline rocks combine the cross section at the depths of 6-10 km. The blocks with the increased velocities are blocks of high density and magnetization. It allows to relate them to intrusions of the basic and ultrabasic composition. The blocks of granite gneiss composition are enclosing rocks for them (velocity 5.6-5.8 km/s, density 2.7-2.8 g/cm^3, magnetization< =0.5a/m).

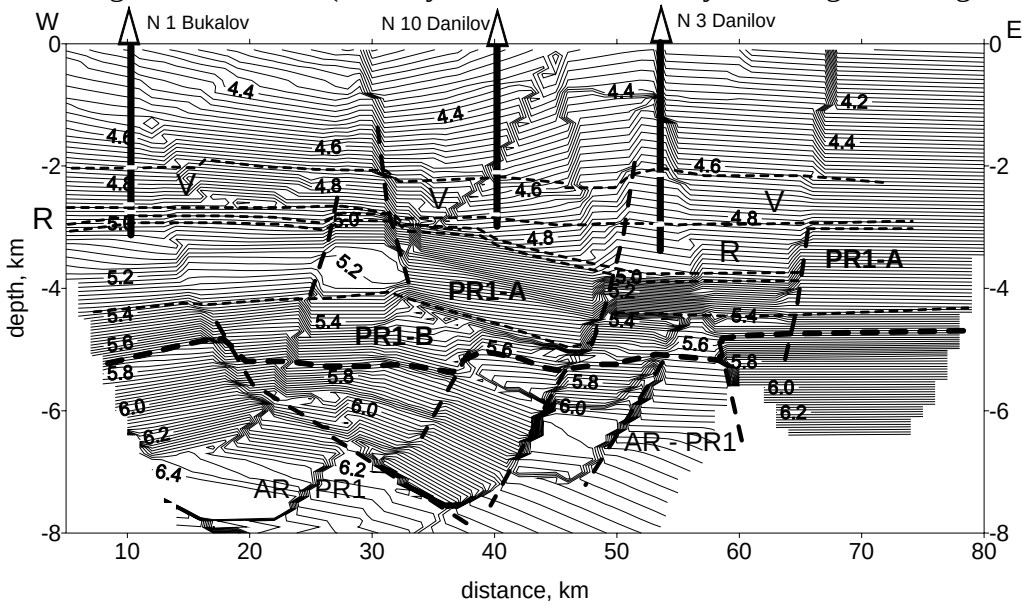

Fig.2. Seismic cross section along profile VI with geological interpretation. Thin lines are velocity contours. Contour interval is 0.02 km/s. The faults are shown by heavy dash lines. Intermediate seismic boundaries are designated by dash lines. Double dash line is top of Lower Proterozoic basement. Most heavy dash line is top of the crystalline basement. Letters R and V denote the layers of Riphean and Vendian age. Location of geological boudaries are shown on the data of wells. Vertical exaggeration is 1:5.

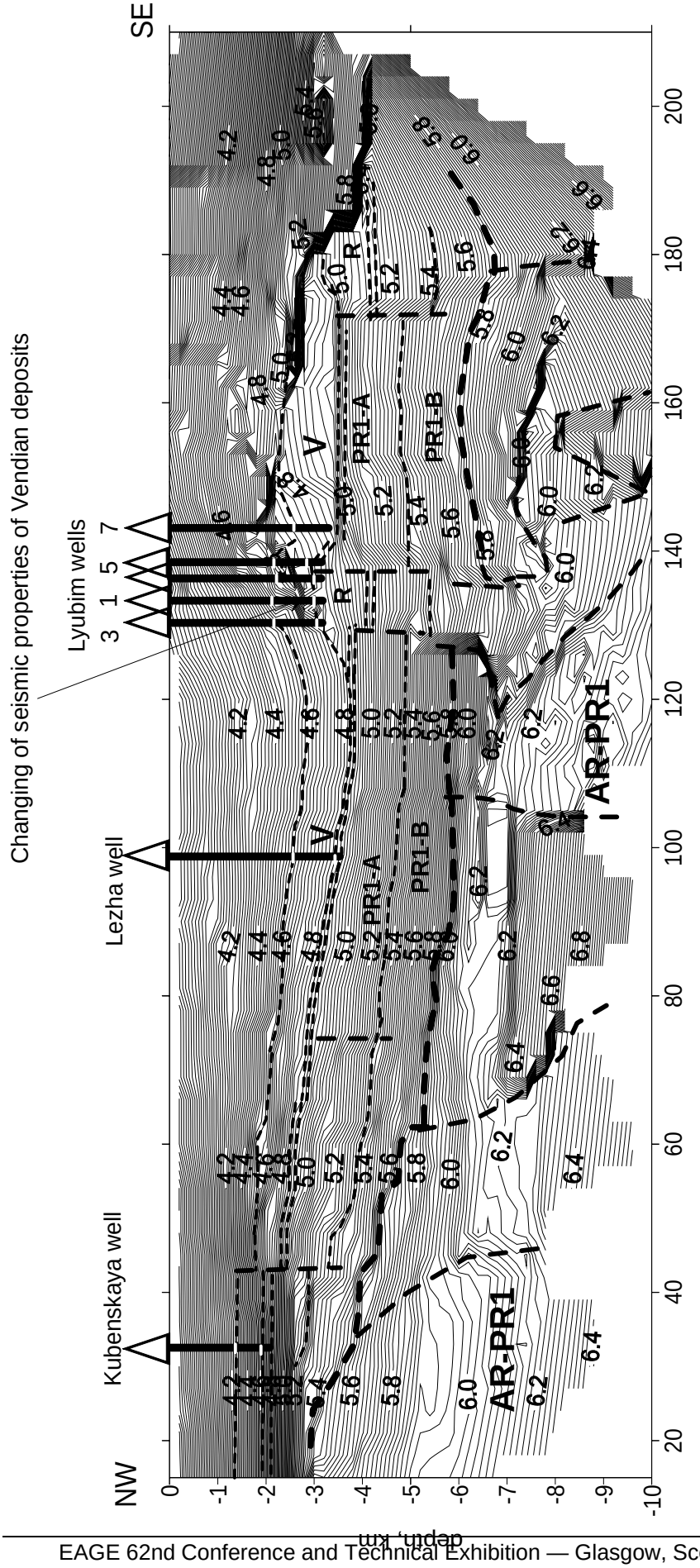

Fig.3. Seismic cross section along profile Kubenskoe-Kuznetsovo with geological interpretation. Thin lines are velocity contours. Contour interval is 0.02 km/s. Vertical exaggeration is 1:6. Location of seismic boundaries is compared with well data. Others designations are in fig.2.

Above a ductile layer designated in a fig. 2 as PR1-B, with velocities from 5.4 up to 5.7 km/s is disposed. Faults absent in it practically. This layer, apparently, is sedimentary layer.

Above it an ancient (layered) strata of Early Proteroizoic age settles (PR1-A in a fig. 2), the top of which is coordinated to the data of wells. That it is sedimentary strata, except for subhorizontal layering, rather low values of velocities 5.0-5.4 km/s and density 2.6 - 2.68 g/cm^3 testify. Early Proterozoic age of these deposits is established on the well data. This layer is broken by subvertical faults onto prismatic blocks. It means, that brittle deformations here were advanced. Arched form of this layer indicates at compressive tectonic regime at the period of sedimentation.

Further upward between the raised and lowered blocks of the Lower Proterozoic basement the sites filled by sediments of Riphean age (on the data of wells) are located. In the seismic sections they are traced according to structural attributes.

Uppermost layer, traced in the sections, is the layer of Vendian age by thickness from 800 m up to 1-1.2 km. This layer everywhere is coordinated to wells. The velocity values in Vendian deposits are 4.6-4.9 km/s. It is some effective velocity, as the low detail of observations does not allow to define velocity more precisely.

Seismic cross section along profile Kubenskoe–Kuznetsovo that passes approximately in the meridian direction, is shown in a fig. 3. The same layers are traced here. A number of the important structural features, characteristic for the area as a whole, can be seen here. It is, first of all, that ancient sedimentary layer of Early Proterozoic age pinches out in the direction of boards of the structure. In a southern part of the profile in the basis of the cross section, in the crystalline basement at the depths of 6 - 8 km thrust plates are traced, under which there are relatively low velocity, probably younger rocks. In the upper part of the cross section there are structures of an inverse sign - uplifts of blocks of Lower Proterozoic basement. Riphean sediments are located in intervals between these blocks. The structural swells formed by Vendian layers are traced here on the data of wells and in seismic cross sections. Such form is evidence of conditions of compression. In the cross section in the region of Lyubim wells a changing of seismic properties of Vendian layer is noted. In northwest half of the profile the velocities 4.6 - 4.8 km/s and high values of gradient of velocity are characteristic for them. The boundaries of the layer are poorly distinguished. In southeast part of the profile values of velocity are 5.0 - 5.1 km/s, the gradient decreases, the layer is sharply distinguished in velocity cross section. Such differences are characteristic for northwest and southeast half of the area on the whole.

Conclusion

At Early Proterozoic time Archean layers were reworking in process of intrusive, volcanic and tectonic activity. The rise hot melted masses has caused formation of uplifts and further, as result of their split, formation of rift valleys. Then the central part of the rises was lowered below its regional parts. Sedimentation has filled inside parts of the formed troughs. Lateral stress caused by the further lowering of the central parts of structure, has caused horizontal displacement of edge plates. Therefore the deposits which have collected in the troughs, have appeared buried under more ancient rocks. Continuous process of compression has resulted in subvertical moving of rigid blocks of Lower Proterozoic basement and stipulated formation of structural swells during accumulation of Riphean and Vendian deposits.

References

1. V.B.Piip 1991. Local reconstruction of seismic refraction sections on the basis of homogeneous functions. *Izvestiya, Academy of Sciences, USSR, Physics of Solid Earth* 10, 844-850.
2. D.L.Fedorov 1997. Vendian and Riphean basins and perspectivity on the East European Platform. *Petroleum Geoscience*, vol. 3, part1, February 27-31.