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Detailed Section of the Lithosphere in Angola Basin on the Seismic Refraction Data with Account of Earth Curvature

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SUMMARY

New interpretation of DSS data of 1980th in Angola Basin with homogeneous function method gave seismic section of considerably more informative than previous one. Besides of the curvature of the Earth now was taken in account. Asthenosphere diapir exists in the lithosphere on the boundary of transient zone. Thickness of the crust is increased sharply toward continent along several seaward faults. Two layers with increased velocity, rising in the party of continent, are traced in the lithosphere in central part of the profile. Asthenosphere forms steps inclined in direction to continent. Perhaps, blocks of oceanic lithosphere were moved under continent along asthenosphere top by fault with displacement of about 30 km.

Introduction

Deep seismic sounding (DSS) is one of most effective methods of studying of lithosphere. At the present time DSS works were fulfilled in the all oceans practically. However, system of observation often was not sufficiently full. Besides of interpretation was made in the frame of layer model with constant velocity. Complex structures, which includes faults and local anomalies, were not obtained in the sections.Large seismic investigations were produced along Angola-Brasil geotraverse in Atlantic Ocean in 1980-1987 by Russian Academy of Sciences. The latitude geotraverse is located in about 12° S. Investigation were fulfilled along 6 sub latitude and 2 longitude profiles by length of 500-600 km. Here we consider result of new interpretation of one from the profiles located in Angola Basin and in limits of the Africa shelf (at the East of investigation region). Location of the profile is shown in Figure 1.

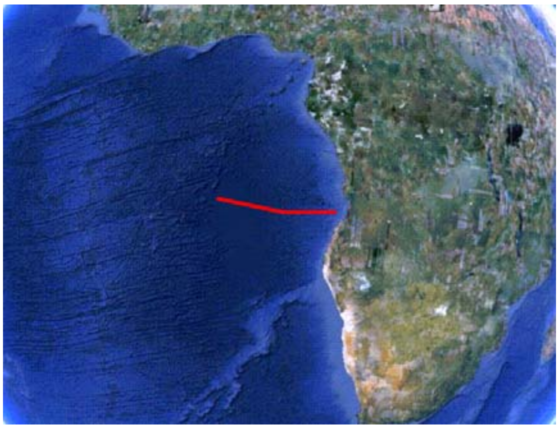

Figure 1 *Location of the profile in the map.*

The profile passes in transient zone of passive margin of Africa continent. Passive margins of the continents are investigated considerably less fully then active margins. Several sections were obtained near Iberia and Labrador shores. An existence of transient type of lower crust with high velocity is marked in Louden, Chain, 1999, Minshull, 2002 and Talwany, Abreu, 2000. Also seaward inclined reflectors characterize these sections. To analyze how reacts the ocean-continental transition along the West African margin**,** when a shortening occurs, an experimental modeling was processed based on shortening of small-scale models formed by two domains analogue to oceanic and continental lithosphere (Dauteuil, O., et al., 2004).
Location of investigated profile in anomalous magnetic field is shown in Figure 2. The change of direction of linear anomalous is observed in region of 3-4°E. The homogeneous function method was used for the interpretation of the profile data. New interpretation of DSS data in Angola basin with homogeneous function method gave considerably more detailed seismic section than previous one. Besides of the curvature of the Earth now was taken in account in the computations. It is necessary for profile whose length more than 1200 km

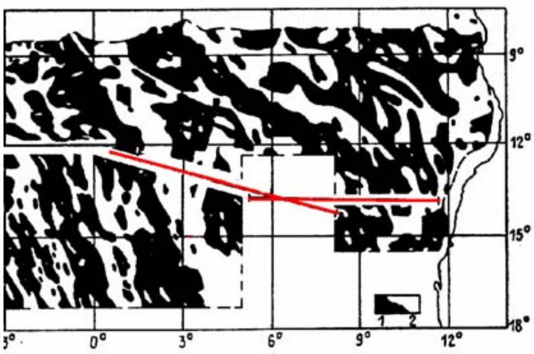

Figure 2 *Location of the profile in anomalous magnetic field (modified from Deep seismic sounding…, 1996)*

Homogeneous function method.

In the present time two methods can be used for interpretation of the DSS refraction data: modeling and tomography methods. The initial model is need for both of them. And result depends on initial model which is usually defined by 1D or traditional methods. Besides of tomography method demands very detailed system of observation. Interpretation by homogeneous function method does not demand any initial model. Identification of waves previously is not produced. It is automatic method. Interpretation consists in computing for every pair of reverse traveltime curves an increasing continuous homogeneous function of two coordinates which approximates real velocity distribution in the section. Algorithm of solving of this problem is published in Piip, 2001. Homogeneous functions are very broad class of 2D function. Contours of this function are curves can have arbitrary form however they are similar each to another. In the polar coordinate homogeneous function has view

$$v = r^m \psi(\varphi),$$

where m is real number and $\psi(\varphi)$ is arbitrary function of polar angle. Rays for two reverse traveltime curves are focused in the deep part of section and thus deep part of the section is best defined. Common section is produced similarly to time CDP section of reflection waves when only deepest zones responding to every pair of reverse traveltime curves are included in depth velocity section (Piip, 2009a). Depth velocity section is represented by velocity values computed in nodes of rectangular grid. Thus different forms of imaging of grid fields can be used for imaging of the sections.

Data.

Sufficiently full system of traveltime curves along the profile was obtained (Figure 3). Interval between sources was 5 km. Autonomic bottom stations were used for recording of signal with interval along the profile of about 150 km. Maximal length of traveltime curve reached 800 km. A blank in observation existed in area of shelf, where shots were forbidden. However bottom stations were located there and the series of traveltime curves, rays for which have penetrated this zone, were recorded.

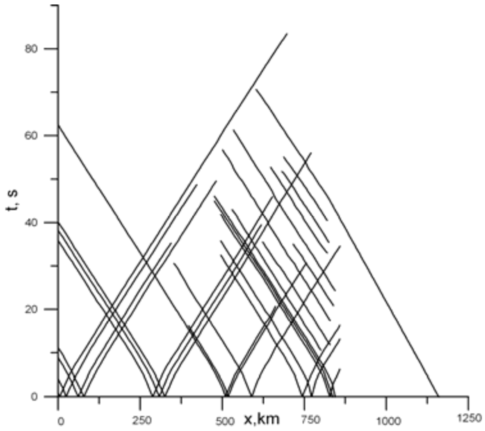

Figure 3 *Observed traveltime curves in Angola basin.*

Interpolation of traveltime curves was applied. Time section of offsets (source-receiver distances) is used for interpolation. Time section for investigated profile is shown in Figure 4. Offset contours are imaged in this time section with constant interval of 5 km.

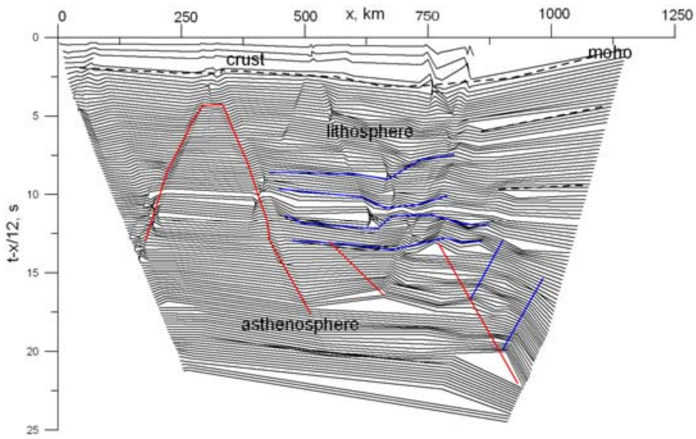

Figure 4 *Time offset section. Contour interval is 5 km. Moho is indicated by dashed line. Boundary of lithosphere bloks are shown by blue lines and diapir and asthenosphere top is limited by red line. Reduction velocity is 12 km/s.*

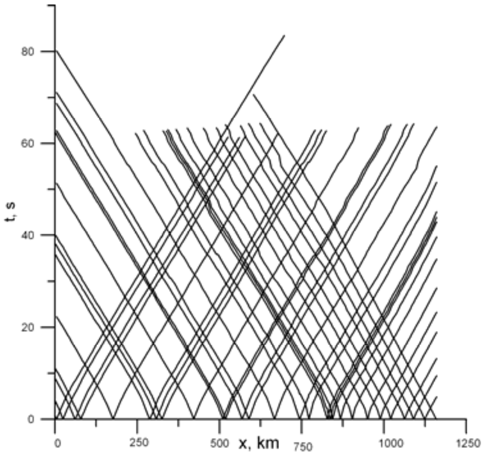

Figure 5 *Observed and interpolated traveltime curves.*

Distance between offset contours is back proportional to values of apparent velocity which is close to real velocity in sub horizontal media. And thus offset section is time section for refraction waves, where the leading features of the actual depth section are displayed. Piip (2001) shows this with using model computations and borehole data.

Such time section is continuous image of traveltimes and it was used for addition of system traveltime curves in the profile. Additional sources were given in the points of 180, 430, 580, 680 km. Also traveltime curves in the shelf were reconstructed with using travel times in mutual points. Interpolated and observed traveltime curves are shown in Figure 5. These traveltimes were used for the inversion. Curvature of the Earth must be taken into account as length of traveltime curves in the profile riches 800 km. Formulae for account of curvature of the earth are published in Piip, 2009. These formulae are truth for 2D arbitrary velocity distribution in round sector of the Earth. At first the traveltime curves are transformed to flat surface of the Earth, where inverse problem is solved. Obtained velocity distribution is transformed back into round sector of the Earth.

Results

Section along this profile, obtained in 1996, is shown in Figure 6 (Deep seismic sounding…, 1996). Water layer by 5 km thickness, crust by thickness of 7-10 km and two-layer lithosphere are obtained in this section. The upper layer of lithosphere of variable thickness from 10 to 15 km possess by velocity about 8.4-8.5 km/s. Lower layer of the lithosphere is located at the depth from 20 to 30 km and it is immersed by steps in direction to continent. Velocity in this layer is 8.8 km/s. Vertical anomalous zone is traced in the region of 4˚ E. This section was obtained using traditional methods of head waves and after the section was specified by forward modeling method.

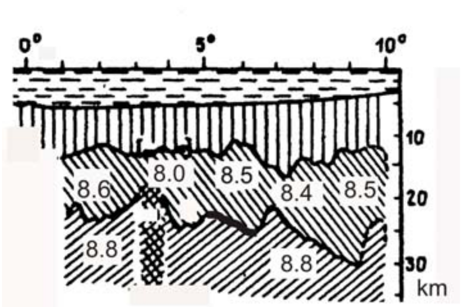

Figure 6 *Section along profile in Angola basin obtained in 1996 (modified from Deep seismic sounding…, 1996)*

New section, automatically computed by homogeneous function method, is shown in Figure 7. Section is represented by grid by size 200 x 100 nodes. Velocity contours are carried out with constant interval 0.1 km/s. Computing of the section was produced, beginning from bottom. Therefore water layer, depth of which is about 5 km, is not imaged in the section.

Thickness of the *crust* is changing from 5 to 7-10 km from west to east in region with oceanic crust. Crust is distinguished by high velocity gradient. Thickness of the crust sharply increases in region of shelf (950 km of profile) to 20-25 km. Several

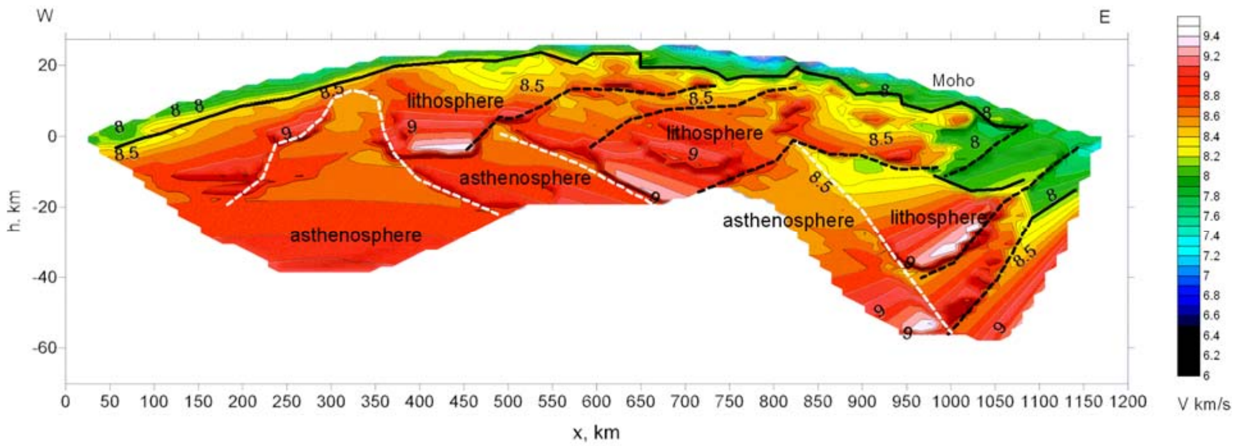

Figure 7 *Section along the profile with account of Earth curvature. Bold black lines are Moho. Boundaries in lithosphere are denoted by dashed black lines and boundaries in asthenosphere are shown by dashed white lines.*

faults, seaward inclined, are traced here.

Lithosphere is characterized by variable velocity which increases from 8.2 to 9.5 km/s from top to bottom. Bottom of the lithosphere forms three steps by amplitude of about 40 km.
Two layers with increased velocity are seen inside of oceanic part of lithosphere in central part of the profile. These layers are divided by layer with decreased velocity (about 8.5 km/s). The layers rise toward continent. Blocks of lithosphere in region of the shelf are divided from oceanic lithosphere by area with low velocity – 8.2-8.4 km/s. Possible that blocks of oceanic lithosphere, keeping a former inclination of borders, were moved under continent along asthenosphere top by fault with displacement of about 30 km. Top of *asthenosphere* forms three large steps in the profile. Velocity inside of astenosphere varies from 8.5 to 9 and gradient of velocity is relatively low. The blocks of asthenosphere are inclined toward continent and depth of asthenosphere is increased in this direction. Asthenosphere diapir by amplitude about 40 km and width in the base of 400 km is distinguished in region of transient zone from ocean to continent in 300-350 km of the profile. Anomalous vertical zone was traced in the same region of the profile in previous section (Figure 6). Reliability of depth section is confirmed by time offset section (Figure 4) Increasing thickness of the crust toward continent, asthensphere diapir, two layers with high velocity can be traced in this time section. It is necessary to remember that time section is deformed depending on values of velocity.

Conclusion.

Interpretation of the seismic data by homogeneous function method with account of curvature of the Earth allowed obtaining informative section of lithosphere in transient zone to Africa continent.
Asthenosphere diapir exists in the lithosphere on the boundary of transient zone. Thickness of the crust is increased sharply toward continent along several seaward faults. Two layers with increased velocity, rising in the party of continent, are traced in the lithosphere in central part of the profile. Asthenosphere forms blocks inclined in direction to continent. Perhaps, blocks of oceanic lithosphere were moved under continent along asthenosphere top by fault with displacement of about 30 km.

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