Basin architecture and lithosphere structures of Western Central Asia – Uzbekistan: from geophysical studies

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Abstract. This paper presents an integrated geophysical study of the Western Central Asia (WCA) in the Uzbekistan area. It presents new interpretations of deep seismic sounding (DSS) data and new analyses of potential fields data. An integrated model of the physical properties and lithosphere structures displays distinct features that are related to tectonic history of the study WCA-Darius area. Task-oriented complex geological and geophysical research revealed in the lithosphere of western Uzbekistan series of crust blocks with abnormal petrophysical characteristics and established some correlation dependences between the distribution and placement of these objects (in plan) with deposits of minerals.

1. Introduction.
Western Central Asia represents an unusually complicated collage of different aged tectonic blocks and zones both of accretion and collision character, with associated intramontane belts and several basins (Figure 1). This is dominated by Alpine deformation associated with the collision of India and Arabia, distributed in large belts running from the Caspian Sea to the Pamir and the Tien Shan range. North of this belt are the Turan and the South Kazakh platforms. The large area between the Caspian Sea and the Tien Shan/Pamir ranges is mainly covered by Upper Permian to Quaternary sedimentary successions. The most recent deformation of much this area evidently occurred in an intraplate setting. The present-day Tien Shan mountains now lie more than 3000 km or more from the India-Eurasia plate boundary; they were within the Asian land mass when Indian-Asian collision began some 50 My ago. A similar situation holds for the Pamirs. The underlying crustal architecture formed from Late Palaeozoic times. Thus, the present-day geology, including its numerous sedimentary basins and intervening uplifted areas including basement rocks, represents an intricate “convolution” of a series of crustal forming and deforming events from the Late Palaeozoic onwards.

Figure 1. Main basins and orogenic belts of Western Central Asia [1].
2. Methods.
Seismic studies of the crust began in the study area in the mid-1950th. Specifically, several deep seismic sounding profiles across the Turan plate were carried out by different organizations of the former USSR. A database derived from a series of seismic and seismological studies was used for the identification of velocity heterogeneities in deep horizons of the consolidated crust as the basis for further calculations of density parameters, hypsometrical position of the surface of the heterogenic fundament diagnostics of the pre-Jurassic formation composition and the gravitational effect of the Mesozoic-Cenozoic thicknesses.

The deep structure construction in our study was based on the materials of studies conducted in 1980s of series of regional seismic profiles DSS-ECW: Farab-Tamdybulak, Romitan-Darbazatau, Tamdy, Muruntau, Kokpatas (Zunnunov, 1985 [2]; Tal-Virsyk, 1982 [3]; Babadjanov et al, 1986 [4]; Mordvintsev, Sidorova 2003 [5], 2004 [6], 2012 [7]). In these publications it was described some separate seismic profiles and we have analyzed and summarized materials of deep seismic sounding, gravity and magnetic anomalies in unified GIS format. The results of different seismic studies were in different stages of completion. Old seismic data have been reprocessed and remodeled following the logical schema on Fig.2 and position of the main suture zones are presented in our new interpretation.

Figure 2. Logical schema of interpretation.

Our methodology consists of two consecutive stages including: 1) methodology of integrated geological-geophysical processing and interpretation of potential fields and seismic profiles cross-cutting study area; 2) methodology of creation of unified model in ArcGIS-10.1. Each of these stages is divided into more detailed sub-stages.

The system of seismic observations provided the tracing of refracted waves in the earth crust, reflections from the surface of Mohorovicic discontinuity and crustal borders. Location of regional seismic profiles DSS-ECW is presented in Fig.3. The results of field observations in all profiles enabled obtaining temporary cross-sections, which subsequently formed the basis for the calculation of velocity model. The program of calculation of velocity field along the profile provided smooth transitions of velocity parameters from one geoblock to another. During the modeling along seismic profiles, three-dimensionality of the crust objects was taken into account. The study and inventory of distribution of rock density in the Mesozoic-Cenozoic rocks preceded the use of gravitation anomalies (in Bouguer reduction) for geological construction. A real distribution of density was taken into account, as well as its growth as the depth also grew.

3. Results.
Reviewing and reinterpreting the geophysical and geological data for the Western Central Asia region reveals a number of interesting features. The results of field observations in all profiles enabled obtaining reflection-time sections, which subsequently formed the basis for the calculation of velocity cross-sections. The system of observations provided the tracing of refracted waves in the earth crust, reflections from the surface of Mohorovicic discontinuity (Fig.4). The depth of the Mohorovicic discontinuity varies from 37 to 45 km with a general tendency to increase towards the mountain structures of the Southern Tien Shan and the South-Western spurs of the Gissar Mountains. Relief is
contrast with alternating variations in shape, size and strike depressions and uplifts. Many distinguished structural elements are limited or broken by tectonic faulting with amplitudes of 1-3 km. Karakum - Tajik continent has varied terrain of Moho. Within the study area its surface has clear down warping in the north-west (up to 43 km) and the south-east (45 km) directions. These areas are divided by two brachy anticlines (up to 39-40 km). North dome closes the line with two similar structures, but located within Southern Tien Shan and forming a single region of uplifts of northwest trending. From interpretation of seismic and gravity data identified a number of tectonic faults, quite clearly manifested in the relief of the surface. The main trend is northwest, parallel to the extension of the main tectonic elements of the region. In the south and south-east of the region it is separated faults of north–south and north-eastern directions.

So, analyzing all available information obtained mainly from seismic, gravity and magnetic data, we are presenting a summary of data and a tectonic synthesis of the western part of the intermediate units of Western Central Asia. It is observed different pattern and hypsometry of Paleozoic basement to the north and south from the Bukhara – Gissar fault (Fig.5).

Brunet et al. [8] use a set of depth-structure maps and isopach maps as well as regional cross-sections to examine the tectono-sedimentary evolution of Amu-Darya Basin during the late Paleozoic and the Mesozoic. Detailed analysis of a series of cross-sections from the Bukhara-Khiva area allows Modvintsev et al. [9] to examine, in detail, the evolution of the northeastern margin of the Amu Darya Basin during the Mesozoic (focusing mainly on the Jurassic). Sections are based on subsurface data: seismic lines, boreholes and depth-structure maps. The structures of the Bukhara step and the deeper Chardzhou step, which together form the basin margin, are described and compared. An extensional event controlling the deposition of the Early-Middle Jurassic-age series is clearly documented by the cross-sections. This event resulted in the formation of new normal faults and/or the reactivation of a series of Late Paleozoic structures, accommodating the infill of the topographic lows by siliciclastic successions, initially continental and later marine. Subsidence declined markedly from Middle Callovian times onwards, coeval with the deposition of the Middle Late Jurassic carbonate succession, passing upwards into a phase of thermal subsidence during the Cretaceous.

Northern unit (Bukhara step) characterized by the predominance of uplifts with amplitudes ranging from 1.0 to 2.0 km, separated by small saddles (Babadjanov et al, 1986). The southern unit (Chardjou step) consists of a complex system of troughs and uplifted blocks, with a predominance of the first. The northern boundary of the Chardjou step is the Bukhara-Gissar fault, and it southern limit is the Amu Darya fault. Amplitude of troughs is 1.5-2.5 km, and 0.5-1.5 km uplifts. Most downthrown blocks are located in the central and eastern areas. Submergence depth of the basement within these blocks reaches up to 9.0 km.

Width of Bukhara-Gissar fault reaches 20-30km, and it is a system of contiguous and variously oriented dislocations of strike-slip type (Yakubov et al, 1976 [10]). Appeared in the Early Paleozoic time, it was actively developed during the Jurassic and Neogene. It is dominating the northern dip of the fault at an angle of 70°. According to DSS profiles Farab-Tamdybulak and Romitan – Darbazatau the fault intersects the Earth’s crust and Moho surface of 2-4km, and there is down faulted south wing (Mordvintsev, 2003). There are located huge amplitude gravity step and clear sublatitudinal linear magnetic anomaly. Positions of main Paleozoic suture zones within the lithosphere of Uzbekistan are clarified (Fig.6,7). Task-oriented complex geological and geophysical research revealed in the lithosphere of western Uzbekistan series of crust blocks with abnormal petrophysical characteristics and established some correlation dependences between the distribution and placement of these objects (in plan) with deposits of minerals.
Figure 3. Location of regional seismic profiles DSS-ECW: F-T -Farab-Tamdybulak, R-D -Romitan-Darbazatau, T-Tamdy, M - Muruntau, Ko - Kokpatas, Kr- Kt- Karabekaul-Koitash, Sm-Sr- Samarkand-Sarikazgan.

Figure 4. Depth of Mohorovicic discontinuity of Uzbekistan territory.

Figure 5. Surface of basement of Uzbekistan (based on information from Volvovsky et al,1966; Tal-Virsky, 1982; Zunnunov 1985)
Also the analysis (Sidorova et al, 2006 [11], Sidorova&Mordvintsev, 2012 [12]) of petrological and geophysical models of depth profiles Tandý, Muruntau, Kokpatas revealed: 1) large blocking of the Earth crust, increasing from Moho to the surface, 2) vertically offset of blocks along deep faults, reaching the mantle 3) displaced in the sedimentary-metamorphic layer rootless blocks of granitoids and existence of quartz-diorite and granite-gneiss layers in composition of upper crust, 4) complex morphology of surface of upper boundary of the lower crust, conditioning location in it high-velocity blocks, 5) two types of mantle origin structures - rift and hopper-shaped.

Our special attention is devoted to potential geophysical fields and results of interpretation of seismic profiles, which are the base for conclusions about deep lithosphere structures of the DARIUS domains. Huge sedimentary basins (Amy Darya, Usturt, Fergana, Syr Darya) rich in oil and gas resources are
located in Western Central Asia. Paleozoic pre-basin history has played a key role in determining the location and style of basin development numerous small Mesozoic and Cenozoic fault-bounded sedimentary basins form an intricate pattern both concordant and discordant to the early Paleozoic regional fabric. In line of this the detailed studying structure, a structure and parties’ Paleozoic formations on representative basic sites and the crossings, accompanied by drawing up of level-by-level and summary cuts (sections), large-scale geological mapping was conducted. In the Western Central Asia during the last three years a significant number of new works and new ideas developed on the tectonic and stratigraphic evolution. The state of art reveals a very heterogeneous set of data. These data commonly deal either with particular basins or mountain belts, or specific domains of investigation. We combined all available seismic, magnetic and geothermal data with the revealed peculiarities of the tectonically objects, geological structures, and to show their interrelated temporal and spatial development for general understanding of the regional tectonic and geodynamic evolution in Western Central Asia. All the final products created using ArcGIS&RS methodologies: the spatial database combine :1) DEM on the base of the Shuttle Radar Topographic Mission (SRTM) dataset with spatial resolutions of 30’’ and 3’ respectively; 2) 3-D models of crustal basement associated with basins and intrabasinal areas and Mohorovicic surface, using the reinterpretations of seismic reflection and refraction sections of DSS and ECW profiles; 3) 3-D potential fields modeling; 4) tabular database of tectonic, stratigraphical, boreholes and geochronological data; 5) various types of original geological information concerning the Paleozoic to Present geological evolution of the region.

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