Interpretation of 3-D MT survey data in the southeastern Bukharo-Khivinsky oil and gas prospective region of Uzbekistan

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Summary

Introduction

Uzbekistan first used electroprospecting methods for hydrocarbon exploration in 1931. Since 1970, the main electroprospecting techniques used by Uzbekgeofizika (the main geophysical contractor in Uzbekistan) have been MT, LOTEM, and IP (Berdichevsky et al. 2001, Ingerov et al., 2003). MT was the principal method, but application until ca. 1995 was limited by several factors including heavy truck-mounted equipment, restricted frequency range, and insufficient computer capability. Therefore, MT was often followed by LOTEM for greater accuracy and detail and by IP, which can provide parameters associated with hydrocarbon presence in prospective structures. This combined approach increased the success rate of deep drilling. (Ingerov et al., 2003). Uzbekgeofizika acquired modern multifunction EM equipment in 2007; its portability and accuracy has enabled improvements in the application of EM methods to hydrocarbon exploration. The annual EM production of Uzbekgeofizika has attained 6000 MT sites and 2000 LOTEM and IP sites. By the end of 2010, Uzbekgeofizika had acquired over 16 000 MT sites with the new equipment. This large amount of new data generated a high-priority requirement for appropriate qualitative and quantitative interpretation. The authors here analyse some interpretation approaches for 3-D MT data acquired in the Buzakhur area in south Uzbekistan. The closely spaced Buzakhur 3-D MT grid was designed to supplement the uncertain seismic structural map and also to identify prospective targets indicated by local EM anomalies.

Survey Location

The survey area is 10 km from the town of Guzar in the Kashkadarya region near the Uzbekistan borders with Turkmenistan and Afghanistan in the southeast part of the Bukharo-Khivinsky hydrocarbon basin (Figure 1). The terrain is rough, mountainous, and very difficult for transport, so all equipment transportation from site to site was done by foot and sometimes with pack animals.

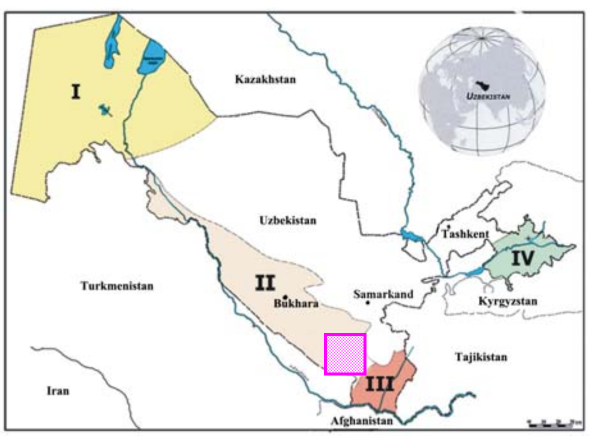

Figure 1: Hydrocarbon reservoirs in Uzbekistan: I, Usturtsky; II, Bukharo-Khivinski; III, Sukhardaryinsky; IV, Fergansky. The cross-hatched rectangle is the MT survey area.

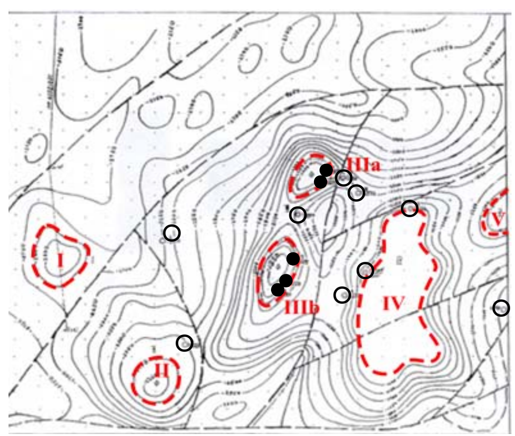

Figure 2: Latest seismic structural map (top of carboniferous sedimentary formation of Upper Jurassic). Conjectural outlines of positive structures: I, Kuchuc; II, Chuchuc; IIIa,b, East Buzakhur; IV, Karabay; V, Karayil. Contour lines show the top of the bed; black dashed lines are faults. Open circles are unproductive deep wells; solid circles are productive; dots are MT sites of the main grid.

Geological Setting

The survey area is in the southeast part of the Beshkent depression, which is the most complicated geological structure in the oil-and-gas-prospective Bukharo-Khivinsky region (Figure 1). On the east side, the area is connected to the southwest part of the Gissar orogen. Complex sediments include more than 4 km of Cenozoic and Mesozoic terrigenous and carbonate sediments, which thin to the east. The geoelectric section is layered (approximately 1-D) with average resistivity of 2–20 Ω·m and some resistive layers, less than 300 m thick, with resistivity of 30–150 Ω·m.

The East Buzakhur structure was discovered in 1983 by 2-D CRP seismic. It was prepared for drilling in 1984 and was modelled as an anticline structure with amplitude 250 m and size (within –2450 m or J3 reflective horizon) of 10.5 km x 2.7–4.0 km. Of six boreholes, #2 and #5 discovered gas in the J3 carbonate layer, but the other four encountered fluid only in the same layer. Based on these six boreholes and the seismic data, a structure map on the J3 reflective horizon was constructed in 1989.

More drilling was done in 2005–2008 to prepare the structure for development. Boreholes #11, #12, and #16 discovered gas, but #17 met the productive horizon below the gas–water contact level. Additional boreholes were unproductive. An attempt to apply 3-D seismic was unsuccessful because of rough terrain and the presence of high-velocity layers in the top part of the section. On the basis of all the boreholes in the area and seismic re-interpretation, a new structure map was constructed in 2008 with significant differences from the previous map (Figure 2). The map indicates five prospective anticlinal structures (I to V). A 3-D MT survey was done in 2008 to get accurate information about the complicated structure of this area.

MT Data Acquisition and Processing

A total of 1017 MT sites were collected on a 16 km^2 grid (Figure 3). Spacing was 200 m x 400 m, or 200 m x 200 m for detail. The survey used 17 Phoenix Geophysics SSMT System 2000 receivers in the frequency range 300 Hz to 2000 s. One receiver was installed at a permanent remote reference site; four 5-component receivers and twelve 2-component receivers were used on the grid. Thus, only 25% (total 217) of the MT sites had vertical magnetic component (H_Z) measurements. Axis X was directed to the north and axis Y to the east. In spite of difficult terrain, monthly production was more than 400 MT sites. The standard Phoenix technique was used for data processing and editing. In spite of some EM noise from power lines and railroads, the data were good enough for both qualitative and quantitative interpretation.

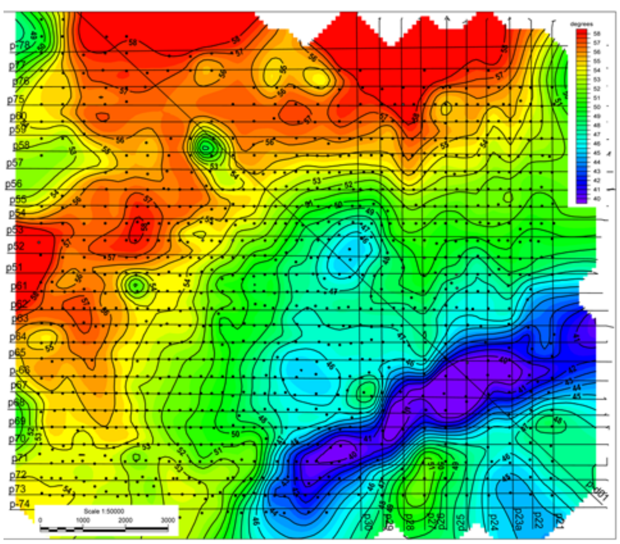

Figure 3: Invariant phase map at 3 seconds.

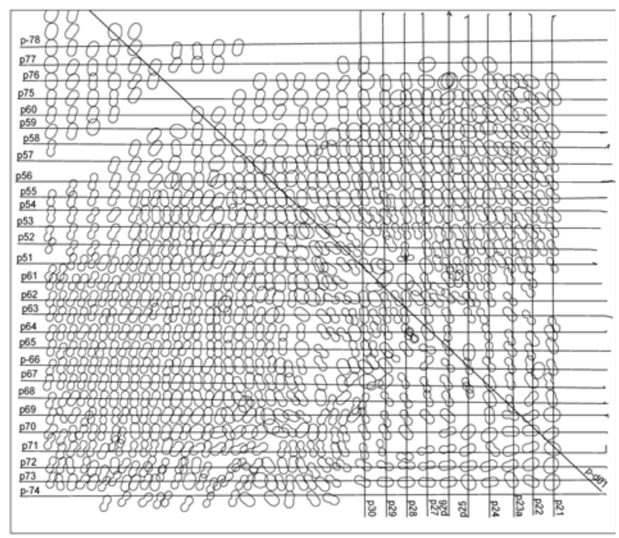

Figure 4: Impedance polar diagrams at 100 seconds.

Data analysis, interpretation and survey results

Data interpretation was performed in 2008–2010 in the Uzbekgeofizika office in Tashkent by Uzbekgeofizika and Phoenix experts, using WinGLink software. Figure 3 shows invariant phase at period 3 s. Phase generally decreases from NW to SE; total conductance thus behaves similarly, which is interpreted as basement rising from NW to SE. Figure 3 clearly shows the East Buzakhur Structure, striking approximately 020 degrees azimuth; a significant fault on the east side of the structure; and the fact that the structure is divided in two parts: north and south (Figure 2, IIIa and IIIb). Figure 3 also shows interesting new features, southeast of the already-known East Buzakhur structure. Here we can see at least two new bright structures (high phase values) striking approximately 060 degrees azimuth, quite different from the East Buzakhur structure. The brightest part of this structure (lowest phase values, purple colour) is situated at the south part of prospective structure V (Karayil), which had been identified using sparse seismic and the 13 deep drill holes shown in Figure 2.

Figure 4 shows impedance polar diagrams for each site, at period 100 s. In most of the area, an approximately N–S strike predominates. In the southeast part, which includes the East Buzakhur and Karayil structures, the polar diagrams outline a complicated circular figure. Due to the approximately N–S strike of the main impedance, a regular system of N–S (TE mode) and E–W (TM mode) analytical profiles was created. Figure 5 shows the TE (upper) and TM (lower) resistivity pseudo-sections on profile P52, which crosses the north part of the East Buzakhur structure and passes two drill holes: #16 (productive) and #19 (dry).

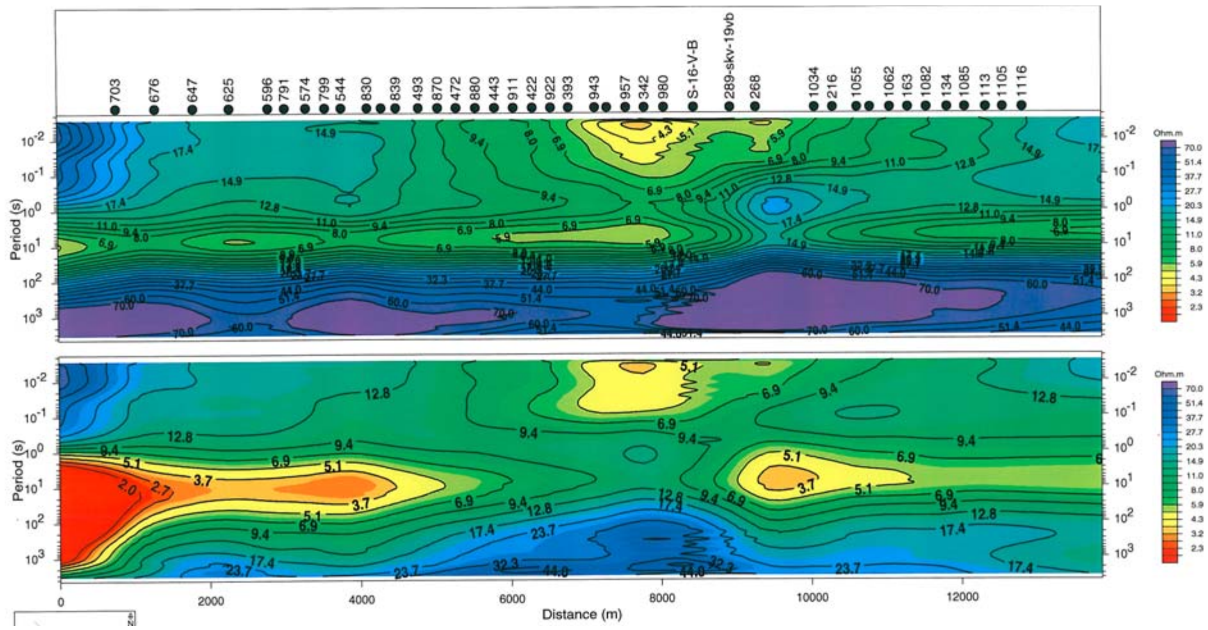

Figure 5: TE (top) and TM resistivity pseudo-section along profile P52.

Figure 6 shows the corresponding TE/TM impedance phase pseudo-sections. Both pseudo-sections show bright anomalies (local phase minimum) above productive structures, narrower in TM mode and much wider in TE mode. A weaker phase anomaly (local minimum) seen near MT site #596 is related to the Kuduk structure (structure I of Figure 2). Its weakness is explained by the smaller size of the structure and also because profile #52 is actually offset from the structure, somewhat to the north. In summary, phase and resistivity anomalies, related to productive gas structures, are clearly seen on MT parameter maps and pseudo-sections.

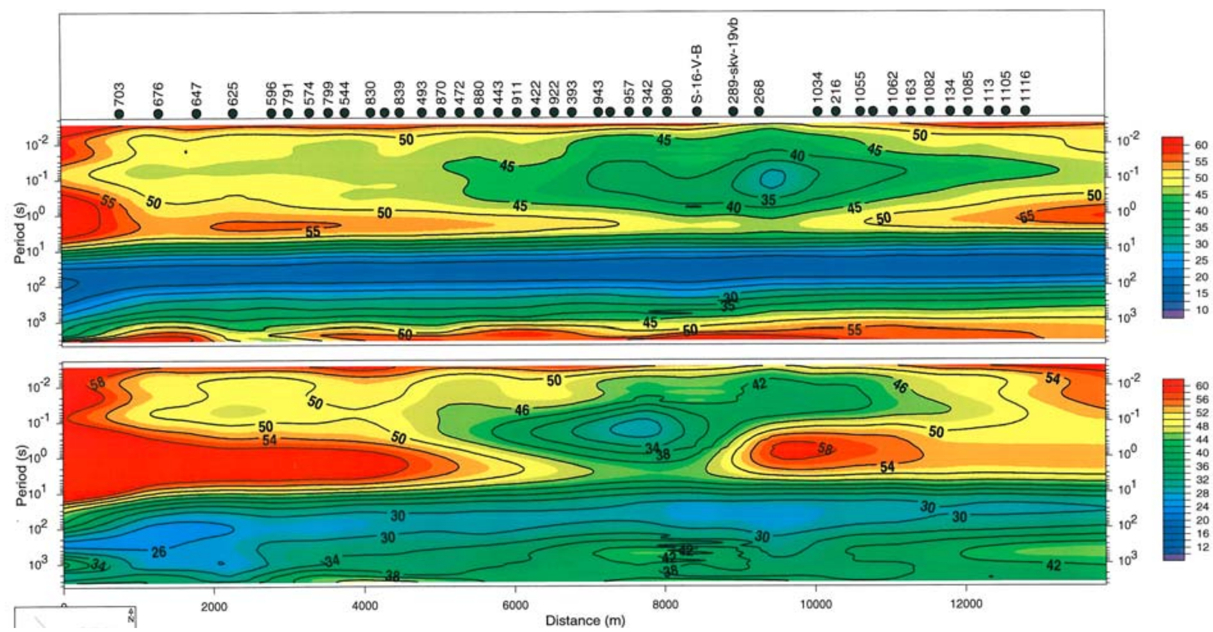

Figure 6: Impedance phase pseudo-section along profile P52.

To summarize, the first stage of interpretation was to locate such anomalies using an optimal set of MT parameter maps. (A planned future step is to compare the subjective (visual) and objective (statistical, computer) approaches for locating faults and prospective structures.)

The second step was to create a 1-D inversion of static-corrected amplitude and phase curves, using WingLink's 45-layer 1-D OCCAM inversion. The next step was to create a 2-D inversion on every latitudinal profile. Figure 7 shows a Mackie 2-D sharp boundary inversion along profile P52.

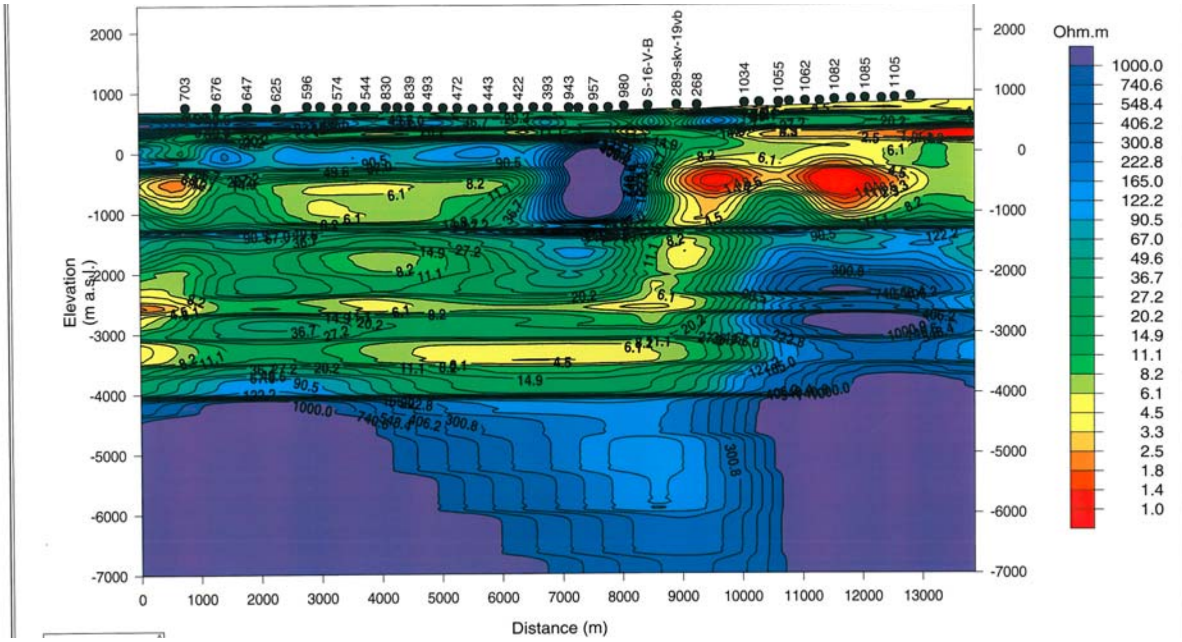

Figure 7: Results of 2-D inversion along profile P52.

Figure 7 reliably identifies areas prospective for hydrocarbons in the north part (Structure IIIa) of the East Buzakhur structure. The east bounding fault dips at approximately 70 degrees just west of site 289; well #19 passes through the fault plane. Note the low resistivity of the deeper sedimentary horizon below the East Buzakhur structure (implying good porosity/permeability) as well as the low resistivity zone in the basement. A weak positive resistivity anomaly identifies an area related to the Kuduk structure, in the west part of the profile.

Conclusions – East Buzakhur 3-D MT Survey

The survey was carried out at high production rates in difficult mountain terrain in a relatively short period (2.5 months). The survey aided the understanding of complicated geological structures; localized faults of different strike; and identified anomalies above gas deposits. The derived set of 2-D models along profiles can help constrain realistic 3-D resistivity models.

EDITED REFERENCES

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