O5-1 EFFECT OF FORMATION SHEAR AZIMUTHAL ANISOTROPY ON RESERVOIR PRODUCTION IN THE OBAIYED FIELD, WESTERN DESERT, EGYPT

MOHAMMED BADRI[1], THEODORE KLIMENTOS [2] and SHERIF SOUSA [3].
[1] Schlumberger Oilfield Services,P.O.BOX 790/11728 Maadi Cairo 11431 Egypt
[2]Schlumberger GeoQuest, Egypt.
[3] Badr El Din Petroleum Company, Egypt

Borehole sonic measurements have been traditionally used in the past in formation evaluation such as porosity and detection of hydrocarbon. However, recent development in sonic research allowed measurements of shear wave velocity in slow formations along two orthogonal directions. The variation of shear wave velocity with azimuth is known as shear anisotropy. The acquisition of orthogonal shear waves is obtained through generating flexural waves from two orthogonal dipole transmitters and two sets of receivers in orthogonal planes.

A tectonically fractured formation displays azimuthal anisotropy to shear waves. A shear wave polarized parallel to the fractures of a formation will propagate faster than a shear wave polarized perpendicular to the fracture strike. Not long ago, dipole shear anisotropy evaluation from cross dipole measurements was introduced. This technique has been very successful in identifying producing intervals by providing information on fractures through the evaluation of shear-wave anisotropy. The direction of the fast shear wave also provides information on stress and fracture orientation. More specifically, shear wave anisotropy investigates a volume of formation up to 3-5 borehole diameters away from the borehole, and thus can indicate fractures missed by other techniques.

In the Obaiyed Field, Western Desert, gas was discovered in the Lower Safa sandstone formation of estuarine deposits Mesozoic age at depth of approximately of 4000 m. The reservoir's total thickness is about 65-80 m in the area. It is characterized with low porosity about 8-12% and low permeability with some thin higher permeability intervals contributing to the majority of the well flow. The top Lower Safa (Top prospective sequence) map showed consistent fault trend, predominant NW-SE en-chelon fault pattern with overburden horizons, which dissected the older deep-seated NNE-SSW fault system.

Formation azimuthal anisotropy measurements have been used in improving the definition of local stress and its relation to faults mapped from 3D surface seismic data. Based on surface seismic interpretation of the Lower Safa formation one major fault trend was observed trending along northwest-southeast direction. Formation azimuthal shear anisotropy measurements acquired in a recent well showed an east-west stress orientation. This orientation indicates a local in-situ stress direction different from what has been mapped using 3D surface seismic data. We attribute the azimuth of the in-situ stress due to local disturbance of the stress regime since the well was drilled in small horst block within a major graben.

Figure 1 shows shear wave anisotropy results in well A over the reservoir section at depth of 4000 m. The shaded area in the depth track of each figure is the most important information because we can determine whether or not the rest of the results are based on the anisotropy observation. The left edge of the shaded area shows the effect of the offline amplitude minimization and be used as an anisotropy quality control indicator. The right edge of the shaded area shows how much anisotropy is present. Track 1 shows the GR, Caliper and borehole azimuth log curves. Tracks 2 and 3 display the fast shear azimuth (stress direction) and the fast and slow (dashed curve) shear slownesses, respectively. In track 3, whenever there is anisotropy the two slowness curves separate accordingly. The curves on the left and right of track 3 indicate the quantitative DT and time based anisotropy, respectively. Track 4 contains the fast and slow waveforms after processing. Over the anisotropic zones the waveforms separate. Shear anisotropy can be caused by a system of aligned cracks or stress imbalance.

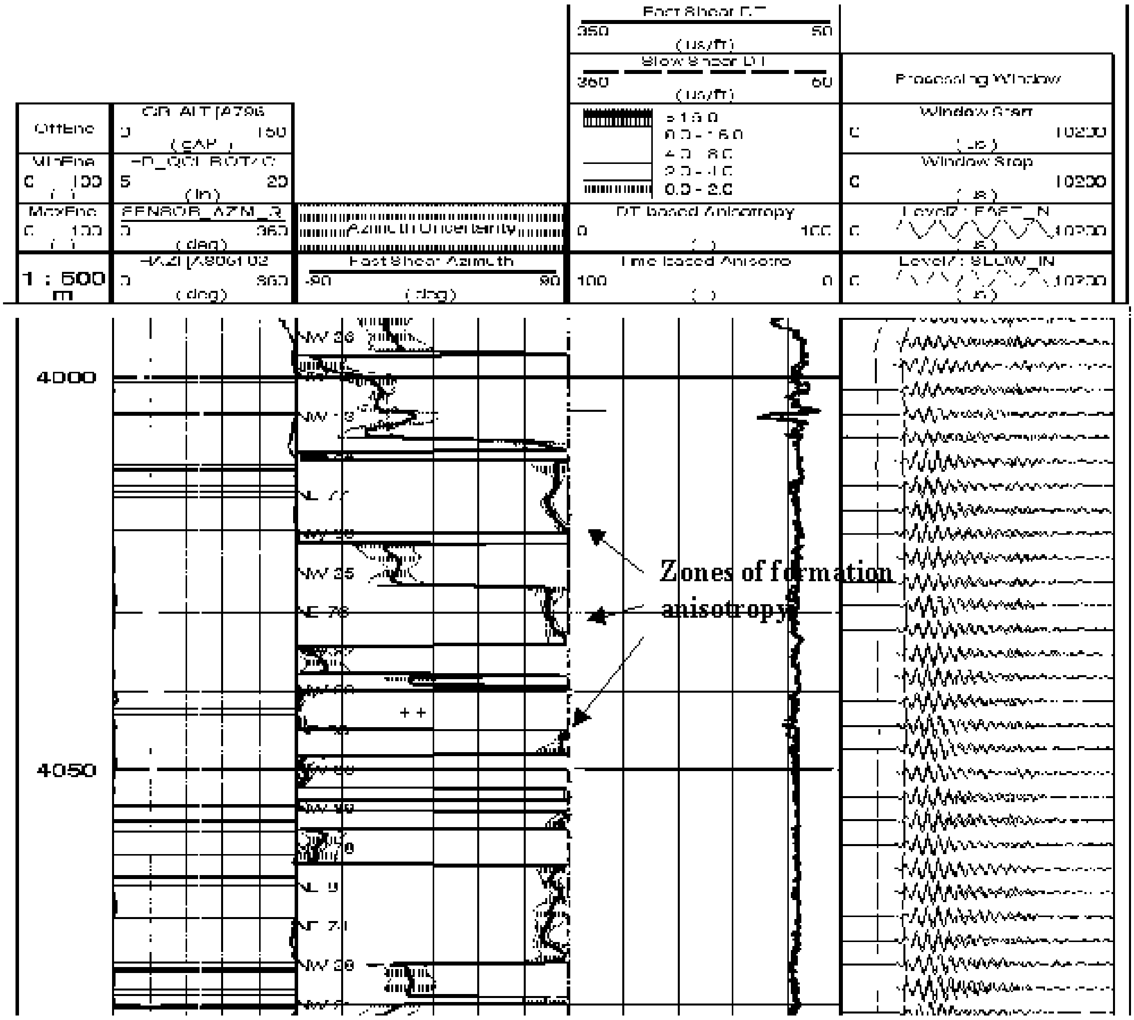

Fig. 1. Formation azimuthal shear anisotropy determined from well A.

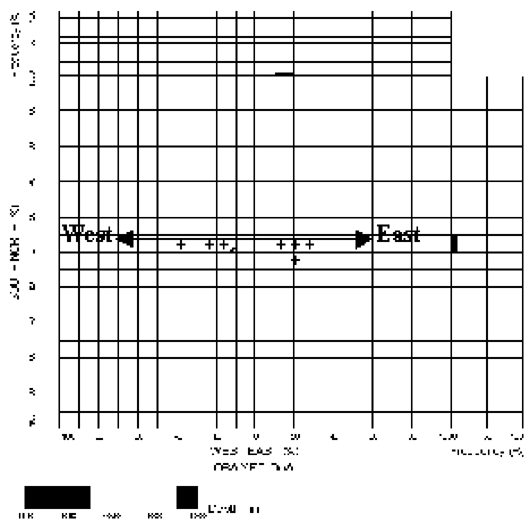

Fig. 2. Azimuth of in-situ stress over the reservoir section.

In this particular well, two different zones of significant shear anisotropy ranging from 15 to 20% can be identified as shown in Figure 2. The shallow interval between 4012-4020 m shows anisotropy azimuth trending along E-W direction. The deeper interval between 4042 and 4048 m also shows a significant shear anisotropy with trending along E-W, as shown in Figure 2. The orientation of the measured azimuthal anisotropy being different from the interpreted fault pattern on surface seismic data indicates that local in-situ stress around the wellbore is affected by both fault trends. This information of local in-situ stress variability was very valuable since well A was planned for hydraulic fracturing.

The main conclusions drawn from this study are the following:

- Two major zones of formation azimuthal anisotropy were identified. Both zones showed significant shear-wave anisotropy of magnitude about 15-20% with a trend along E-W direction.

- Local in-situ stress orientation found from well data is different from fault patterns interpreted from 3D surface seismic data. The measured stress direction found to be influenced by the combined effect of two existing major fault trends in the area generated by two different tectonic orogenies.

- The derived formation azimuthal anisotropy presents very valuable information in understanding fluid flow path, drainage pattern, and providing anisotropic velocities needed for surface seismic analysis.