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INTEGRATING SEISMIC INTERPRETATION WITH WELL DATA TO DETERMINE THE STRUCTURE EVOLUTION AND DEPOSITIONAL ENVIRONMENT OF THE LOWER MEMBER OF THE ACACUS FORMATION, CONCESSION NC4, GHADAMIS BASIN, LIBYA

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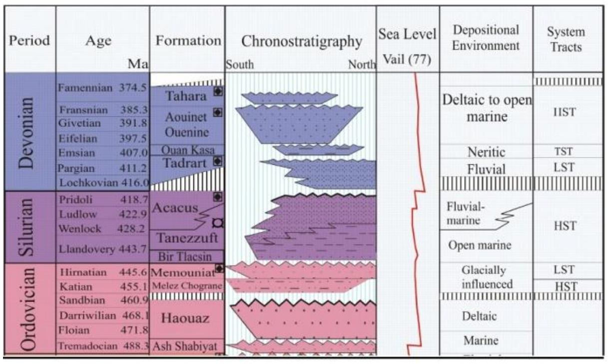
***Abstract*—** The lower member of Akakus formation represents one of the main important hydrocarbon accumulations in the NC4, Ghadamis basin. It consists interbedded sand stone shale that was deposited during the late Silurian. High quality 3D seismic reflection data and well logs in the study area provide a good insight into the structure evolution and the depositional environment of the lower member of Akakus formation in the Ghadamis basin. The time structure map of lower member of the Akakus formation indicated that the high structure in northwest of the study area and the lower structure in the southwest of the study area. This structure was interpreted as the anticline that was caused by pre-Devonian uplift. The lower member of the Akakus formation was eroded by pre-Devonian tectonic movement as a result the variation thickness of lower member of Akakus formation. The sigmoid progradatoinal pattern was identified by top lap angularity of seismic amplitude and instantaneous phase attribute across east to west of the study area. This pattern was interpreted as deltaic environment which was deposited during late Silurian. Integrating seismic reflection amplitude with well logs data were used to determine funnel shape. This shape was characterized by coarsening upward sequences.

I. INTRODUCTION

The Silurian sequence of western Libya was represented by two formations which are the Akakus and Tanezufet formations (Fig. 1). The Tanezzuft Formations (early Silurian) comprises of a sequence of graptolitic shale with minor streaks of very fine-medium-grained sandstones and siltstones at the top and base of the formation. The shale is characterized by grey, blocky to fissile, pyritic, micacous and non-calcareous. The base of the Tanezzuft is obviously marked by the radioactive shale unit that is dark brown to black and rich in carbonaceous material (El-Mehdawi,2000). The Akakus Formation (middle-late Silurian) consists of coarsening-upward regressive sequences of shallow marine sandstones. The Akakus Formation has been divided into three members (Lower, middle and upper) (Bracaccia et al. 1991). The sandstone of the lower member of Akakus Formation considers as a regressive member resulting the main reservoir in the Ghadamis basin. The middle transgressive member is represented by a thin silty sandstone The upper Akakus is regressive member that is characterized by marine shale which is coarsen upward into shallow marine and continental sandstones. The Akakus Formation is buried by Tadarat Formation (Shahlol, 2000).



Studies of lower Akakus have published by several authors. (Bracaccia et al. 1991) suggest that the geometrical and lithological characters this sand body of lower Akakus could be related to a depositional regression (deltaic?). This study integrates 3D seismic data with well logs to find out the evidences that enhance suggestion of Bracacia's, Carcano's and Drera's publication. In addition, this study determines the structure evolution of lower Akakus using seismic interpretation.

Fig.1. stratigraphic sections showing the Tanezzuft Formation and the lower Akakus Formation (modified from Hassan 2010).

II. BACKGROUND

2.1. Location of the study area

The study area is situated within concession or block NC4, which is located along the northern margin of the Ghadamis Basin (Figure 2). Concession NC4 occupies an area of 1,762 km2 , situated approximately 200 km southwest of Tripoli.

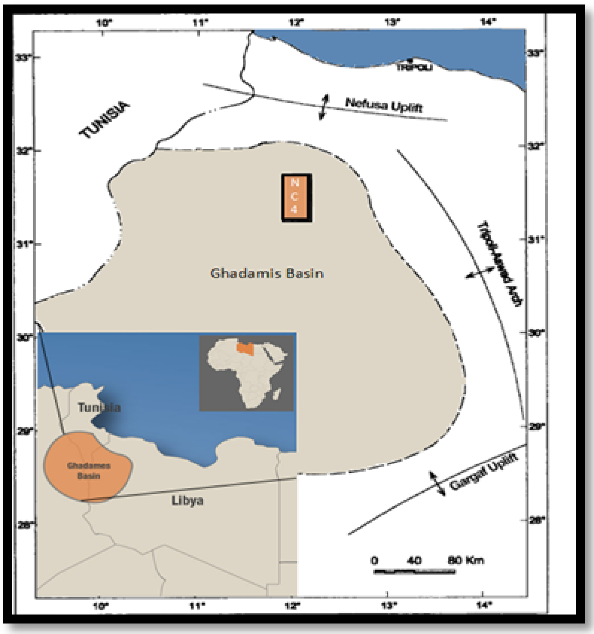


Fig. 2. Map illustrates the Ghadamis Basin and the location of the study area (modified from Shahlol, 2000)

2.2. Stratigraphy

The sedimentary sequence of the Ghadamis Basin was disturbed by several unconformities, including intra-Ordovician,Late Silurian (Caledonian), Carboniferous Permian (Hercynian), and Cretaceous (Austrian). The thick Paleozoic succession of the intracratonic phase and the overlying, thinner deposits of the Mesozoic sag phase were separated by the Hercynian unconformity (Figure 3).

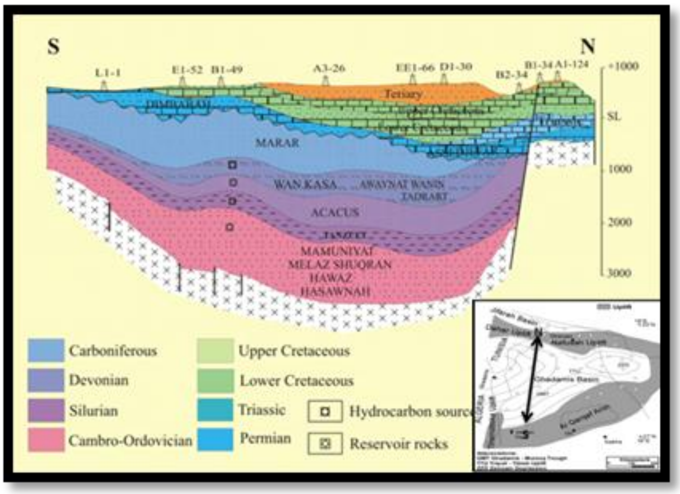


Fig.3**.** North-South cross-section of the Ghadamis Basin (Hassan, 2010).

The lower Akakus Formation in Ghadamis basin has been studied by subsurface data. The thickness of lower Akakus reaches to 1000 ft in Wells A1-NC3A and about 750 ft in well A1-NC1. It comprises predominantly of white, and occasionally light grey fine to medium-grained and coarse-grained glauconitic sandstones (El-Mehdawi,2000). The depositional environment of the lower Akakus sandstone in Ghadamis basin has been interpreted as transition from fluvial channel sandstones in the south, through coastal deltaic sandstones and siltstones, to offshore marine siltstones in the north. This sandstone considers the best secondary porosity which determine as coastal/deltaic sandstones (Hallet,2002).

III. DATA AND METHOD

3.1. DATA

The 3D seismic survey covers an area of 73.464 km2 in concession NC4 in the Ghadamis Basin (Fig. 4). Seismic data was acquired by the Arabian Gulf Oil Company (AGOCO). It was made available in the SEG-Y format, which was imported to the Kingdom Suite software. It has a bin-spacing of 25 m. The migrated data was zero phase containing 950 inlines and 635 crosslines. The two-way travel time was 4 seconds. Seven wells were penetrated within concession NC4.

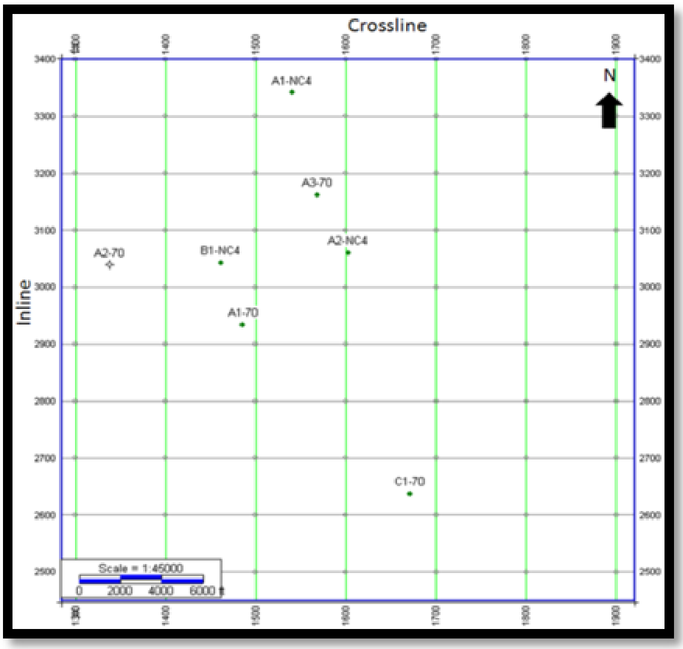


Fig. 4. Basemap of the seismic survey and location of the seven wells (green dots) in concession NC4 in the Ghadamis Basin. The North-South lines are crosslines and the East-West lines are inlines.

3.2. WELL LOG DATA

This study was based on several wire-line log data obtained from the seven wells. A suite of wire-line logs in digital format were utilized to determine the lithology .Both the formation tops and the check shot points were provided by AGOCO.

3.2.1. Gamma Ray (GR).

The gamma ray log is a measurement of the natural radioactivity in the formations. The elements in sedimentary formations include potassium (K), thorium (Th), and uranium (U). Each influenced the natural gamma radiation recording. Black shale demonstrated the highest level of radioactivity, as it is abundant with radioactive elements. The gamma ray was used to determine lithology (Bassiouni, 1994).

3.2.2. Sonic logs (DT).

Sonic logs measure the interval transit time of a compressional sound wave traveling through rocks. The sonic log device is comprised of one or more ultrasonic transmitters and two or more receivers. There is relation between the porosity and the sonic travel times. Therefore, short travel times of 50 microseconds are indicative of low porosity, hard, and dense rock. Long travel times of 95 microseconds, however, are related to softer, lower density, and higher porosity (Asquith and Kryqowski, 2004).

3.2.3. Density logs (RHOB).

The unit of density logs is grams per cubic centimeter (g/cm3) and is marked by the Greek letter Ø (rho). The density log has two separate density values: the bulk density and the matrix density. The bulk density is the density of the entire formation (solid and fluid parts). The matrix density is the density of the solid framework of the rock.

3.3. Software

The 3D seismic was interpreted using the SMT Kingdom Suite software (Version 8.6). This software is developed by the Seismic Micro-Technology (SMT). SMT is a windows-based seismic interpretation and geological application. This study used four packages. 2d/3d-EarthPAK was applied to interpret the horizons, display and edit wells, generate maps, and construct cross-sections. SynPAK was used to generate synthetic seismograms and tie well data with seismic data.

IV. RESULTS AND DISCUSSIONS

4.1. Seismic structure map of lower member of Akakus formation.

The 3D seismic and well logging determine the structure evolution of lower Akakus Formation in the study area. In the area under consideration, the lower Akakus Formation is the main oil and gas productive from the Ghadamis Basin. The top horizon of lower Akakus was interpreted and mapped using seismic to well calibration and its seismic continuity. The top of the lower Akakus formation is identified in the seismic sections by its low amplitude and weak continuous and energetic amplitudes (Fig.5).

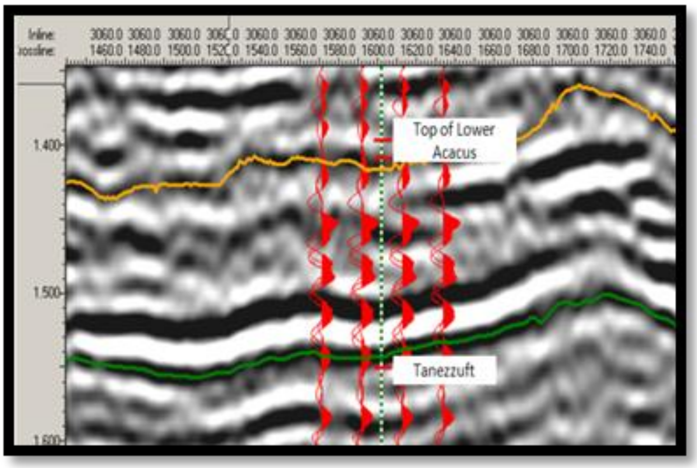


Fig.5. Inline 3060 with the interpreted horizons. green color indicates the Tanezzuft Formation, and yellow color is the top of the lower Akakus.

Figure 6 identifies the structure map of lower Akakus. This map shows structural highs in the northeastern part of the study area. Furthermore, Monoanticline (high structure) was observed in the southeast direction of the study area. Structural low were identified in the southwest. From time structure map of lower Akakus conclude that the lower Akakus was influenced by pre Devonian uplift. This uplift was caused by the collision of Godwana with laurentia and Avalonia (Sutcliffe et al. 2000).

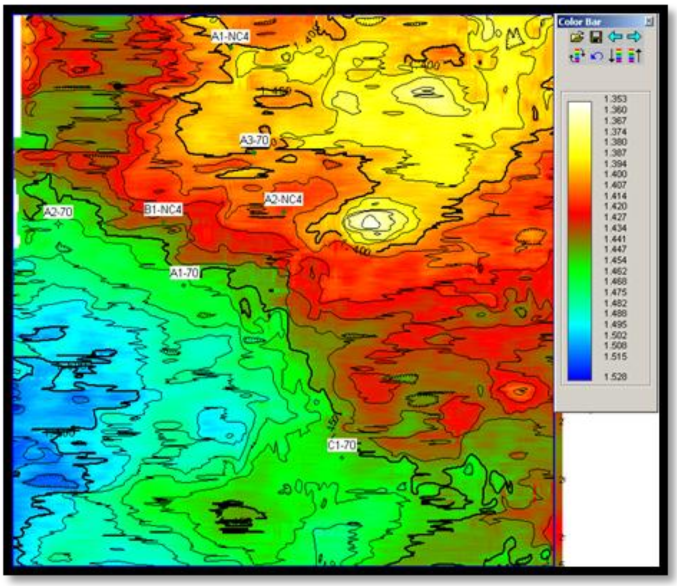


Fig. 6. Time structure map of the lower Akakus horizon showing numerous anticlines formed by the pre-Hercynian movement.

1.2. seismic stratigraphic interpretation

Seismic stratigraphic interpretation in the study area was based on integrating the seismic amplitude with the log curve facies and isopach maps. The seismic data are displayed on variable area with dark blue color representing peak and dark brown representing trough. Instantaneous phase was also used to identify the reflector continuity. The purpose of using instantaneous phase were to equalize the weak and strong reflectors, and to determine the depositional configuration and sequence boundaries.

Seismic inline 3362 (Fig. 7) runs over the northern margin of the study area. This inline illustrates a lenticular shaped reflection pattern. This pattern is recognized by a combination of sigmoid and oblique patterns. This pattern is interpreted as progradational pattern (deltaic facies). The tops of sigmoid and oblique pattern are characterized by toplap angularity and reflection variability. Moreover, Well logging tying with seismic section has been utilized to determine the funnel shape that also confirms the progradational pattern (deltaic facies) (Fig. 8) . this facies is characterized by coarsening upward sequence. Thus, this deltaic facies was deposited by eustatic fall in sea level and basin tectonic.

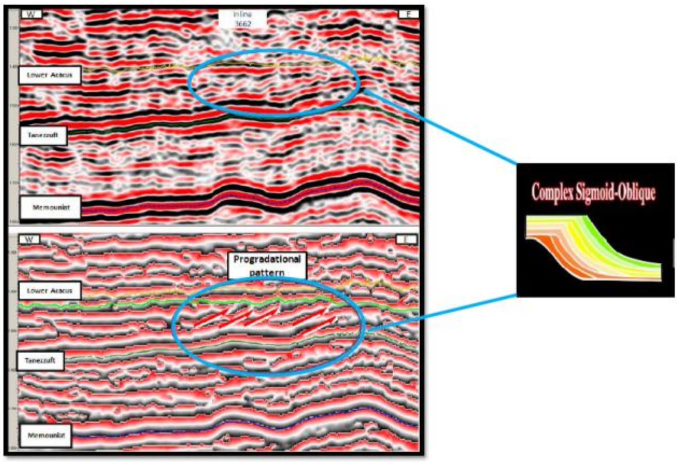


Fig. 7. Seismic section display along inline 3662 indicating the deltaic environment in the lower Akakus reflectors.

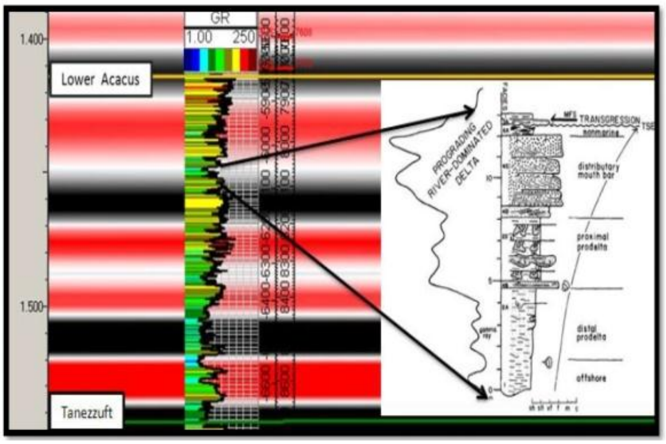


Fig. 8. Gamma ray log from well A2-NC matching with seismic section illustrating delta environment in the lower member of Akakus horizon.

The isopach map of lower Akakus indicates that the variation of thickness decreases from north to south (Fig. 9). Furthermore, the range of thickness is between 290 ft (blue) and 635 ft (yellow) in the study area.

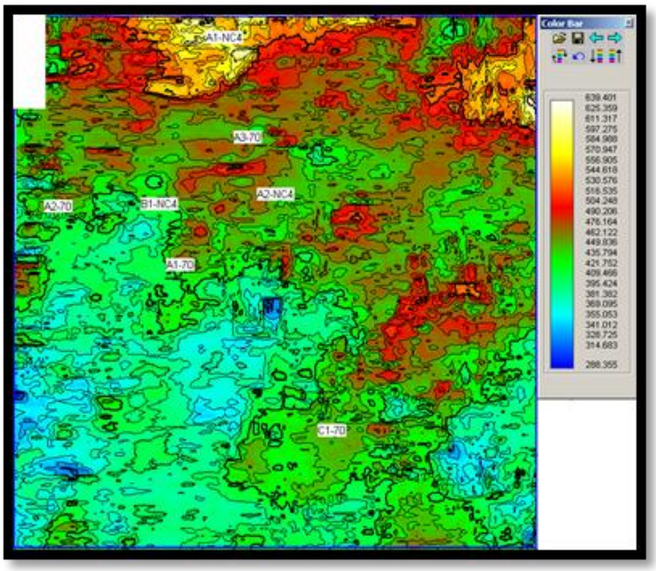


Fig.9. Isopach map of the lower Akakus Formation illustrating the variation of thickness in the study area.

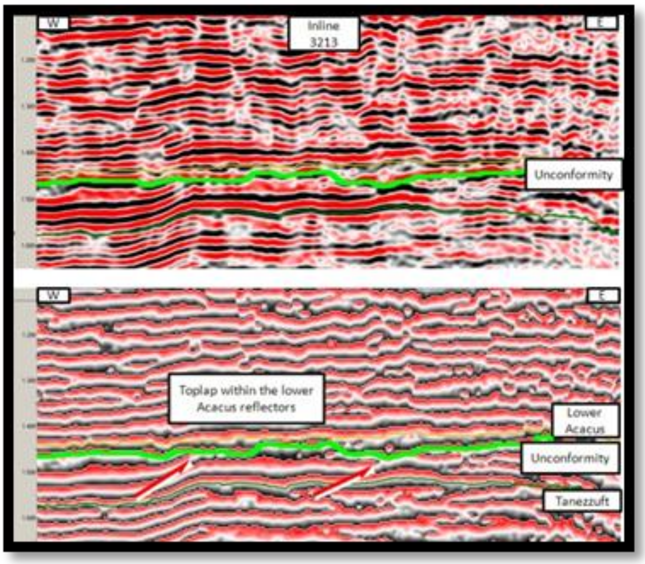


Fig.10.Seismic section and instantaneousphase along inline 3213) indicating the unconformity within the lower Akakus reflectors.

Inline 3213 (Fig. 10) illustrates truncation feature which is toplap. This toplap is interpreted as unconformity surface feature which is identified as consequences of the pre-Devonian uplift movement. By using isopach map of lower Akakus linking with inline (3213) can conclude that the lower Akakus was uplifted and eroded by pre-Devonian uplift (Fig. 11).

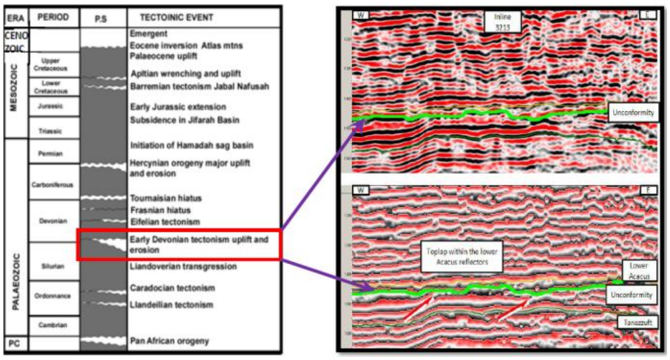


Fig. 11. seismic section tying with columnar section showing the pre-Devonian uplift.

V. CONCLUSION

by using 3D seismic and well logging in concession NC4, Ghdamis basin conclude that the high structure map and low structure map of lower Akakus was caused by pre Devonian uplift during Caledonian origin. In addition, the depositional environment of lower Akakus interpreted as the progadational pattern (deltaic environment) by integrating log curve facies with the seismic sections. Also, this pattern is determined by the seismic configuration (sigmoid and oblique patterns). Finally, the unconformity surface in the top of lower Akakus formation was identified by seismic reflection events (toplap, truncation, and termination) in seismic sections. This unconformity was caused by pre Devonian erosion.

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