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Possible carbonate buildups in the Palaeocene sequence at the North-eastern margin of Ajdabia trough

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Highlights

- **The platform-basin relation-ship in a carbonate setting in the north-eastern shelf margin of Ajdabia Trough have been studied.**
- **The observed mounds in the seismic stratigraphic analysis of the Palaeocene sequence are interpreted as carbonate build-ups.**
- **Hydrocarbon reserves may be stored in the Palaeocene carbonate build-ups where potential seals over this platform would be expected because the section mainly consists of lime mudstone and shale.**

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ABSTRACT

Analysis of the seismic section from the eastern margin of Ajdabia Trough has resulted in a detailed study of carbonate buildups in the Palaeocene sequence. The main significant features identified in the seismic stratigraphic analysis are isolated mound features within the sequence in the northern shelf area. However, occasional discrete mounds of more diffuse seismic character have been seen in the extreme north-eastern part of the area, in an SW-NE trending feature. Large mounded structure of more than 200 ms thick and is composed of discontinuous, chaotic reflectors has been identified. Evidence for similar mound characters exists at the north-eastern part of the study area. The isolated mounds are draped and onlapped by later Palaeocene sediments.

The observed mounds in the Palaeocene sequence are interpreted as carbonate build-ups, which are usually mound-shaped biogenic deposits that display marginal onlapping reflections, whereas the overlying reflections drape the reefs, and the underlying reflections exhibit pull-down effect. This pattern may indicate growth of carbonate build up during the early Palaeocene time. From an exploration point of view, these features within the Palaeocene sequence probably contain the potential for stratigraphic hydrocarbon plays in the area.

1. Introduction

The results presented in this study are based mainly on the geological and geophysical investigation of the Paleocene sequence in north-eastern Ajdabia Trough and presents the approach used to explore possible carbonate build-ups in this sequence. The area of study is located at the hinge-zone between Cyrenaica Platform and Sirte Basin (Fig. 1). The main objective of this research is to identify and recognise occasional discrete mound features of more diffuse seismic character, seen within the Palaeocene sequence in the north-eastern shelf of Ajdabia Trough. These mound features may point to discrete organic carbonate build-ups.

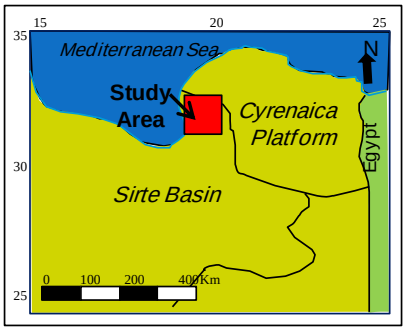

Fig. 1. Location map of the study area

Many studies have been published on the geology and geophysics of Sirte Basin, and Cyrenaica Platform. Berggren, (1974), studied and described the Tertiary rocks in the Sirte Basin and divided the sequence into a number of stratigraphic units. Subsidence and sedimentation rates have been analysed in the Sirte Basin to determine their relation to facies distribution Gumati & Kanes (1985) and Gumati & Narin (1991). El-Shari (2005) used the backstripping technique in the area to separate the subsidence of the sedimentary basin caused by sediment and water loading, from that caused by the tectonic driving force. The relationship between the stratigraphy and structural setting across the hinge-line in passive continental margins has been studied by El-Shari (2008). Elwerfalli & Stowe, (1998) through surface and subsurface petrographic investigations in NE-Libya, subdivide the lower Tertiary section into three main associations: slope facies association, shallow marine facies association and lagoonal facies association. In general, the Palaeocene facies distribution in the Sirte Basin and Cyrenica Platform has been described by Conley (1971), Brady *at el.* (1980), Bezan (1996), and Elshari (2017).

The availability of seismic and well data in this research provided the opportunity for the study of the platform-basin relationship in a carbonate setting, and testing occurrence of carbonates build-ups in the Palaeocene sequences. Seismic and well data from north-eastern margin of Ajdabia Trough enables seismic facies analysis, and interpretation Palaeocene depositional sequences in the area. Two and three-dimensions seismic reflection data tied to

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nineteen wells have been used. Generally, data quality decreases in faulted areas, and in the deeper sequences toward the southwest. Wire-line logs of sonic and gamma-ray types in a number of wells are used in this study.

3. Regional tectonic and depositional setting

During the late Cretaceous and Tertiary, the area of study was located on a broad carbonate platform that bordered the northern margin of the African continent (Del Ben & Finetti, 1991; Buxton & Pedley, 1989). During these times, there was a major marine transgression in the area coincident with the general eustatic high stand of sea-level (Pitman, 1978). This widespread marine transgression was associated with intense rift-related subsidence throughout the late Cretaceous in the western Cyrenaica. The first phase of extension and initial subsidence was followed by widespread thermally driven subsidence through the Tertiary period (El-Shari, 2005).

A widespread marine transgression, following basin subsidence, during the early Tertiary period. Carbonate depositional systems demonstrate distinctive patterns that often develop as a result of erosion and deposition in carbonate environments. Along horsts, carbonate banks and reefs under open marine conditions may be developed (Fig. 2). After this transgression, a shallow-marine environment was established across the area, and thick intervals of carbonate with a minor amount of siliciclastic and evaporite sediments were deposited on a carbonate ramp. During Palaeocene and Eocene time, normal faulting occurred, mainly as reactivation along a hinge-line between the Sirte Basin and Cyrenaica Platform (El-Shari, 2008). Generally, rapid thickening of the syn-rift section is noticed at the hinge-line. The post-rift sequence formed a relatively simple sedimentation model in which the section shows an overall thickening towards the southwest.

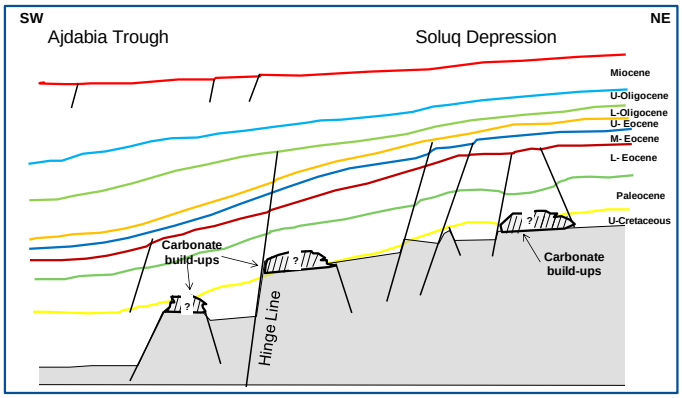

Fig. 2. SW-NE geo-seismic cross section showing the possible development of carbonate build-ups on structural blocks.

The carbonate platform on the north-eastern margin of the Ajdabia Trough contains a record of interactions between the factors that controlled carbonate platform deposition during the Palaeocene time. Development of this carbonate platform is an excellent example of interaction between regional effects and governed by thermal subsidence following extension (El-Shari, 2008). The shelf edge is the most sediment-starved part of the margin and given suitable climatic conditions, carbonate deposition can occur at rates equal to subsidence thus maintaining and building the platform. This carbonate is interbedded with shale in some places, indicating transgressive and regressive sedimentary cycles (Fig. 3). However, the Palaeocene carbonate facies are confined to the platform, while the deep open marine facies are restricted to the structural low areas. The most important structural features in the area were extensional normal faults, which occurred at the basin margin. Most faults are truncated by the end of the Middle Eocene time (Fig. 2).

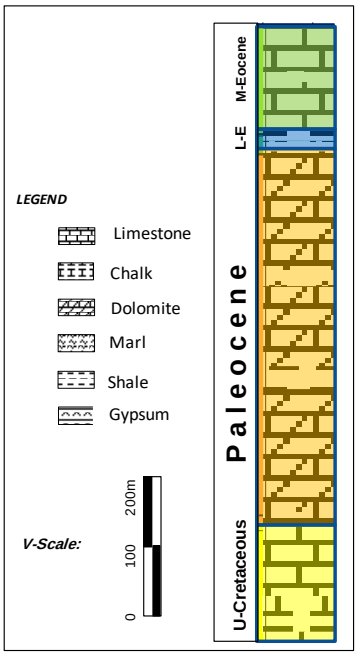

Fig. 3. Part of lithological log in well I1-41 summarised the lithology of the Palaeocene Sequence in the study area.

4. Rimmed Shelves vs Carbonate Ramps

Generally, the rimmed shelves are characterised by the development of reefs and carbonate bodies along the shelf margin, and the depths are shallow adjacent to the shelf-break, even subaerial if islands have formed (Fontaine *et al.*, 1987). The shelf margin is characterised by a near-continuous rim of barrier reefs and/or skeletal-oolitic sand shoals. Increases in the basinward slope may occur tectonically, due to differential subsidence or extensional faulting, or it may occur as a result of differential sedimentation between the basin margin and the basin centre (El-Shari, 2008). However, a ramp may develop into a rimmed shelf through differential subsidence along a hinge-line. The carbonate ramp may evolve into rimmed shelves as a result of high carbonate production on the forming shelf edge or, through reef growth (Fig. 4).

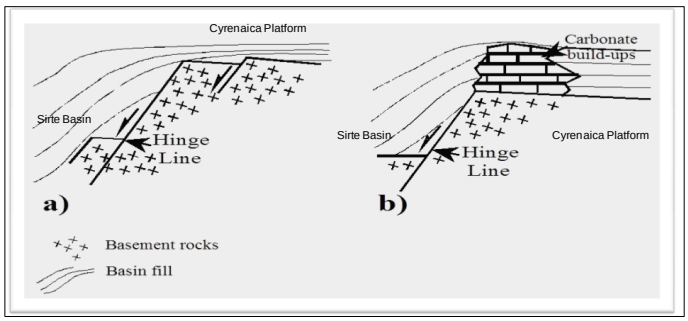

Fig. 4. Possible structures at carbonate margins across a hinge-line, a) open shelves, and b) rimmed shelves.

During highstand systems tract deposition, shallow-marine sedimentation rates are commonly greater than subsidence and the eustatic rise, thus leading to deposition of aggradational or progradational parasequence sets (Sarg, 1988; Tucker, 1991). These sediments include muddy and sandy shoreface deposits, platform-interior patch reefs and grainy shoals, shelf-edge reefs and shoals, and basin-margin and slope facies.

However, the shape of the northeastern margin of Ajdabia Trough, extending NW-SE, suggests a structural influence. The structures have played a very essential role in terms of controlling where deposition takes place (El-Shari, 2008). The earlier platform is faulted to form a series of horsts and grabens and has undergone rapid submergence, with carbonate upbuilding being localised on

the highs, while the grabens become sites of deep-water sedimentation. Thus, this may give the possibility of development of carbonate bank or reef complexes above the hinge-line (Fig. 4).

5. Seismic Faceis Analysis

Many seismic sections, representing dip and strike profiles, are fully interpreted in this research. Two-way time structure map of the sequence shows a continuing dip of the horizon towards the southwest (Fig. 5). Major normal faults of the NW-SE trend and downthrown southwest have been interpreted on the top of the sequence.

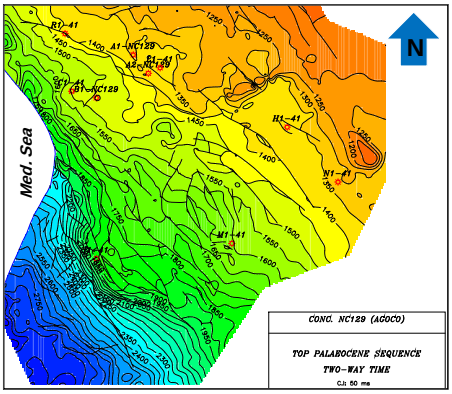

Fig. 5. Time structure contour maps of top Palaeocene sequence in the Northeastern part of Ajdabia Trough.

Based on the internal seismic reflection parameters such as the configuration, continuity, amplitude, interval velocity and external form of each seismic facies, the Palaeocene seismic sequences were interpreted. Seismic facies analysis were used to determine lithological and stratigraphic variations within the sequence, based on their position and lateral relationships to other seismic facies. The main significant features recognized in this seismic facies analysis are isolated mound features within the Palaeocene sequence in the north-eastern shelf area. The reefal construction is characterised seismically by a mound shape and onlap of surrounding reflections. Bubb and Hatlelid (1977) proposed definite criteria for recognising the buildups: the boundary outline, which includes the reflection configuration and onlap of overlying reflections, as well as seismic facies changes defining the buildup.

Generally, on the seismic section; the reefs topography can be identified by; mounded shapes; internally chaotic seismic facies; weak internal amplitude; draping of overlying sediments; onlapping of flanking reflection cycles; and pull-down phenomenon. However, complex sedimentary bodies such as carbonate mounds are characterized by a combination of geometric shapes from seismic reflections. It is generally an association of chaotic, subparallel and concave up features. According to these criteria and others, a number of mounds observed in the Palaeocene sequence are interpreted. Generally, the internal configuration within Palaeocene sequence is characterised by variable-amplitude and variable-continuity. On the platform, the Palaeocene seismic reflections are generally parallel or sub-parallel with variable amplitude and discontinuous reflection configuration (Fig. 6).

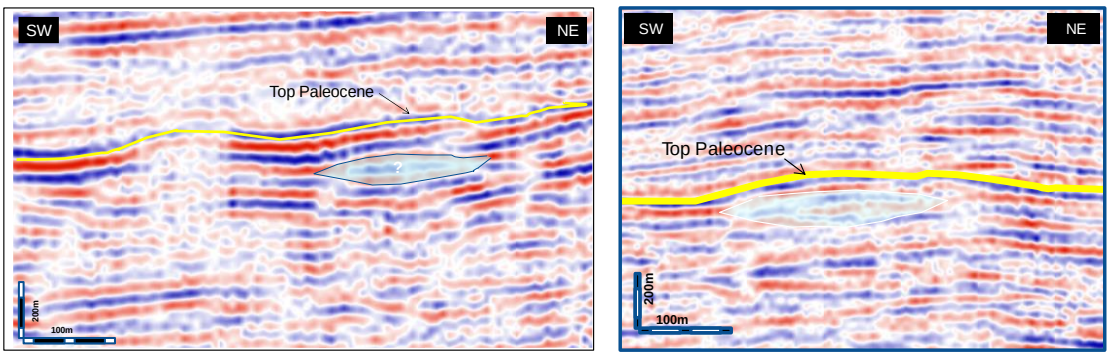

Fig. 6. Part of two seismic section, dip lines, clearly shows lateral seismic facies in the northern part of the area.

Furthermore, occasional discrete mounds of more diffuse seismic character have been identified in the extreme northeastern part of the area, in an SW-NE trending feature. Online NC129-89-56, a large mounded structure of about 600 m width is seen (Fig. 7). It is more than 200 ms thick and is composed of discontinuous, chaotic reflectors. Evidence for similar mound characters exists at the northeastern part of the study area. The isolated mounds are draped and onlapped by later Palaeocene sediments.

The observed mounds in the Palaeocene sequence are interpreted as carbonate buildups, which are usually mound-shaped biogenic deposits that display marginal onlapping reflections, whereas the overlying reflections drape the reefs, and the underlying reflections exhibit pull-down effect (Fig. 8). This pattern may indicate growth of carbonate buildup during the early Palaeocene time. Further evidence for such features already exists on the Amal Platform (the south-eastern margin of the Sirte Basin), where similar buildups have been interpreted within the Palaeocene section (Sola & Ozcicek, 1990).

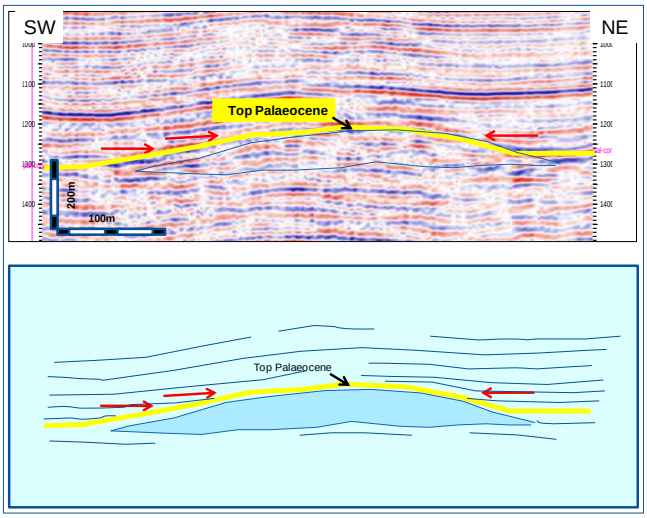

Fig. 7. Part of seismic line NC129-89 shows relatively large mound shape and onlap of surrounding reflections interpreted as reefal build-ups forming on a carbonate ramp during the early Palaeocene time.

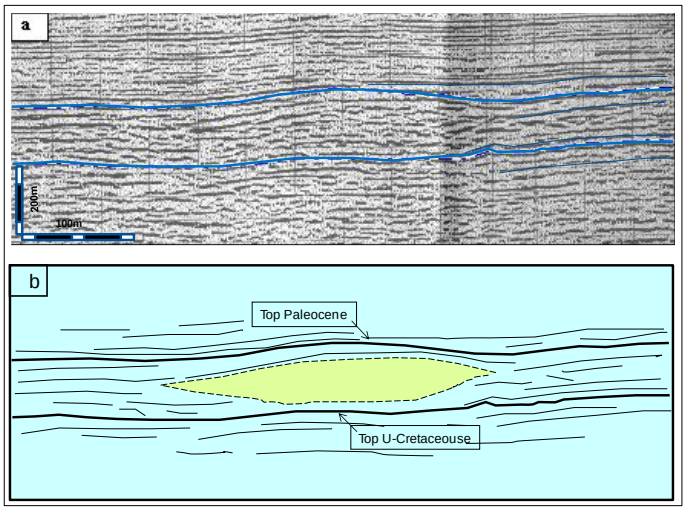

Fig. 8. Part of the seismic section in the study area shows a mound feature with clear internally chaotic seismic facies and pull-down effect.

6. Palaeocene Build-ups as Hydrocarbons Reservoir

In general, carbonate ramps form major reservoir zones with wide opportunities for stratigraphic and structural trapping and lateral variations in reservoir quality (Burchette & Wright, 1992). Organic build-ups in mid or outer-ramp locations commonly form ideal stratigraphic traps sealed by onlapping basinal facies or by down lapping mud-textured distal high stand sediments. In the Sirte Basin, the Palaeocene reservoirs have large amounts of hydrocarbon. In the eastern basin, the bioclastic coral-rich boundstones and grainstones of the Upper Sabil Formation form the main reservoir (Spring & Hansen, 1998). In addition, the Palaeocene rocks are composed of shoals and pinnacle reefs facies, and these are one of the major hydrocarbon reservoirs of the area (Brady *et al.,* 1980; Bezan, 1996).

However, in the last thirty years attempts to develop the hydrocarbon resources have been increased in this area. The existence of many sedimentary cycles with a corresponding source, reservoir, and seal rocks ranging in age from Upper Cretaceous to Miocene, suggest that exploration for hydrocarbons in this region could be potentially very successful. A better understanding of the stratigraphy in the north-eastern margin of Ajdabia Trouhg, may help to find out the prospective lithostratigraphic unit for hydrocarbon potential by identifying potential structural-stratigraphic traps (Fig. 9).

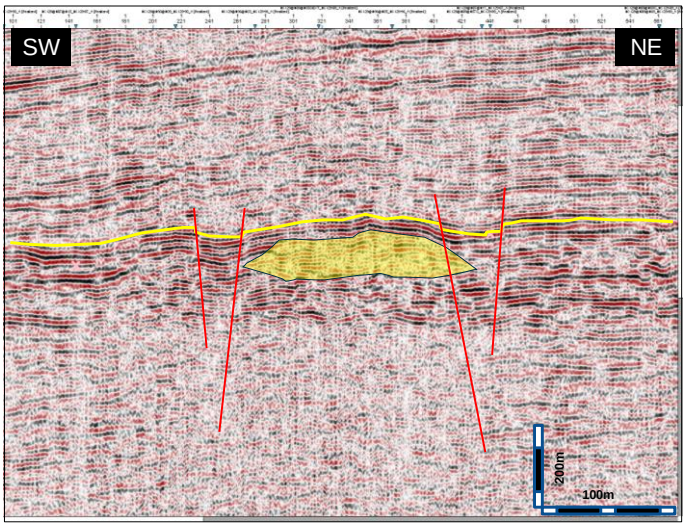

Fig. 9. Part of the the seismic section in the study areas shows possible combined hydrocarbon traps developed within the Palaeocene Sequence.

The main hydrocarbon reservoir in the northeastern Ajdabia Trough is the porous and permeable dolomitic rock unit of the Paleocene sequence. The reservoir properties are related to dolomitization processes. The cap rock for this reservoir in the area is the shales of the lower Shale sequence (Early Eocene). Furthermore, in the area, organic build-ups may form ideal stratigraphic traps sealed by onlapping basinal facies or by down lapping mud-textured distal highstand sediments. The overlying argillaceous Lower Eocene carbonate may provide a good seal facies.

7. Conclusions

In the north-eastern shelf margin of Ajdabia Trough, mound shape features have been identified within carbonate rocks within the Palaeocene sequence. These features interpreted as carbonate build-ups forming towards the basin margins on a carbonate ramp during the early Palaeocene time. They range in diameter between about 200 to 600 m and of more than 200 ms thick. However, these features had not been previously detected in the study area.

The common criteria observed on seismic sections on the development of carbonate build-ups in the Palaeocene Sequence are; marginal onlapping reflections, the overlying reflections drape the reefs, and the underlying reflections show a pull-down effect.

From an exploration point of view, hydrocarbon reserves may be stored in this carbonate build-ups. Potential seals over the drowned Palaeocene platform would be expected to be relatively good and really extensive because the section mainly consists of lime mudstone and shale.

8. Recommendations for Further Work

The main risk from this investigation; is the reservoir present or not? It means, is it reefal build-up? Or it is just a pop-up structure containing deep water non-reservoir facies. Furthermore, there are some uncertainties due to the lack of a consistent seismic response, as some of the mound features shows sub-parallel internal facies, which suggest off-reef facies. Therefore, ddetailed sedimentological work on the Palaeocene sequence sediments from existing core material, particularly in the north-eastern part of the area, would help to determine whether carbonate build-ups are present. In addition, a 3D-seismic survey in the area would lead to an increased understanding of the complex trap architectures and possibly result in new discoveries.

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