Basin Analysis and Tectonic Evolution of the Upper Campanian-Maastrichtian Succession, Southern Iraq

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Abstract

The tectonic development of the Mesopotamia basin in southern Iraq was studied by calculating subsidence and sedimentation rates for eleven wells distributed over the study area. This was done by calculating backstripping for the Upper Campanian-Maastrichtian sequence. The subsidence rates increased in the south of the region near the Su-4, Su-1, and Lu-2 wells in the Hartha Formation, while the basin of the Shiranish Formation appeared to increase towards the northwest near the Ns-2 well. Then, the subsidence rates in the next formation, Tayarat, increased towards the south, near the wells. Su-1, Su-4, Lu-2. The Hartha Basin was divided into two tectonic parts based on the above. The Shiranish Basin was affected by uplift.

Keywords: Basin rebuilding; Tectonic development; Upper Campanian-Maastrichtian; Geohistory analysis; Southern Iraq

1. Introduction

The Upper Campanian-Maastrichtian cycle in Iraq represents distribution succession that started with a significant transgression and almost covered the whole of Iraq after the termination (Budy, 1980).

Because of their importance in the oil industry in the northern and southern parts of Iraq and neighboring countries, the Hartha and Shiranish formation sediments, which correspond to the Upper Campanian-Maastrichtian cycle, have been thoroughly investigated. Beds of the sequence are almost contemporaneous, being replaced by each other. Local age variation occurred in the Late Campanian-Maastrichtian time interval, primarily where facies-bound beds intertongued (Jassim and Goff, 2006). Numerous attempts have been made to categorize the rock units from this period based on their lithofacies, biofacies, and depositional locations in paleogeography. The most significant of these attempts was Budy's division (1980), which combined these units based on similarities in their facies and paleogeographic locations and divided them into groups based on their depositional environments, such as Hartha and Tayarat Facies, which represent fore-reef deposits, as well as Shiranish Facies, which represent offshore deposits.

The study area consists of many selected oil fields, which are distributed in Mesopotamian foredeep basin, as shown in Fig. 1. The study area is characterized by a thick sedimentary cover that increases toward east, short and large lengths folds with a north-south direction in the southern part of the sedimentary basin and northwest-southeast in the eastern part of the sedimentary basin along the passive margin (Al-Zaidy and Al-Mafraji, 2019; Abbas et al., 2022).

This research aims to interpret the Upper Campanian-Maastrichtian basin development during geohistory analysis where the primary thickness and subsidence rates were utilized to determine the changes in accommodation values and, therefore, their effect on sequence formation.

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A sedimentary basin is made up of layers with various lithologies that were formed throughout the age. Therefore, the thickness, lithology, and age of the horizons dividing the strata are the primary pieces of information in the burial history. A surface in the layer of a certain moment is considered a horizon. Hence, the more accurate phrase is chronohorizon. Although stratigraphic categorization is of complex terminology, the terms horizon and formation will be used in this context. Here, a formation is essentially the layer within two successive horizons (Magnus, 2010).

The objective of the geohistory study (restoring the primary thickness) is to determine and eliminate the impacts of load compression, deposition of sediments, changes in paleo bathymetry, and sea level changes. When backstripping is employed in search of information on the evolution of the depositional mechanism, the expression geohistory analysis (or burial history) is frequently used (Einsels, 2000).

Fig. 1. Location map of the studied area shows the wells and oil fields

2. Materials and Methodology

Stratigraphic and tectonic information are required to work a geohistory and determine the subsidence rates. This information comprises stratigraphic units that indicate the current thickness for the researched succession from the oil fields' final reports and earlier research. The kind of lithology, ages of Beds, and estimated paleo-water depths from the geological research for the stratigraphic sequence of Iraq. Most of these issues can be addressed using thick stratigraphic sections of relatively shallow-water formations and only long-term, large-scale alterations (Angevine et al., 1990). The flow diagram (Fig. 2) shows steps of the geohistory analysis and calculations, which were carried out in its various steps using equations, elements and constants prepared by many researchers, such as Van Hint (1978); Steckler and Watts (1978); Sclater and Christie (1980); Hardenbol et al. (1981); Falvey and
Deighton (1982); Gradstein et al. (1985); Guidish et al. (1985); Haq et al. (1987); Hegarty et al. (1988); Steckler et al. (1988).

3. Paleoenvironment and Stratigraphy

The Late Campanian to Maastrichtian succession is a wide distribution succession in the geological setting of Iraq. The depositional cycle of this succession starts with a transgression stage and almost covers the entire Iraqi basin (Buday, 1980).

Because the Late Campanian to Maastrichtian sediment is important reservoir units found in neighboring countries and the northern and southern parts of Iraq, they have been studied relatively extensively.

A significant onlap happened in Late Campanian-Maastrichtian: Iraq was immersed through the Maastrichtian (Fig 3). It is distinguished via a robust westerly onlap onto a regional unconformity. The Hartha Formation is the main onlapping unit within the Late Campanian-Maastrichtian cycle. Over most
of the Khleisia High and Stable Shelf, it is a conformable overlying by the Shiranish Formation (Bellen et al., 1959; Al-Sadooni, 1996), which in turn is overlain towards the west and SW by the Tayarat and Digma formations. These units transmit to the north and east directions and locally throughout deep half-graben into the Shiranish Formation. Towards the thrust front, the Shiranish Formation passes laterally into the Hadiena, Bekhma, and Aqra formations, which pass NE into the Tanjero Clastic Formation (Aqrawi et al., 2010).

The Hartha Formation was defined and described for the first time by Rabanit in 1952 from the Zubair oil field (Zubair-3) in Mesopotamia in southern Iraq (Owen and Nasr, 1958).

Israa and Al-Zaidy (2023) divided the Hartha Formation into upper and lower components in the middle of Iraq. Al-Sadooni (1996) specified eight lithofacies depending on petrographic and petrophysical properties. These contain local rudist biostromal carbonates, echinoderm-rich packstones, and grainstones with shallow–water large foraminiferal shoal facies; and peloidal facies divided by deeper–water marly and fine-grained muddy carbonates. The formation is Explanation as an open platform deposition in middle Iraq (Aqrawi et al., 2010).

The lower contact of this bed is commonly an unconformity and often marked as a basal conglomerate. In comparison, the upper limit with the Shiranish Formation (pelagic sediments) in south Iraq is a conformable surface. The Hartha Formation was deposited in the fore-reef to shoal sedimentation environments. Locally, the Stable Shelf's edges are characterized by a lagoonal back-reef association facies. The Khlesia High may have been the site of the reef association facies’ deposition, which is shown through the debris reef limestone that serves as the detrital limestone layers in this succession in certain boreholes (Jassim and Goff, 2006).
The Shiranish Formation was deposited during the transgression period after the sea level fall marked by the glauconitic contact (SBI) with the Kometan Formation. According to the general facies observation with the gamma-ray and resistivity logs patterns, there are two major units in this Formation (Al-Zaidy, 2017).

The Aliji basin was characterized by the decrease in accommodation values to the northeast direction and the increase in all the other parts of the study area. A comparison of the setting of this basin with the Umm Er Radhuma basin gives clear evidence of the tectonic impact coming from the northeast (Menshed and Al-Zaidy, 2021).

The post-Cretaceous erosion significantly reduces the formation's thickness on the Stable Shelf. The thickness of this formation in the south of Iraq ranges from 200m to 250m. In northern Iraq, a formation thickness of more than 350 m was observed. On the high constructions of the Steady Shelf, the actual thicknesses are mostly lower than 100 m (Buday, 1980).

Figs. 4 and 5 show the studied succession distribution with two directions to illustrate the basin depocenter and varying thickness in this area.

![Fig.4. Present thickness map of Late Campanian to Maastrichtian succession in the studied area](image)

Fig.4. Present thickness map of Late Campanian to Maastrichtian succession in the studied area
Fig. 5. Geological cross sections show the distribution and thickness of Late Campanian to Maastrichtian succession.
4. Basin Rebuilding and Analysis

The decompacted thickness rates were rebuilt as a genuine thickness distribution following the use of the Backstripping process, and the hiatus period (eroded units) and tectonic influences throughout the Late Campanian to Maastrichtian were recalculated (Table 1 and Fig. 6).

Table 1. Backstripping and restoring the initial thickness (T) and porosity (Ø) of the researched succession in well Halfaya-I

<table>
<thead>
<tr>
<th>Formation</th>
<th>Depth (m)</th>
<th>Present thickness (m)</th>
<th>Initial thickness (m) and porosity (restored)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibdibah/Samas</td>
<td>1343</td>
<td>1340</td>
<td>T=1340 Ø=0.2963</td>
</tr>
<tr>
<td>Fattah</td>
<td>1902</td>
<td>559</td>
<td>T=0.254 Ø=0.1937</td>
</tr>
<tr>
<td>Jorhe</td>
<td>1913</td>
<td>11</td>
<td>T=13.44 Ø=0.3658</td>
</tr>
<tr>
<td>Ghar</td>
<td>1923</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
<tr>
<td>U. Kirkuk</td>
<td>2079</td>
<td>156</td>
<td>T=183.86 Ø=0.3857</td>
</tr>
<tr>
<td>L. Kirkuk</td>
<td>2262.5</td>
<td>193.5</td>
<td>T=184.54 Ø=0.3483</td>
</tr>
<tr>
<td>Dam Evans</td>
<td>2262.5</td>
<td>0</td>
<td>T=6.4 Ø=0.000</td>
</tr>
<tr>
<td>Jadalia</td>
<td>2401</td>
<td>198.5</td>
<td>T=4.1 Ø=0.000</td>
</tr>
<tr>
<td>Rm</td>
<td>2401</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
<tr>
<td>Ular Ev Rawfum</td>
<td>2401</td>
<td>0</td>
<td>T=E Ø=0.000</td>
</tr>
<tr>
<td>Miji</td>
<td>2401</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
<tr>
<td>Tayyar</td>
<td>2401</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
<tr>
<td>Sharanish</td>
<td>2401</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
<tr>
<td>Barha</td>
<td>2401</td>
<td>0</td>
<td>T=0.00 Ø=0.000</td>
</tr>
</tbody>
</table>

Fig. 6. The burial history curve shows the time–initial thickness (decompacted) for the studied succession in well Hf-I
4.1. Hartha basin

The basin of the Hartha Formation is characterized by one main depocenter located southwest of the studied area near the Suba and Luhais oil fields, with a maximum decompacted thickness of about 400 m (Fig. 7).

![Fig.7](image)

**Fig.7.** The restored initial thickness map for the Hartha Formation shows the basin depocenter

The Hartha basin was characterized by decreasing depositional available space toward the northeast and increasing in the southwestern part of the study area (Fig.9). A comparison setting of This basin provides an obvious index of the tectonic influence arriving from the northeast (Fig.10), where depicts the presence of a distinct uplifting in the research area's northwestern portion. in general, and divided this basin into two tectonic parts.

To determine the paleogeographic for the Hartha succession basin, we must rebuild the Late Cretaceous basin by calculating the total subsidence with the rate of deposition and then the available deposition space.

The total subsidence map for this succession shows an uplifted area (Fig. 8) near the Riffaee, Noor, and Halfaya oil fields with the lowest subsidence values. The high subsidence area appeared in the southwest at the Suba and Luhais oil fields, while the moderate values appeared as a lineament from Nasiriya to West Qurna-Zupair. The Hartha basin was characterized by decreasing depositional available space toward the northeast and increasing in the southwestern part of the study area (Fig.9). A comparison setting of this basin provides an obvious index of the tectonic influence arriving from the northeast (Fig.10), where refers to the presence of a distinct uplifting in the northwestern part of the studied area, and divided this basin into two tectonic parts.
**Fig. 8.** Total subsidence map for the Hartha basin shows the high subsidence part (Red) and the uplifted part (Purple)

**Fig. 9.** The real accommodation values map for the Hartha basin
4.2. Shiranish Basin

The decompacted thickness of the Shiranish Bed suggests that the presence of two main centers characterizes its sedimentary basin. The first significant one is situated in the oil field of Nasiriya, west of the area under study, and is initially roughly 340 m thick (Fig. 11). The second depocenter is located at the West Qurna oil field, where the initial thickness values are moderate at around 260 m. The study area’s northeastern and southeast regions have the lowest values (Fig. 12).

High subsidence values are shown at the Nasiriya oil field on the overall tectonic subsidence map for the Shiranish basin, while the moderate values show in the West Qurna oil field. The uplifted part appeared in the northeastern part near the Noor and Halfaya oil fields and the southeastern part near the Zubair oil field (Fig. 13).

At this phase, we notice that the basin was influenced via complete uplifting procedures from two directions (northeast and southeast). This results from a quite shallow basin (Hartha strata), with the northern section of the basin exposed due to the northwest transgression event.
Fig. 11: Restored isopach map for Shiranish Formation showing the basin depocenters

Fig. 12: The real accommodation values map for the Shiranish basin
4.3. Tayarat basin

The Tayarat basin is characterized by one major depocenter according to initial thickness values. This depocenter is located south of the studied area near the Suba and Luhais oil fields, with values about 320 m (Fig. 14).

Fig. 14. Restored isopach map for Tayarat Formation showing the main basin depocenter
The whole tectonic subsidence spread in the studied area because high subsidence rates in the Suba and Luhais oil fields are present in the southern part during this phase. Moderate values were found along the lineament from Nasiriya to West Qurna and Majnoon oil fields. Low rates of subsidence were found at the Riffaee, Halfaya, and Noor oil fields (Fig.15). The stage of this era is symbolized as a regression stage with high uplifting during the late stage (Fig.16), where the sea level has been fallen and exposed northeastern and eastern parts of the researched area by shallow and restricted sediments (Tayarat bed) (Fig.17).

A distinct tectonic uplift that began in the northeast and decreased in the southwest marked the end of this era. This demonstrates the resumption of northeastern tectonic activity as evidenced by the visible continental collision during the subsequent stage with the deposition of the Aliji Formation (Fig.18).

Fig.15. The total subsidence map for the Tayarat basin shows the high subsidence area (Red) and the uplifted area (Purple)
Fig. 16. The real accommodation values map for the Tayarat basin

Fig. 17. 3D paleogeography model (real accommodation) for Tayarat According basin
Shiranish Basin, it was affected by uplift processes from two directions, northeast and southeast, and due to this, an extremely shallow basin formed with its northern portion exposed during the Transgression. The depocenter of Shiranish Formation at the western part of studied area showing high values of subsidence and accommodation.

At the end of this period (Late Cretaceous), the Tayarat Formation was deposited during the regression stage. Where the tectonic uplift began to increase towards the northeast near No-1, Ri-1 and Hf-1, and this indicates that the tectonic movement’s reactivation. To the south of study area near Su-1, Su-4, Lu-2 and Zb-1 the subsidence and accommodation values were increased with increasing of depositional rate for Tayarat Formation.

Due to continental collision, which was affected upon the next stage during the deposition of the Alaiji Formation (Eocene). The Aliji basin is characterized by inverse tectonic pattern, where appeared the uplifted area to the southwest part (No-1, Ri-1 and Hf-1), and subsidence area to the northeast of study area (Su-1, Su-4 and Lu-2).

To stratigraphic features the studied area is divided into two tectonic basins are northeast basin and southwest basin. The northeastern basin matches Samawa - Nasiriya Subzone and the southwest basin matching to Zubair Subzone, which was separated by tectonic lineament extending from Nasiriya-West Qurna and Zubair oil field.

5. Conclusions

The tectonic development of the Mesopotamia basin in southern Iraq was studied by calculating subsidence and sedimentation rates for eleven wells distributed in the study area. This was done by calculating of backstripping for The Upper Campanian-Maastrichtian sequence (Hartha, Shiranish and Tayarat formations).

According to the relationships among the depositional rate (accumulation rate), subsidence rate and accommodation rate, the studied basin is characterized by:-

Hartha Basin was divided into two tectonic parts, the first to the northeast near No-1, Ri-1 and Hf-1 which characterized by low subsidence and accommodation values (uplifted area). The second to the southwest near Su-1, Su-4 and Lu-2, which characterized by high values of subsidence and accommodation.
References


