Stratigraphy and Depositional Environment of Mauddud Formation in Ratawi Oil wells of Southern Iraq

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Abstract. The Mauddud Formation is Iraq's most significant and widely distributed Lower Cretaceous formation. This Formation has been investigated at a well -23 and a well-6 within Ratawi oil field southern Iraq. In this work, 75 thin sections were produced and examined. The Mauddud Formation was deposited in a variety of environments within the carbonate platform. According to microfacies analysis, studying of the Mauddud Formation contains of twelve microfacies, this microfacies Mudstone to wackestone microfacies, bioclastic mudstone to wackestone microfacies, Miliolids wackestone microfacies, Orbitolina wackestone microfacies, Bioclastic wackestone microfacies, Orbitolina packstone microfacies, Peloidal packstone microfacies, Bioclastic packstone microfacies, Peloidal to Bioclastic packstone microfacies, Bioclastic grainstone microfacies, Peloidal grainstone microfacies, Rudstone microfacies. Deep sea, Shallow open marine, Restricted, Rudist Biostrome, Mid – Ramp, and Shoals are the six depositional environments in the Mauddud Formation based on these microfacies.

1. Introduction
The Mauddud Formation was originally described by Henson of the Qatar Petroleum Company's subsurface section, well Dukhan No. 1. Ain Mauddud [1] is the source of its name. [2] Mauddud Formation is a subsurface, largely neomorphosed and dolomitized limestone. The Mauddud Formation's lower contact is gradational and conformable with the Nahr Umr, Lower Balambo, and Sarmord Formations. In Iraq's North Central, North, and Northeast, the top contact has a break and is either nonsequential or unconformable; it is an unconformity [3]. Mauddud Formation is 55 meters thick and composed of limestone rich in Orbitolina and Trocholina samples at the type locality where the formation was originally identified. The Mauddud Formation was discovered in the Northern Arabian Gulf, particularly along the Saudi Arabia–Kuwait border, to be made up of limestone with thicknesses varying from 30.5 to 97.6 meters. [4], [5] utilized the Zubair well no.3 as a supplemental type section for the Mauddud Formation in Iraq. They described the formation as a detrital organic limestone with strata of blue to green shale that was locally pseudo oolitic creamy in color [6]. The Mauddud Formation fades between Wara and Nahr Umr in western Kuwait, as well as on the eastern face of the Hail – Rutbah Arch [7]. The age of the Mauddud Formation is still debated, with some claiming an Albian age and others claiming a Cenomanian date. Abundant fossils cited by [8] support an Albian age. Because of the widespread presence of certain Orbitolina concave group species, the formation was previously thought to stretch into the Cenomanian [8]. In Middle and Southern Iraq, the Mauddud Formation is the most common Lower Cretaceous Formation. The aims of study include microfacies analysis, depositional environment interpretation and determination of the sedimentary cycles of the Mauddud Formation.
Figure 1 Albian paleogeography map show the depositional basin of Mauddud Formation (Jassim and Goff 2005).

2. Location of study area
The study region lies in the southern portion of Iraq, figure 2, on the stable shelf of the Mesopotamian basin. The Ratawi field lies 50 kilometers west of Basra, and it is a flat, semi-desert terrain positioned inside the tectonic components at the platform edge of the Mesopotamian fore deep. And it progressively drops to sea level as it approaches the north, while its highest point reaches around (120) m. at sea level as it approaches the south, figure 3.

3. Methodology
In this study the Mauddud formation section was reported from the A well -23, A well -6. Table (1). Studying Petrography of these wells by thin sections examination which prepared in the workshop of the Department of Geology, these thin sections have been studied by the aid of binocular microscope in order to determine the fossils content and then Microfacies Analysis, then recognize depositional Environment and stratigraphic analysis and determine the sedimentary of Mauddud formation in studied oil wells.
Table 1: Sampling for the collected borehole

| Well no. | Top (m) | Bottom (m) | Mauddud Core samples | Thin section |
|----------|---------|------------|----------------------|--------------|
| A.23     | 2575    | 2691       | 27                   | 35           |
| A.6      | 2458    | 2596       | 29                   | 40           |

Figure 2 Location map of the study wells

Figure 3 Isopach map of Ratawi Field of Mauddud Formation in the study area.
4. Results and discussion

4.1. Petrography

Petrographic analysis of (75) thin section of samples from the A well -23 and A well - 6, as they were used in this study. On the basis of Dunham's classifications, thin sections were categorized [9]. Microfacies are identified and classified into facies associations based on grain, fabric, and biocontent differentiation. According to studies, the carbonate grains of the Mauddud Formation are both skeletal and non-skeletal. Skeletal grains are mostly composed of benthonic foraminifera, Mollusca, algae, reef, and rudist, whilst non-skeletal grains are mostly composed of peloids, Ooids, and lithoclastic. The foraminifera in the Mauddud Formation are mostly skeletal grains. [10] Foraminifera are benthic organisms that live in or on sediments on the seafloor. Planktonic foraminifera dwelling in the upper 100 meters of the seas were mentioned in the Mauddud Formation. The Orbitolinidae are enormous benthic foraminifers that dominated the Early to Mid-Cretaceous period, figure 4a, 4b, 4c, 4d, 4e, 4f. Nezzazata less common in this formation. figure 5a). Milionis are also important structural granules, respectively, figure 5b. [11] "Calcareous algae are important in micropaleontology as records of ancient life, and they can be used in the interpretation of paleoenvironments and age determination" of strata. figure 5c. The bioclastic of Mauddud Formation include rudist, echinoderm, coral fragments and Mollusca, figure 5e. Peloids are generally spherical, ellipsoidal rounded or sub rounded, to irregular in shape and commonly has high organic contents. Fecal pellets, produced by deposit-feeding animals, figure 5f. There is a difficulties in the segregation of the two types in thin sections, so the term lithoclastic had been used by many authors [13]. Limeclastic or limestone clast is suitable [12]. [13] the groundmass or matrix denotes the interstitial material between larger grains. In Mauddud Formation the groundmass is composed of micrite and/or Microspar which formed by neomorphism. Micritization, neomorphism, dissolution, cementation, dolomitization, and compaction are some of the diagenetic processes that have been influenced by the Mauddud Formation.

Figure 4: Explain the types Orbitolna, a-Iraqia simplex(Henson) sp (A . 23, depth . 2585m), b- Orbitolna sefini sp, (A . 23, depth .2515m), c-Neoiraqia sp (A .23 , depth . 2520m), d- Orbitolna concave sp ( A . 6, depth .2655m), e- Orbitolina conica sp (A . 6, depth .2674m), f-Conicorbitolina conica sp( A . 23, depth .2589m).
Figure 5 Explain the types skeletal and non-skeletal grains, a- Nezzazata sp, (A  23, depth 2482 m ),b- Miliolids, (A  6, depth.2630 m),c- Calcareous algae(A  6, depth .2639 ),d- Echinoderm spine sp (A  6, depth 2618 m ),e- mollusca, (A  23, depth.2630M),f- peloidal (A  6, depth .2651).

4.2. Microfacies

In Mauddud Formation microfacies, there are twelve distinct microfacies include Mudstone to wackestone microfacies, Bioclastic mudstone to wackestone microfacies, Miliolids wackestone microfacies, Orbitolina wackestone microfacies, Bioclastic wackestone microfacies, Orbitolina packstone microfacies, Peloidal packstone microfacies, Bioclastic packstone microfacies, figure 6a,b,c,d,e,f. Peloidal to Bioclastic packstone microfacies, Bioclastic grainstone microfacies, Peloidal grainstone microfacies, Rudstone microfacies, figure 7a, b, c, d, e, and f.
Figure 6 Explain the types microfacies, a- Mudstone to wackestone microfacies (A . 23, depth 2467 m), b- Bioclastic mudstone to wackestone microfacies (A . 6, depth 2642 m), c- Miliolids wackestone microfacies (A . 23, depth 2643 m), d- Orbitolina wackestone microfacies (A . 23, depth 2629 m), e- Bioclastic wackestone microfacies (A . 6, depth 2577 m), f- Orbitolina packstone microfacies A . 23, depth (2660 m).

Figure 7 Shows the types microfacies, a- Peloidal packstone microfacies (A . 6, depth (2617 m), b- Bioclastic packstone microfacies (A . 23, depth (2485 m), c- Peloidal to Bioclastic packstone microfacies (A . 6, depth (2610 m), d- Bioclastic grainstone microfacies (A . 6, depth 2517 m), e- Peloidal grainstone microfacies (A . 23, depth 2585 m), f- Rudstone microfacies (A . 23, depth 2600 m).
4.3. Depositional Environment

The kind of microfacies largely affected the Mauddud Formation's paleoenvironment. The depositional texture and grain types (skeletal and non-skeletal) were used to determine the known microfacies. Flugel's suggested models of standard microfacies and carbonate depositional environment belts were compared to facies associations [14]. Six major environments were recognized, they are open marine, deep sea, restricted and shoals figures 8, 9.

4.3.1. Deep marine environment

Bioclastic mudstone to wackestone microfacies describes the deep marine association facies in A–6 wells. Planktonic foraminifera, benthonic foraminifera bioclasts, and tiny benthic foraminifera on a backdrop of mainly micrite suggest deposition below typical wave base and under low-energy hydrodynamic circumstances. The presence of planktonic and echinoderm pieces, as well as fine bioclastic, might indicate a deep marine environment on the outer ramp. Dissolution is a critical diagenetic process. A well - 23 the facies of mudstone to wackestone microfacies. This microfacies is compared to Wilson's microfacies [15].

4.3.2. Shoal environment

The shoal environment is a belt of strong tidal current and wave activity that runs along the carbonate platform's seaward edge. In this environment, deposition depths are less than (5-10) meters above wave-base [16]. Peloidal grainstone microfacies and Peloidal packstone microfacies characterize this habitat in the Mauddud Formation. Grain supported texture distinguishes these microfacies. Benthic foraminifera, Mollusca, rudist pieces, and peloids make up this collection. The peloids have been sorted and rounded to perfection. This facies is typically seen on high-energy shoals [14].

4.3.3. Shallow open marine environment

One of the most frequent facies in the Mauddud Formation carbonates in the research region is the shallow open marine facies association. This is the formation's most frequent facies connection Microfacies such as orbitolina wackestone, orbitolina packstone, Peloidal to bioclastic packstone, and bioclastic grainstone define it. The bioclasts are silt to sand in size and some cases coarser, and at various levels within the succession, a specific type of bioclasts may locally dominate, especially the rudist bioclasts which occur as well worn (sand- size or coarser) angular or tabular grains. Other important fossils include benthonic foraminifera such as Orbitolinids, Nezzazata, miliolid, Textularia, calcareous green algae, coral, and coralline algae with echinoderms and gastropods. Sponge spicules, bryozoa, brachiopod, and pelagic foraminifera were less common. The Orbitolina flourished in tropical to subtropical water along shallow coastlines where the temperature would have been between 15 and 25C [17]. Orbitolina occurrence with miliolids suggests shallow water, and its association with rudist fragments may indicate deeper more open water [18].

4.3.4. Restricted marine environment

Miliolids wackestone and Mudstone to wackestone make up the majority of this facies relationship. Miliolids, Textularids, Nezzazata, and much more benthonic foraminifera are numerous and varied. Coral pieces, rudist fragments, and mollusks are among the other fossils found. The matrix is basically fine lime mud, with a significant amount of argillaceous material in certain instances. In a lagoonal setting, this pattern may be observed [19].
4.3.5. Mid – Ramp environment
The bioclastic Wackestone and packstone make up most of the Mid-Ramp facies association. Rudistid packstone and Orbitolina wackestone are two other significant microfacies. The main skeletal grains include Orbitolina, Nezzazata, rudist fragments, and pelecypods. The primary diagenetic processes in this facies relationship are dolomitization and dissolution.

4.3.6. Rudist Biostrome environment
Rudstone is the main component of this microfacies. This association is mostly comprised of Rudist fragments and Orbitolina shells. The reef is a carbonate formation with an organism-built wave-resistant structure [16], Wilson's facies belt -5 of organic buildup [15] and Flugel's facies belt -5 of organic buildup [20].

![Figure 8. Microfacies succession and depositional environments of Mauddud Formation in A-23 well](image)
Figure 9. Microfacies succession and depositional environments of Mauddud Formation in A-6 well.

5. Conclusion
The Mauddud Formation in A well - 23 and A well -6 in Ratawi oil field southern Iraq is composed. Petrographic study in Mauddud Formation shows types fossils the following: -Iraqia simplex(Henson) sp, Orbitolina sefini sp, Neorica simplex, Orbitolina conica, Conicorbitolina conica, mesoritolina(subconcava) sp, Orbitolina qatarica(Henson) sp, Nezzazata sp, Rudist fragments, Textularia sp, algae, Echinoderm spine, Mollusca. Twelve microfacies have been identified, and depending on these microfacies have been distinguished six depositional environments in a Mauddud Formation, including deep marine environment, shoals environment, shallow open marine environments, restricted marine environment, mid – ramp environment, rudist biostrome environment. Twelve types of microfacies were identified these microfacies.

6. References
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