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Ostracoda as a paleoecological indicators for the Maastrichtian – Upper Eocene succession in North and Western Iraq

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Abstract:

Ostracode assemblages have been utilized for the study of the paleoecology of the Maastrichtian – Upper Eocene succession (Hartha, Shiranish, Aaliji, Kolosh, Jaddala and Avanah formations) in North and Iraq, represented by five sections, including four boreholes, Anah well-2, Mityaha well-1, Makhul well-2, Chemchemal well-2 and Jabel Sinjar outcrop section. According to the different environmental factors affecting on the ostracode ecology, such as salinity, depth, temperature, oxygenation, substrate and food supply; and depending on the distribution of ostracode assemblages within the studied sections, nine ecofacies have been recognized indicating shallow brackish or brackish- marine water, neritic marine, inner shelf, inner to middle shelf, inner to outer shelf, middle shelf, middle to outer shelf, outer shelf, and outer to upper bathyal environments. So, the depositional palaeoenvironment of the formations of the study area are determined.

The presence of the genera *Leptocythere* and *Callistocythere* within the Jaddala Formation in Mityaha well- 1 section indicate to the rising of the Khlesia- Mosul uplift during the Late Eocene, which is separating the basin of deposition into two bio-provinces; the Mediterranean Bio-province in the west and the Indo - Pacific Bio-province to the east – southeast.

Keywords: Ostracoda, Maastrichtian – Upper Eocene succession, paleoecology.

الأوستراكودا كدليل بيئي قديم لتتابع الماسترختي – الأيوسين الأعلى في شمال وغرب العراق

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الخلاصة:

أن تجمعات الأوستراكودا قد أستخدمت لدراسة البيئة القديمة لتتابع الماسترختي – الأيوسين الأعلى (تكوينات الهارثة والشيرانش والعليجي والكولوش والجدالة والآفانة) في شمال وغرب العراق، متمثلة بخمسة مقاطع، تشتمل على أربعة آبار وهي بئر عنة –2 وبئر متياهة –1 وبئر مكحول –2 وبئر جمجمال –2، أضافة الى المقطع المكشفي في جبل سنجار. استناداً الى العوامل البيئية المختلفة المؤثرة على بيئة الأوستراكودا، مثل الملوحة والعمق ودرجة الحرارة وكمية الأوكسجين المذاب وطبيعة القاع والتجهيز الغذائي؛ واعتماداً على توزيع مجاميع الأوستراكودا ضمن المقاطع قيد الدرس، فقد تم تشخيص تسع سحنات بيئية لها الدلالة الى بيئات المياه الخليطة او الخليطة – البحرية الضحلة والبحرية النرتية والرف الداخلي والرف الداخلي الى الأوسط والرف الداخلي الى الخارجي والرف الأوسط والرف الأوسط الى الخارجي والرف الخارجي والرف الخارجي الممتد الى النطاق الأعلى للأعماق. لذا، فأن البيئة الترسيبية القديمة لتكوينات هذه الدراسة قد تم تعينها. أن تواجد الجنسين *Leptocythere* و*Callistocythere* ضمن تكوين الجدالة في مقطع بئرمتياهة – 1، يشيران الى أرتفاع نهوض الخليصية– الموصل خلال الأيوسين المتأخر والذي قسَم حوض ترسيب الجدالة الى منطقتين حياتيتين، منطقة البحر الأبيض المتوسط الحياتية في الغرب ومنطقة المحيطين الهندي – الهادي الحياتية في الشرق والجنوب الشرقي.

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Introduction:

Ostracode assemblages have been utilized for the study of the paleoecology of the Maastrichtian – Upper Eocene succession (Hartha, Shiranish, Aaliji, Kolosh, Jaddala and Avanah formatios) in North and Iraq, represented by five sections, including four boreholes, Anah well-2, Mityaha well-1, Makhul well-2, Chemchemal well-2 and Jabel Sinjar outcrop section.

Ostracods probably originated in a marine environment and the largest number of species still inhabits the pelagic and benthic realms of the ocean from the shoreline down to several thousand meters, and from the equator to polar seas. Some species flourish in brackish waters and some are found even in hypersaline environments. Ostracoda have also undergone ecologic radiation in fresh-water environments, from which they are known since the Carboniferous. Some lineages of both fresh water and marine ostracods have even invaded terrestrial niches, living in the moist humus of the forests [Harding, 1955; in: 1], in the aerial part of the fresh-water floating plant accumulations [Danielopol and Vespremeanu, 1964; in: 1]. Wherefore the Ostracoda of Microfossils that important to indicate about the palaeoecology, because of their ability to be occurred in most environment, and have inner and outer morphological variations that indicate about the changes in the environmental factors such as oxygenation, salinity, temperature, substrate, depth and food supply [2]. Information on recent and fossil ostracoda from Iraq is scarce and thus it is not possible to say anything meaningful about ecology at the species level. The palaeoecological interpretation is based on comparison with data from other sources such as indicator genera combined with stratigraphical and sedimentological observations. Interpretation by means of indicator genera has a limited value, but comparison on the basis of the predominance of one group of indicator genera can be used to give a general impression of the palaeoecology [3].

The Factors that affect the distribution of Ostracoda:

The distribution of Ostracoda is controlled by a large number of environmental factors that play a major role in the distribution these factors must be studied to identify the Paleoecology of the Ostracoda, which are: oxygenation, salinity, temperature, substrata, depth and food supply.

1- Salinity:

Salinity is the most fundamental factor determining the distribution of ostracods, as it has a decisive influence on the physiology of the organism [1].

Fresh-water assemblages are taxonomically distinct from marine faunas and few species can thrive in both marine and fresh-water environments. For these species the salinity extremes usually represent marginal conditions of their existence. The near-shore species are often strongly euryhaline, some capable of supporting oligohaline to normal marine conditions, since there are wide oscillations of salinity caused by run-off and rain waters. The brackish waters of lagoons, estuaries, marshes, inland salt pools and lakes are inhabited by a characteristic assemblage of euryhaline and typically brackish species which have several traits in common: with decreasing salinity foraminifera and other marine groups gradually disappear and the dominant position in the microfaunal assemblage is assumed by the ostracods. The brackish communities are invariably composed of a relatively small number of species. The reduced diversity of organisms may best be explained by the instability of most brackish-water environments [1].

Ostracods are ubiquitous in aquatic environments with species and genera living under well-defined salinity ranges within the freshwater to hypersaline range. Three main salinity assemblages are distinguishable: freshwater (<0.5‰), brackish-water (0.5–30‰) and marine (30–40‰). Hypersaline assemblages (>40‰) mainly contain euryhaline marine and brackish-water forms [4].

2- Depth:

Depth in itself does not affect ostracod distributions. However, a number of important ecological factors including hydrostatic pressure, temperature, salinity and dissolved oxygen change with depth and are paralleled by changes in ostracod faunas and diversity [4]. With increasing depth, stability of the environment generally increases, whereas the energy level of the environment decreases. Progressive increase in depth is generally accompanied by decreasing grain size of the sediments, decreasing light penetration and vegetation cover. Below the photic zone, the food supply also decreases. Observations suggest that the depth-correlated factors are of greater importance for the ostracode distribution than depth itself. In high-energy shallow waters, both diversity and density of ostracods are lower than in deeper and more stable offshore environments. Somewhat below the photic zone, however, the ostracode populations become again less diverse and less dense [1]. According to investigations of Benson, 1975 [in; 1], the true deep-sea ostracode fauna of present-day oceans consists of fewer species than found at many single shallow-water localities. This deep-sea, psychrospheric fauna occurs in marine regions where water temperature does not exceed 10°C and is typical in waters where temperature is 4°C or cooler. Pressure may be a physical barrier to the distribution of species which are adapted to specific depth conditions (stenobathic). Many ostracods, however, are adapted to considerable depth range (eurybathic) [1].

3-Temperature:

Latitudinal temperature control of shallow-water species has given rise to numerous localized (endemic) assemblages ranging from high latitudes (at temperatures below 0°C) to the subtropics and tropics (where they may live in waters up to 51°C) [4].

Among ostracods some species are widely eurythermal, while others are bound to a narrow temperature range. The cold-loving deep-sea species are termed psychrospheric; the cold-loving marine shallow-water species, cryophilic, and the warm-loving, thermophilic. As is true for many other marine organisms, shallow marine ostracode assemblages of the low latitudes are considerably more taxonomically diverse than those of high latitudes. Temperature alone, however, need not account for diversity differences. Extended evolution under stable conditions, especially under a stable nutrition supply, would allow increased diversification of assemblages [1].

4- Oxygenation:

Generally, the colour of the ostracod test coming from a normally oxygenated environment varies from white to light brown, but sometimes it is dark brown or black. Most species of ostracoda from subsurface samples are characterised by a dark test, and, those from surface samples vary from white to light brown [3]. Oertli, [5] explained that the black colour of some ostracods was due to pyritization. Normally, close to the sediment surface there is a phase of aerobic decay during which bacteria utilize dissolved oxygen for the oxidation of organic matter. However, after death some individuals escape destruction until they are buried at a depth to which dissolved oxygen does not penetrate at which point the remaining organic matter suffers a phase of anaerobic bacterial decay. The decomposition of proteins sets free considerable amounts of hydrogen sulphide formed by anaerobic decay and this reacts with iron oxides to form iron-sulphides, the so-formed pyrite replacing part of the Calcite [Michal, 1968; in 3].

5- Substrate:

The nature of the substrate has a pronounced effect on the composition of ostracode communities [1]. Living ostracods are predominantly benthic or pelagic throughout their life cycle. Benthic ostracods occupy freshwater and marine habitats [4]. Benthic ostracods inhabit either the bottom or live on marine plants or animals. The sediment-inhabiting species live either at the surface of the sediment, or within the sediment, thus forming part of the infauna. That the composition of the ostracode communities as well as the density of individuals are strongly dependent on the kind of sediment can best be seen when considering populations living in the same area, at the same depth, and under similar salinities and temperatures. Coarse grained sediments, like clean sands or oolites, support only a small ostracode population, whereas mud-mixed sands and pelitic sediments usually have a larger and much more diversified ostracode fauna. Size and shape of the sedimentary particles as well as the degree of their compaction are factors, which control the distribution of the ostracode infauna. The ostracods are more numerous in the few upper centimeters of the sediment, but may live at least to 15 cm. The size of interstices of the sand is a size-limiting factor for burrowing species, but this size-limitation does not affect mud-burrowing ostracods. The phytal ostracode community (the plant-dwelling community) is also rich and diversified and distinctive assemblages characterize different marine plants [1].

6- Food supply:

High organic content of the sediment has been considered to be a factor controlling ostracode distribution on the west coast of Florida by Hulings and Puri, 1965 [in; 1]. The deep sea ostracode fauna of the Mediterranean Sea seems to be controlled by the amount of nutrients as, according to Puri and others, 1969 [in; 1]. The abyssal plains closer to land have a higher number of ostracode species than more distant abyssal regions.

The Ostracoda as environmental indicators:

- Genus *Argilloecia* Sars, 1866, indicates outer shelf environment [6].
- Genus *Aurilla* Pokorny, 1955, indicates Epi-Neritic, eurythermal environment [7].

- Genus *Bairdia* Sars, 1866, indicates very shallow water environment was common up to depths of (15-25) metres. [Maddocks, 1964; in 3], [7], [Benson, 1961; and Rosenfeld and Raab, 1974; in; 8]. And indicates depths of marine water environment [6, 9-14 and Morsi and Speijer, 2003; in; 15]. *Bairdia ilaroensis* indicates inner to outer shelf environment [6] and refer to deep sea environment ranging from (400-500 m) depth. [Peypouquet *et al*., 1986; in 16].
- Genus *Brachycythere* Alexander, 1933, indicates inner to middle neritic setting [7] [EL-Nady, 1995 & 2001, in; 8] and indicates middle neritic zone of normal marine salinity [6]. *Brachycythere* cf. *oguni* Reyment indicates middle to inner shelf environments [6].
- Genus *Callistocythere* Ruggieri, 1953, indicates shallow water environment, when it is strongly reticulate or ornamented lateral surface with well - developed eye tubercle) [3].
- Genus *Clithrocytheridea* Stephenson, 1936, indicates Epi- neritic (and possibly brackish) environments [7].
- Genus *Cushmanidea* Blake, 1933, indicates shallow water environment [3].
- Genus *Cytherella* Jones, 1849, indicates inner to middle neritic environment [8]. Indicates open, shallow marine environmental [7 and Benson, 1961; and Rosenfeld and Raab, 1974; in; 8]. Indicates depths of marine water environment [6, 9 - 14, and Morsi and Speijer, 2003; in; 15], and indicates deep sea environment ranging from 400-500 m depth [Peypouquet *et al*., 1986; in; 16]. *Cytherella lagenalis* Marliere indicates inner to outer shelf environment, while *Cytherella* sp.1 indicates middle to inner euhaline shelf environment [6].
- Genus *Cytheropteron* Sars, 1866: The species *Cytheropteron lekefensis* indicates an outer neritic environment [7], outer shelf environment [6 and 17] and indicates neritic marine environment [Shahin, 2000; in 18]. *Cytheropteron toshkaensis* indicates middle to outer shelf environment [6].
- Genus *Dactylia* Apostolescu, 1961: indicates middle to outer shelf environment.
- Genus *Hemicytherura* Elofson, 1941, indicates epi- neritic environment [7].
- Genus *Krithe* Brady, Corsskey and Robertson, 1874, indicates shallow water environment [3], outer shelf to upper bathyal [15], deep sea environment ranging from 400-500 m depth [Peypouqet *et al*., 1986; in; 17] and indicates outer neritic environment [7]. *Krithe* cf. *solomoni* Honigstein indicates outer shelf environment [6].
- Genus *Leptocythere* Sars, 1925: Some species of this genus typically in estuarine (Brackish water), others mainly in shallow marine (littoral) environment. [7].
- Genus *Loxoconcha* Sars, 1866, indicates a brackish environment (indicate a very shallow environment with brackish conditions, well developed nodes) [3]. *Loxoconcha pseudopunctatella* indicates warm shallow normal saline water in euphotic zone and water depth less than (20-50 m). [Wells, 1967 and Cheetham, 1966; in; 19]. *Loxoconcha blanckenhorni* indicates middle shelf environment [6].
- Genus *Paracypris* Sars, 1866, indicates inner to middle neritic environments [8]. And indicates open, shallow marine environmental [Benson, 1961; and Rosenfeld and Raab, 1974; in; 8], *Paracypris nigerensis* indicates middle neritic zone of normal marine salinity [17], indicates deep sea environment ranging from 400-500 m depth [Peypouquet *et al*., 1986, in; 17]; and indicates inner euhaline shelf [6]. *Paracypris jonesi* Bonnema and *Paracypris* sp. A indicate middle to outer shelf environment [6].
- Genus *Paradoxostoma* Fischer, 1855, indicates epi- neritic environment. Representatives of the genus are typical plant- dwellers [7].
- Genus *Parakrithe* Van Den Bold, 1958, indicates deep sea environment ranging from 400-500 m depth [Peypouquet *et al*., 1986, in; 16], and outer neritic environment [7]. *Parakrithe crolifa* indicates shallow euhaline inner shelf as well as the deep outer shelf depths [6].
- Genus *Pedicythere* Eager, 1965, indicates middle to inner euhaline shelf environment [6].
- Genus *Pontocyprella* Lyubimova, 1955, indicates outer shelf to upper bathyal environments [15] and indicates outer neritic environment [7]. *Pontocyprella recura* Esker indicates outer shelf environment [6].
- Genus *Pontocypris* Sars, 1866, indicates neritic, active swimmers environment [7].
- Genus *Propontocypris* Sylvester- Bradley, 1947, indicates shallow water environment [Maddocks, 1964, in; 3].

- Genus *Semicytherura* Wagner, 1957, indicates very shallow water environment [Maddocks, 1964, in; 3].
- Genus *Stenocypria* G.W. Muller, 1901, indicates outer shelf environment [7].
- Genus *Uroleberis* Triebel, 1958, indicates euhaline inner shelf or lagoonal environment [6].
- Genus *Xestoleberis* Sars, 1866, indicates a very shallow environment with brackish conditions, with well -developed nodes [3]. This genus indicates an inner to middle neritic environment [8]. And reflecting an open marine, moderately deep neritic conditions [7]. *Xestoleberis tunisiensis* and *Xestoleberis kiseibaensis* indicate an outer to inner euhaline shelf environment [6].

Ecofacies:

According to the distribution of Ostracoda within the sections of the study area, it has been divided into nine Ecofacies, which are:

- **Ecofacies- 1:** Characterised by the following ostracoda assemblage: *Callistocythere* sp., *Cushmanidea* sp., *Leptocythere* sp., *Loxoconcha pseudopunctatella* and *Semicytherura* sp., which indicating shallow (brackish or brackish - marine water) environment.
- **Ecofacies- 2:** Characterised by the following ostracoda assemblage: *Aurilla* sp., *Clithrocytheridea* sp., *Cytheropteron lekefensis*, *Hemicytherura* sp., *Paradoxostoma* sp. and *Pontocypris* sp., which indicating a neritic marine environment.
- **Ecofacies- 3:** Characterising the inner shelf environment that contains the following ostracoda species: *Paracypris nigerensis* and *Uroleberis triebeli*.
- **Ecofacies- 4:** Characterised by an inner to middle shelf environmental facies and contains the following ostracoda species: *Brachycythere* cf. *oguni*, *Cytherella* sp.1 Bassiouni and Luger and *Pedicythere glabrata*.
- **Ecofacies- 5:** Characterised by an inner to outer shelf environmental facies, the following ostracoda species are common here: *Bairdia ilaroensis*, *Cytherella lagenalis*, *Paracypris jonesi*, *Parakrithe crolifa*, *Xestoleberis kiseibaensis* and *Xestoleberis tunisiensis*.
- **Ecofacies- 6:** Characterised by middle shelf environmental facies. It is represented by *Loxoconcha blanckenhorni*.
- **Ecofacies- 7:** Characterised by middle to outer shelf environmental facies and contains *Cytheropteron toshkaensis*, *Dactylia bapaensis* and *Paracypris* sp. A Bassiouni and Luger.
- **Ecofacies- 8:** Characterised by an outer shelf environmental facies, this ecofacies comprises the following ostracoda assemblage: *Argilloecia* sp. Bassiouni and Luger, *Krithe* cf. *solomoni*, *Parakrithe crolifa* and *Stenocypria* sp.
- **Ecofacies- 9:** Characterised by an outer shelf to upper bathyal environment. It is represented by *Pontocyprella recurva*.

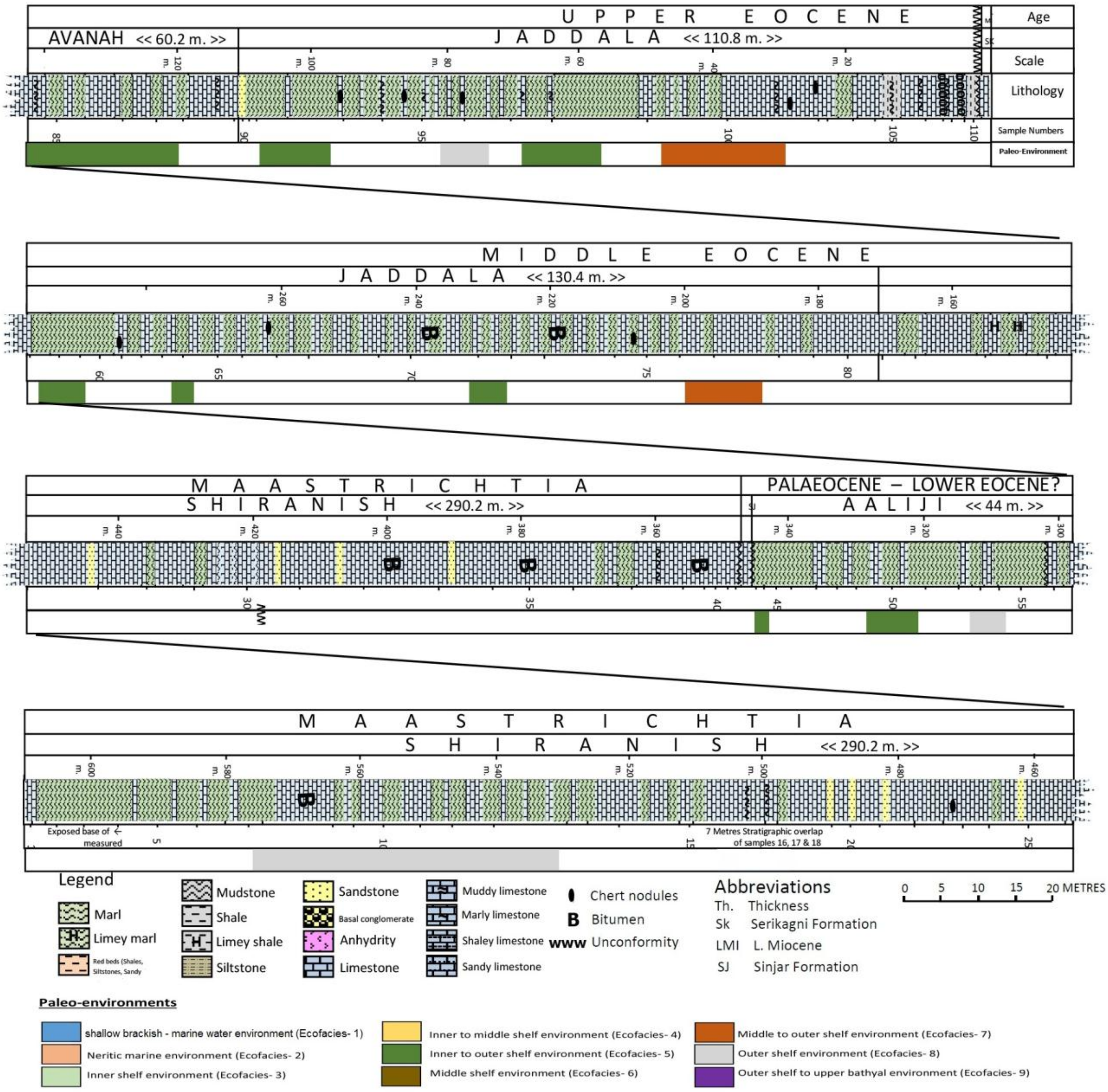

Figure 1- Palaeo- environments of Jabel Sinjar Section

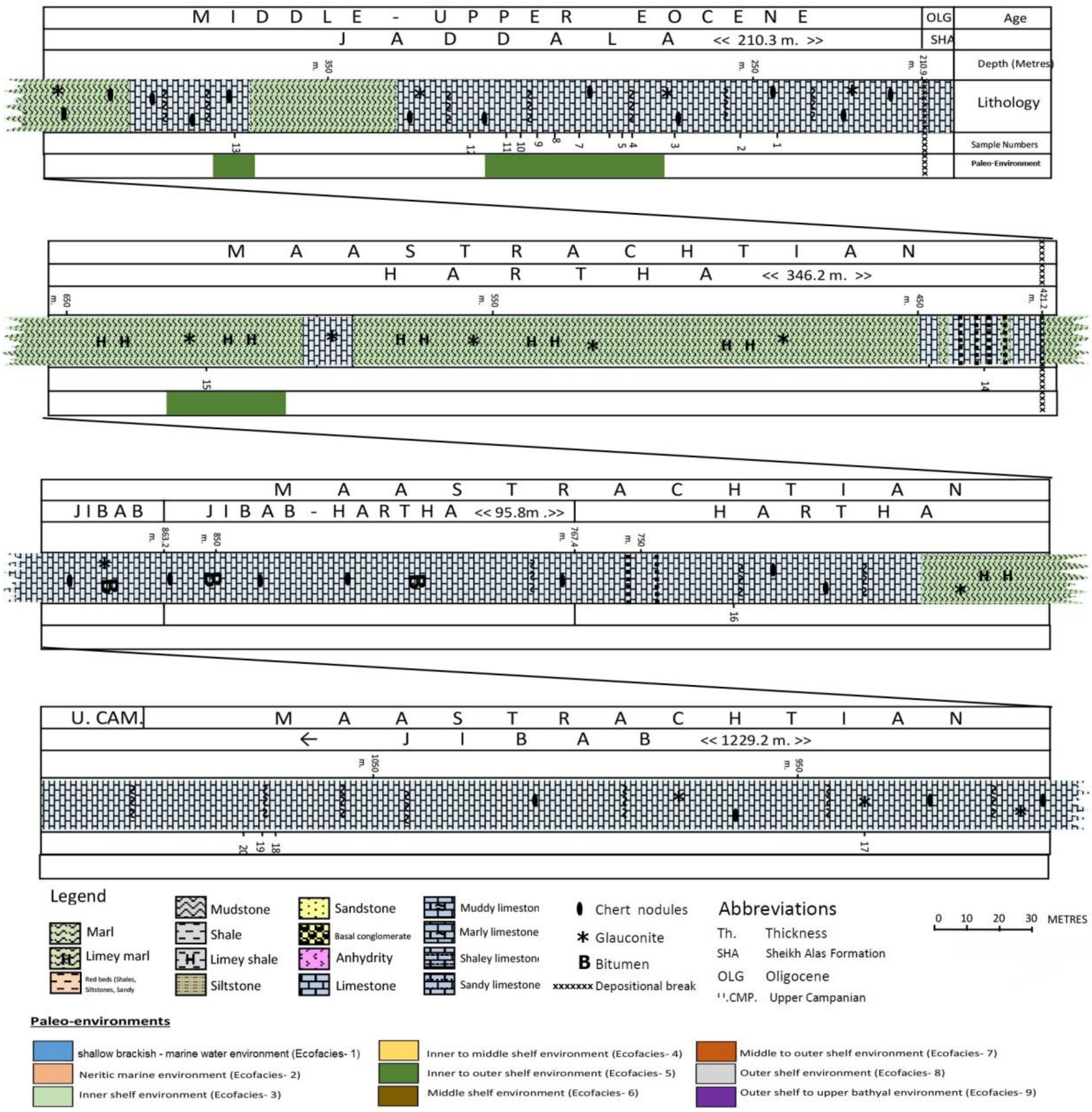

Figure 2 - Palaeo- environments of Anah well section.

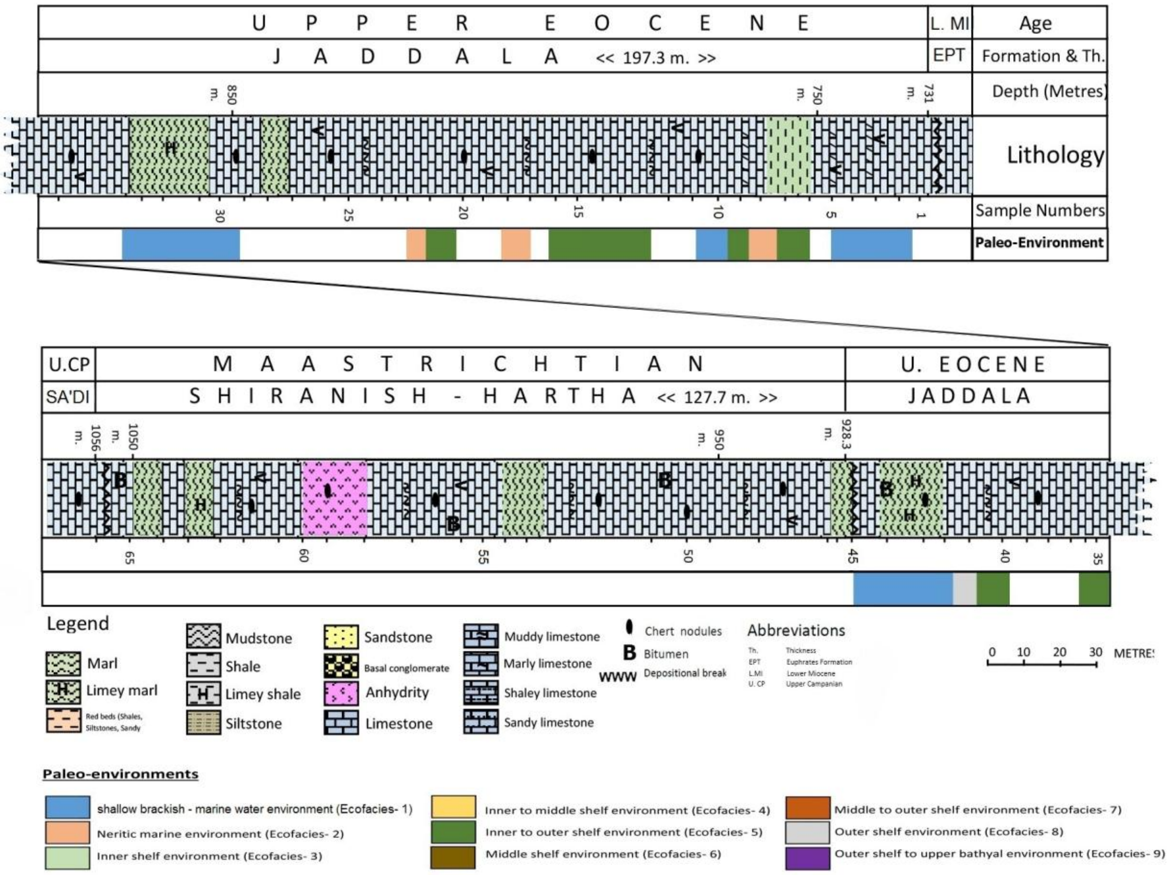

Figure 3 - Palaeo- environments of Mityaha well -1 section.

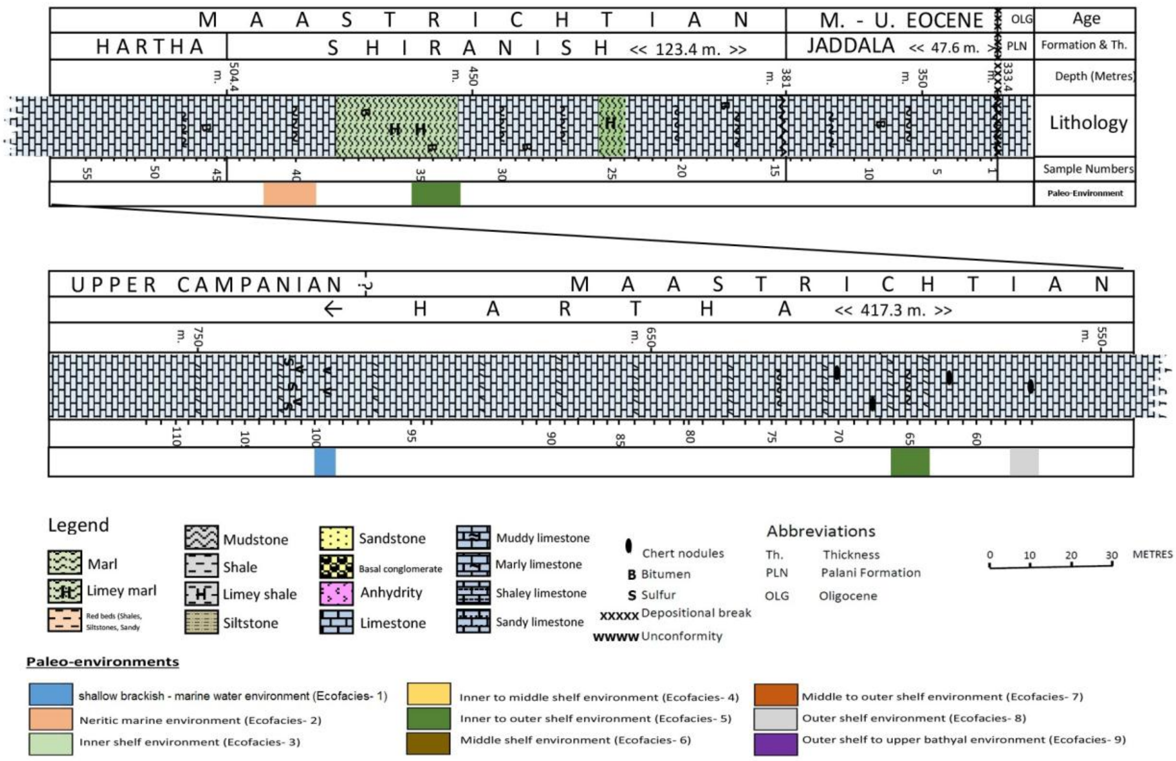

Figure 4 - Palaeo- environments of Makhul well-2 section.

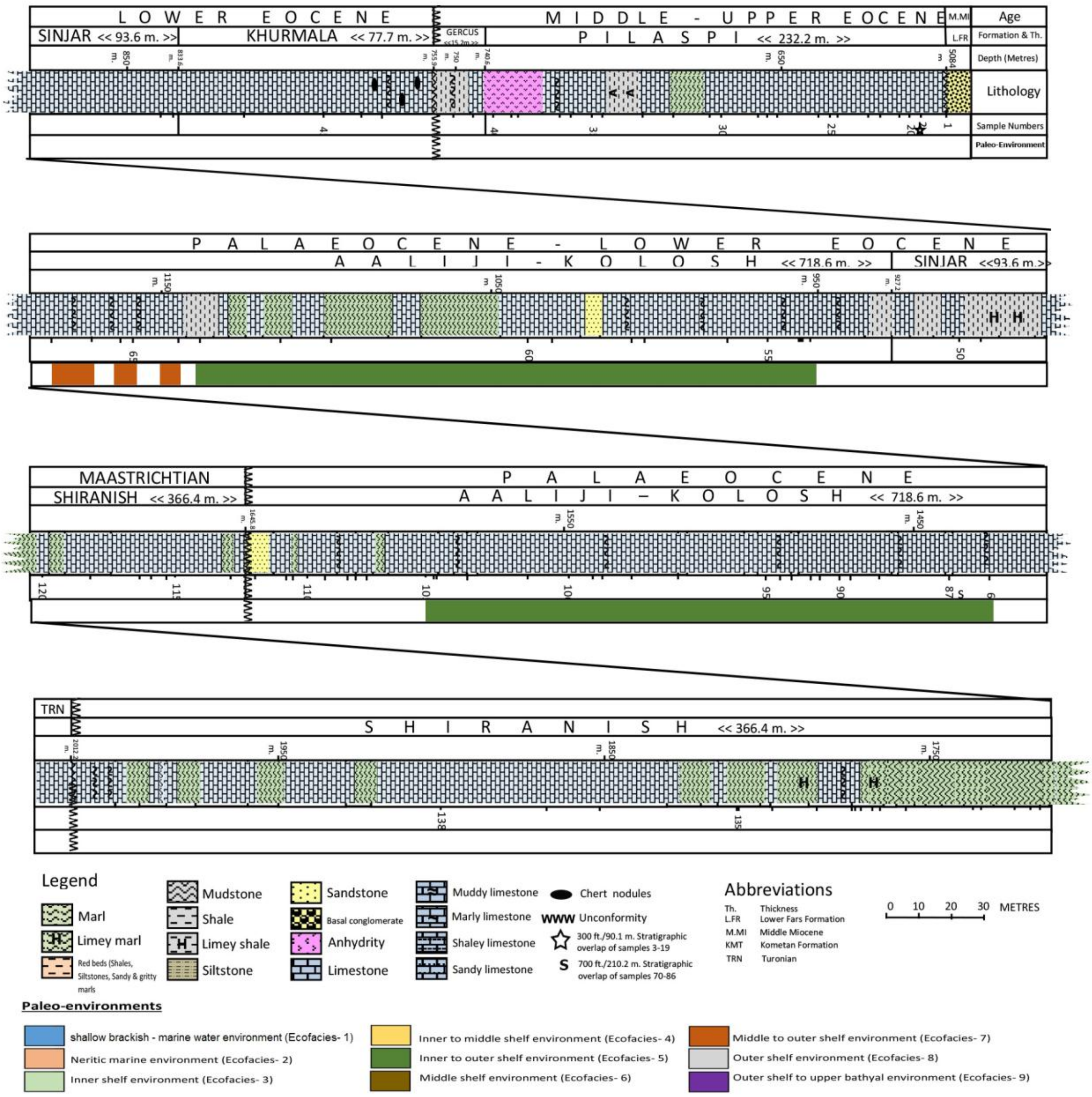

Figure 5 - Palaeo- environments of Chemchemal well- 2 section.

Paleoenvironments

The paleoenvironment of the studied formations in the study area, have been determined according to the presence of ostracoda assemblages within the successive beds of each formation in the studied sections (Figures: 4- 1, 4- 2, 4- 3, 4- 4 and 4- 5); they are as follow:

1. **Hartha Formation:**
   This formation deposited in Ecofacies - 1 (shallow marine water), Ecofacies -5 (inner to outer shelf) and Ecofacies -8 (outer shelf) within Makhul well- 2 section, and Ecofacies -5 (inner to outer shelf) within Anah well- 2 section.
2. **Shiranish Formation:**
   This formation is deposited in Ecofacies - 8 (outer shelf) within Jabel Sinjar section. In addition, the Shiranish Formation in Makhul well- 2 section is deposited in Ecofacies -2 (neritic marine) and Ecofacies - 5 (inner to outer shelf).
3. **Aaliji Formation:**
   This formation is present within Jabel Sinjar section and characterised by Ecofacies -5 (inner to outer shelf) and Ecofacies - 9 (outer shelf to upper bathyal).
4. **Aaliji/ Kolosh Formation:**

This mixed formation is present within Chemchemal well- 2 section and characterised by Ecofaces - 5 (inner to outer shelf) and Ecofacies - 7 (middle to outer shelf).

5. **Jaddala Formation:**

This formation within the Jabel Sinjar Section is deposited in different environments characterized by Ecofacies - 3 (inner shelf), Ecofacies - 5 (inner to outer shelf), Ecofacies - 6 (middle shelf), Ecofacies -7 (middle to outer shelf), Ecofacies - 8 (outer shelf) and Ecofacies - 9 (outer shelf to upper bathyal). While the Jaddala Formation within Mityaha well -1 section is deposited in Ecofacies -1 (shallow brackish - marine water), Ecofacies -2 (neritic marine), Ecofacies -5 (inner to outer shelf) and Ecofacies -8 (outer shelf), and deposited in Ecofacies -5 (inner to outer shelf) within Anah well- 2 section.

The Jaddala Formation within the Mityaha well- 1 section, comprises the genera *Leptocythere* and *Callistocythere* which are evidence to the basin shallowing, and indicate to the rising of the Khlesia- Mosul uplift during the Late Eocene. This uplift was separating the Jaddala basin into two bio-provinces; the Mediterranean Bio-province in the west and the Indo- Pacific Bio-province to the east – southeast.

6. **Avanah Formation:**

This formation is present within Jabel Sinjar section, and characterised by Ecofacies - 5 (inner to outer shelf) and Ecofacies - 7 (middle to outer shelf).

Conclusions:

The depositional paleoenvironments of the Hartha, Shiranish, Aaliji, Kolosh, Jaddala and Avanah formations in the study area (North and Western Iraq) have been determined according to the presence of ostracoda assemblages within the successive beds of each formation; they are as follow:

- Hartha Formation is deposited in a shallow marine water and inner to outer shelf environments within Makhul well- 2 section and Anah well- 2 section.
- Shiranish Formation is deposited in outer shelf environments within Jabel Sinjar section. In addition, the Shiranish Formation in Makhul well- 2 section is deposited in a neritic marine and inner to outer shelf environments.
- Aaliji Formation is present within Jabel Sinjar section where deposited in an inner shelf extending down to the upper bathyal. While the Aaliji/ Kolosh Formation is present within Chemchemal well- 2 section, which is deposited in an inner to outer shelf environments.
- Jaddala Formation is deposited in different environments within Jabel Sinjar section ranging from inner shelf to the upper bathyal. While this formation within the Mityaha well-1 section is deposited in a shallow (brackish or brackish - marine water) environment, neritic marine and inner to outer shelf environments, where the genera *Leptocythere* and *Callistocythere* evidence to the basin shallowing in this borehole, and indicate to the rising of the Khlesia- Mosul uplift during the Late Eocene. This uplift was separating the Jaddala basin into two bio-provinces; the Mediterranean Bio-province in the west and the Indo- Pacific Bio-province to the east – southeast. In Anah well-2 the Jaddala Formation is deposited in an inner to outer shelf environments.
- Avanah Formation is deposited within inner to outer shelf in Jabel Sinjar section.

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