GEOLOGY OF IRAQ

Cretaceous

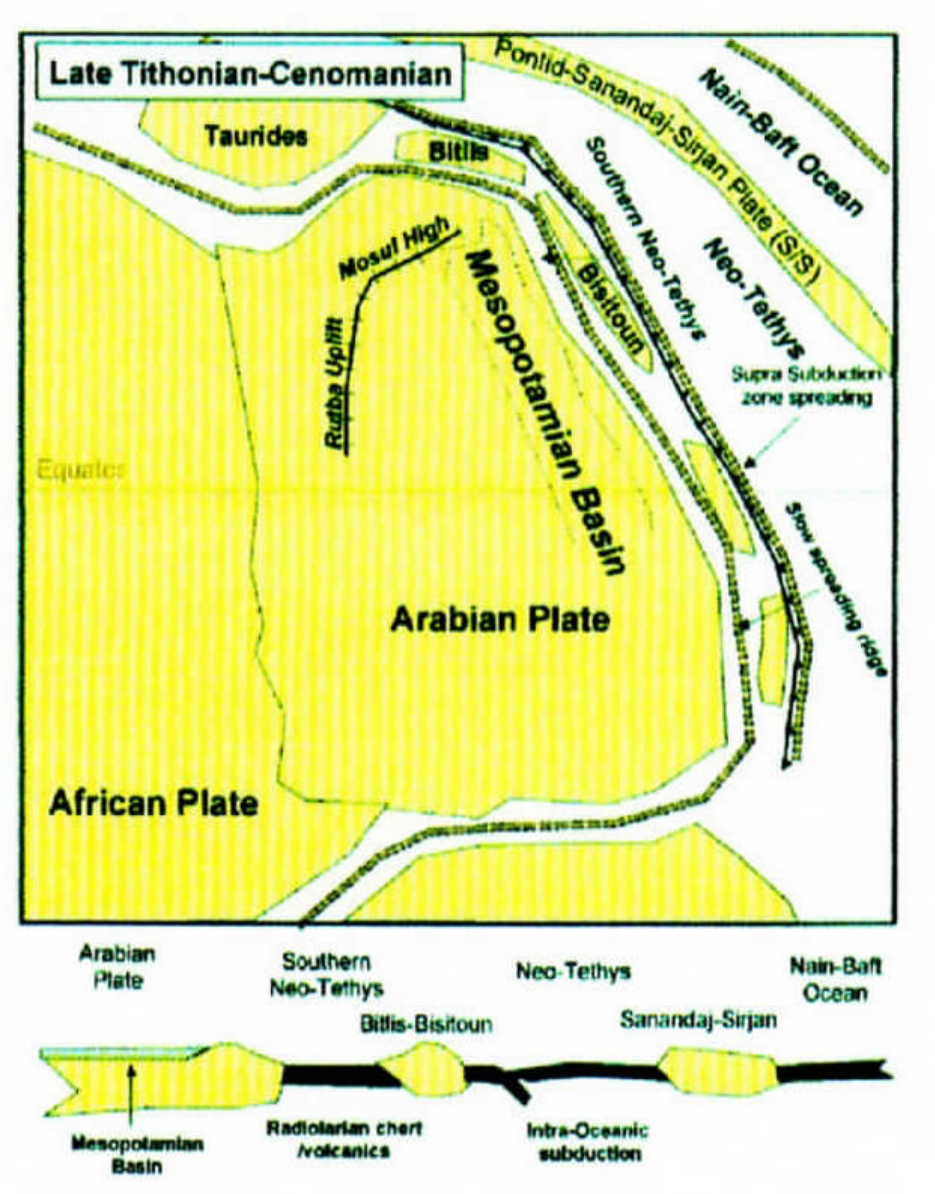
Throughout the late Paleozoic, Mesozoic, and Paleogene, the Middle East and North Africa lay on the southern shelf of the Tethys Ocean. The Middle East was bounded in the south and southwest by the Arabo-Nubian Shield. Henson (1951) divided the Middle East into four structural-paleogeographical zones: The Arabian Shield, the stable shelf, the mobile shelf, and the Orthogeosyncline. Buday in 1980 utilizing the work of Bolton (1955-1958), divided the Orthogeosyncline into Eu- and Miogeosynclinal realms, and further subdivided the Paleogene Eugeosynclinal realm into three: Qandil and associated groups as an inner belt, the Walash facies in the centre and the Naopurdan group as an outer belt. The Eugeosynclinal realm is mainly found in Iran and Turkey. Buday re-described the Eugeosynclinal realm of Iraq in 1980 in an attempt to unify his previous work (1973) and other studies carried out in neighboring Iran and Turkey. As a result he divided the Eugeosynclinal realm into an outer sedimentary- volcanogenic belt consisting of the Naopurdan and Walash units of Tertiary age, and an inner, mostly metamorphosed zone (Qandil) of pre-Tertiary and Tertiary age.

Henson (1950), Dunnington (1955-1960), A1-Rawi (1975, 1978) and Buday (1980) ascribed the thickness and facies changes to deep seated faults in the Arabo-Nubian basement.

Jassim and Goff (2006) revised the work of Buday (1980) and Buday and Jassim (1987) according to the new ideas of plate tectonics and sequence stratigraphy.

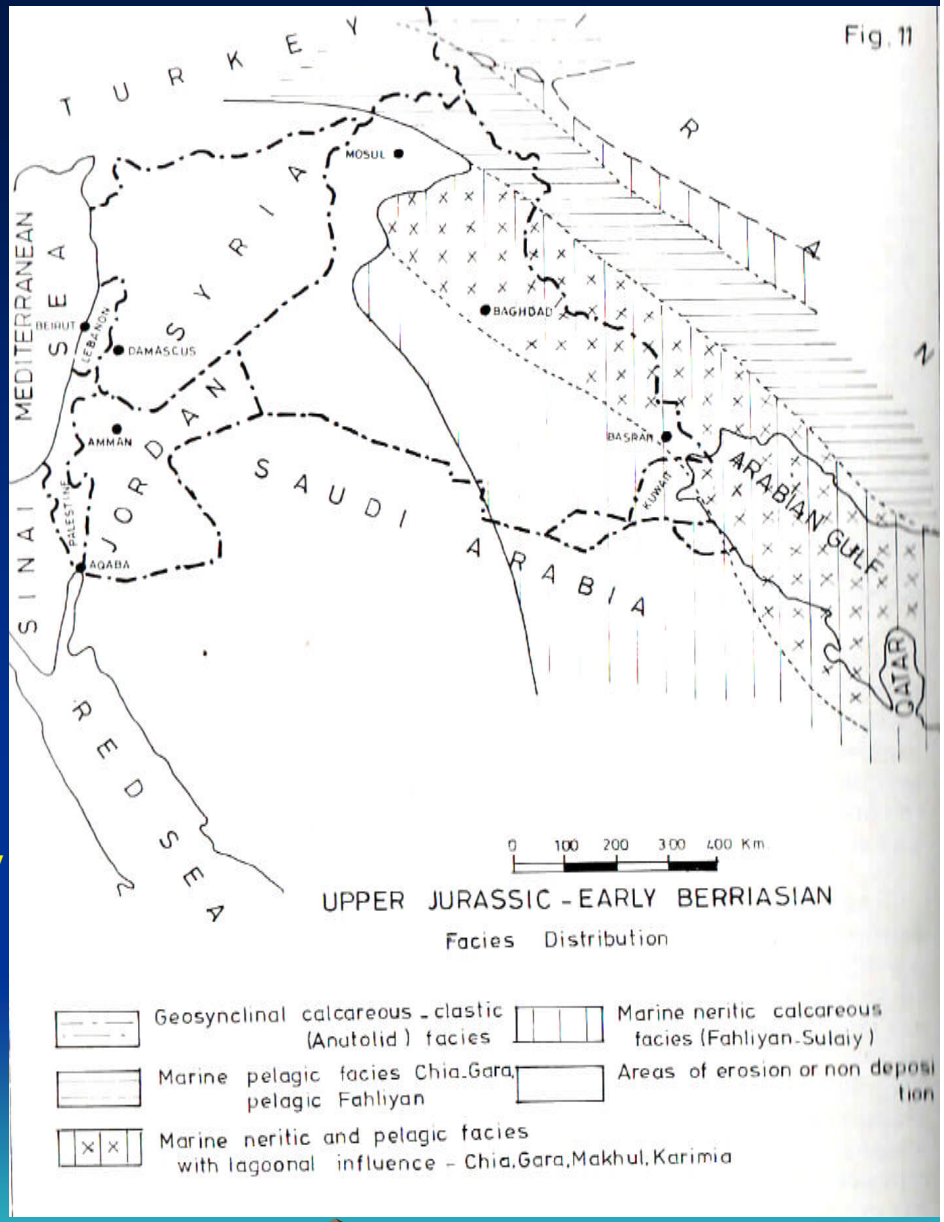
The Tithonian - Middle Berriasian stages are marked, at the beginning, by a temporary cease of the tectonic unrest. There is an important regional unconformity of Mid Tithonian age (149 Ma) on the Arabian Plate which marks the boundary between Megasequences AP7 and AP8 (Sharland *et al.*, 2001). This unconformity may be a “break up unconformity” which formed as a result of a possible phase of ocean floor spreading around the northern margin of the Arabian Plate with the opening of a southern Neo – Tethys Ocean. In Late Tithonian time major paleogeographic changes occurred in the northern and eastern Arabian Plate which are not explained by previous plate tectonic models of the region (Jassim & Goff, 2006).

Consequently, the lagoonal saline deposition had been replaced by neritic to pelagic sedimentation in a paleogeographically relatively uniform basin.



During the Berriassian, the Kimmerian tectonic unrest had been renewed. The areas of the High Folded Zone and of the adjacent units in the northeast and the area of the Nahr Umr – Mussaiyib paleouplift and those lying to the southwest of it were uplifted and a residual basin, lying mainly on the Foothill Zone and on the northeastern parts of the Mesopotamian Zone developed between them and was filled in with the Karimia Mudstone Formation.

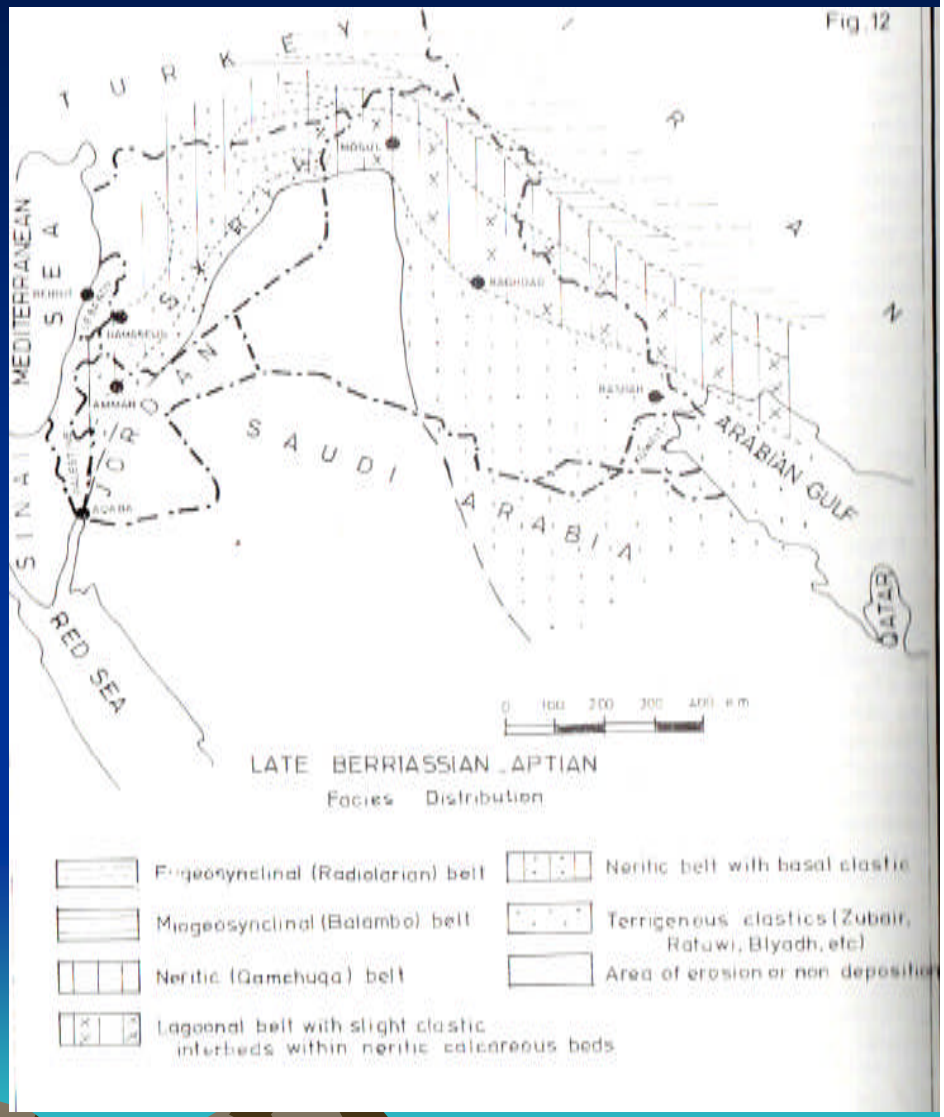
Buday (1980) mentioned that it should be stressed that the Intra-Berriasian movements are confined mainly to the areas lying relatively near to the geosyncline. The prevailing parts of the Stable Shelf in Saudi Arabia were not affected by these movements at all. On the remaining parts of the shelf the Tithonian – Berriasian neritic sedimentation, which began after the closure of the Kimmeridgian anhydritic sedimentation, continued into the Valanginian.



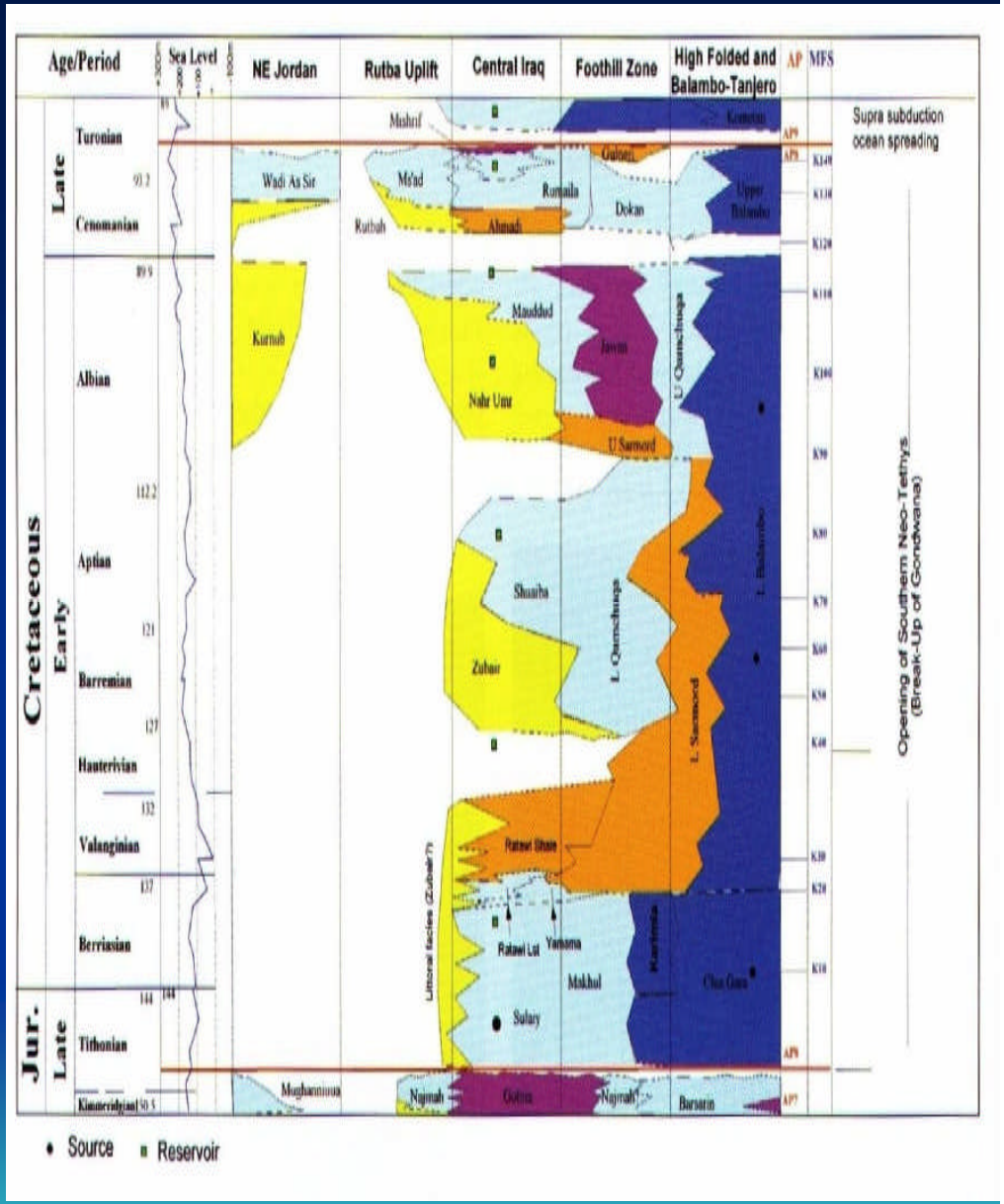
A. THE BERRIASIAN–APTIAN SUBCYCLE

The paleogeographic development during the Late Berriasian – Aptian was directed by that land mass, which was progressively rising in the west and southwest and comprising the Mardin and Khleisia Uplifts in the north (the first until the Aptian) and the Shield and essential parts of the Stable Shelf in the south (Ditmar *et al.,* 1971). On the Iraqi territory, lying to the east and north of that continent, a system of troughs, marked by different type of sedimentation, developed. These troughs were separated from others by ridges running roughly in northwest – southeast, i.e. Zagros direction and were mostly superimposed on the old ridges which affected the sedimentation in earlier times too.

On the extreme northeastern areas of Iraq, there were troughs developed and separated from the basins of the Unstable Shelf by a new ridge running in Zagros direction between the Rikan and Zibar areas in northwest and the Sirwan areas in the southeast.



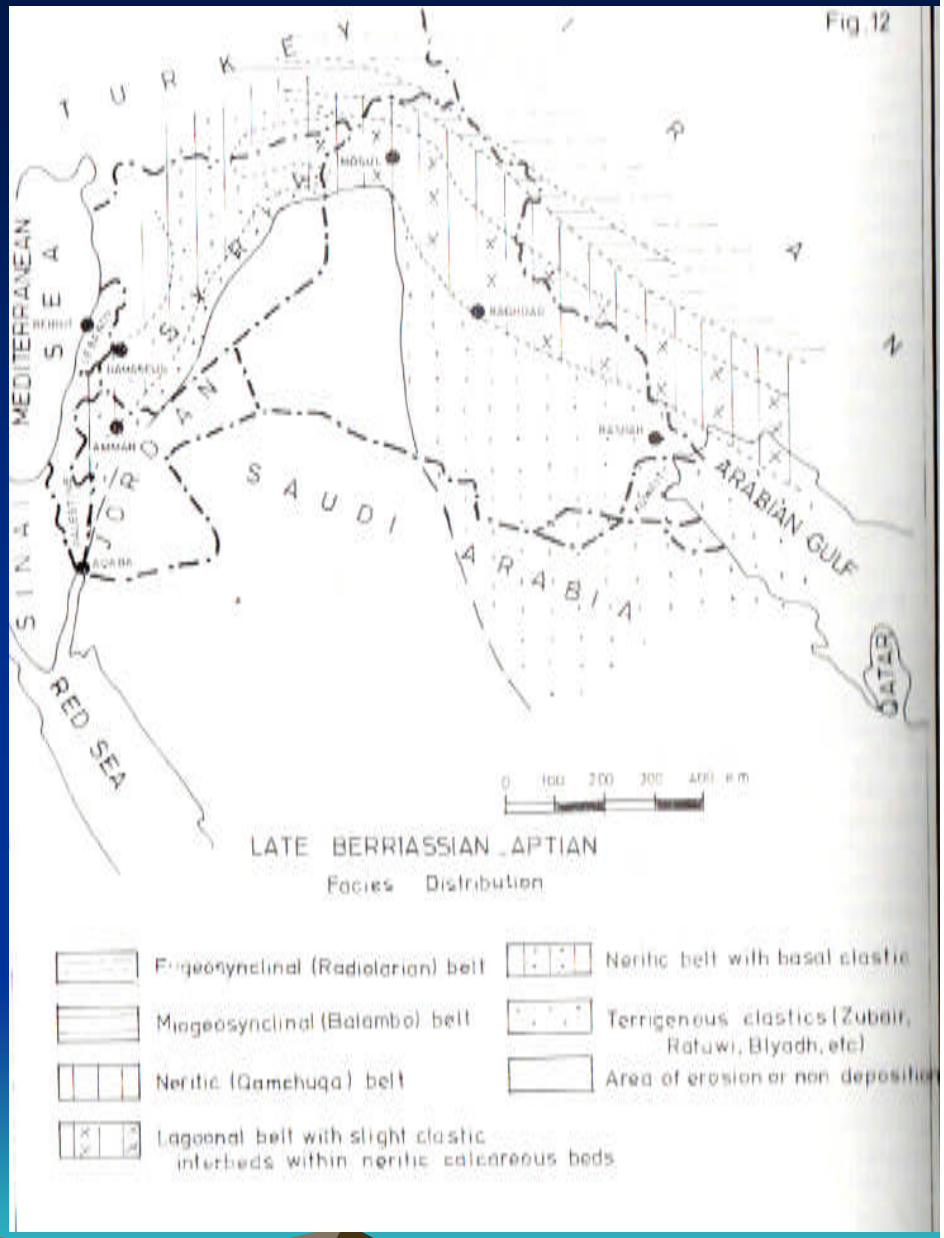
Jassim & Goff (2006) argued that the Late Tithonian – Early Turonian Megasequence AP8 was deposited in a large intra – shelf basin contemporaneous with a new phase of ocean floor spreading in the Southern Neo – Tethys. The opening of the Southern Neo – Tethys led to drifting away of a narrow microcontinent; a new passive margin formed along the NE margin of the Arabian Plate. The Rutbah Uplift formed the western margin of the Mesopotamian Basin; while the NE margin was formed by a carbonate ridge along the north facing passive margin of the Southern Neo – Tethys.



The **Ratawi Formation** is composed in the type locality of dark, slightly pyritic shales, interbedded in the lower part with stringers and beds of buff, pyritic, pseudoolitic, detrital limestone with fossils, in some areas contains inlayers of sandy shales and sands.
The thickness of the formation in the type area ranges between 220-300m, decreases towards the west and north partly due to the facies passage into the synchronous Zubair.

The formation represents the sediments of a partly euxinic lagoon fringing the shore of the Lower Cretaceous sea at the beginning of the Valanginian transgression in southern Iran and in the adjacent parts of Kuwait and Saudi Arabia. Jassim & Goff (2006) considered the upper Ratawi shale as a pro-delta facies passes both upwards and westwards into the sandy deltaic Zubair facies.

The fossils indicate Hauterivian age for the upper-prevalently shaley-part, the lower part is not precisely dated and supposed to be Valanginian.
Both contacts are conformable. The formation passes gradually into the Zubair Formation.

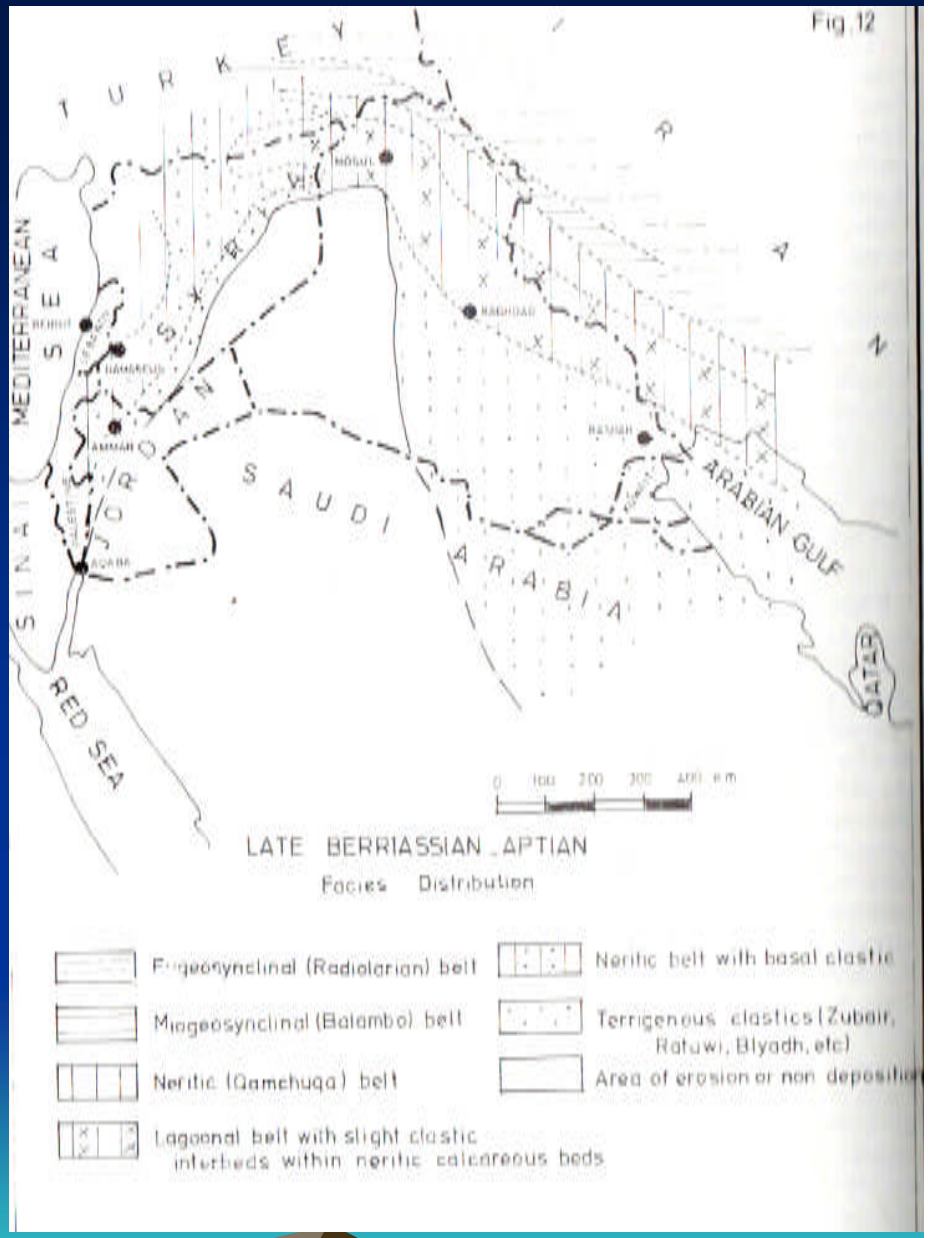


The **Zubair Formation** is essentially composed of alternating shales and sandstones with some siltstones. The variation in lithology displays some regularity, towards the shore the amount of the pelitic components rapidly decreases. In the west the formation is composed mostly of sands only. Towards the basin the formation contains more and more shales and becomes almost purely shaly near the Dujaila area.

The formation represents a littoral, partly deltaic, sedimentary sequence composed of the products of erosion of the Arabian Shield and Stable Shelf which were uplifted during the late Kimmerian movement.

Fossils are abundant; the age of the formation, as determined on the basis of both fossils and regional correlation, is Hauterivian till Early Aptian.

The contacts of the formation are mostly gradational and conformable.

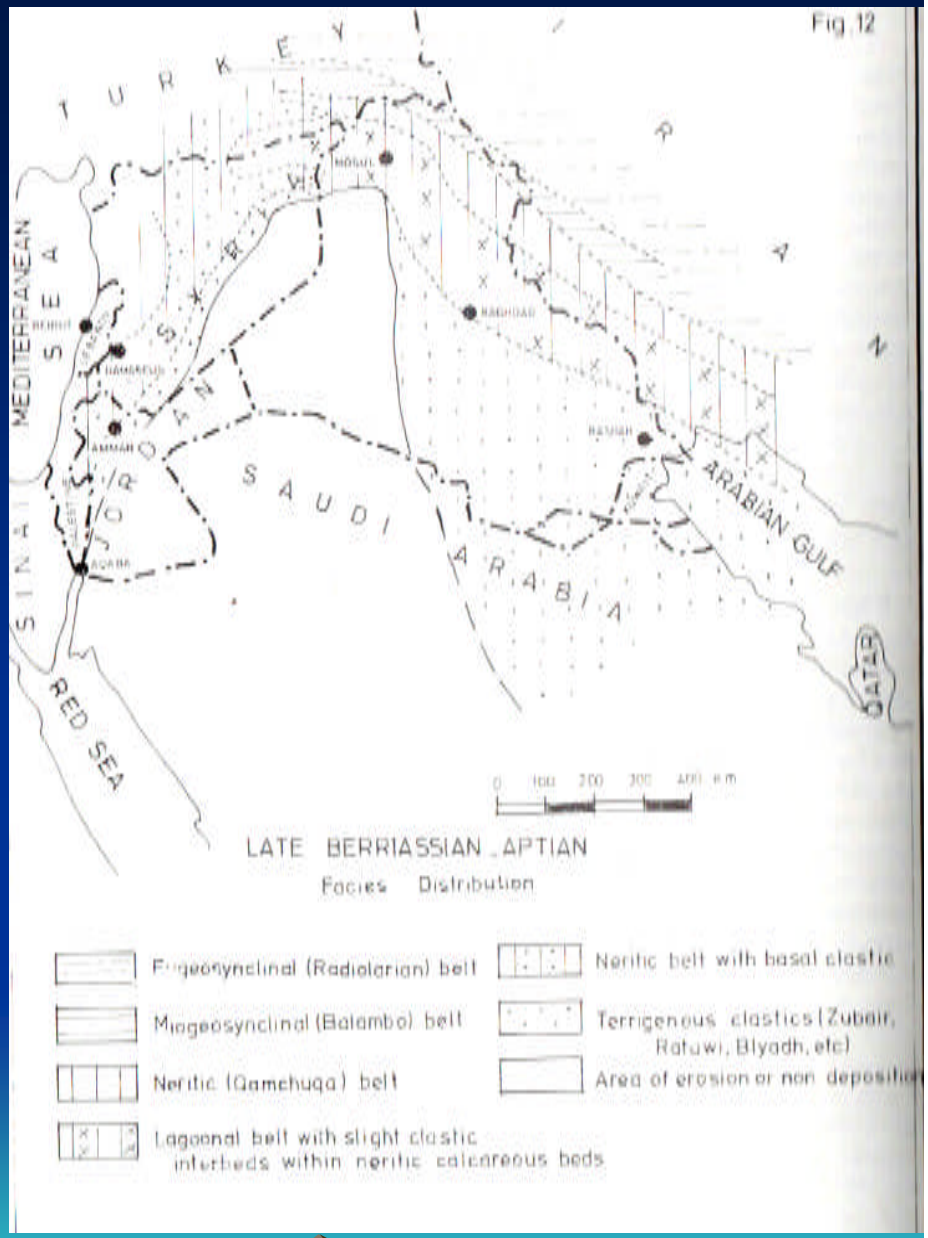


The **Garagu Formation** is composed of oolitic sandy limestone, with marls and sandstones in its upper and lower parts, and of organic detrital limestone in its middle part.

The formation represents the sediments of the lagoonal realm outside the reach of the stronger terrigenous supply. Based on the evidence of fossils the age can be clearly defined as late Berriasian – Hauterivian.

The **Lower Qamchuqa** Formation is represented by massive, rather argillaceous. fossiliferous limestone, with some disseminated quartz silt, sometimes glauconitic, often dolomitized, interbedded with crystalline dolomites. The formation was deposited in a purely- marine neritic environment (carbonate inner shelf facies (Jassim & Goff, 2006)), not at all, or to a very slight degree affected by terrigenous supply.

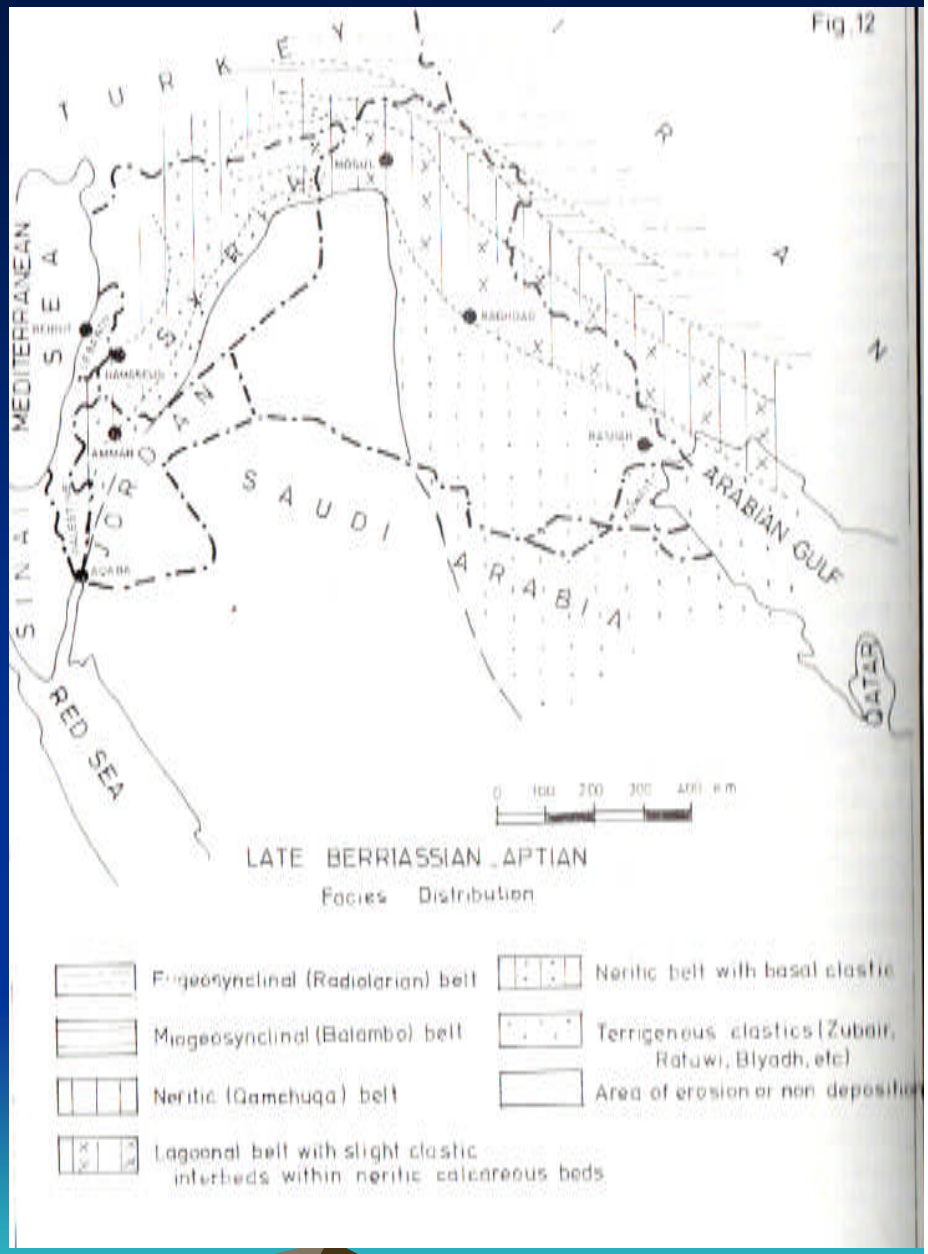
The age of the formation is firmly established as Hauterivian till Aptian. The contacts of the formation are mostly conformable.



The **Lower Sarmord Formation** is composed in the type area (Surdash anticline) of a monotonous sequence of brown and bluish marls, with alterations of manly neritic limestone. The age of the formation is late Berriasian – Aptian. The formation often intertongues with both the Balambo and Qamchuqa Formations and in such areas it is impossible to make a clear distiction between those formations.

The formation represents the sediments of the deeper parts of the marine neritic zone (outer shelf to basinal (Jassim & Goff, 2006)).

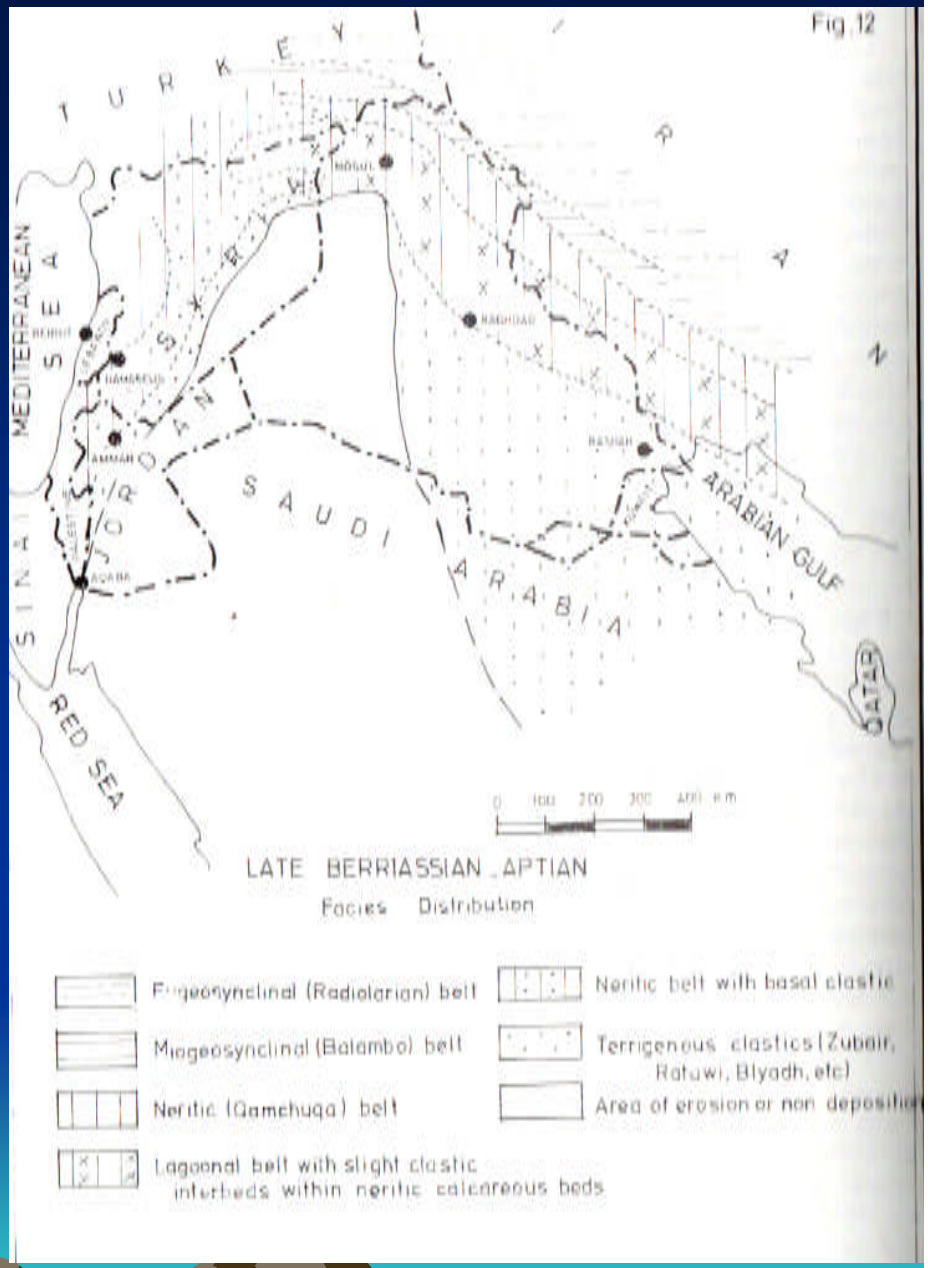
Fossils, mainly microfossils are very abundant. The contacts of the formation are different in accordance with the position of the section. The tongues are conformable, as it is in the type section.



The **Balambo Formation** embraces the deep water bathyal sediments deposited in the outer shelf - basinal areas of north and northeastern Iraq during almost the whole Cretaceous i. e from the Valanginian up to the Turonian (Buday, 1980, and Jassim & Goff, 2006)).

The **Lower Balambo Formation** is thin - bedded blue ammonitiferous limestone, with intercalations of olive green marls and dark blue shales. Fossils are very abundant. The age of the Lower Balambo is certainly Valanginian-Albian.

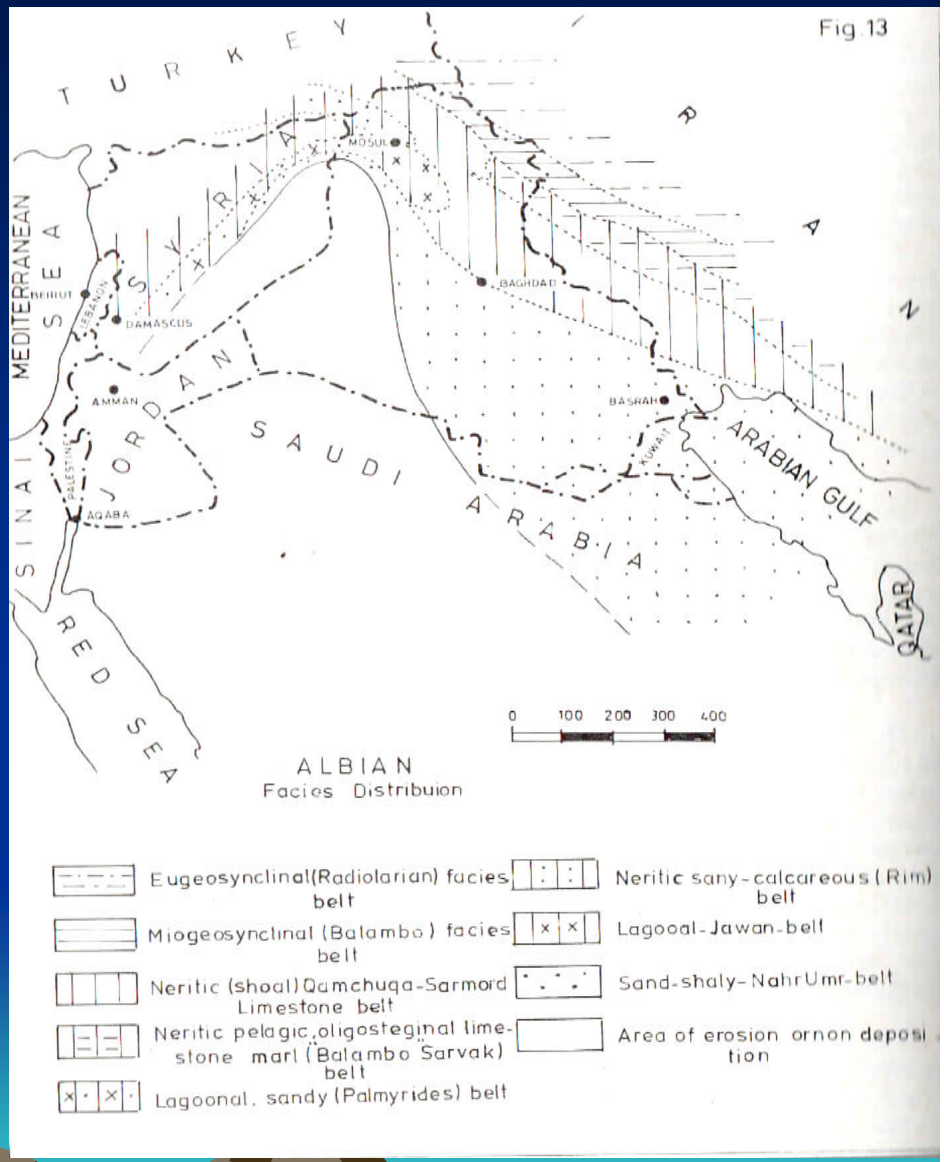
The lower contact of the formation in the type section and area seems to be non sequential, but without visible unconformity. The basal Valangin-ian and the Berriasian are missing there. The upper boundary of the Lower Balambo Formation is always gradational and conformable.



B. THE ALBIAN SUBCYCLE

The paleogeographical development during the Albian did not principally differ from that, which started in the Late Berriasian. The Sedimentation continued without any break and roughly with the same facies distribution. In the areas on and near to the Stable Shelf, however, the Albian is separated by a break from the Aptian and the Albian sediments are transgressive. This is the reason why the Albian is treated as a separate subcycle.

Buday (1980) mentioned that the pelagic Balambo Formation continued without interruption, and the same for the neritic belt, where the sedimentation on the Upper Qamchuqa complex with Sarmord and Balambo tongues continued. The neritic belt was, however, broader than its Valanginian – Aptian predecessor and reached the middle parts of the Foothill Zone. To the southwest, there is a lagoonal facies zone (Jawan local basin), which lay essentially on the remaining part of the Foothill Zone.

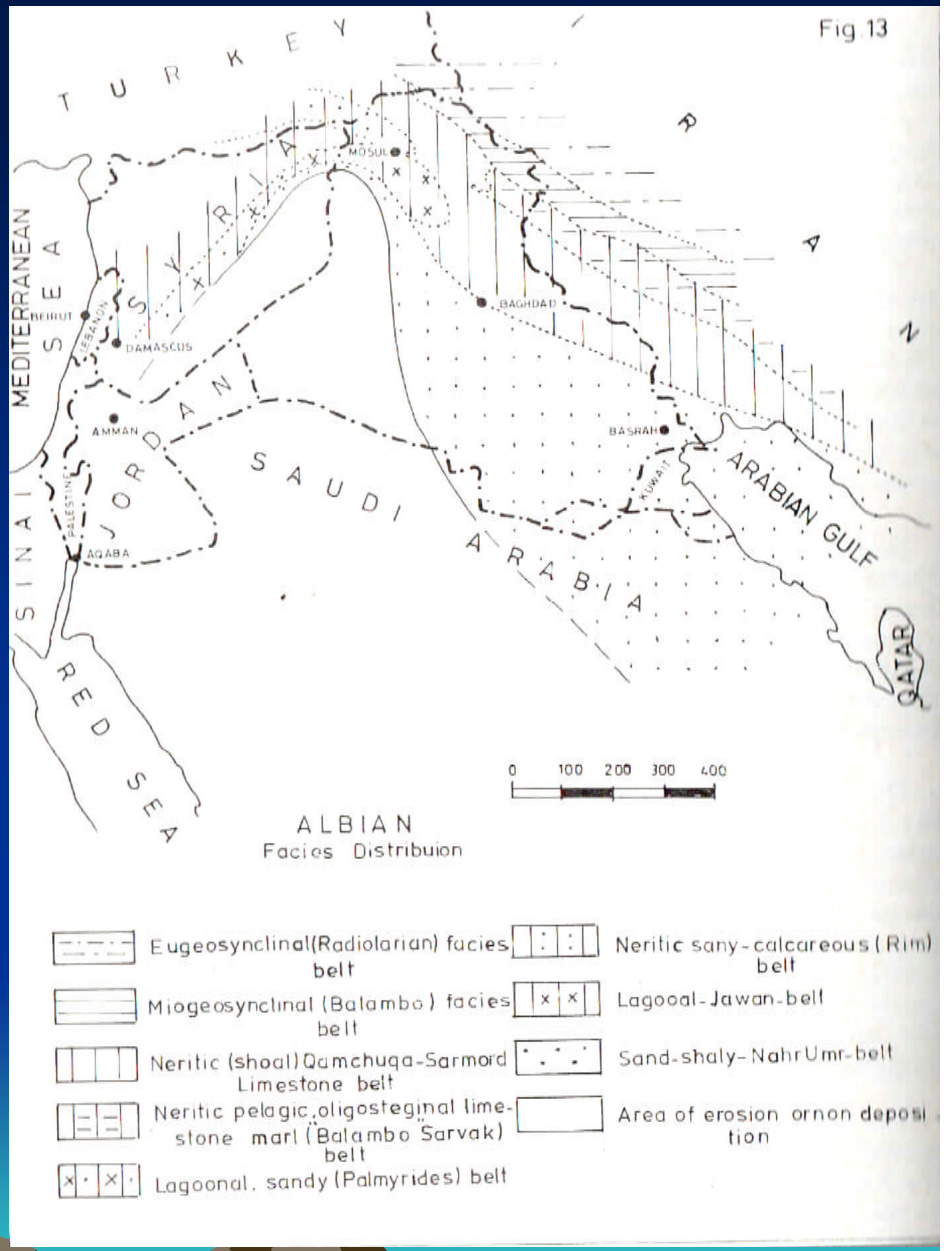


Nahr Umr Formation is composed of black shales interbedded with medium to fine grained sands and sandstones with lignite, amber, and Pyrite.

The formation is clearly terrigenous, shallow water, littoral sediment, comprising deltaic sequences and some continental (lignite) and neritic marine inlayers (limestone with fossils) too. It was considered by Jassim & Goff (2006) as clastic inner shelf facies.

Fossils found in the formation are mainly foraminifera. The age of Nahr Umr Formation is Albian.

The lower contact of the formation is conformable and gradational. The upper contact of the formation is conformable in Iraq.



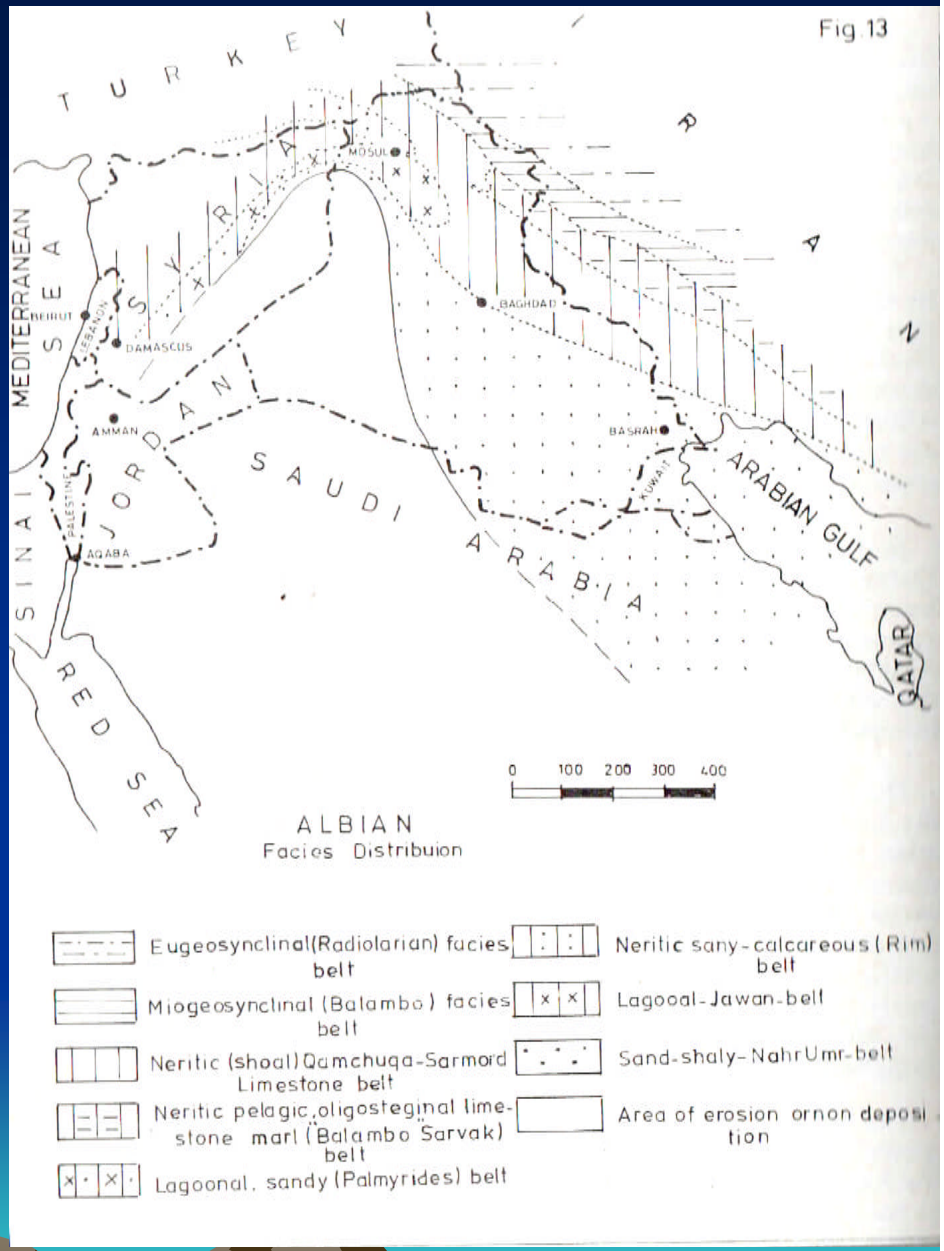
The **Rim Formation** has a very restricted areal distribution. The formation is composed of silty pyritic marls, marly siltstones, thin sandstones and anhydritic marls.

The formation represents a shallow water nearshore environment with lagoonal influences, without a deltaic character, deposited within the inner shelf (Jassim & Goff, 2006).

Fossils were not found. The age of the formation is therefore not clearly defined and might be determined as Albian with possible Aptian parts at its base.

The **Jawan Formation** is composed of pseudoolitic limestone, marly limestone, marly dolomites, recrystallized limestone, and anhydrites. The formation is clearly a neritic, semi- lagoonal, and deposited in the inner shelf (Jassim & Goff, 2006).

Fossils are relatively rare and bear evidence on the hypersaline environment of the basin. The, age of the formation is Albian.

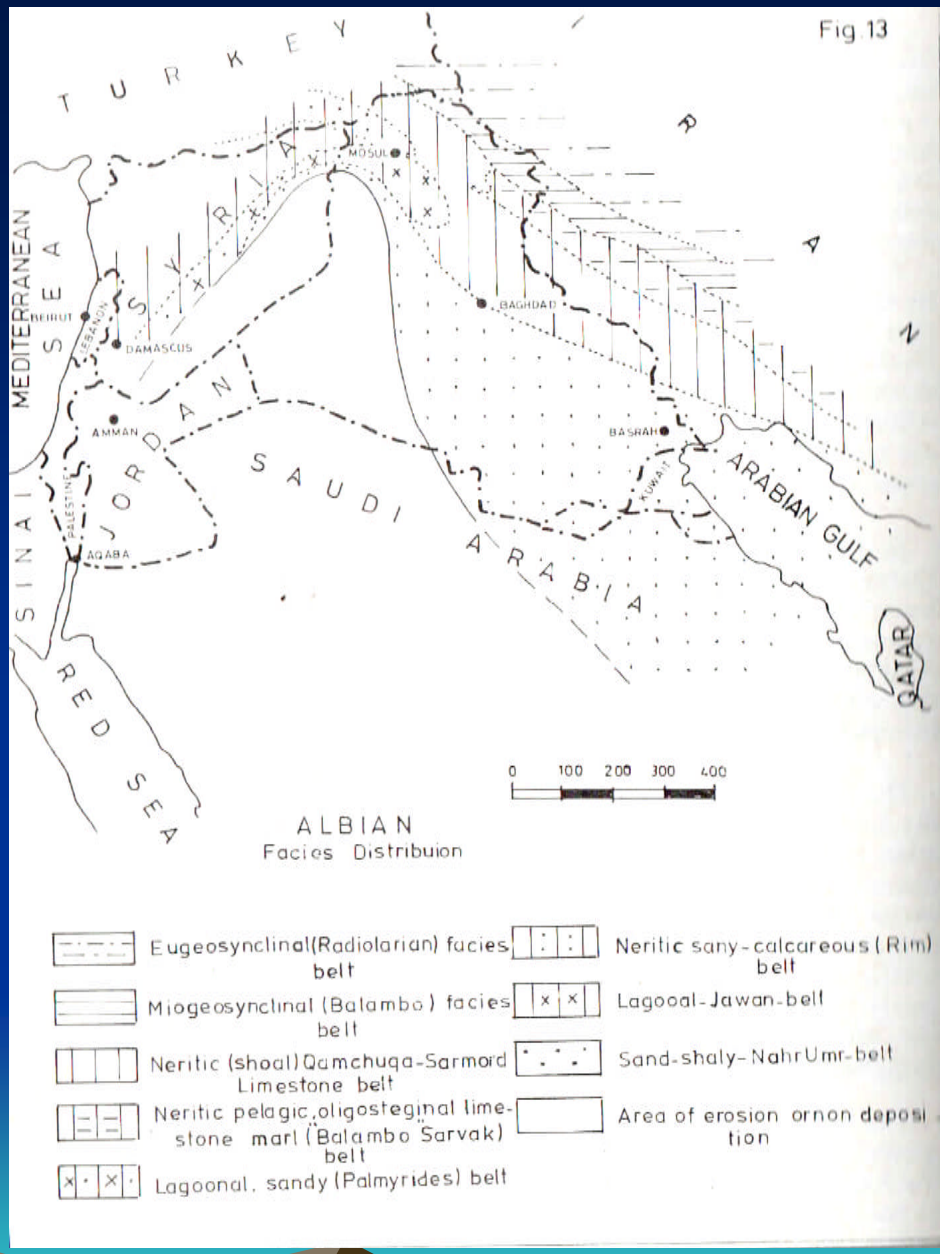


Upper Qamchuqa and **Mauddud Formations** are lithologically practically identical and are of the same age. They are consist prevalently of dolomites, replacing neritic organic - detrital limestone and of non dolomitized detrital limestone.

The formations were deposited in neritic, sometimes shoal environment (carbonate ramp (Jassim & Goff, 2006)). Fossils are abundant mainly in the Mauddud part. The age is Hauterivian – Albian.

Upper Sarmord Formation is a relatively not too widespread unit, consist-ing of marl, marly limestone, and neritic limestone, sometimes with some shales and shaly limestone.

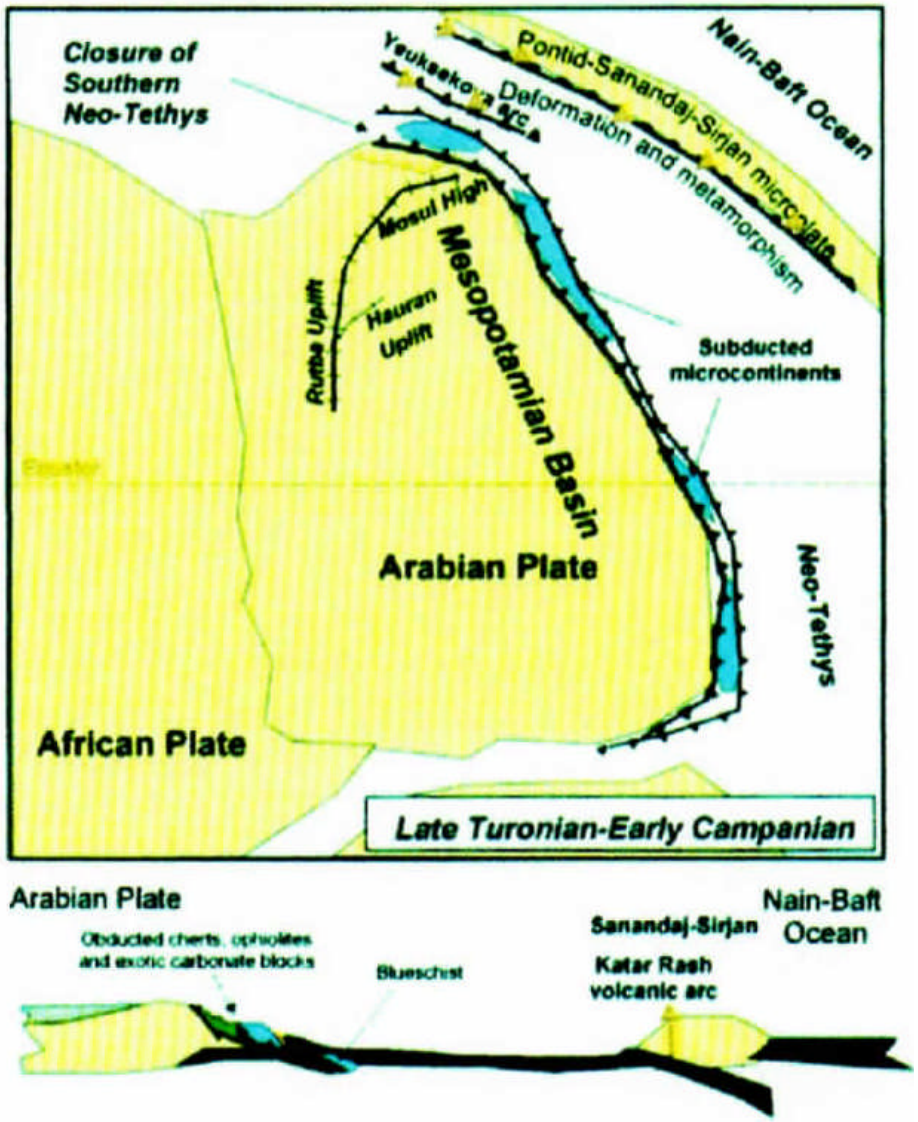
The environment of deposition is the deeper neritic. Fossils are relatively rare, indicating Albian age. The formation has a strongly patchy distribution.



2- THE CENOMANIAN - LOWER CAMPANIAN CYCLE

In Late Cenomanian – Early Turonian time the micro- continents that had split of the Arabian Plate in Late Tithonian time approached the trench of the intra- oceanic subduction zone. The onset of growth of N-S trending structures in S Iraq, Kuwait, and Saudi Arabia at this time may have been caused by the diachronous collision of these micro-continents with the fore-arc region above the trench. A foreland basin formed around the northern margin of the Arabian Plate in response to loading of the crust by thrust sheets generated as a result of compression (Jassim & Goff, 2006).

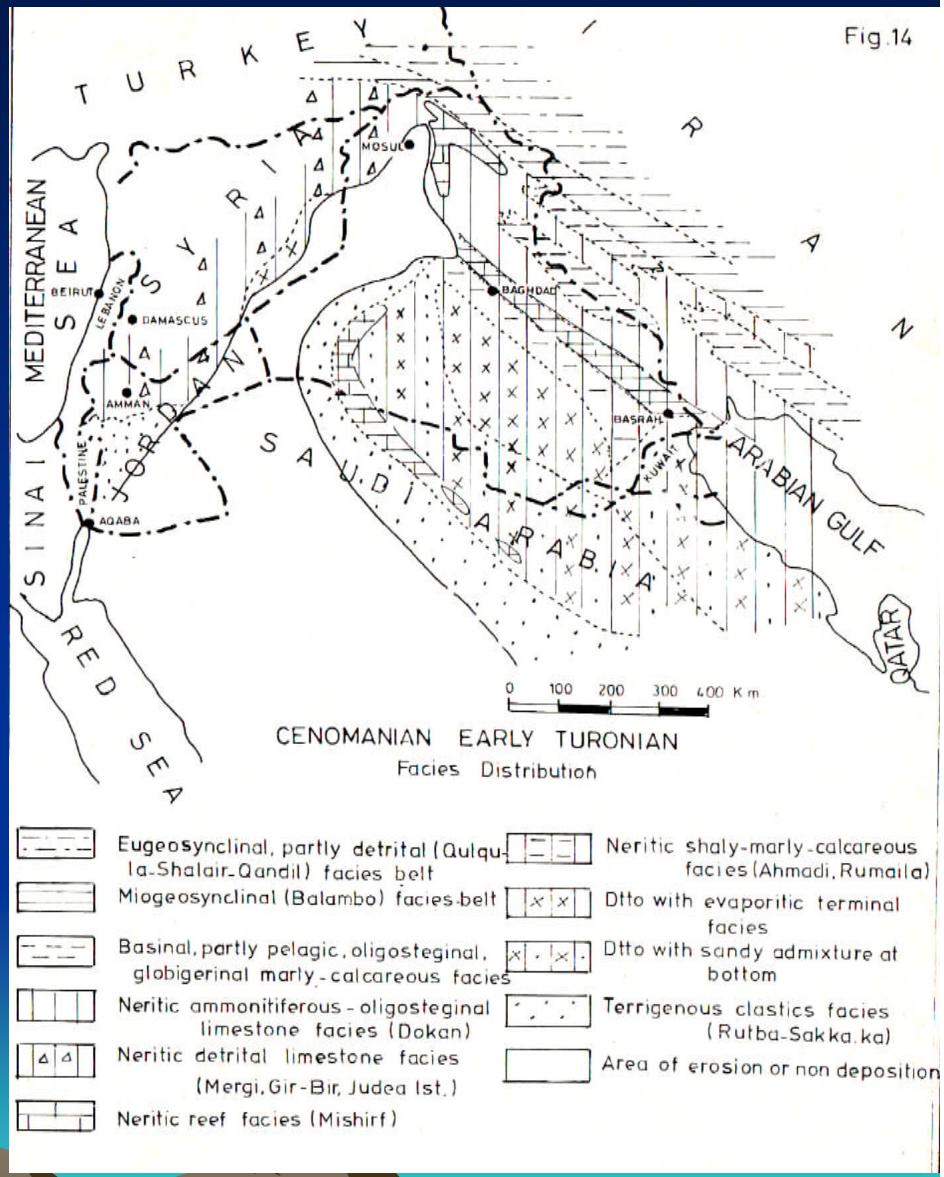
The Cenomanian - Lower Campanian formations were deposited during an epoch marked by strong tectonic unrest throughout the area. The tectonic unrest was caused ,by the strong Mid Cretaceous orogeny (Austrian – Subhercynian passes).



A. THE CENOMANIAN – EARLY TURONIAN SUBCYCLE

This subcycle was terminated by a new wave of the Mid Cretaceous orogeny in the area. Because these movements belong to the paroxysmal Subhercynian phases of that orogeny, the pulses of the movements were repeated in shorter intervals and were more intensive. The individual movements affected the Unstable Shelf very strongly and caused the several gaps, facies changes, and the irregular distribution of the sediments of the relatively long Turonian - Lower Campanian Subcycle.

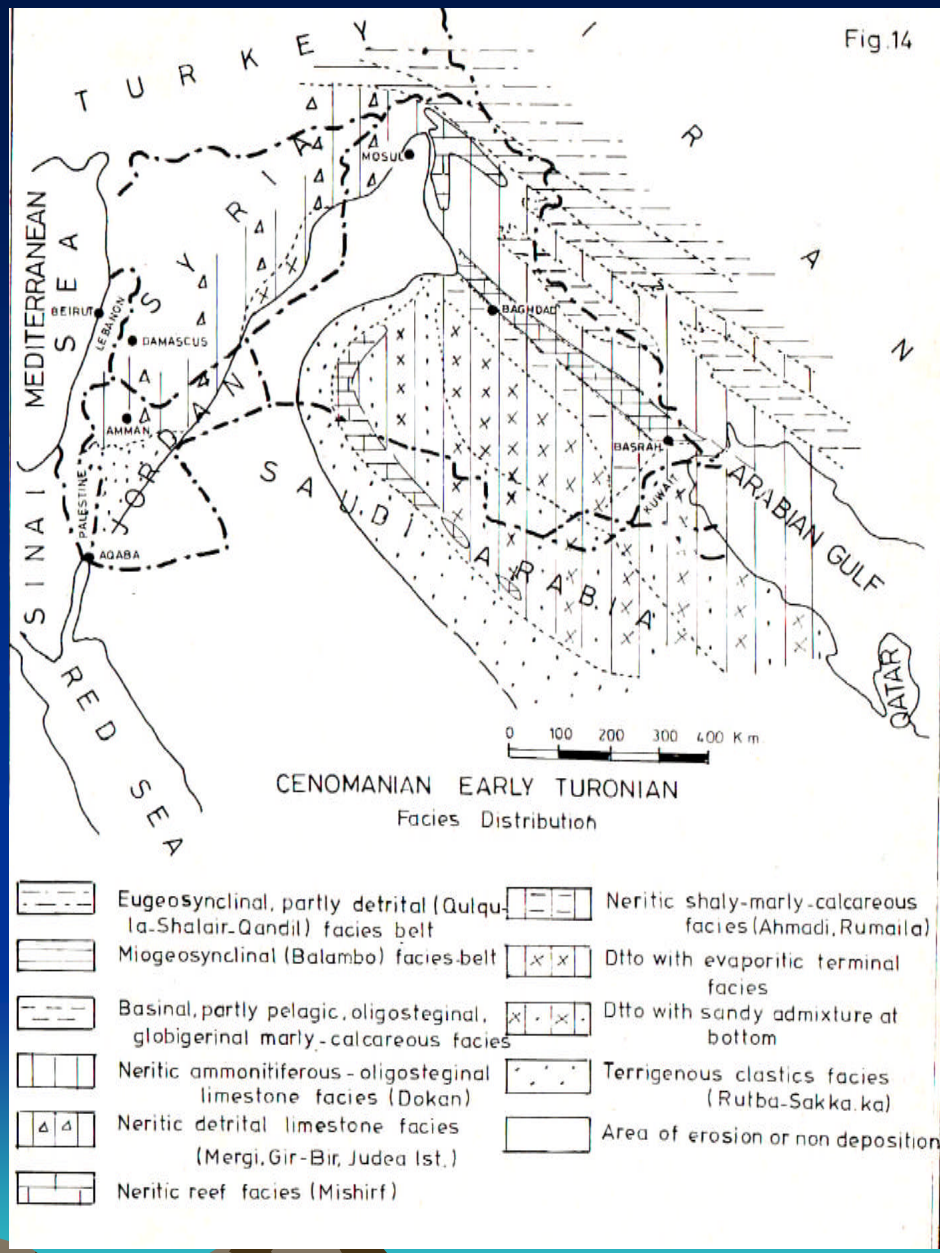
A common feature of the subcycle had been the progressive shifting of the sedimentary basins towards the southwest, and simultaneously, the progressively older age of the transgressions in the same direction (Buday, 1980).



The **Rutbah Formation** represents sediments of the beginning of the Middle Cretaceous transgression on the Stable Shelf in Iraq. It consists of white varicolored, locally ferruginous, coarse to fine grained, cross bedded quartz sands and (locally calcareous or argillaceous) sandstones, or quartzites.

This Formation was laid down mostly in continental, exceptionally in littoral marine environment, which was considered by Jassim & Goff (2006) as inner shelf facies. The age of the formation was controversial.

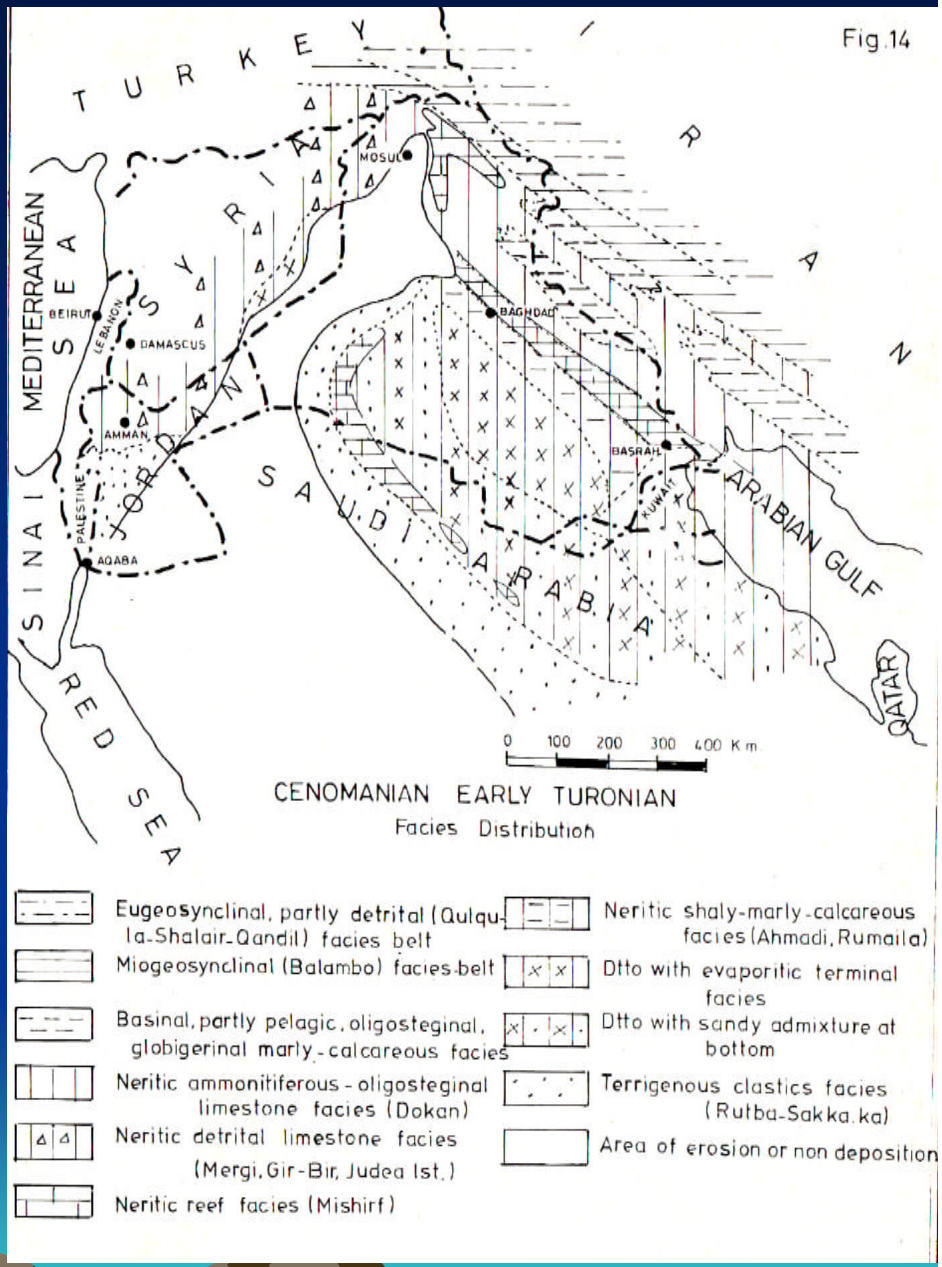
The **Ahmadi Formation** is composed of shales, grey in the lower parts and green, greenish - grey, and chocolate brown in the upper division. At the base a limestone bed, characterized by the ostracod species *Cythereis Bahraini.* This formation represents the sediments of shallow water (inner shelf facies (Jassim & Goff, 2006)), with strong terrigenous effect, marine basin, fringing the depositional area of Wasia delta in Saudi Arabia. The age of the formation is Cenomanian.



The **Rumaila Formation** consists of two rock types i.e. fine –grained, marly,oligosteginal limestone, and marls above, and fine -grained, chalky limestone below.

This Formation was deposited in a deep inner shelf (Jassim & Goff, 2006), subsiding basin with locally and temporarily occurring lagoonal conditions, connected mainly in the north with anomalous salinity, testified by the dwarfed character of the fauna. The deeper basinal conditions were temporarily interrupted, and neritic normal saline sedimentation took place. In the north terrigenous clastics indicate the nearby continent and its local oscillations.

Fossils are relatively rich. The age of the formation, including all facies, ranges within the Cenomanian – Early Turonian.



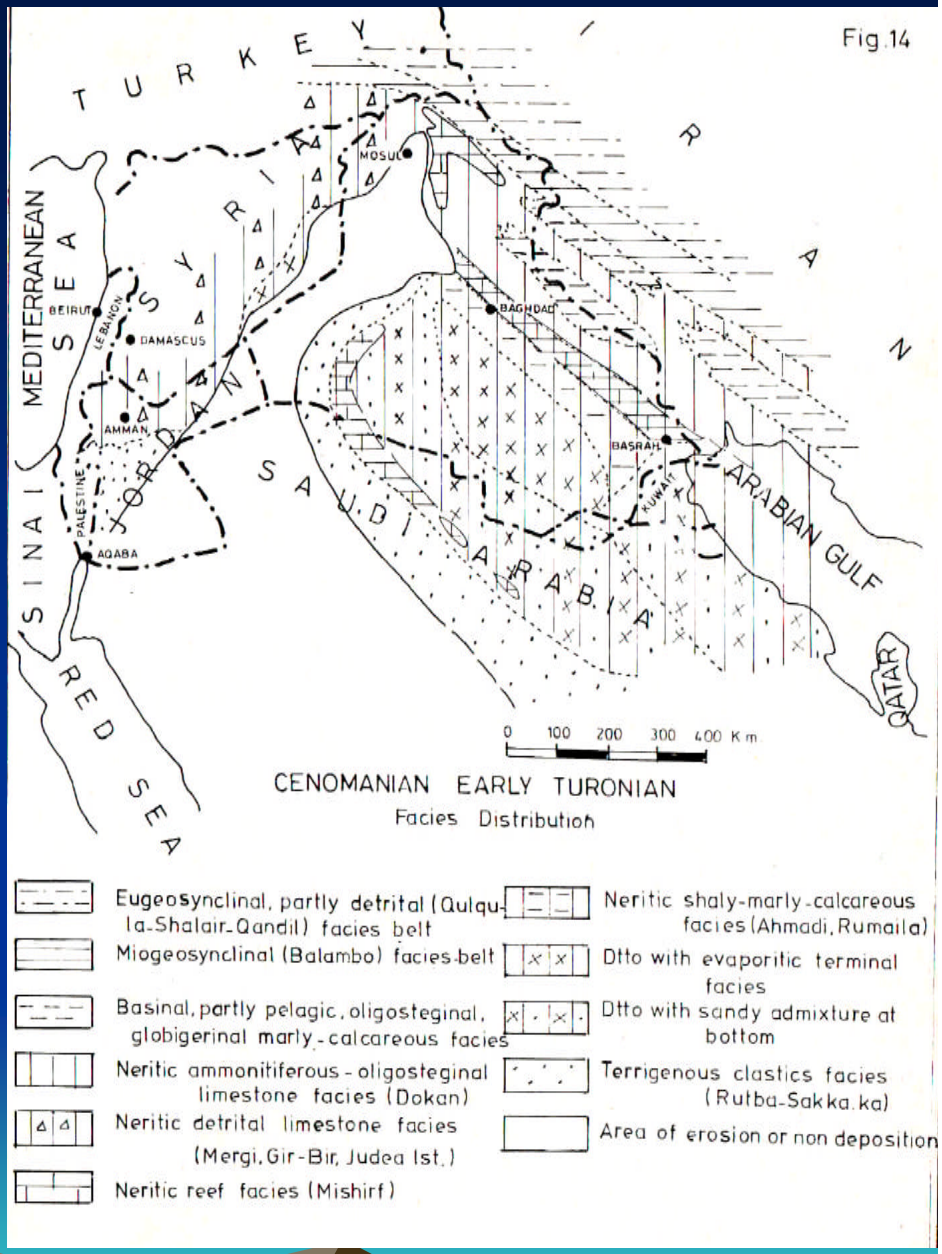
The **Mishrif Formation** is composed of grey–white, dense, algal limestone with gastro-pods and shell fragments above, and of brown, detrital, porous, partly very shelly and foraminiferal limestone, with banks of Rudists below.

The formation was deposited in typical oolitic, reef or fore-reef environment, considered as rudist reef facies, with the exception of the **M'sad facies** in the Rutbah area, where littoral influences are clearly evidenced and considered as inner shelf facies (Jassim & Goff, 2006).

Fossils are very abundant. The age of the formation is Cenomanian (most probably higher) and very Early Turonian.

The contacts of the formation is, as a rule, conformable.

The **Kifl Formation** is composed mainly of anhydrites and of oolitic and pseudoolitic limestone, representing the deposits of a relic lagoon with mostly hypersaline sedimentation and in some places freshwater sedimentation too. Considered by Jassim &Goff (2006) as evaporitic inner shelf lagoonal facies. The age is Cenomanian–Early Turonian.



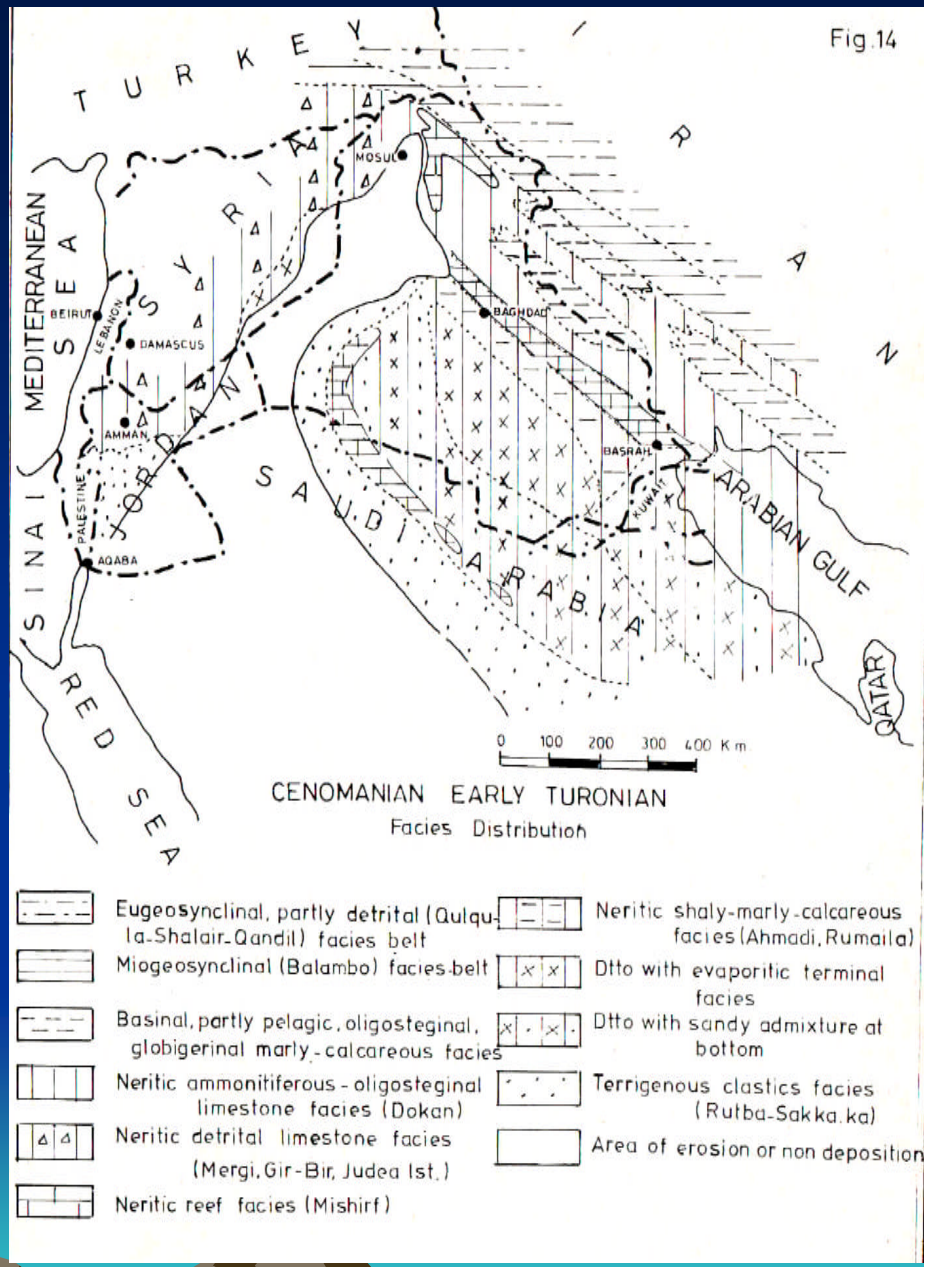
The **Dokan Formation** consists of light colored grey and white oligosteginal limestone, locally rubbly, with glauconitic coatings of the pebble - like masses.

The environment of the deposition was that of restricted deep basin (Jassim & Goff, 2006), evidenced by the abundant pelagic faunal elements, including *Ammonites*. The age of the formation is Cenomanian throughout. Both, the contacts of the formation are unconformable.

The **Upper Balambo Formation** represents mainly the Cenomanian and Turonian, and cannot be lithologically separated from the Valanginian - Albian Lower Balambo.

The formation is composed of a monotonous sequence of thin bedded globigerinal, passing downwards to radiolarian limestone. The environment, of the formation is marine deep neritic - bathyal, with pelagic faunas, considered by Jassim &Goff (2006) as open marine facies.

The age is Cenomanlan and Turonlan.

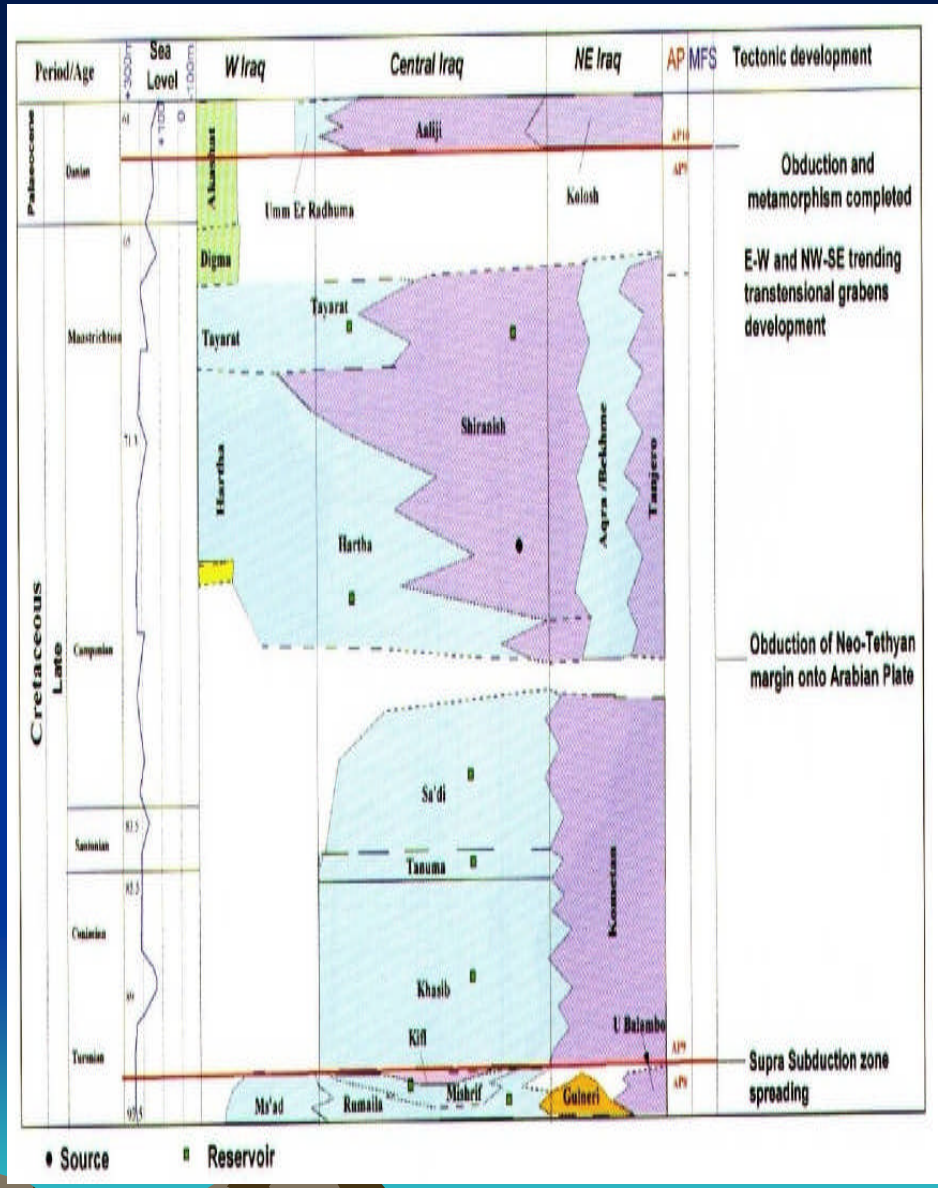


B. THE TURONIAN - LOWER CAMPANIAN SUBCYCLE

At the end of the Turonian the renewed movements caused the rising of the ridge area and the origin of a deeper basin along its southwestern margins. This late Turonian basin occupied a territory, which had been uplifted till the Turonian. The basin is situated mainly on the area of the Makhul Subzone of the Foothill Zone and occupied the marginal parts of the Stable Shelf around the Khleisia Uplift too, forming there east - west trending embayment in the Anah, Mushorah, and (?) Makhul area (Buday, 1980).

Jassim & Goff (2006) stated that the Late Turonian – Danian Megasequence **AP9** is the most widespread megasequence in Iraq.

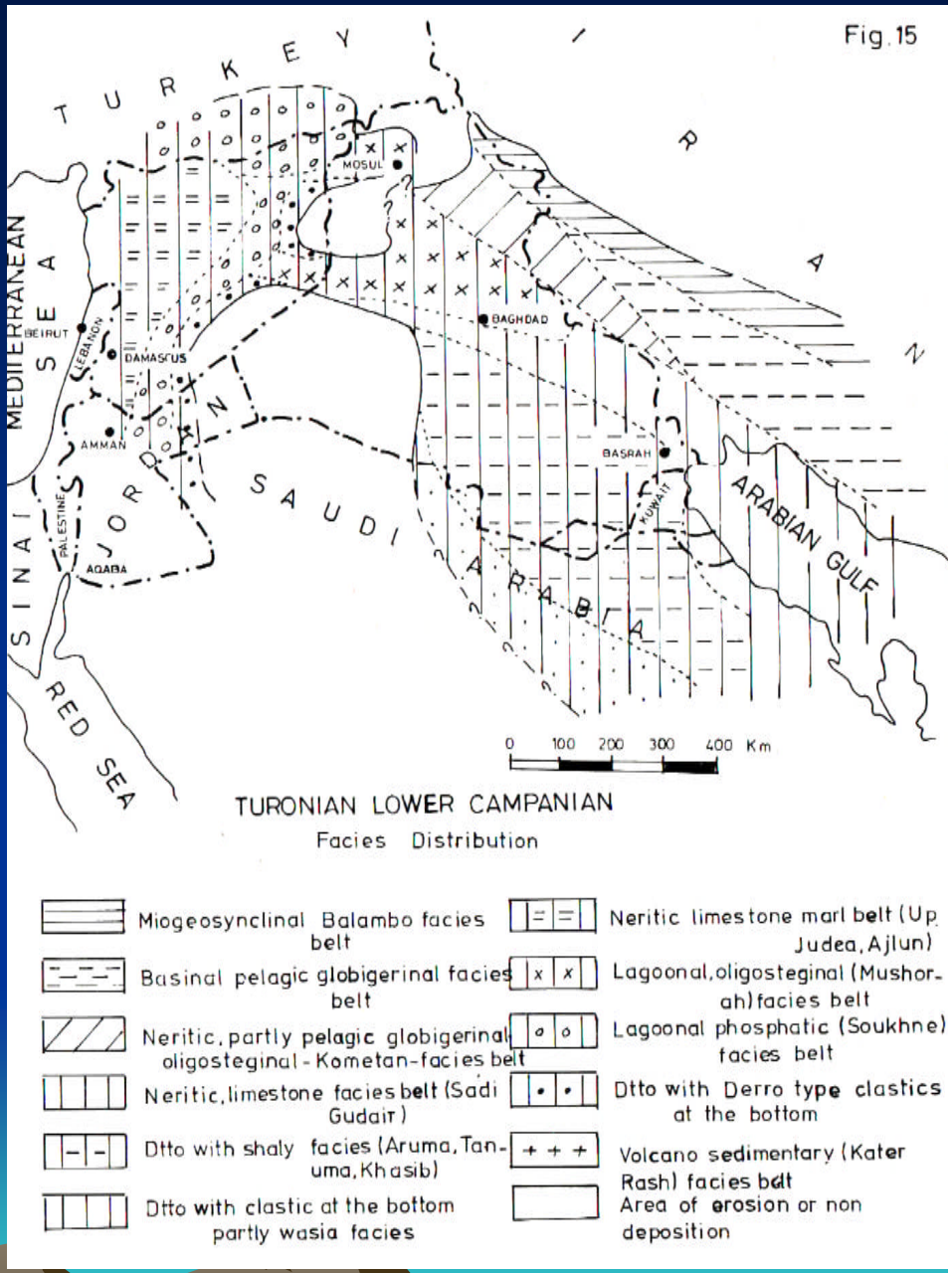
This basin was continuing towards the southeast, but it became shallower and less subsiding on the area of the Mesopotamian Zone to the southeast of Kut and Dujaila.



The **Khasib Formation** is the most near shore unit of this Subcycle. The formation has a bipartite lithological division. The lower part (20 m. thickness) is composed of dark grey and greenish grey shale, alternating with grey, fine grained, marly limestone. The upper division (30 m. thickness) consists of grey, fine grained, marly limestone only.

The depositional environment of the formation had been mostly lagoonal as evidenced by the prevailing oligosteginal fauna and by the dwarfed character of the other Fossils, so it was considered by Jassim & Goff (2006) as deep inner shelf and lagoons. The position of the sequence favours the Turonian-Lower Campanian age.

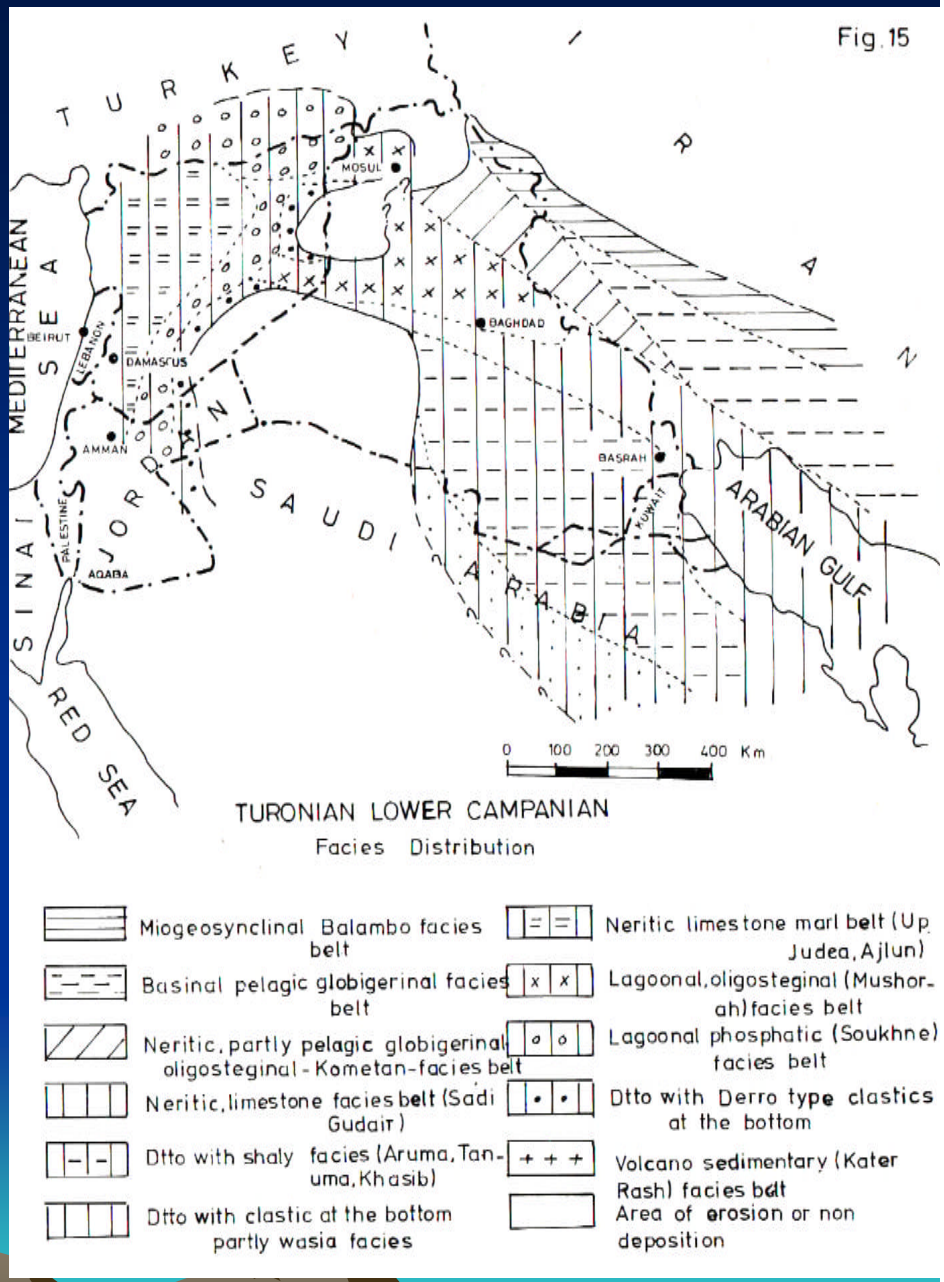
The **Tanuma Formation** is composed of black fissile, sometimes pyritic shale with streaks of grey, microcrystalline, marly, detrital limestone, sometime glauconitic. the sediments of a near shore basin with apparently sometimes restricted communication with the open sea and with partly euxinic, partly lagoonal episodes. The fossils are not decisive for age determination.



The **Sa'di Formation** is the highest, thickest, and most widespread formation of the tripartite Turonian - Early Campanian Subcycle of South Iraq.

The formation being composed of white, chalky, marly, globigerinal limestone with one well developed marl bed of 60 m. thickness. The formation is typical neritic sediment, with clearly marked open sea influences, testified by the frequent occurrence of planktonic foraminiferal faunas (deep inner shelf facies (Jassim & Goff, 2006)).

The age of the formation was not exactly ascertained. Similarly as it is suggested for the Khasib and Tanuma, Saidi considered by Buday (1980) as a younger part of the Turonian - Lower Campanian Subcycle. The lower contact of the formation is usually conformable and gradational. The upper boundary is usually an unconformity.

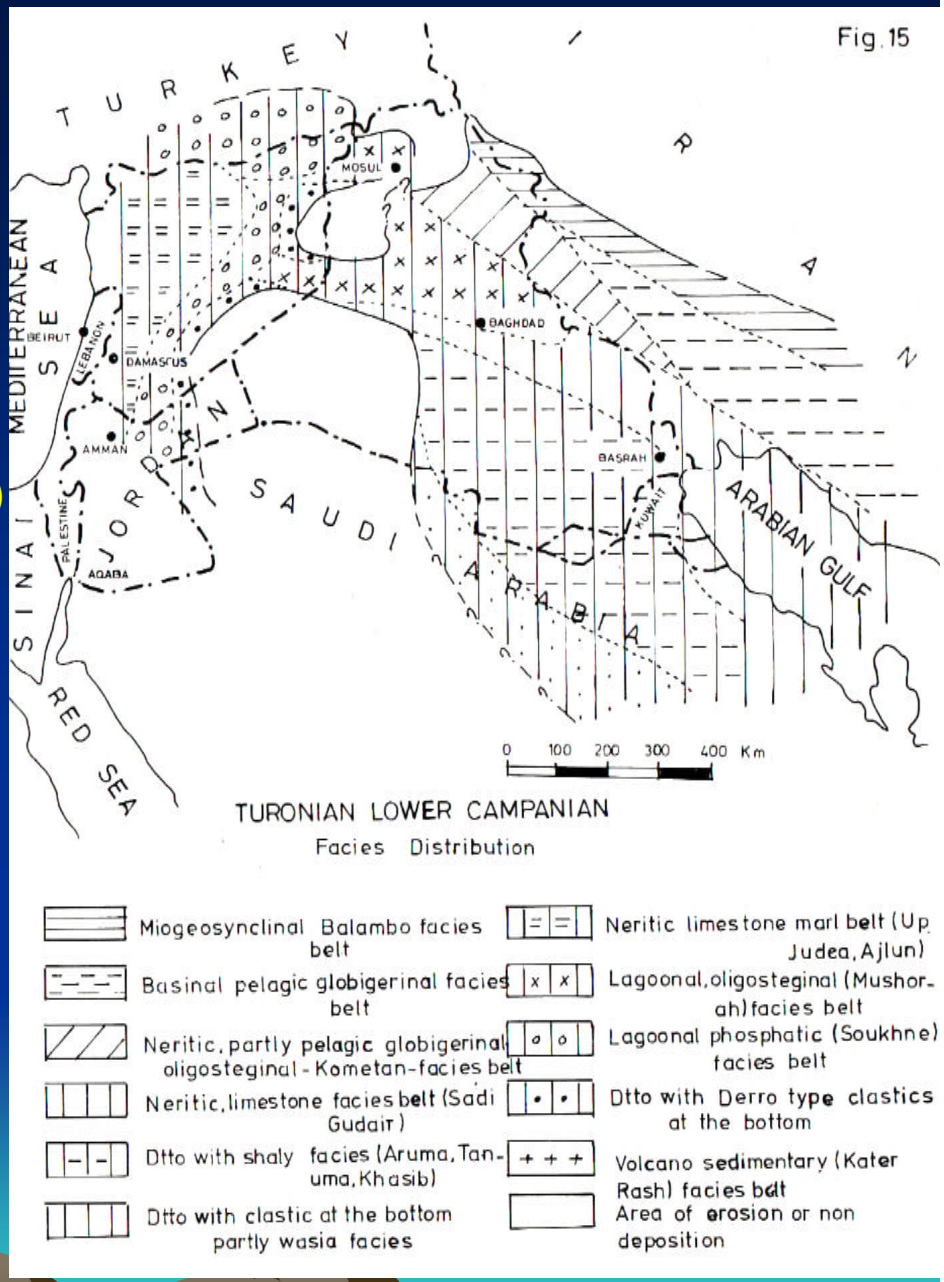


The **Kometan Formation** is the most widespread Turonian formation of northern and central Iraq. The formation is composed of light grey, thin bedded, globigerinal - oligosteginal limestone, locally silicified, with chert concretions in occasional beds, and glauconitic, especially at the base.

The formation had been laid down in different environments, attributed by Jassim & Goff (2006) as outer shelf and basinal. The **Mushorah** facies represents the purely oligosteginal facies, deposited in a partly isolated basin, in which, sometimes, hypersaline conditions occurred.

The **Gulneri Formation** occupies a somewhat peculiar position within this subcycle, because it is separated by breaks from both the underlying Cenomanian and the overlying Turonian units.

The formation consists of black, bituminous, finely laminated, calcareous, shale with some glauconite and collophane in its lower part. Considered by Jassim &Goff (2006) as a restricted deep basin facies. The age of the formation is Lower Turonian.

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