Facies analysis of the Middle to Late Cambrian tidalites in Zarand area - Central Iran

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Abstract

The Middle to Late Cambrian deposits have several outcrops in Kerman Province - Central Iran. These deposits have been introduced as Kuhbanan Formation. This formation has a thickness of about 330 meters in east of Zarand city and has been studied for tidal facies analysis. The Kuhbanan Formation is disconformably overlain with Ordo-Silurian clastic deposits and also the formation is disconformably underlain by the Top Quartzites of the Early Cambrian Dahu Formation. Based on stratigraphic studies, the Kuhbanan Formation is devided into 4 members in Zarand area. All deposits in members 1 and 3 and some deposits of member 4 were formed in tidal flats. Field and petrographic studies of the Kuhbanan tidalites led to recognization of carbonate, siliciclastic, and mixed carbonate-siliciclastic facies groups. Detailed facies analysis of the Kuhbanan Formation resulted in recognition of three sequences (3^{rd} order cycles) equivalent to the second half of the Sauk Sequence. After a global sea-level rising in the Late Early Cambrian and during the expanding of shallow seas, these deposits were formed on the northern margin of the Gondwana Super Continent in a rift basin as homoclinal ramp facies.

Keywords: Kuhbanan Formation, Cambrian, Tidalites, Ramp, Zarand, Central Iran

Introduction

The first Cambrian fossils discovered in Central Iran were identified by King among the material collected near Kuhbanan by R. C. Jennings and K. Washington Gray (in Hukriede *et al*., 1962). The fauna included Redlichia chinensis Walcott, Anomocare megalurus, Obolus (?) sp., and Hyolithes sp., indicating late Early Cambrian to Middle Cambrian age. The beds containing these fossils from a 20-40 m thick zone of black platy limestone, shale and dolomite reaching a thickness of about 200 meters and unconformably overlying the top quartzite of the Dahu Formation. Hukriede *et al*. (1962) found the fossil-horizon to be a persistent marker in the wider Kerman-Kuhbanan-Ravar area. The Cambrian beds of Kuhbanan seem to correlate with the Kalshaneh Formation of the Tabas area and with some members of the Mila Formation of Northern Iran.

Methods of study

To determine facies types and their lateral and vertical variations of the Kuhbanan Formation in Zarand area, one outcrop section was studied (Fig.1). A total of 280 thin sections and polished surfaces of representative lithofacies were studied to provide petrographic details (composition, texture, fabrics and structures) to enhance the field descriptions. Grains and matrix percentages were estimated using visual percentage chart in Flügel (1982). The textural scheme of Dunham (1962) was used to classify carbonate rocks, but here

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the upper size limit for matrix was considered to be 60 microns. The siliciclastic facies classified according to Folk's ideas (Folk, 1974). Facies types and their depositional settings are determined based on compositional, textural, fabrics and structural (field and petrographic) criteria and comparison with modern and ancient environments (e.g., Purser, 1973; Tucker and Wright. 1990; Flügel, 2004).

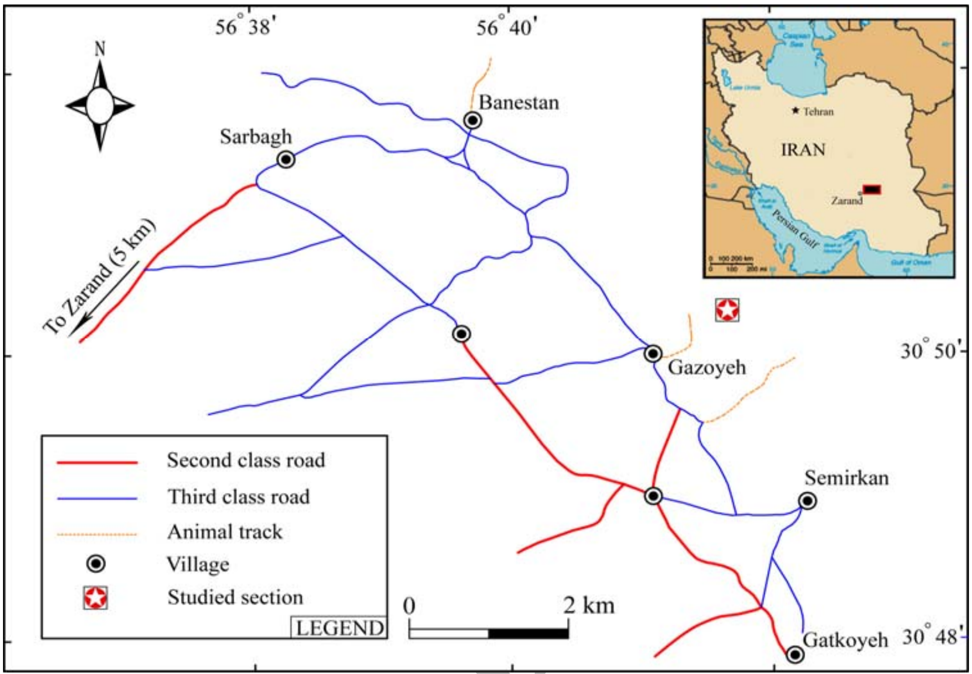


Fig.1 Simplified map of the study area in northeast of Zarand City, Kerman Province

Regional stratigraphy

The Kuhbanan Formation (Middle - Late Cambrian) has several outcrops in Kerman Province-Central Iran. Huckriede *et al.* (1962) introduced the same deposits for the first time. This formation has a thickness of about 330 meters in east of Zarand city (Fig.1) and has been studied for tidal facies analysis. The Kuhbanan Formation is disconformably overlain with Ordo-Silurian clastic deposits and also the formation is disconformably underlain by the Top Quartzites of Early Cambrian Dahu Formation (Fig.2). Based on stratigraphic studies, the Kuhbanan Formation is devided into 4 members in Zarand area (Fig3). Members 1 and 3 mostly consist of sandstones, clastic mudstones and some dolomite layers. Members 2 and 4 consist of limestones and dolomites (Fig.4). All deposits in members 1 and 3 and some deposits of member 4 were formed in tidal flats.

Facies analysis and depositional environ-ments

Field and petrographic studies of the Kuhbanan Formation led to recognition of a wide spectrum of facies that are grouped into the following facies associations:

1- Carbonate facies association: This facies association consists of four facies groups that belong to (A) tidal flat, (B) lagoon, (C) bioclastic/ oolitic barrier and (D) open marine. These groups consist of the following facies:

A- Tidal flat facies:

A_1) Laminated dolomudstone with evaporite casts and birdseyes (supratidal environment) (Fig. 5A).

A_2-1) Sandy dolomitic lime mudstone (upper intertidal sub-environment) .

A_2-2) Dolomitic lime mudstone (upper intertidal sub-environment) (Fig. 5B) .

A_2-3) Dolomitic peloid lime mudstone/ wackestone (middle intertidal sub-environment).

A_2-4) Oncoidal, undulatory, columnar and domal dolomitized stromatolite boundstone (intertidal environment and tidal channel sub-environment) (Fig. 5C) .

B- Lagoonal facies:

B_1) Sandy peloid packstone (shallow lagoon) (Fig. 5D).

B_2) Dolomitized ooid peloid wackestone (deeper lagoon).

B_3) Sorted bioclast peloid grainstone (back barrier logoon) (Fig. 5E) .

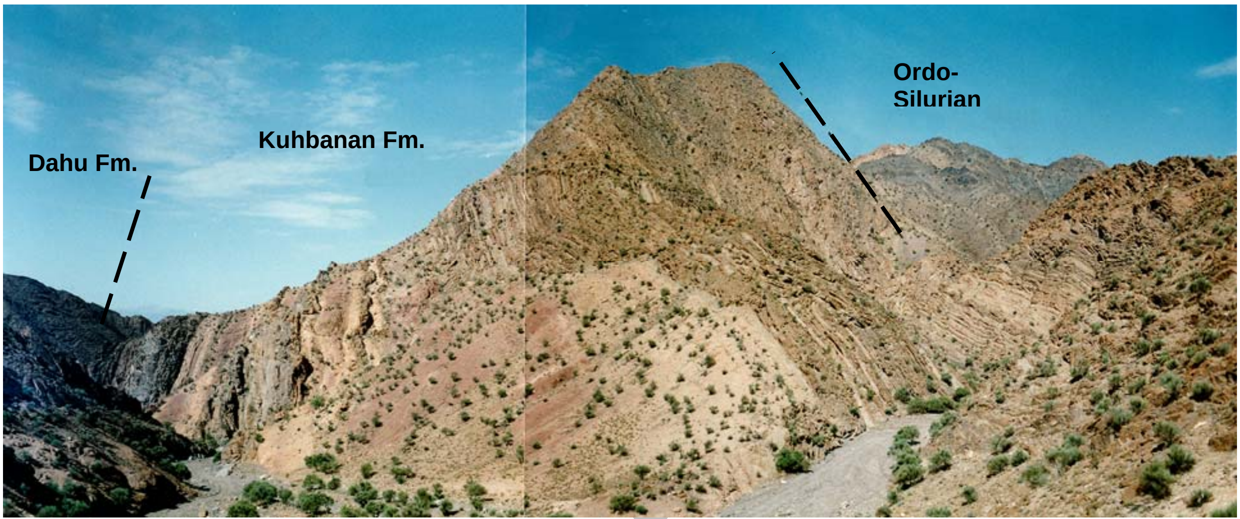


Fig.2 A complete section of the Kuhbanan Formation in Zarand area- view to the west.

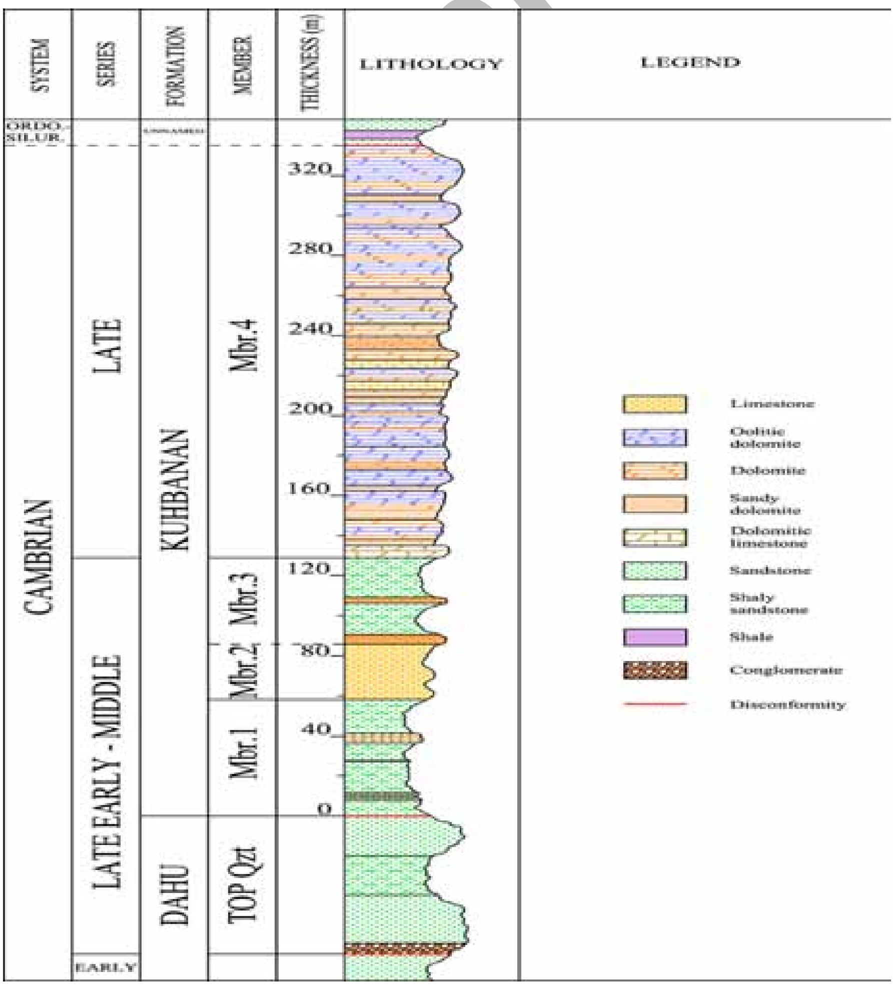


Fig.3 Stratigraphic column of the Kuhbanan Formation in Zarand area

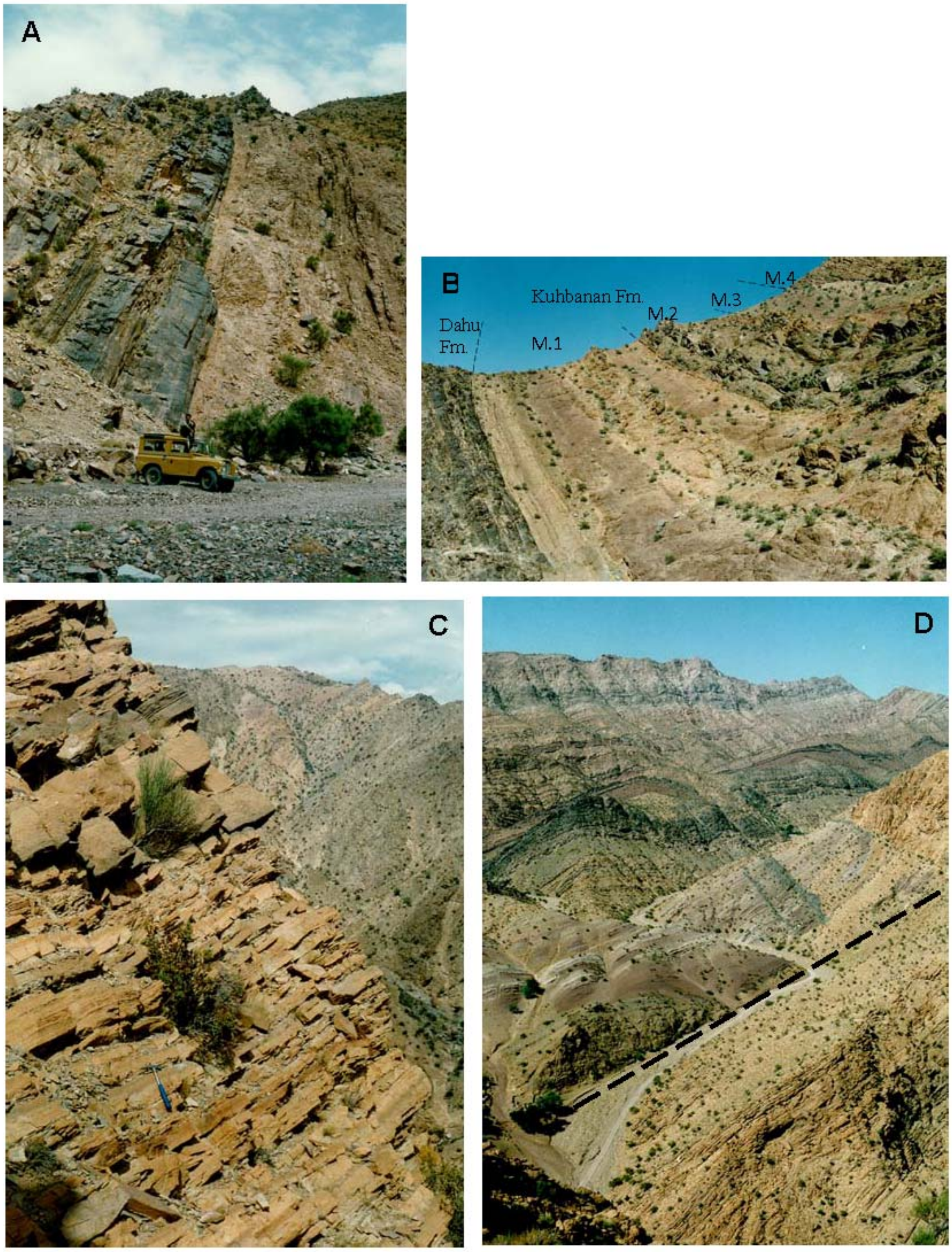


Fig.4 A) Erosional contact between purple shales (right) and the Top Quartzite (left) of the Dahu Formation, view to the southeast. B) Alternation of carbonate and siliciclastic rocks of the Kuhbanan Formation members, view to the west. There is an erosional contact between Dahu and Kuhbanan Formations. C) Tidal carbonates in member 4 of the Kuhbanan Formation, view to the east. D) Upper erosional contact of the Kuhbanan Formation (down) and Ordo-Silurian rocks (up), view to the northeast

C- Barrier facies:

C_1) Sorted ooid grainstone (oolitic bar).

C_2) Sorted echinoderm grainstone (bioclastic bar) .

C_3) bioclast ooid grainstone (oolitic/ bioclastic bar) (Fig. 5F).

C_4) Unsorted fossiliferous/oolitic intraclast grainstone (barrier tidal channel).

D- Open marine facies:

D_1) Bioclast packstone (fore barrier sub-environment).

D_2) Bioclast wackestone (Shallow marine) (Fig.6A).

D_3) Bioturbated lime mudstone (deeper marine).

2- Siliciclastic facies association: This facies association mostly consists of some terrigenous mudstones/shales with mud cracks. These facies were deposited in intertidal environment.

3- Mixed carbonate-siliciclastic facies association: This group of facies has almost equal amounts of detrital grains and carbonate matrix. Detrital grains are bimodal in origin and are found as eolian rounded coarse sands and fluvial angular fine sands. These mixed facies can be found as dolomitic subchertarenites to sandy dolomites (Fig.6B). Sedimentary structures such as bioturbation and Wavy, lenticular and flaser beddings are common in mixed carbonate-siliciclastic tidal facies. The mixed facies with abundant sands were formed in lower intertidals, but the carbonate rich mixed facies were deposited in upper intertidals.

Facies interpretation and depositional model

In this section, only tidal deposits of the Kuhbanan Formation have been explained. Laminated dolomudstones with evaporite casts, anhydrite/gypsum pseudomorphs and mud cracks are common supratidal facies in the Kuhbanan Formation. Presently, these dolomite types are formed in the Bahamas and the Florida supratidal flats and in sabka areas in the Persian Gulf (Shinn, 1986). Sandy dolomudstones, dolomitized bioturbated peloid mudstones/wackestones and dolomitized stromatolite boundstones are the facies which were deposited in intertidals. Criteria for recognizing intertidal deposits are those related to exposure and include desiccation cracks, fenestrae, evaporate mineral growth, soils and related features.

Lamination is a distinctive feature in intertidal deposits and reflects alternations of sediment input and microbial activities. Sediment transported on to intertidal flats from adjacent subtidal areas, principally during storms, is commonly deposited as millimeter alternations of mud and silt to sand-grade carbonate material. Coarser layers are commonly rippled or graded and mostly peloid-rich (Davies, 1970b; Park, 1977; Hardie & Ginsburg, 1977; Wanless, Tyrell *et al.*. 1988). Where tidal flats are overgrown by mats of cyanobacteria and algae (most common in elevated salinities), these trap and bind fine material to generate a laminated sediment (microbial laminate; also called criptalgal laminate, fenestral laminate or loferite). Microbial communities on tidal flats produce flat mats, or ones with tufted, crinkled or pustular surface morphology (e.g. Logan, Hoffman & Gebelin, 1974; Kinsman & Park, 1976). Under suitable conditions microbial mats can form domal structures or stromatolites; those with relief of more than a few centimeters generally appear to have formed in lower intertidal to subtidal areas (Tucker & Wright, 1990). Irregularities in mat morphology can also be caused by desiccation, mat expansion during growth, evaporate mineral precipitation, or blisters and fenestrae caused by gas generated during decomposition. Mat morphology is less regular in the upper intertidal and supratidal zones where desiccation is severe and fine lamination is rarely preserved. On the lower intertidal flats, in less restricted areas, grazing and borrowing organisms may disrupt or prevent mat growth (Wright & Burchette, 1996).

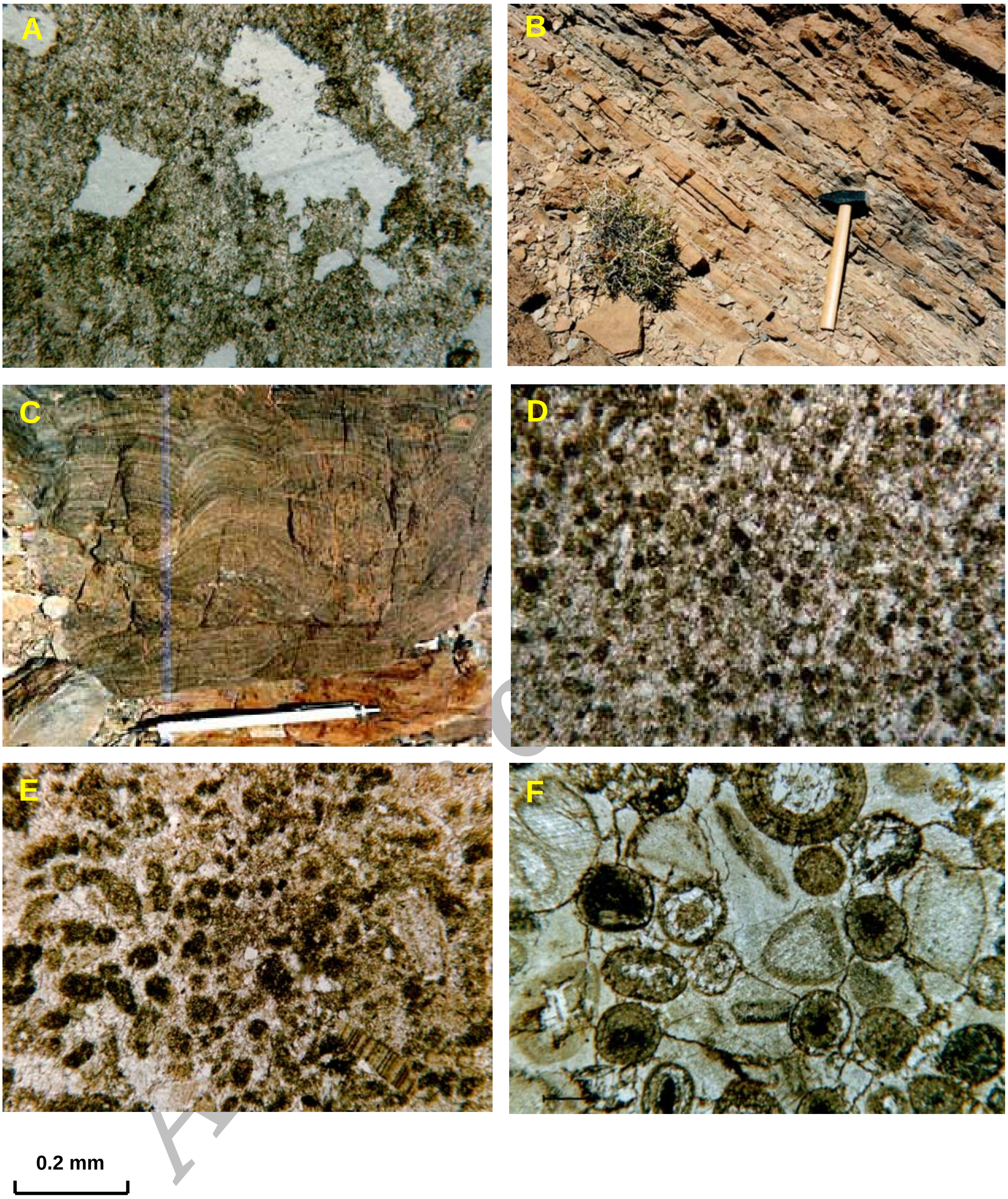


Fig.5 Various facies of the Kuhbanan Formation: A) Supratidal laminated dolomudstone with evaporite casts, birdseyes and fenestra (facies A1). B) Upper intertidal thin bedded dolomitic lime mudstone (facies A2-2). C) Intertidal columnar and domal dolomitized stromatolite boundstone (facies A2-4). D) Lagoonal sandy peloid packstone (facies B1). E) Back barrier sorted bioclast peloid grainstone (facies B3). F) barrier bioclast ooid grainstone with well preserved single ooids and abundant echinoderm fragments (facies C3).

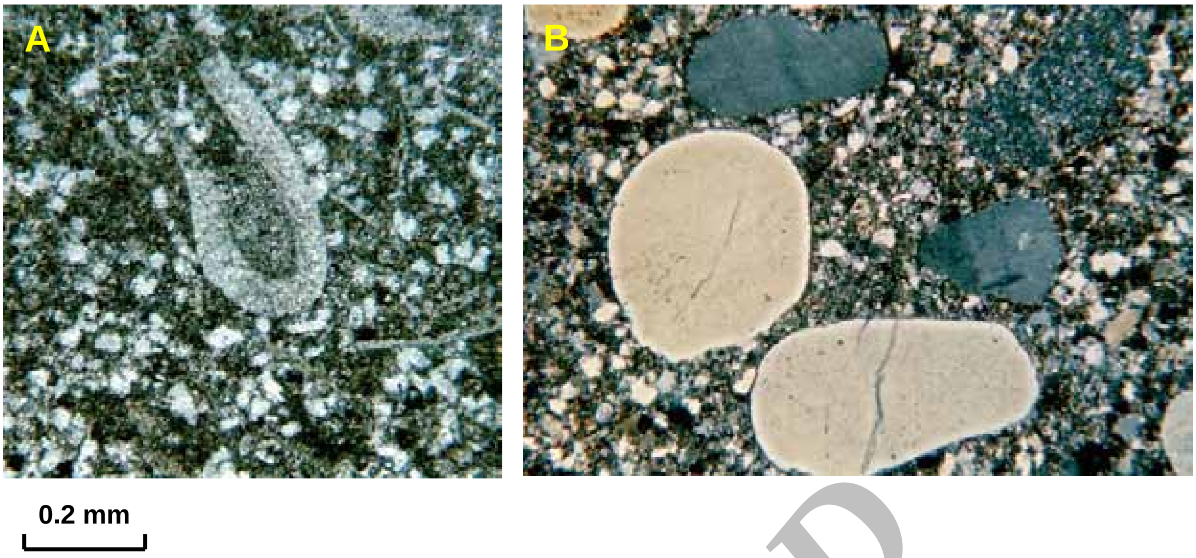


Fig. 6 Various facies of the Kuhbanan Formation: A) Shallow-marine silty bioclast trilobite wackestone (facies D2). B) Bimodal dolomitic subchertarenite to sandy dolomite (mixed carbonate-siliciclastic tidal facies).

The intertidal stromatolitic facies are very common in the Kuhbanan Formation. These stromatolites were formed as patch reefs, oncoids (microbial balls), laterally-linked hemispheroids (LLH-C type) and vertically-stacked hemispheroids (SH-V type) (Logan *et al.*, 1964). Stromatolite bioherms were deposited in agitated shallow tidal channels. There are the same bioherms in the Bahamas (Dill *et al.*, 1986). Some intraclastic layers (flat pebble intrabasinal conglomerates) as proximal storm facies have been recognized among carbonate tidalites of the Kuhbanan Formation.

The siliciclastic tidal facies of the Kuhbanan Formation consist of some clastic mudstones (argillites with mud cracks), and the mixed carbonate-siliciclastic tidal deposits have almost equal amounts of detrital grains and carbonate matrix. As mentioned before, the detrital grains are bimodal in origin and are found as eolian rounded coarse sands and fluvial angular fine sands. These mixed facies can be found as dolomitic subchertarenites to sandy dolomites. Sedimentary structures such as bioturbation and Wavy, lenticular and flaser beddings are common in mixed carbonate-siliciclastic tidal facies. The mixed facies with abundant sands were formed in lower intertidals, but the carbonate rich mixed facies were deposited in upper intertidals.

Microfacies analysis and stratigraphic data indicate that the Kuhbanan deposits were sedimented on a homoclinal ramp (Read, 1985) during Middle to Late Cambrian (Figs.7 and 8). The ramp was a gently sloping surface with a slope of less than 1°. The wave agitated zone was close to the shore, not at a shelf break some distance seaward of the shoreline. In the schematic models, carbonate facies occurrence has shown in four depositional environments. In addition, the amounts of various allochems and the relative energy of the environments have shown as well. We suppose that After a global sea-level rising in the Late Early Cambrian (Vail *et al.*, 1977) and during the expanding of shallow seas, these deposits were formed on the northern margin of the Gondwana Super Continent in a rift basin (Lasemi, 2001) as homoclinal ramp facies.

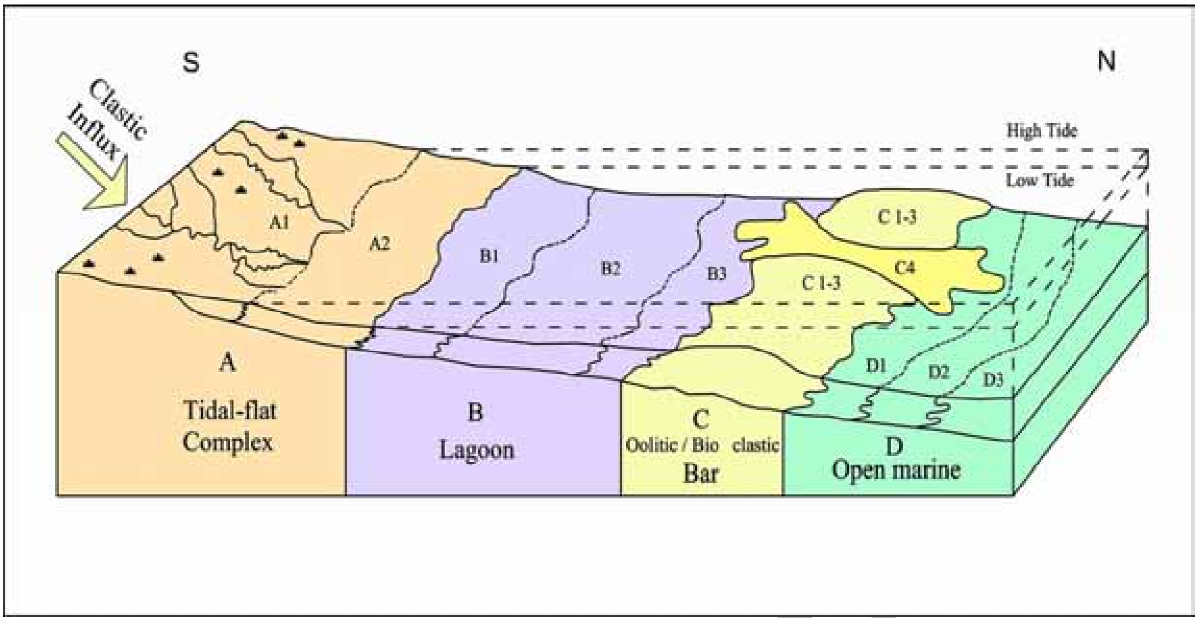


Fig. 7 A scheme of homoclinal ramp as depositional model of the Kuhbanan Formation.

Sequence stratigraphy

Detailed facies analysis of the Kuhbanan Formation resulted in recognition of three sequences (3rd order cycles) equivalent to the second half of the Sauk Sequence (Sloss, 1963). Fig.9 shows that how various facies associations were deposited vertically on the platform. The lithofacies variations reflect different energy levels, tidal ranges, biotas and climates. According to Walther's law (Middleton, 1973), these facies could formed laterally beside each other at the same time. As different parts of the sequences, some small to large scaled parasequences were deposited along the Kuhbanan succession (figs.10 and 11). The peritidal deposits of the Kuhbanan platform interior have been occured in a thick succession comprising tens of discrete meter-scale shallowing-upwards sediment-ary parasequences (fig.9).

Conclusions

1- The Cambrian Kuhbanan Formation in the study area has a thickness of 330 meters and consists of four members. Most of the deposits were sedimented in tidal flat environments.

2- Three major carbonate, siliciclastic and mixed carbonate-siliciclastic facies groups were recognized in Kuhbanan succession.

3- The studied rocks were deposited on a carbonate platform type of homoclinal ramp during protopaleotethys rifting.

4- Three 3rd order cycles (sequences) and several parasequences were recognized in the Kuhbanan Formation.

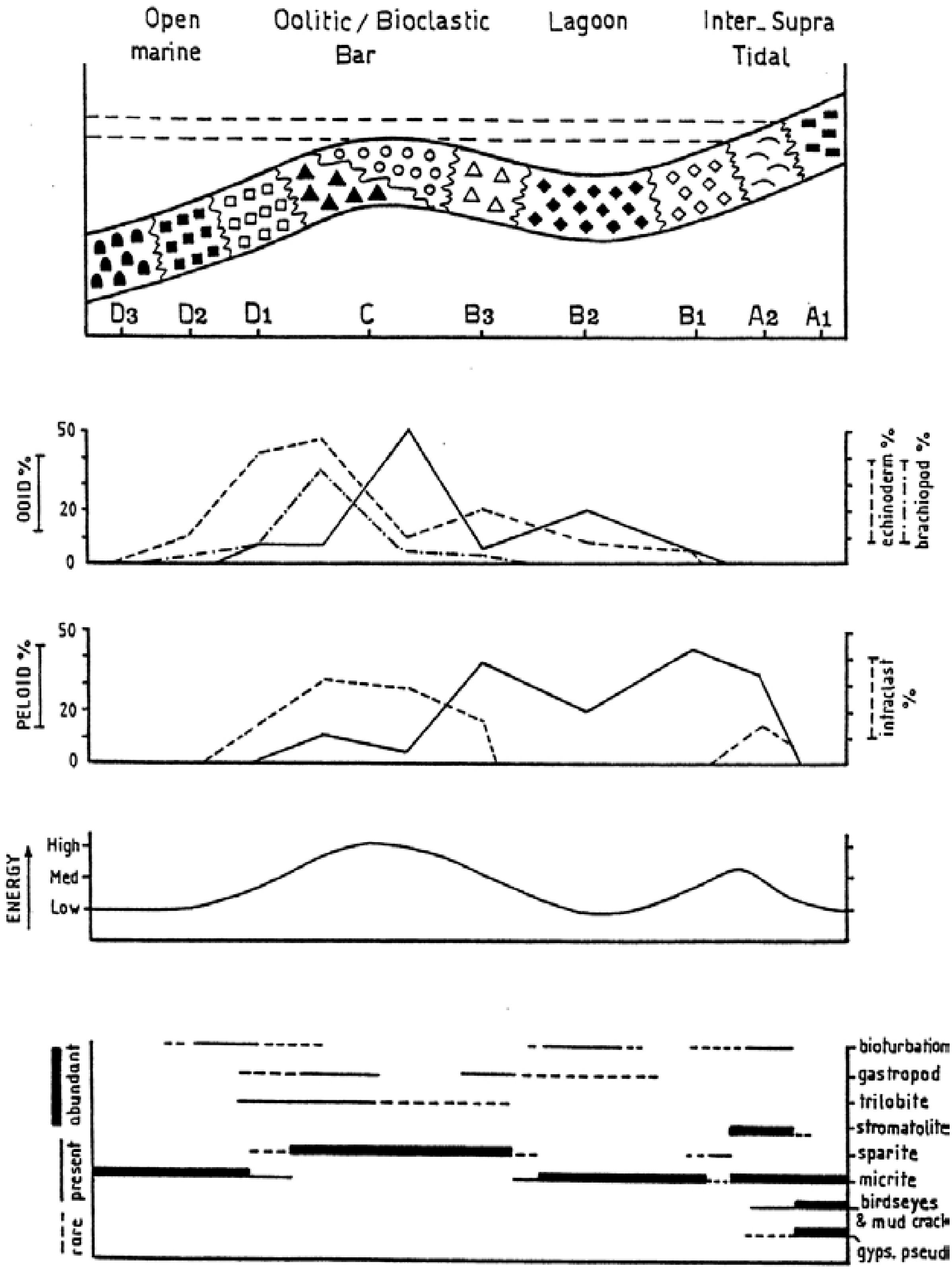


Fig. 8 The amounts of various allochems and the relative energy of the sedimentary environments in the Kuhbanan carbonate platform during Middle-Late Cambrian.

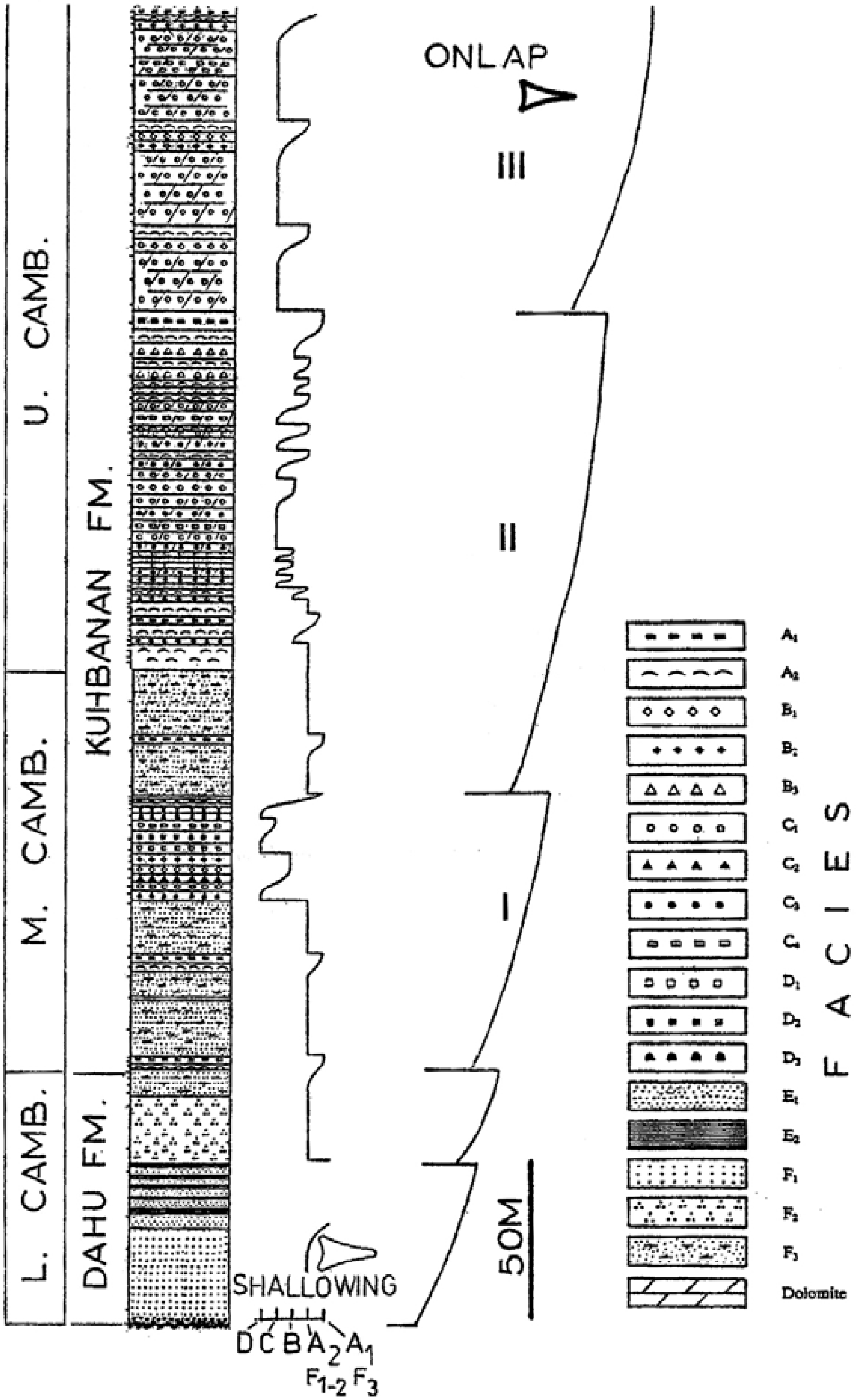


Fig. 9 Facies column and sequence stratigraphy of the Kuhbanan Formation in Zarand area.

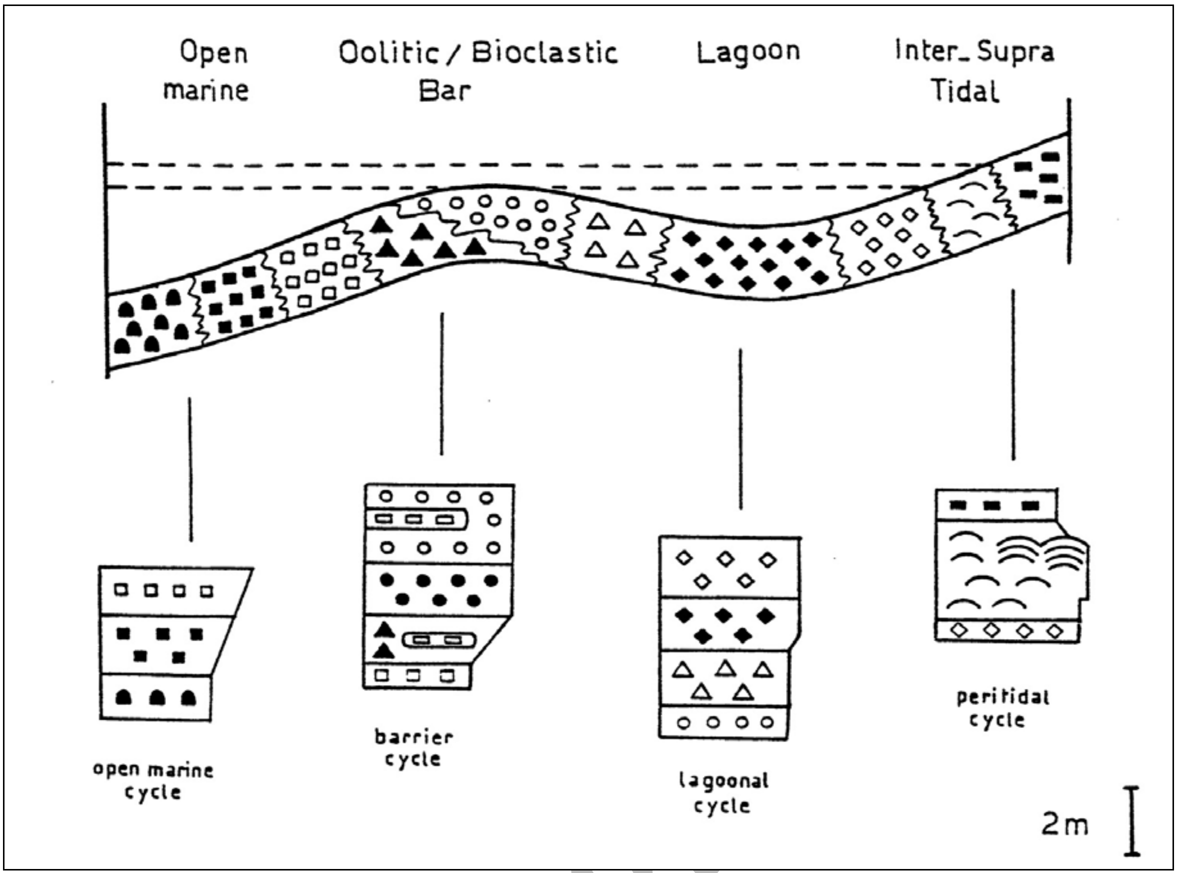
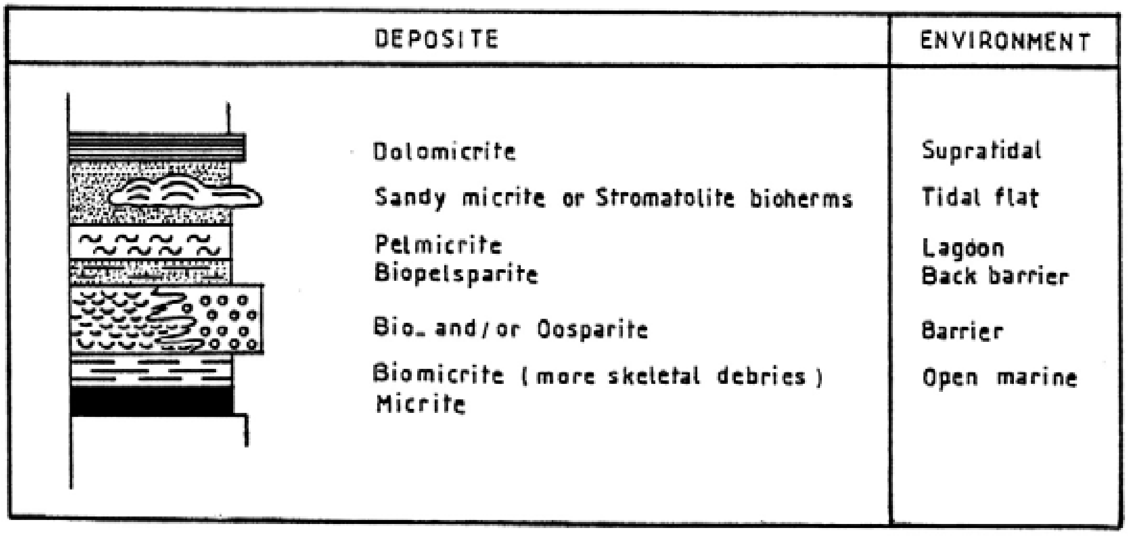


Fig. 10 Various parasequences of the Kuhbanan Formation relative to different depositional environments. The peritidal cycles are more common.



DEPOSITE	ENVIRONMENT
Dolomicrite	Supratidal
Sandy micrite or Stromatolite bioherms	Tidal flat
Pelmicrite Biopelsparite	Lagoon Back barrier
Bio_ and/or Oosparite	Barrier
Biomicrite (more skeletal debries) Micrite	Open marine

Fig. 11 Suggested typical parasequence for carbonate facies of the Kuhbanan Formation.

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