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Lithofacies and microbiofacies of the Upper Cretaceous rocks (Sadr unit) of Nakhlak area in Northeastern Nain, Central Iran

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Abstract

The Upper Cretaceous rocks of Nakhlak area are of great importance due to their unique characteristics, occurring in a solitary mountain near the village of the Nakhlak in Central Iran and attaining a thickness of up to 258 meters. The Cretaceous rocks are bound by two thrust faults at the bottom and at the top, and are defined as the Sadr unit for the first time in the present study. The Upper Cretaceous rocks (Sadr unit) of the Nakhlak area were mainly deposited in shallow to deep marine environments.

The Sadr unit consists of siliciclastic-carbonatic rocks, which can be subdivided into 10 members. Paleontological data from different members of the Sadr unit indicate a Late Cenomanian to Maastrichtian? age.

Key-words : Foraminifera, Algae, Cretaceous, Sadr, Nakhlak, Central Iran

1. Introduction

The Cretaceous rocks of Nakhlak area are situated northeast of Nain (north of Anarak) in Central Iran, covering an area between longitudes 53°.4′ N to 53°.54′ N and latitudes 30°. 30′ E to 33°.37′ E (Figs. 1, 2). In this area, there are rock deposits from the Upper Cretaceous (Late Cenomanian to Maastrichtian?), which attain a thickness of up to 258 meters and are defined as the Sadr unit in the present study for the first time. Of course the Sadr unit is differentiated as a rock unit and cannot be used as a stratigraphical unit. The Sadr unit consists of sandy limestones, calcareous sandstones, sandy-marly limestones, sandy dolomitic limestones and reefal limestones.

The Sadr unit was mainly deposited in shallow to deep marine environments and contains economically valuable minerals. The most important ores are lead, zinc and silver (Bariand, 1963; Burnol, 1968; Holzer and Ghassemipour, 1969; Cherepovsky *et al.*, 1982). These rocks have been a subject of interest for many geologists due to its well-exposed section, considerable thickness, varieties of sedimentary sequences, sedimentary environments, and tectonostratigraphic position. Also, the fast biological changes and the extinction of many fossil groups at the end of Cretaceous time, as well as their causes is of major interest to paleontologists.

The first research on the Anarak area was carried out by Stahl (1897). "Between 1929 and 1969" German geologists carried out some investigations concerning the economical geology in this region.

Davoudzadeh and Seyed-Emami (1972) studied the stratigraphy and paleontology of the Triassic rocks of the Nakhlak area. Vaziri (1996) carried out the lithostratigraphical and biostratigraphical study of the Triassic rocks of the Nakhlak area and described the sedimentary environments of these rocks. He also prepared a geological map of the Nakhlak area on a 1:20.000 scale.

The microfossils of the Sadr unit were studied by Khosrow-Tehrani (1977). He suggested a Cenomanian to

Campanian age for these rocks. The present study shows that the age of the Sadr unit is Late Cenomanian to Maastrichtian? (Fig. 4).

The Sadr unit is bound by two thrust faults at the bottom and at the top. The underlying rocks are Triassic deposits (Pl. 1, fig. 1) of the so-called "Nakhlak group" (Alam, Baqoroq and Ashin formations) and the overlying rocks are Paleocene deposits (Vaziri, 1996, 2001)(Pl. 1, fig. 2).

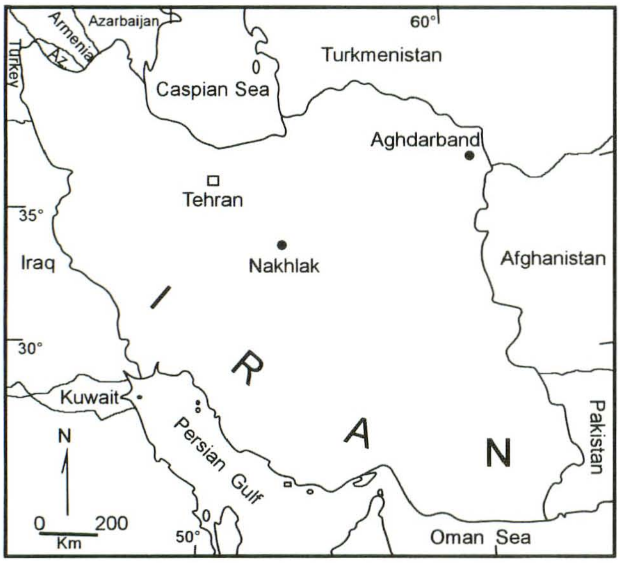

Fig. 1 Location map of the Nakhlak and Aghdarband areas in Iran.

2. Lithostratigraphic description of the Sadr unit

The Sadr unit, overlying the Triassic deposits (Late Scythian-Early Carnian?) by a thrust fault, consists of carbonatic and siliciclastic rocks and can be subdivided into 10 members based on the facies characteristics (Fig. 3).

Member 1 (10 m):

Alternating light grey, medium to thick-bedded sandy limestones and dark grey, thick-bedded cherty limestones with pelecypods (Pl. 1, fig. 3). This member includes the following microfossils (thin sections no. H.N-1 ~ 4): **Foraminifera:** *Globotruncana* sp., *Hedbergella* sp., *Nummofallotia apula* Luperto Sinni, *Pseudolituonella reicheli* Marie, *Ovalveolina ovum* (D'Orbigny) Emend, *Textularia* sp., *Valvulammina* sp. (Pl. 2, figs. 1, 3); **Algae:** *Paraphyllum* sp., *Solenopora* sp.

Member 2 (57 m):

Alternating cream to light green, thin-bedded sandy-marly limestones and light grey to green, thick-bedded marly limestones with brachiopods, echinoid spines,

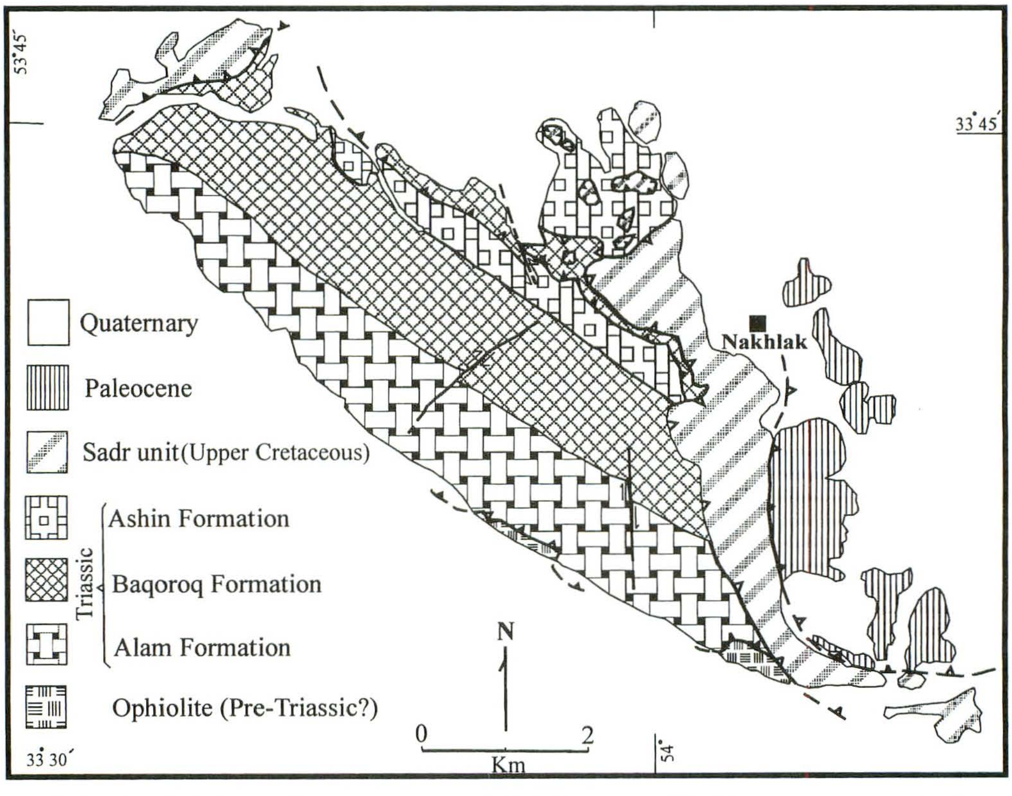

Fig. 2 Geological map of the Nakhlak area (Location shown in Fig. 1), after Alavi *et al.*, 1997.

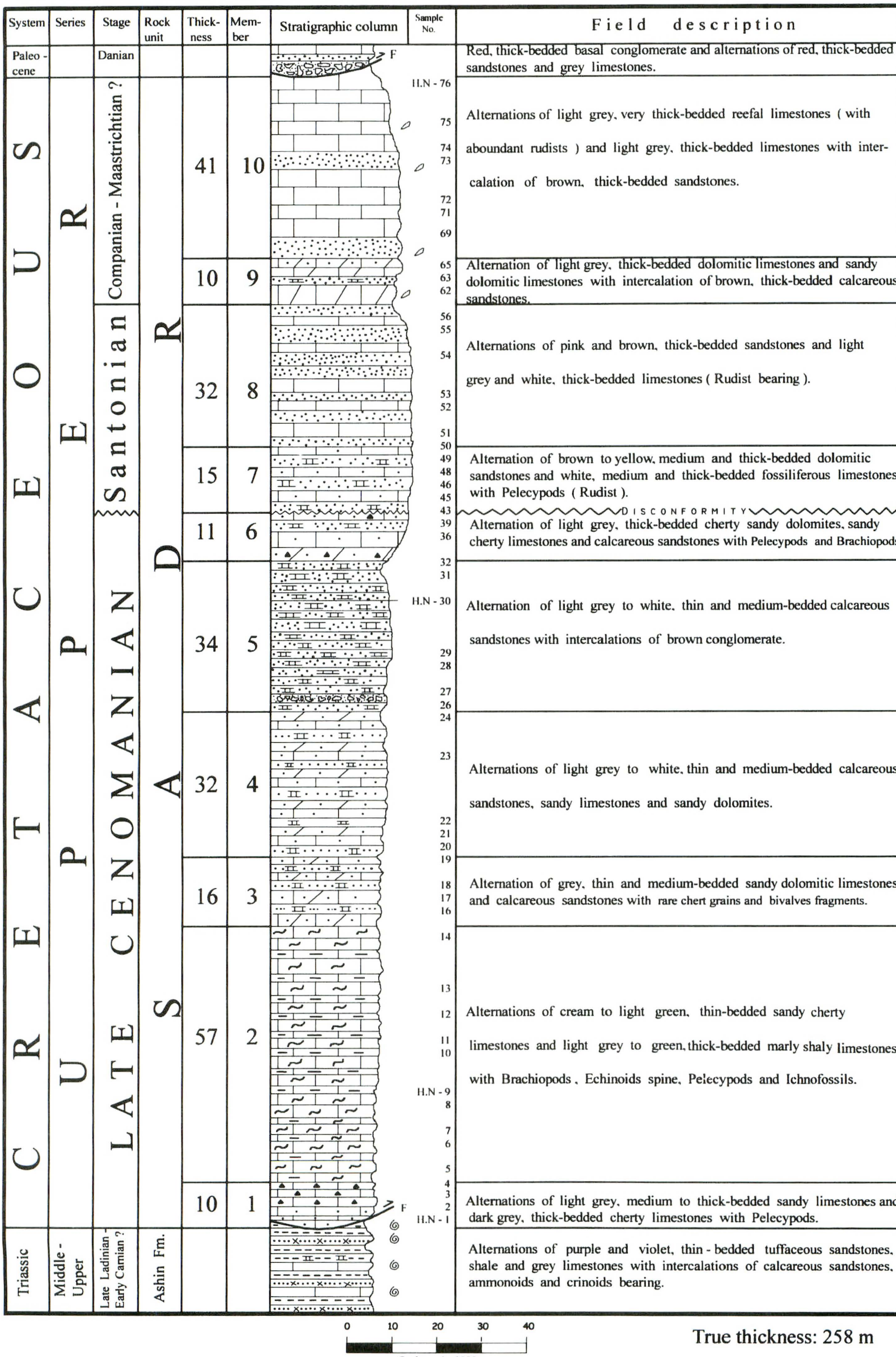

Fig. 3 Lithological characteristics of the Sadr unit in the Nakhlak area, Central Iran.

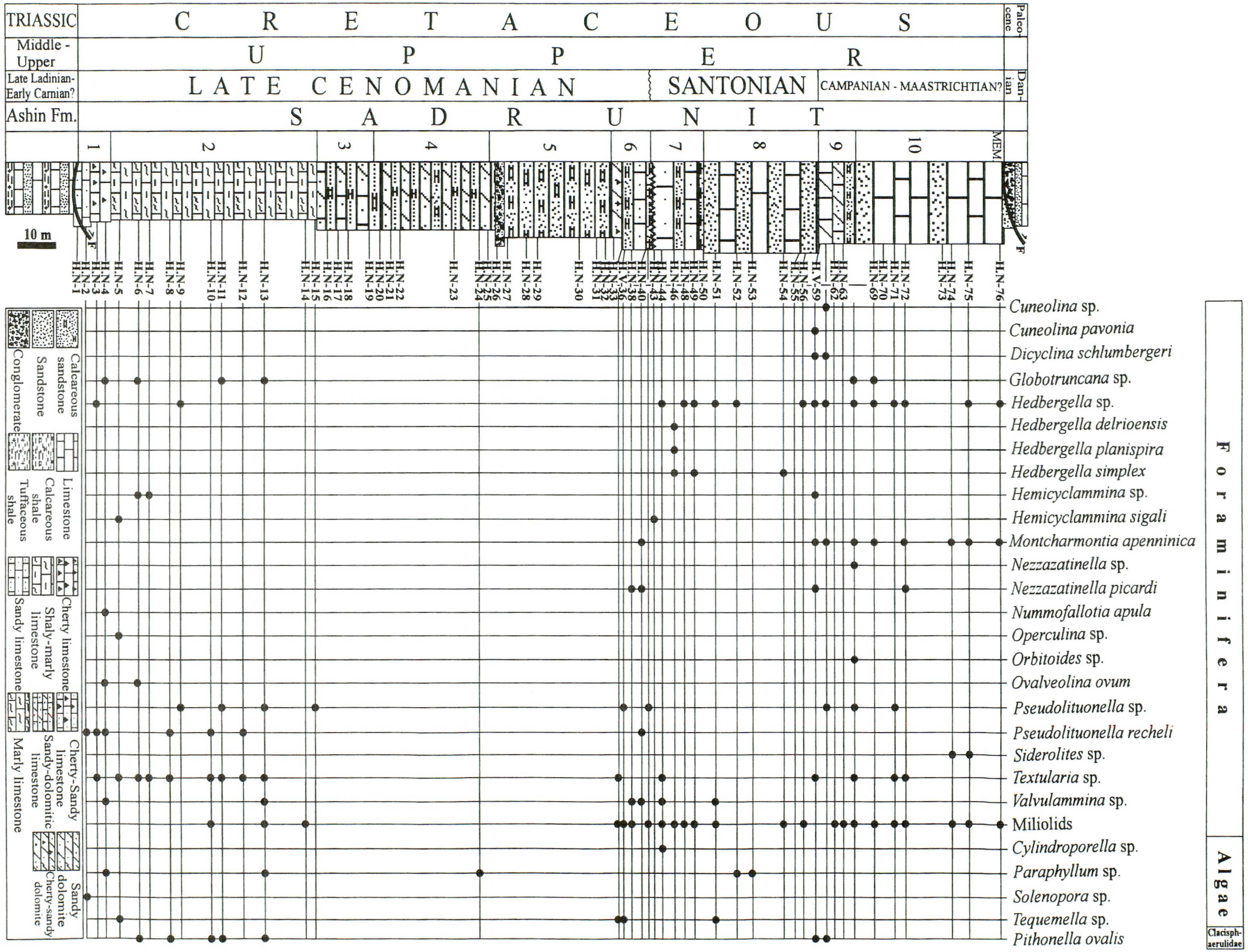

Fig. 4 Stratigraphic distribution of microfossils in the Sadr unit, Nakhlak area, Central Iran.

pelecypods and ichnofossils (Pl. 1, fig. 4). This member includes the following microfossils (thin sections no. H.N-5 ~ 15): **Foraminifera:** *Globotruncana* sp., *Hedbergella* sp., *Hemicyclammina sigali* Maync, *Hemicyclammina* sp., *Operculina* sp., *Ovalveolina ovum* (D'Orbigny) Emend, *Pseudolituonella reicheli* Marie, *Pseudolituonella* sp., *Textularia* sp., *Valvulammina* sp., Miliolids (Pl. 2, fig. 2); **Algae:** *Paraphyllum* sp.; **Calcisphaerulidae:** *Pithonella ovalis* (Kaufmann). Additional fossils are echinoids of the *Epiaster* sp. and *Hemiaster* sp.

Member 3 (16 m):

Alternating grey, thin and medium-bedded sandy dolomitic limestones and calcareous sandstones with rare chert grains and bivalve fragments (thin sections no. H.N-16 ~ 19). No fossils were found in this member.

Member 4 (32 m):

Alternating light grey to white, thin and medium-bedded calcareous sandstones, sandy limestones and sandy dolomites. This member includes algae of the *Paraphyllum* sp. (thin section no. H.N-24)

Member 5 (34 m):

Light grey to white, thin and medium-bedded calcareous sandstones with intercalations of brown conglomerate (Pl. 1, figs. 5, 6). This member lacks any fossil remains (thin sections no. H.N-26 ~ 32).

Member 6 (11 m):

Alternating light grey, thick-bedded sandy-cherty dolomites, sandy-cherty limestones (Pl. 1, fig. 7) and calcareous sandstones with pelecypods and brachiopods. This member includes the following microfossils (thin sections no. H.N-33 ~ 42): **Foraminifera:** *Montcharmontia apenninica* (De Castro), *Nezzatinella picardi* (Henson), *Pseudolituonella reicheli* Marie, *Pseudolituonella* sp., *Textularia* sp., *Valvulammina* sp., Miliolids; **Algae:** *Terquemella* sp.

The mentioned microfossil assemblages in members 1, 2 and 6 suggest Late Cenomanian age for these members.

Member 7 (15 m):

Alternating brown to yellow, medium and thick-bedded dolomitic sandstones and white, medium and thick-bedded fossiliferous limestones with pelecypods (Rudists). This member includes the following microfossils (thin sections no. H.N-43 ~ 50): **Foraminifera:** *Hedbergella delrioensis* (Carsey), *Hedbergella planispira* (Tappan), *Hedbergella simplex* (Morrow), *Hedbergella* sp., *Hemicyclammina sigali* Maync, *Textularia* sp., *Valvulammina* sp., Miliolids (Pl. 2, figs. 10, 11); **Algae:** *Cylindroporella* sp.

The member 7 overlies the member 6 disconformably and there are no Turonian-Coniacian deposits. Biostratigraphical studies of the Upper Cretaceous rocks by Khosrow-Tehrani (1977) in the Choopanan and Hafttoman areas (adjacent to the Nakhlak area) and also by Faryabi (2003) in the Kerman area have shown that there is a hiatus of deposition during Turonian-Coniacian time.

Member 8 (32 m):

Alternating pink and brown, thick-bedded sandstones and light grey and white, thick-bedded rudist bearing limestones. This member includes the following microfossils (thin sections no. H.N-51 ~ 58): **Foraminifera:** *Hedbergella simplex* (Morrow), *Hedbergella* sp., *Textularia* sp., *Valvulammina* sp., Miliolids; **Algae:** *Paraphyllum* sp., *Terquemella* sp.

The mentioned microfossil assemblages in members 7 and 8 suggest Santonian age for these members.

Member 9 (10 m):

Alternating light grey, thick-bedded dolomitic limestones and sandy dolomitic limestones with intercalations of brown, thick-bedded calcareous sandstones. This member includes the following microfossils (thin sections no. H.N-59 ~ 68): **Foraminifera:** *Cuneolina pavonia* D'Orbigny, *Cuneolina* sp., *Dicyclina schlumbergeri* Munier-Chalmas, *Globotruncana* sp., *Hedbergella* sp., *Hemicyclammina* sp., *Montcharmontia apenninica* (De Castro), *Nezzazatinella picardi* (Henson), *Nezzazatinella* sp., *Orbitoides* sp., *Pseudolituonella* sp., *Textularia* sp., Miliolids (Pl. 2, figs. 4-8, 14); **Calcisphaerulidae:** *Pithonella ovalis* (Kaufmann).

Member 10 (9 m):

Alternating light grey, very thick-bedded reefal limestones (with abundant rudists: *Hippurites*, Pl. 1, fig. 8) and light grey, thick-bedded limestones with intercalations of brown, thick-bedded sandstones. This member includes the following microfossils (thin sections no. H.N-69 ~ 76): **Foraminifera:** *Globotrancana* sp., *Hedbergella* sp., *Montcharmontia apenninica* (De Castro), *Nezzazatinella picardi* (Henson), *Pseudolituonella* sp., *Siderolites* sp., *Textularia* sp., Miliolids (Pl. 2, figs. 9, 12, 13, 15).

The mentioned microfossil assemblages in members 9 and 10 suggest Companian to Maastrichtian? age for these members. Member 10 includes also the following rudists: *Agriopleura* sp. and *Vaccinites vredenburggi* Kühn.

Paleocene deposits (Pl. 1, fig. 2) separated by a thrust fault (Vaziri, 1996, 2001) cover the top of the Sadr unit. The pebbles and fragments of the Upper Cretaceous limestones in the basal red conglomerate and conglomeratic sandstones of the Paleocene sequence and the sedimentation gap at this boundary indicates that there is a disconformity between the Sadr unit and the Paleocene rocks and that the thrusting is secondary.

The Paleocene rocks (Danian-Thanetian) of the Nakhlak area consist of red, basal conglomerate and alternations of red, thick-bedded conglomeratic sandstones, sandstones, green marls, dolomite and grey limestones (Pl. 1, fig. 2) and are defined as the Khaled unit by Ipchiler (2004) for the first time. The sedimentary environment ranges of the Khaled unit include continental environments and shallow marine of the continental margin to deep pelagic environments.

3. Sedimentary facies and depositional environment of the Sadr unit

The sedimentary succession of the Upper Cretaceous rocks (Sadr unit) in the Nakhlak area are subdivided into three groups, including carbonates, siliciclastic, and mixed carbonatic-siliciclastic facies. The sedimentological and paleontological data indicate that these rocks were mainly deposited in shallow to moderately deep marine environments. There is no evidence of sedimentation in continental environments among the different rock types. The carbonate facies, showing various sedimentary structures and textural characteristics, were deposited in different sub-environments. Some rocks have laminations, evaporate pseudomorphs, fenestral fabrics, and mud cracks, indicating tidal flat environment. Other deposits with micritic matrix belong to restricted marine environments. Some facies include bound macrofossils such as rudist fragments which accumulated as barrier and patch reefs rocks, alternating with some shales and marls deposited in moderately deep marine environments (below fair weather wave base and storm wave base). The siliciclastic facies were mainly deposited along marine siliciclastic shorelines. Most of these deposits had formed sand bars. The mixed facies types are related to mixed carbonatic-siliciclastic shelves, producing lots of intraclasts of carbonate rocks, a great number of quartz and chert granules, and pebbles in many facies. These facts indicate that, sometimes, the facies were deposited under storm-dominated conditions.

4. Tectonic setting of the Nakhlak region

The Nakhlak region is located in the Central Iran structural region, north of the Yazd block and consists of Ophiolite rocks (Pre-Triassic?) and Triassic, Upper Cretaceous, and Paleocene sedimentary deposits (Fig. 2). The investigations of Davoudzadeh and Seyed-Emami (1972), Ruttner (1991) and Vaziri (1996) have shown that the Triassic rocks of the Nakhlak area are different from all the other areas in Central Iran and cannot be compared with Triassic rocks in other areas of Iran, with the exception of the Triassic deposits known from Aghdarband region in northeastern Iran (Fig. 1).

According to Alavi *et al.* (1997), the position of the Triassic rocks of the Nakhlak area at the time of formation were situated in the southern margin of the Turan plate (southern Laurasia supercontinent), adjacent to Aghdarband and they explain the transportation mechanism of these rocks to its present position in Central Iran structural zone. The Triassic rocks of Nakhlak were separated from the southern margin of the Turan plate in the Late Triassic period, thrusted by the Iran plate. After the counterclockwise rotation of 135 degrees, the micro-continent of east central Iran moved to its final position (Soffel and Forster 1980; Davoudzadeh *et al.*, 1981; Davoudzadeh and Schmidt 1983; Matsumoto *et al.*, 1995).

The comparison between the Triassic rocks of the Nakhlak area and other Triassic rocks of Iran that belonged to the Gondwana supercontinent shows that there is no similarity between them, because the Triassic rocks of other parts of Iran are fundamentally carbonatic facies (dolomite, limestone and dolomitic limestone). These rocks were deposited in a shallow marine environment in the continental shelf, whereas the Triassic rocks of Nakhlak (except for the Baqoroq Formation that has been deposited in continental environment) were deposited in shallow to moderately deep continental slope and even in the continental slope, and are mainly composed of clastic turbidites in most cases mixed with volcaniclastic fragments.

Our lithological and paleontological data indicate that the Upper Cretaceous rocks (Sadr unit) of the Nakhlak area are similar to other Upper Cretaceous rocks in different parts of Central Iran, which belong to the central Iranian plate. Therefore, the Sadr unit after the 135 degree rotation the micro-continent of east central Iran and removing Triassic rocks to the Nakhlak area, overlies on the Triassic rocks by a thrust fault in post Paleocene (Thanetian) time.

5. Summary and Conclusions

1. The Upper Cretaceous rocks of the Nakhlak area occur in a solitary mountain in Central Iran and attain a thickness of up to 258 meters.

2. In the present study, the Upper Cretaceous rocks of the Nakhlak area are called the Sadr unit for the first time.
3. The Sadr unit overlies the Triassic rocks by a thrust fault and are bound by overlying Paleocene through a second thrust fault. In fact, there is a disconformity between the Sadr unit and Paleocene rocks and thrusting is secondary.
4. Paleontological data from different levels of the Sadr unit indicate a Late Cenomanian to Maastrichtian? age.
5. The Sadr unit consists of sandy limestones, calcareous sandstones, sandy-marly limestones, sandy dolomitic limestones and reefal limestones. These rocks were deposited in shallow to deep marine environments and have economically valuable minerals such as lead, zinc and silver.
6. Lithological and paleontological data indicate that the Upper Cretaceous rocks of the Nakhlak area (Sadr unit) are equivalent to the shallow platform carbonate successions of the Upper Cretaceous rocks in Central Iran, which belong to the central Iranian plate.

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Plate 1

Fig. 1:	The Sadr unit and fault-bound Triassic rocks.
Fig. 2:	The Sadr unit and fault-bound Paleocene rocks.
Fig. 3:	Alternation of sandy limestone and cherty limestone in member 1 of the Sadr unit.
Fig. 4:	Alternations of sandy-marly limestone and marly limestone in member 2 of the Sadr unit.
Fig. 5:	Calcareous sandstone of the member 5.
Fig. 6:	Conglomerate of the member 5.
Fig. 7:	Sandy-cherty limestone of the member 6.
Fig. 8:	Reefal limestone with abundant rudists of the member 10.

Plate 2

Fig. 1:	*Pseudolituonella reicheli* Marie, thin section H.N-2; ×100
Fig. 2:	*Pseudolituonella reicheli* Marie, thin section H.N-12; ×100
Fig. 3:	*Valvulammina* sp., thin section H.N- 4; ×100
Fig. 4:	*Dicyclina schlumbergeri* Munier-Chalmas, thin section H.N-59; ×25
Fig. 5:	*Cuneolina pavoni* D'Orbigny, thin section H.N-59; ×20
Fig. 6:	*Cuneolina pavoni* D'Orbigny, thin section H.N-59; ×100
Fig. 7:	*Cuneolina pavoni* D'Orbigny, thin section H.N-59; ×80
Fig. 8:	*Nezzazatinella picardi* (Henson), thin section H.N-59; ×64
Fig. 9:	*Nezzazatinella picardi* (Henson), thin section H.N-72; ×40
Fig. 10:	*Hedbergella simplex* (Morrow), thin section H.N-46; ×100
Fig. 11:	*Hedbergella* sp., thin section H.N-44; ×100
Fig. 12:	*Hedbergella* sp., thin section H.N-76; ×80
Fig. 13:	*Hedbergella* sp., thin section H.N-72; ×80
Fig. 14:	*Montcharmontia apenninica* (De Castro), thin section H.N-59; ×100
Fig. 15:	*Montcharmontia apenninica* (De Castro), thin section H.N-69; ×50

Plate 1

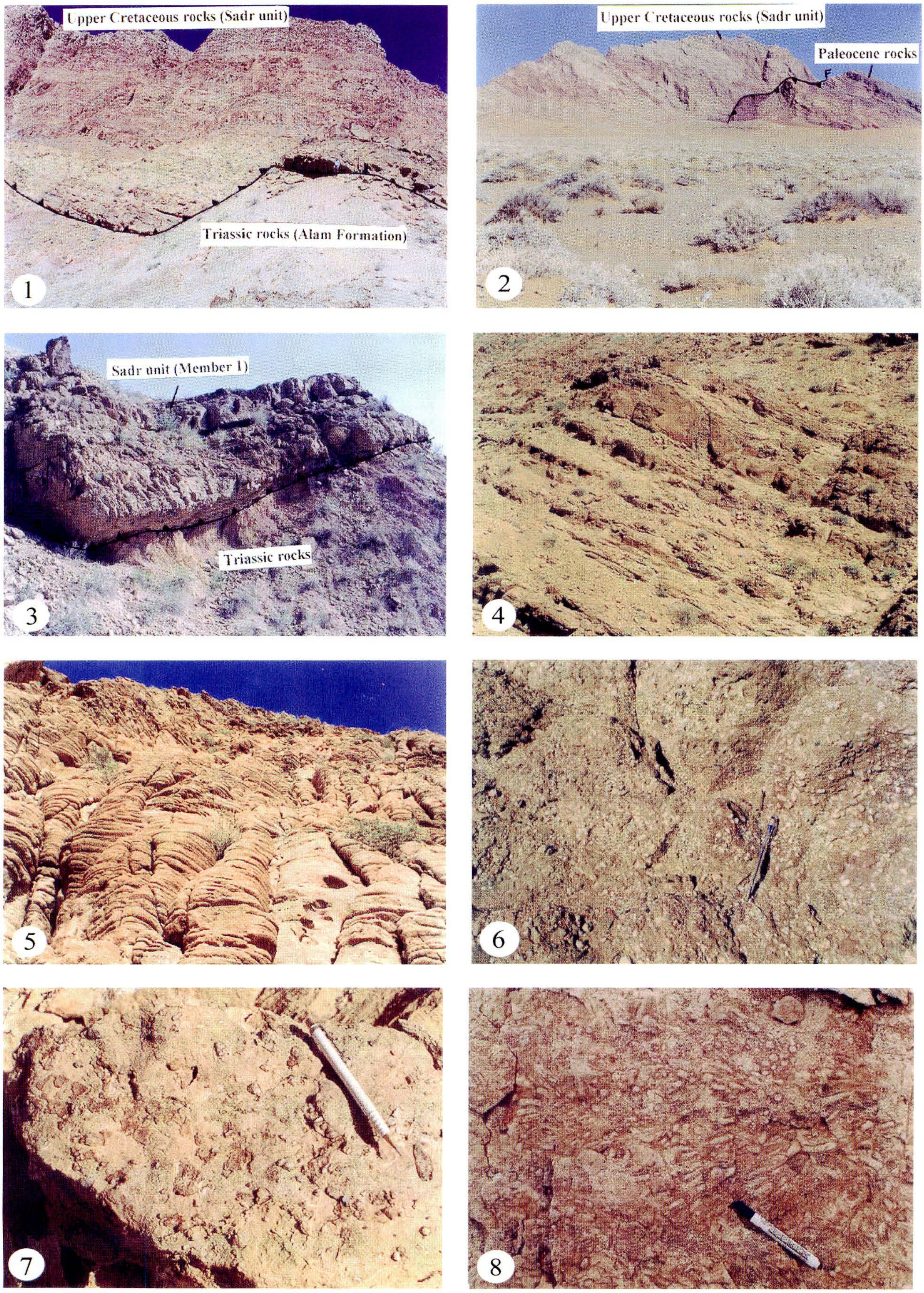
Upper Cretaceous rocks (Sadr unit)
Triassic rocks (Alam Formation)
1
Upper Cretaceous rocks (Sadr unit)
Paleocene rocks
F
2
Sadr unit (Member 1)
Triassic rocks
3
4
5
6
7
8

Plate 2