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First record of ammonites from the Badamu Formation at the Shotori Mountains (Central Iran)

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Key words: Ammonites, Badamu Formation, early Bajocian, Shotori Mountains, Central Iran

ABSTRACT

The following early Bajocian ammonites are described for the first time from the Badamu Formation northwest of Boshrouyeh and southwest of Ravar, Central Iran: *Sonninia propinquans* (Bayle), *Witchellia* [m] *connata* Buckman, *W.* aff. *sutneri* (Branco), *Emileia (Otoites)* cf. *sauzei* (d'Orbigny), and *Emileia (Otoites)* sp. The faunas correspond to the Laeviuscula/Sauzei zones of western and northwestern Europe.

KURZFASSUNG

Aus der Badamu-Formation nordwestlich von Boshrouyeh und südwestlich von Ravar werden zum ersten Mal folgende Ammoniten beschrieben: *Sonninia propinquans* (Bayle), *Witchellia* [m] *connata* Buckman, *W.* aff. *sutneri* (Branco), *Emileia (Otoites)* cf. *sauzei* (Orbigny) und *Emileia (Otoites)* sp.. Die Faunen entsprechen den Laeviuscula/Sauzei -Zonen des unteren Bajocium von West- und Norddwesteuropa.

Introduction

The ammonites described in this paper have been collected from the Badamu Formation in the Shotori Mountains and from Ravar area, during field investigations in winter 1998/99. Apart from two specimens of *Emileia (Otoites)*, the fauna consists exclusively of 44 small sonniniids.

The locality in the central Shotori Mountains lies directly on the northern side of the main road Tabas-Boshrouyeh/Ferdows, about 8km west of the village Esfak (Fig. 1). The geographic coordinates are 34° 00' 48'' N/57° 05' 38'' E. At this locality the Badamu Formation begins with about 3m of yellow-brown weathering, thick-bedded oolitic limestones, which are tectonically strongly disrupted and displaced. It rests on the dark siliciclastics of the Shemshak Formation and is followed by some hundred meters of yellow-olive weathering, sandy shales and marls with intercalations of sandy limestones with marine fauna (corals and bivalves).

The ammonites come from two levels (Fig. 2); (a) from marls directly overlying the basal limestone bed and (b) from the marls following a limestone bed about 15m above the basal limestone. The specimens from the lower level are exclusively inner whorls of sonniniids: *Witchellia* [M] and [m], among them *Witchellia* [m] *connata* Buckman. The upper level yielded, apart from numerous disk-shaped solitary corals and large astartid bivalves, only few ammonites: *Witchellia* aff. *sutneri* (Branco) and *Emileia (Otoites)* sp.

The fauna from the Ravar area comes from the upper part of the Badamu Formation at Sarch Valley, from where a rich ammonite fauna has been reported before (Seyed-Emami 1967; Seyed-Emami et al. 1993). These comprise only two ammonites: *Sonninia propinquans* (Bayle) and *Emileia (Otoites)* cf. *sauzei* (d'Orbigny). The geographic position and stratigraphic level of these specimens are given in Seyed-Emami et al. (1993, figs. 1, 2 e).

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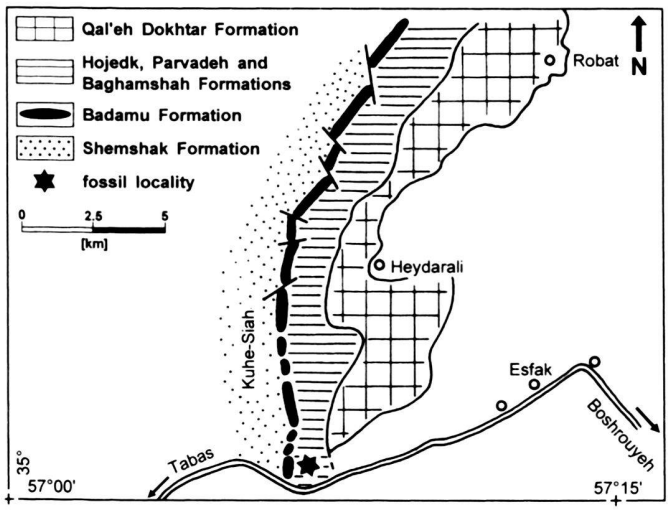

Fig. 1. Geological map of the area west of Esfak (from the Geological Quadrangle Map of Ferdows, 1:250 000; Eftekhar-Nezhad & Ruttner 1977, with corrections).

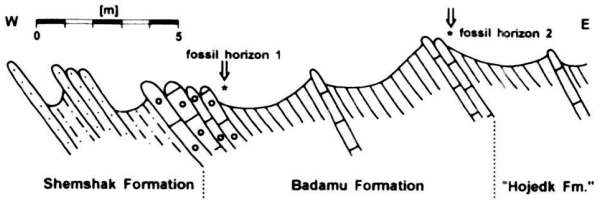

Fig. 2. Schematic cross-section of the Badamu Formation 8km west of Esfak.

Description of the ammonites

The material has been deposited in the Bayerische Staatssammlung für Paläontologie und historische Geologie, Munich, Germany.

Abbreviations

D	diameter in mm
H%	whorl hight as a % of diameter
RB/2	primary ribs on a half whorl
U%	umbilical width as a % of diameter
W%	whorl width as a % of diameter

Sonninia propinquans (Bayle, 1878)
Fig. 3/5

1997 *Sonninia propinquans* Bayle – Rioult et al.: 131; pl. 14, fig. 4.

Material:

A phragmocone with shell from the Sarch Valley, SW Ravar (Kh-98-1).

Description:

Depressed and moderately evolute *Sonninia* with broad-ovate whorl section and a broad, rounded venter. The hollow keel has come off. The ribbing on the inner whorl is coarse. It consists of strong nodes around the umbilicus, alternating with blunt primary ribs. On the outer preserved whorl the nodes vanish and the costation consists of coarse and slightly curved ribs, arising singly or in pairs on the umbilical wall. Ventrally, the ribs project strongly forward and terminate at the keel.

Discussion:

The specimen from Iran matches exactly the one figured by Rioult et al. (1997, pl. 14, fig. 4). Among the specimens figured by Bayle (1878: pl. 4) his fig. 5 resembles the depressed whorl section of our specimen and his fig. 2 the coarse ribbing. The problems of the lectotype of *S. propinquans* have been discussed by Hiltermann (1939, p. 159), Huf (1968, p. 26), Westermann & Riccardi (1972, p. 74), Morton (1975, p. 70) and Fernandez Lopez (1985, p. 47). Similarity exists also to *Sonninia* sp. cf. *S. propinquans* (Fernandez Lopez 1985, pl. 8, fig. 2), but compared to the specimen figured by Pavia (1983, pl. 5, fig. 1) our specimen is much more coarsely ribbed on the inner whorl.

Occurrence:

In western Europe *S. propinquans* occurs in the Sauzei Zone. Rioult et al. (1997, p. 130) report the species from the "Propinquans Zone", which corresponds to the Sauzei Zone. At Ravar, *S. propinquans* was collected together with *Emileia (Otoites)* cf. *sauzei*, indicating the same zone.

Witchellia [m] *connata* (Buckman, 1927)
Fig. 3/2-3

1927 *Zugella connata nov.* – Buckman: pl. 750.
1985 *Witchellia connata* (Buckman) 1927 - Fernandez Lopez: 82; pl. 6, fig. 2; text-fig. 81.

Material: 1 larger and 2 small specimens from W of Esfak (E-99-5, 7, 8).

Dimensions:

	D	U%	H%	W%	RB/2
E-99-5	32	33	40	31	20

Description:

Rather compressed and moderately evolute *Witchellia* with flattened flanks and more or less rectangular whorl section. The venter bears a fairly low, narrow and sharp keel, bordered by broad furrows. The umbilicus is narrow, with a rounded

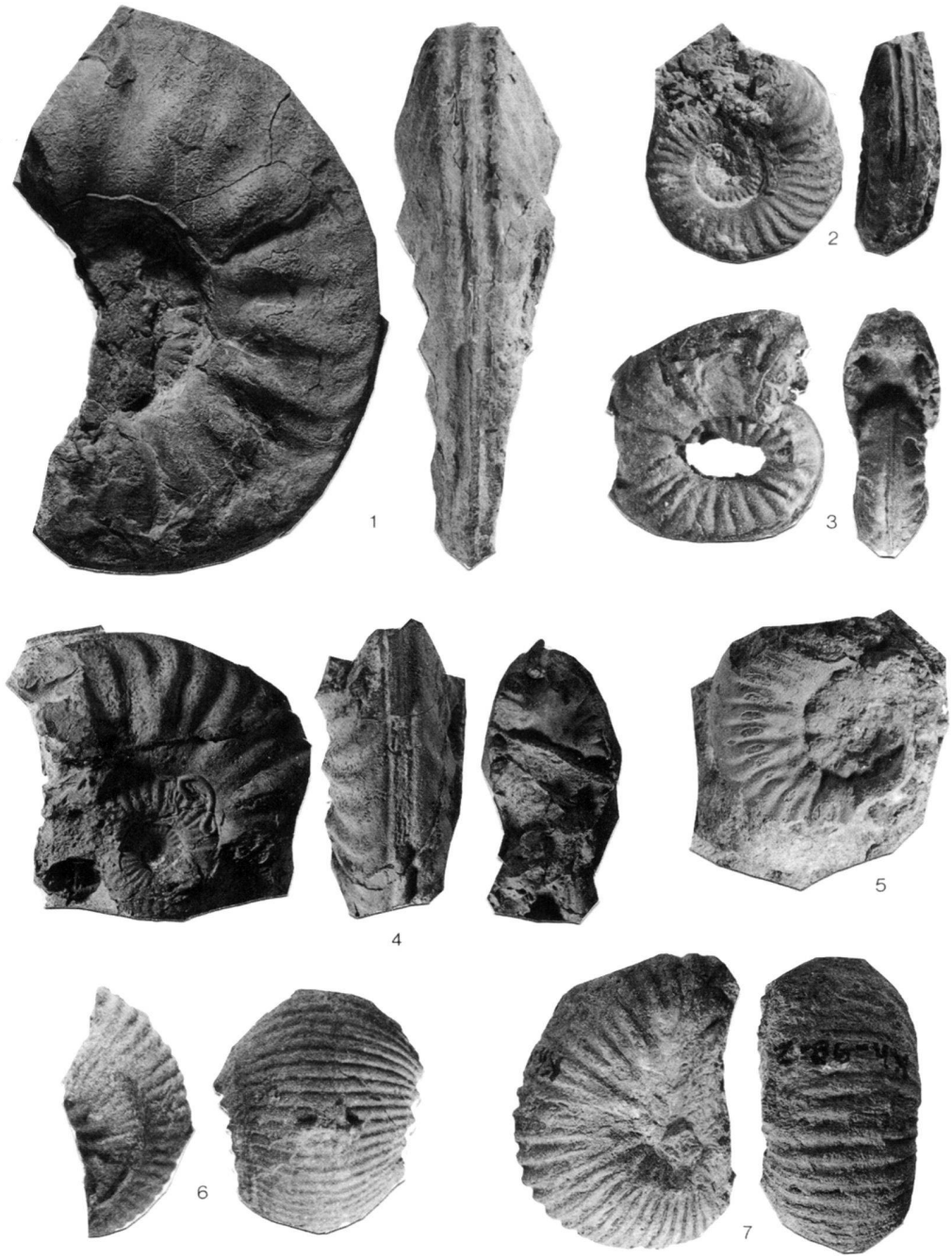

Fig. 3. Ammonites from the Badamu Formation.
1. *Witchellia* aff. *sutneri* (Branco), × 1; phragmocone ends close to where the last whorl fragment starts. W Esfak, NW Boshrouyeh, Shotori Mts. E-99-2.
2. *Witchellia* [m] *connata* (Buckman), × 1; no suture line visible. W Esfak, NW Boshrouyeh, Shotori Mts. E-99-5.
3. *Witchellia* [m] *connata* (Buckman), × 2; phragomocone. Badamu Formation, W Esfak, NW Boshrouyeh, Shotori Mts. E-99-7.
4. *Witchellia* aff. *sutneri* (Branco), × 1; phragmocone. Badamu Formation, W Esfak, NW Boshrouyeh, Shotori Mts. E-99-1.
5. *Sonninia propinquans* (Bayle), × 1; no suture line visible on the last whorl. Badamu Formation, Sarch valley, SW Ravar, Khorand. Kh-98-1.
6. *Emileia (Otoites)* sp., × 2; no suture line visible. Badamu Formation, W Esfak, NW Boshrouyeh, Shotori Mts. E-99-6.
7. *Emileia (Otoites)* cf. *sauzei* (d'Orbigny), × 1; no suture line visible. Badamu Formation, Sarch valley, SW Ravar, Khorand. Kh-98-2.

umbilical border and steep umbilical wall. The ribs arise singly or in pairs at the umbilicus, pass radially or slightly curved across the flanks and curve rather strongly forward, becoming broader and ending abruptly at the ventral furrows. On a smaller and partly shelled specimen the ventral furrows are much fainter, but again clearly developed on the internal mould.

Discussion:

Our specimens closely resemble the holotype of Buckman (1927, pl. 750) and the one figured by Fernandez Lopez (1985, pl. 6, fig. 2). The relationship to the specimens described by Imlay (1973, p. 69; pl. 20, fig. 4; pl. 21, figs. 1-7, 10–11) from Oregon is difficult to evaluate, because of the poor preservation of his material.

Occurrence:

Laeviuscula Zone of England (Callomon & Chandler 1990, p. 97, 102), France (Rioult et al. 1997, p. 43) and Spain (Fernandez Lopez 1985, p. 83).

Witchellia aff. *sutneri* (Branco, 1879)
Fig. 3/1, 4

aff. 1879 *Harpoceras Sutneri* n.sp. - Branco: 92; pl. 5, fig. 2.
? 1969 *Sonninia (Sonninia) schneegansi* Gillet - Seyed-Emami: 109; pl. 4, fig. 3; pl. 12, fig. 1.
aff. 1969 *Witchellia sutneri* (Branco) - Westermann: 110; text-fig. 34 (reproduction of the original figure of Branco).

Material: 2 bigger and 2 smaller specimens from W of Esfak (E-99-1, 2, 3, 4).

Dimensions:

	D	U%	H%	W%	PR/2
E-99-1	81	~33	~38	~30	8

Description:

The bigger specimen E-99-21 is an internal mould of half of the phragmocone. It is moderately evolute with an subrectangular whorl section. The slightly converging whorl sides grade into a steep umbilical wall. The venter is moderately broad and bisulcate-tricarinate, with a fairly high, hollow keel. The ribbing is strong and irregular. At D = 80 mm there are 8–9 blunt and strong primaries per half-whorl, which terminate in rounded bullae before the middle of the flank, from where they bifurcate or, more rarely, trifurcate. The secondaries project strongly forward on the outer half of the flank, terminating at the ventral sulci.

The smaller specimen E-99-12 is an incomplete phragmocone with shell and inner whorls up to 30 mm. The costation on the inner whorl is rather fine and dense, without any tubercles. The ribs arise singly or in pairs at the umbilicus, pass radially or slightly curved across the flanks, become broader and curve strongly forward on the rouded venter and terminate at the ventral furrows. The ribbing on the outer preserved whorl is strong and similiar to the larger specimen. The whorl section is broad-ovate, becoming high-ovate on the last whorl. The keel is rather narrow on the inner whorl, becoming much higher on the outer whorl. The ventral furrows are much weaker on the shell than on the internal mould.

Discussion:

On the outer whorl both specimens closely resemble the original picture of Branco, but the ribbing on the inner whorl of the smaller specimen is much finer and denser. The same differences also exist with respect to *Witchellia sutneroides* Westermann (1969, p. 116; pls. 28–31) from Alaska, which is a close relative of *W. sutneri* (Branco). Moreover there are no tubercles on the inner whorls of the Iranian specimens.

Occurrence:

Probably Laeviuscula Zone. At Esfak, *W.* aff. *sutneri* was found together with an inner whorl of *Emileia (Otoites)* sp. from the Badamu Formation, level 2.

Emileia (Otoites) sp.
Fig. 3/6

Material: A small inner whorl from W of Esfak (E-99-6).

Discussion:

Involute sphaerocone, with a broad rounded venter separated from whorl sides by strongly rounded shoulder on which small, closely spaced tubercles are present. The primary ribs terminate in the tubercles, branching in three or four rectiradiate secondary ribs which cross the venter.

Occurrence:

See *Witchellia* aff. *sutneri*.

Emileia (Otoites) cf. *sauzei* (d'Orbigny, 1846)
Fig. 3/7

Material: 1 fully grown specimen from Sarch valley, southwest of Ravar (Kh-98-2).

Discussion:

In size and ribbing the present specimen shows great resemblance to the neotype of *E. (O.) sauzei* nominated by Westermann (1954, p. 87, pl. 1, fig. 1). Westermann & Riccardi (1979, p. 121) mention a close resemblance of the neotype to *Otoites contractus* (Sowerby). They also regard *Otoites sauzei* as a junior synonym of *Otoites contractus* (Westermann & Riccardi 1979, p. 122).

Biostratigraphic conclusions

The investigated ammonites come from the Badamu Formation northwest of Boshrouyeh (Central Shotori Mountains) and from the upper part of the formation southwest of Ravar and belong to the early Bajocian.

The specimens from the Shotori Mountains come from two levels within the yellow-green marls immediately overlying the basal limestone of the Badamu Formation west of Esfak (Figs. 1, 2). The lower level yielded 44 exclusively small specimens of sonniniids, among them *Witchellia* [m] *connata* (Buckman).

The rest consists of small and indeterminable inner whorls of *Witchellia* [M] and [m]. Stratigraphically, the fauna corresponds to the Laeviuscula Zone of western and northwestern Europe i.e., the *Connata* Horizon of Callomon & Chandler (1990, p. 97, 102) and Rioult et al. (1997, p. 43). The younger level lies about 15m above the lower one. There are only four specimens of *Witchellia* aff. *sutneri* (Branco) and an inner whorl of *Emileia (Otoites)* sp., probably corresponding to the upper Laeviuscula Zone.

The specimens from southwestern Ravar comprise a *Sonninia propinquans* (Bayle) and a nearly full-grown *Emileia (Otoites)* cf. *sauzei* (d'Orbigny). Both come from level 5 of the geological section at Khorand Valley (Seyed-Emami et al. 1993, fig. 2). Stratigraphically the specimens correspond to the Sauzei Zone (= Propinquans Zone) of western and northwestern Europe.

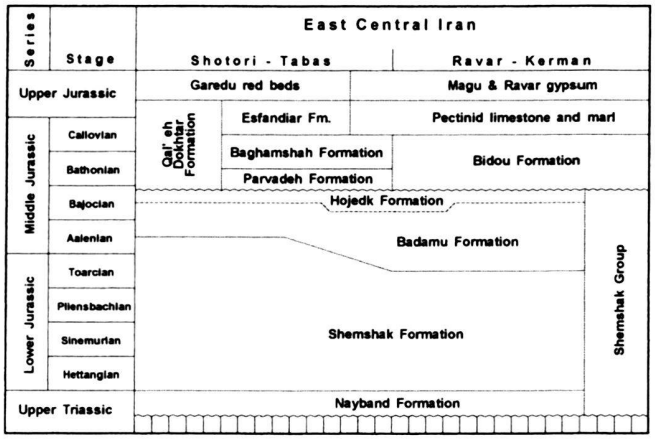

Fig. 4. Lower and Middle Jurassic Formations in eastern Central Iran.

Discussion

Jurassic sediments of east-central Iran have been deposited on parts of the former "Cimmerian Continent", a collage of microplates that collided with the Eurasian (Turan) Plate in the Late Triassic (e.g. Sengör 1990). As a consequence, Jurassic faunas of the area are very close to those of western Europe (e.g. Seyed-Emami et al. in press). During the Jurassic, block movements and resulting strongly differing subsidence rates created a complex facies mosaic.

The Badamu Formation is a conspicuous marine unit within a thick molasse-type sequence, the Shemshak Group (Fig. 4). In particular in the Kerman/Ravar area it has been known for a long time as an important marker bed, separating two siliciclastic and carbonaceous strata, the Shemshak and Hojedk formations. In these areas the Badamu Formation attains a thickness of a few tens of metres or more and contains a rich fauna of ammonites, ranging from Late Toarcian to Early Bajocian in age (Seyed-Emami 1967, 1971, 1988; Seyed-Emami et al. 1993).

Towards north, in the areas of Naibandan, Tabas, and the Shotori Mountains, the Badamu Formation is much less conspicuous and its thickness is reduced. Most records of the "Badamu Formation" from these areas and the listed ammonite faunas in reports and geological maps (Stöcklin et al. 1965; Ruttner et al. 1968; Stöcklin & Nabavi 1971; Aghanabati 1977; Kluyver et al. 1983) refer actually to a younger and in this region more prominent limestone unit, now known as Parvadeh Formation (Seyed-Emami 1971; Seyed-Emami et al. 1991; Aghanabati 1996). The Parvadeh Formation is a succession of oolitic and sponge-bearing microbial limestones and marls, lithologically very similiar to the Badamu Formation. From the Badamu Formation and the subsequent Hojedk Formation, the Parvadeh Formation is separated by an important Mid-Bajocian event (Seyed-Emami & Alavi-Naini 1990) and thus marks the onset of a new tectono-sedimentary cycle transgressing disconformably on the Hojedk Formation or even older formations. The Parvadeh Formation occasionally contains a rich ammonite fauna early to middle Bathonian in age (Seyed-Emami et al. 1991, 1998).

For demonstrating the stratigraphic position of the Badamu and Parvadeh formations within the Middle Jurassic strata of the Shotori and neighbouring areas, a few geologic sections are briefly discussed (Fig. 5):

Esfak section: West of Esfak the Badamu Formation begins with about 3 m of oolitic limestone. It overlies the dark, bedded sandstones of the Shemshak Formation and is followed by some hundreds of metres of yellow-olive weathering argillaceous silts and fine-grained sandstones with thin intercalations of shell beds with marine fauna (oysters) and of intraformational conglomerates. Superficially, this sequence looks much like the Baghamshah Formation and has been mapped as the latter on the geological quadrangle maps of Tabas, Boshrouyeh and Ferdows. However, underlying the hard and ridge-forming limestones of the Parvadeh Formation, which is an excellent marker unit, the silt and sandstone sequence stratigraphically belongs to the Hojedk Formation (Fig. 4) and represents a more fine-grained and more marine facies of this formation, which further to the west is dominated by unfossiliferous cross-bedded sandstones.

Gelkan section: About 30 km southwest of Esfak, at the western slope of Kuhe Gelkan, again about 200 m greenish Baghamshah-like silty shales with thin beds of sandy limestones and marine faunas (bivalves, gastropods) crop out. These are followed, with a slight unconformity, by about 10 to 15 m of oolitic and nodular microbial limestones (Parvadeh Formation) with sponges and early to middle Bathonian ammonites (*Oxycerites*, *Cadomites*, and perisphinctids). The limestones are overlain by about 350 m yellow-green marls of the Baghamshah Formation, which contains the early Callovian ammonite *Macrocephalites* at the boundary beds to the overlying Esfandiar Formation.

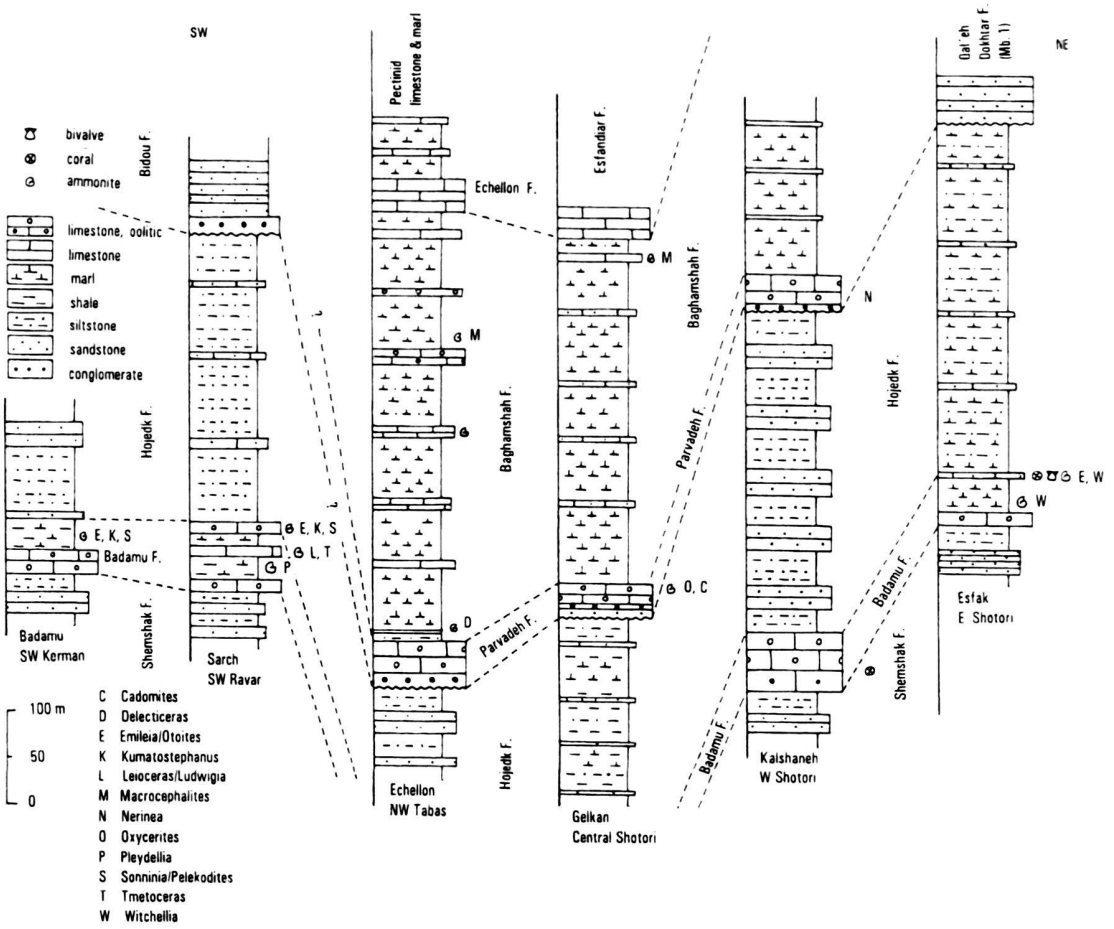

Fig. 5. Correlation of some stratigraphic sections within the Middle Jurassic of the Shotori, Tabas, Ravar, and Kerman areas. C: *Cadomites*; D: *Delecticeras*; E: *Emileia/Otoites*; K: *Kumatostephanus*; L: *Leioceras/Ludwigia*; M: *Macrocephalites*; N: „*Nerinea*"; O: *Oxycerites*; P: *Pleydellia*; S: *Sonninia/Pelecodites*; T: *Tmetoceras*; W: *Witchellia*.

Kalshaneh section: About 40km northwest of Esfak, north of the village Kalshaneh and at the eastern slope of Kuhe Pirhajat, there is a good succession of Badamu, Hojedk, Parvadeh and Baghamshah formations. The Badamu Formation consists of about 30–40 m of thick-bedded, sandy and oolitic limestones with a rich coral fauna. It is followed by 300-400m of hard sandstones and siltstones of the Hojedk Formation. Then follow transgressively about 20 m of thick-bedded and oolitic limestones of the Parvadeh Formation, with a coarse conglomerate and a bed full of nerineids at the base. The Parvadeh Formation is succeeded by typically green-olive silty marls of the Baghamshah Formation, building the core of a syncline.

In conclusion, it is obvious that in the Tabas area and in the Shotori Mountains, contrary to the Kerman/Ravar area, there are two different limestone units within the siliciclastic strata of the Lower and Middle Jurassic: an older and less conspicuous one, the Badamu Formation, and a younger more prominent unit rich in ammonites, the Parvadeh Formation, which forms the base of a new sedimentary megacycle.

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