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# First record of Jurassic (Toarcian – Bajocian) ammonites from the northern Lut Block, east-central Iran

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ABSTRACT:

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A very thick and lithologically rather unusual marine sedimentary succession is described from the Kuh-e-Shisui area, northwestern Lut Block (east-central Iran). It contains a low diversity ammonite fauna comprising the families Dactylioceratidae, Hildoceratidae, Graphoceratidae, Hammatoceratidae, and Sonniniidae, which are concentrated in several levels, indicating the Lower-Lower Middle Toarcian, Upper Toarcian, Aalenian, and Lower Bajocian. The ammonite fauna, consisting of 21 taxa, described for the first time from the Lut Block, corresponds to that of the Badamu Formation of the Kerman-Ravar region (southern Tabas Block, to the west of the Lut Block), but is far less diverse. An exception is the occurrence of Lower Toarcian Harpoceratinae and Hildoceratinae, which hitherto have not been recorded from east-central Iran. The ammonite fauna is closely related to that of northwestern Europe.

**Key words**: Ammonites, Jurassic, Toarcian, Aalenian, Bajocian, Lut Block, Central Iran.

## INTRODUCTION

East-central Iran, originally a microcontinent that collided as part of the Cimmerian continent collage (SENGÖR 1990) with Eurasia in the Late Triassic, contains a thick and superbly exposed Jurassic sedimentary succession. Most of the Jurassic rocks are found on the so-called Tabas Block, the middle one of three blocks that constitute the so-called Central-East Iranian Microcontinent (CEIM; TAKIN 1972). The other two blocks are the Yazd Block in the west and the Lut Block in the east. Large areas in the northern Lut Block are covered by Tertiary (Paleogene) volcanic rocks. Jurassic sedimentary strata are only sporadically distributed in that area and are poorly known. A comparatively complete and continuous succession occurs along a north-south trending range, extending for more than 50 km from Kuh-e-Takherg in the north to Shekasteh Kasuri in the south (STÖCKLIN & *al*. 1972, p. 23) and at Kuh-e-Birg, north of Khur (STÖCKLIN & *al*. 1972; LOTFI 1995). The most complete succession known so far crops out at the Kuh-e-Birg, which was briefly visited by the authors in winter 2002. There, most of the Middle and Upper Jurassic lithostratigraphic units, known from the north-eastern Shotori Mountains (N Tabas Block; WILMSEN & *al.* 2003), such as Parvadeh, Baghamshah, Qal`eh Dokhtar Limestone, Esfandiar Limestone, and Garedu formations are well developed. In this section, the black oolitic limestone below the Baghamshah Formation, which has been attributed to and mapped as Badamu

Formation (STÖCKLIN & *al.* 1972; LOTFI 1995) is in reality analogous to the Parvadeh Formation. Consequently, the underlying strata are not Shemshak Formation but correspond to the Hojedk Formation.

The Jurassic succession described in this paper lies at Kuh-e-Shisui, about 30 km south of the road from Boshrouyeh to Ferdows (Text-fig. 1). It corresponds to the strongly sandy facies and layers of brown sandy limestone with corals and bioherms reported by STÖCKLIN & *al.* (1972, p. 21 and 25, fig. 2) from the same area and attributed to the lower part of the Qal´eh Dokhtar Formation. The succession begins with about 400 m of thick-bedded and quartzitic, cross-bedded sandstones, in the upper part alternating with up to 20 m thick oolitic grainstones, which contain marine faunas (sponge-microbial patch reefs, marls with corals, the large bivalve *Ctenostreon* and belemnites). Lithologically similar sequences crop out in the mountain range between Kuhpayeh and Bolbolu (SE Kerman; HUCKRIEDE & *al.* 1962) and at Kuh-e-Rahdar (Kalmard area, NW Tabas; AGHANABATI 1977), which are attributed to the Toarcian-Lower Bajocian Badamu Formation.

At Kuh-e-Shisui, the thick-bedded quartzites and limestones are followed by ca 125 m of yellow-green silty and sandy marl, heavily bioturbated and with intercalations of lenticular limestones bodies that contain sponges, corals, bivalves, crinoids, spines of echinids, and few poorly preserved Lower Toarcian ammonites (Harpoceratidae, Dactylioceratidae). This unit is followed by ca 80 m of violet to green calcareous sandstones and sandy limestones with marly intercalations and Upper Toarcian/Aalenian ammonites. The uppermost part of the succession consists of about 100 m of yellowish and reddish bioturbated silty marls with intercalations of reddish limestones that yielded a few gastropods, belemnites, and Lower Bajocian ammonites. The underlying as well as overlying strata of the succession are covered either by sand dunes or Tertiary volcanic rocks.

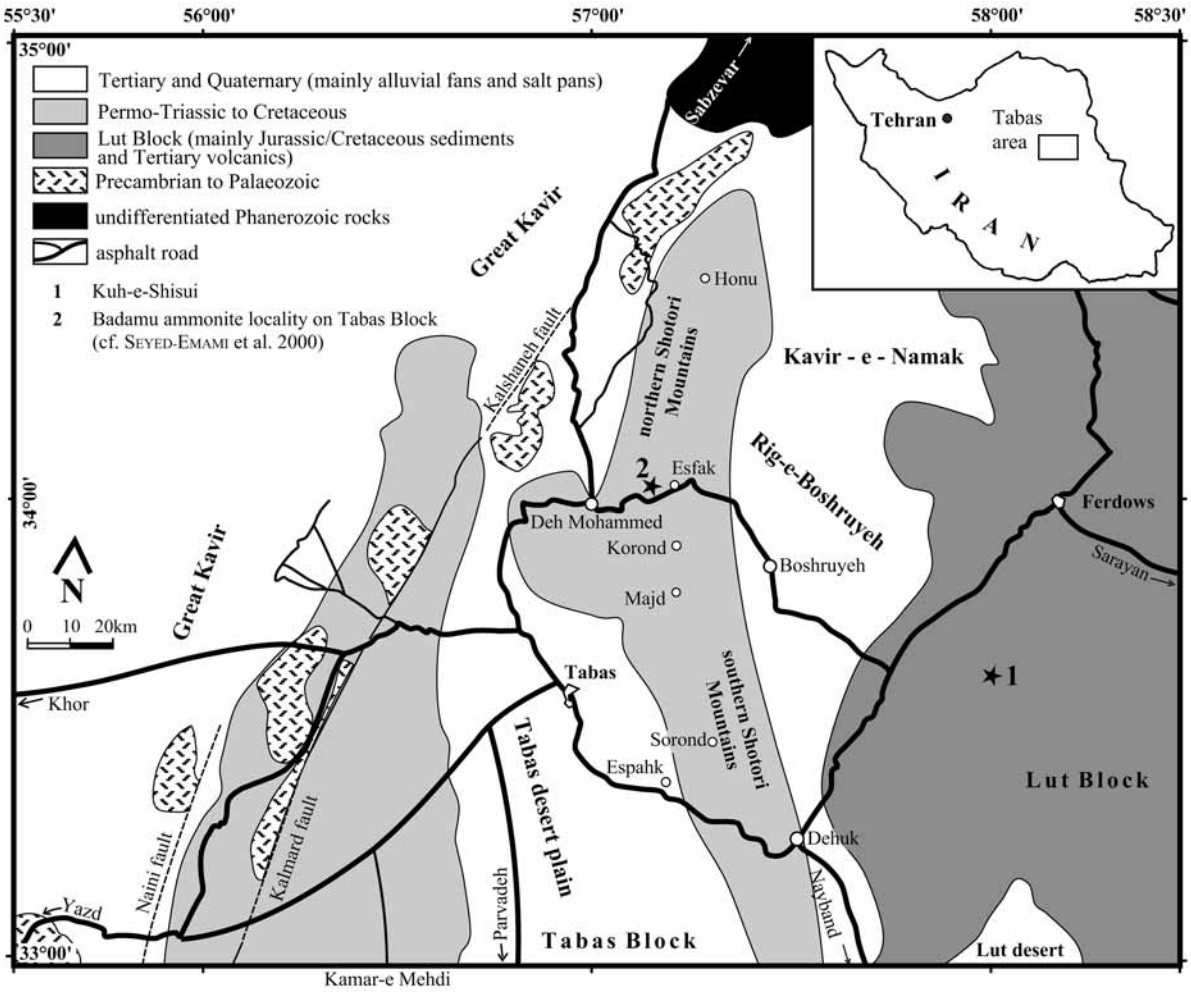



Fig. 1. Simplified geological map of the northern part of the Tabas and Lut Block, east-central Iran, with indication of the ammonite locality at Kuh-e-Shisui (1) and the ammonite locality of SEYED-EMAMI & *al.* (2000) west of Esfak (2)

## THE SECTION (TEXT-FIG. 2)

The section (co-ordinates: N 33°37´11´´, E 58°00´08´´) starts on top of the monotonous sequence of cross-bedded quartzitic-arkosic sandstones and oo-grainstones. The boundary to the overlying softer unit is marked by a 80 cm thick fine-conglomeratic crinoid rudstone with quartz pebbles up to 5 mm in diameter. The soft unit is about 125 m thick and consists largely of yellow-green, heavily bioturbated, silty to fine-sandy marl. Occasional decimetre-thick bioclastic fine-grained sandstone, sandy bio-floatstone or bio-packstone beds are intercalated which, locally, developed into small microbial-sponge or microbial-coral patch reefs, up to 30 cm in height. Apart from the frame-building sponges, corals, and microbial crusts, the patch reefs and laterally adjacent beds contain a rich fauna of bivalves, crinoids, echinid spines, serpulids, and belemnites as well as a few poorly preserved Lower Toarcian ammonites (harpoceratids and dactylioceratids).

This unit gradually grades into massive to well bedded, predominantly bioturbated, partly bioclastic, violet to green calcareous fine-grained sandstones, ca. 96 m in thickness. Thin intercalations of calcareous sandstone, sandy bio-packstone and coarse-grained bioclastic sandstone with sharp erosional lower surfaces form the base of 2-12 m thick parasequences. The basal bed of a cycle is followed by bioturbated sandstone. Altogether seven such cycles are developed within the lower 37 m of the unit. The following well bedded sandstones consist of alternations of beds of calcareous sandstones and non-calcareous ("gritty") sandstones. A marly intercalation at 186 m contains Upper Toarcian ammonites (ammonite level 3). The following 12 m of fine-grained sandstone/silty fine-sand interbeds are heavily bioturbated by *Zoophycos*. A 200 cm thick bed of well bedded strongly fine-sandy packstone (ammonite level 4, Upper Toarcian-Lower Aalenian) concludes the unit.

Next follows a 32 m thick coarsening-upward unit that grades from silty marl to reddish-brown fine-grained sandstone and is heavily bioturbated by *Zoophycos*. Ammonites, belemnites and gastropods occur sporadically (ammonite level 5, Upper Aalenian).

The uppermost part of the succession consists of about 100 m of pale-green silty marl to silt with sparse intercalations of red-brown fine-grained sandstone beds that yielded a few belemnites and Lower Bajocian ammonites (ammonite level 6). Most beds are bioturbated (*Zoophycos, Chondrites*) but some exhibit remains of parallel lamination or small ripple lamination.

The underlying as well as overlying strata of the succession are covered either by sand dunes or Tertiary volcanic rocks.

## DEPOSITIONAL ENVIRONMENT AND SEQUENCE STRATIGRAPHY

The drastic change from large-scale trough cross-bedded medium-grained sandstones to silty fine/silty marl at the base of the measured section corresponds to a relatively abrupt deepening of the depositional environment and is here interpreted as representing a sequence boundary. Relicts of lowstand systems tract deposits are preserved as a microconglomeratic lag at the base of the transgressive systems tract, the transgressive surface coinciding with the sequence boundary. The lower part of the succession represents a low energy environment below storm wave base. The small patch reefs that formed at several levels most likely correspond to phases of reduced sediment input, probably in connection with flooding surfaces of parasequences that are poorly developed because of the relatively deep, offshore environment. With gradual shallowing, starting at around 130 m and expressed by an increase in grain size, the parasequences are more clearly developed (from 128-166 m). Thin calcareous, bioclast-rich sandstones, often with sharp, erosional lower surfaces, and occasionally with remains of sedimentary structures, represent transgressive lags that are followed by bioturbated sandstones of the shallowing phase. The scarcity of sedimentary structures and the abundance of the trace fossil *Zoophycos*, an indicator of relatively deep offshore, low energy conditions (e.g. SEILACHER 1967) indicate that even during late highstand the sea floor most likely was below storm wave base and only influenced by rare storms, the resulting sedimentary structures subsequently having been obliterated by bioturbation.

The next sequence starts at 192 m with a 60 cm thick bioclastic, partly bioturbated, partly ripple-bedded fine-grained sandstone grading into ammonite-bearing marly silt with thin sandstone intercalations. These transgressive sediments are overlain by bedded sandstones of the highstand systems tract.

A third sequence boundary is developed at 213 m, the 200 cm thick sandy packstone that overlies it corresponding to the early transgressive systems tract of the next, 38 m thick depositional sequence. Another sequence boundary at 245 m defines the base of the last depositional sequence recognized. Gradual increase in grain size from silty marl to silt suggests that in the last 30 m of the succession we are dealing again with highstand deposits.

In summary, the upper Lower Jurassic to lower Middle Jurassic sediments of the Kuh-e-Shisui area correspond to low energy, offshore shelf environments, situated generally below or, at the most, just above storm wave base. The sedimentation pattern reflects changes

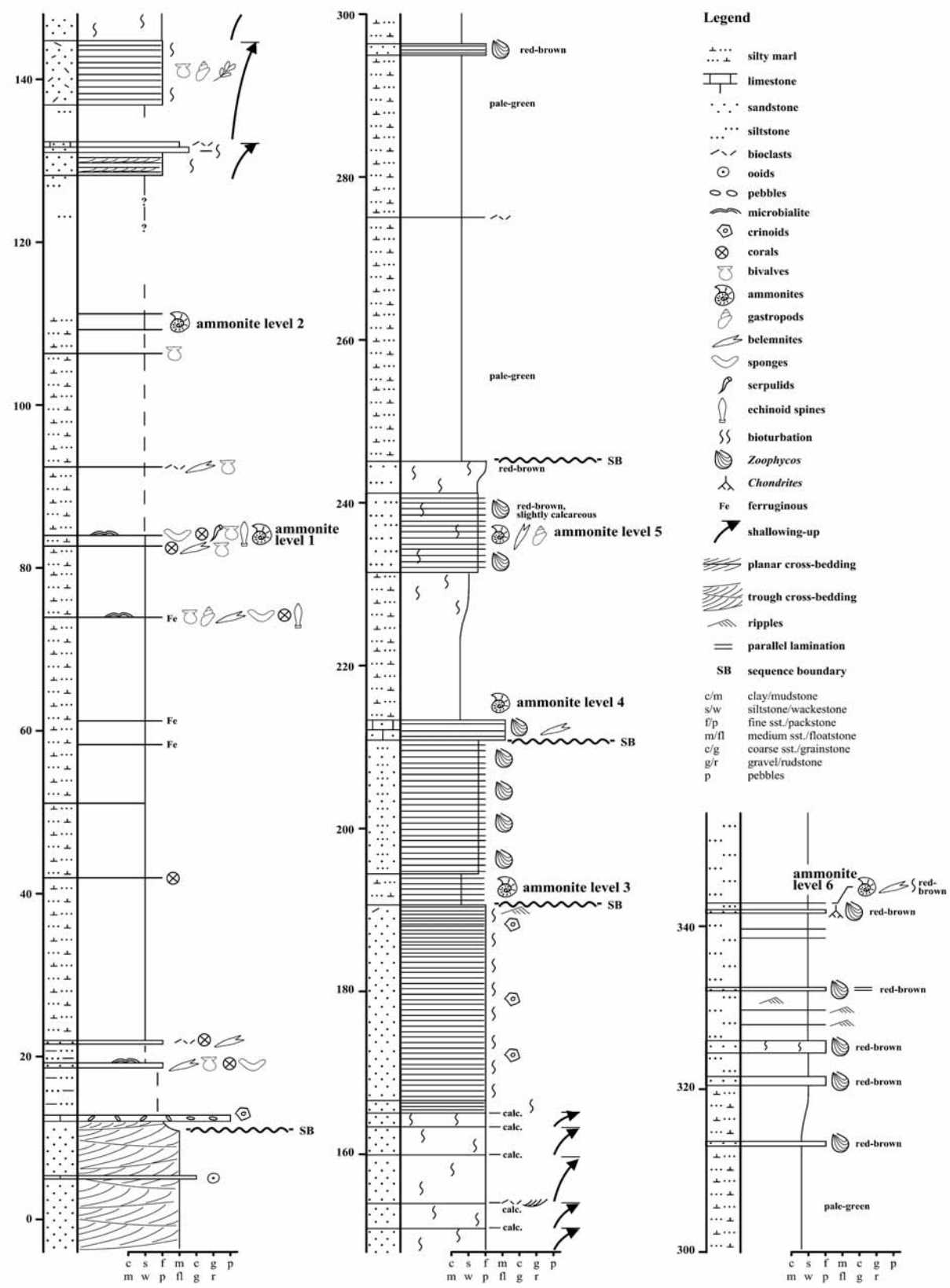



Fig. 2. Detailed log of the Toarcian-Lower Bajocian succession at Kuh-e-Shisui, Lut Block, east-central Iran (scale in meters)

in water depth of two orders of magnitudes (depositional sequences and parasequences) and a clear dominance of siliciclastic input over carbonate sedimentation, the rare thin carbonate beds being composed of bioclasts and skeletal elements that accumulated during times of reduced input of siliciclastic material.

## DESCRIPTION OF THE AMMONITES

The material has been deposited in the Bayerische Staatssammlung für Paläontologie und Geologie, Munich, Germany. As most of the described ammonite taxa are well known from European epicontinental basins, the following synonymy lists only contain some more recent quotations.

Abbreviations:
D diameter in mm
H% whorl height as a % of diameter
U% umbilical width as a % of diameter
W% whorl width as a % of diameter
RB primary ribs on a whorl

Order Ammonoidea ZITTEL 1884
Suborder Ammonitina HYATT 1889
Superfamily Eoderoceratacea SPATH 1929
Family Dactylioceratidae HYATT 1867

### *Dactylioceras (Orthodactylites) semicelatum* (SIMPSON 1843)
(Pl. 1, Fig. 1a, b)

1843. *Ammonites semicelatus*; SIMPSON, p. 20.
1980. *Dactylioceras (Orthodactylites) semicelatum* (SIMPSON); HOWARTH, p. 646, pls 80, 81; pl. 82, figs 11-12; text-figs 2-3 [with synonymy].

MATERIAL: Seven small, partly fragmentary specimens from ammonite level 2: 020212-3(3-4); 020216-1 (1-2, 1-3, 1-5, 1-9, 1-10, 1-11).

Dimensions:

| specimen | D | U | H | W | RB |
|---|---|---|---|---|---|
| 020216-1-10 | 35 | 44 | 32 | 30 | 50 |

DESCRIPTION: Specimen 1-10 is a phragmocone with parts of the original shell. The umbilicus is moderately wide, the whorl cross-section is ovate, slightly higher than wide. Greatest breadth is near the umbilicus, falling slightly towards the narrowly rounded venter. The slightly prorsiradiate ribs are sharp, relatively dense, simple or bifurcating. Ventrolateral tubercles are developed on the remaining specimens.

DISCUSSION: The Iranian specimens fit well the morphotype varieties of *D.* (*O.*) *semicelatum* as discussed and illustrated by HOWARTH (1980).

STRATIGRAPHIC RANGE: Lower Toarcian (Tenuicostatum Zone).

### *Dactylioceras* sp. ex gr. *D.* (*Orthodactylites*) *tenuicostatum* (YOUNG & BIRD 1822)
(Pl. 1, Fig. 2)

MATERIAL: 2 fragments of an outer whorl from ammonite level 2: 020212-3(3-2); 020216-1(1-12).

DISCUSSION: Due to the poor preservation, a specific determination is not possible. However, considering the extremely wide umbilicus and the fine ribbing, our specimens fit well into the group of *D.* (*O.*) *tenuicostatum* (YOUNG & BIRD), discussed and figured by HOWARTH (1980, p. 650, pl. 82, figs 1-10, 13-14).

STRATIGRAPHIC RANGE: Lower Toarcian (Tenuicostatum Zone).

### *Dactylioceras* sp. nov.
(Pl. 1, Fig. 3a, b)

MATERIAL: 2 specimens from ammonite level 2: 020212-3(3-2, 3-7).

DESCRIPTION: The larger specimen (020212-3-7) with a diameter of 38 mm is partly crushed. It is remarkably involute, with a high-ovate whorl cross-section and extremely fine and dense, simple or bifurcating ribs. The smaller specimen (020212-3-2) has a diameter of 15 mm. It is relatively involute, with high-ovate whorl cross-section and rather arched venter. The ribbing is fine, dense and slightly irregular, simple or bifurcating.

DISCUSSION: The present specimens cannot be compared satisfactorily with any described species of *Dactylioceras*. According to ELMI (written comm. 11/2003) it may well be a new genus. With regard to the dense ribbing it shows similarities to *D. (Orthodactylites) crosbeyi* (SIMPSON) figured in HOWARTH (1973, pl. 1, fig. 4a, b). Concerning the closed umbilicus it looks rather like *D. (O.) hoelderi* (HILLEBRANDT & SCHMIDT-EFFING 1981, pl. 2, fig. 3). A similar specimen was

described as *Dactylioceras (Iranodactylites) ketevanae* subgen. nov. et sp. nov. (REPIN 2000, p. 39-40, pl. 3, figs 1, 2) from the Shemshak Formation of Shahmirzad, SE Alborz, nothern Iran. However, *D. (I.) ketevanae* REPIN appears to be more evolute and more compressed, and our limited material is not sufficient for erecting a new species or even genus.

STRATIGRAPHIC RANGE: Lower Toarcian.

*Peronoceras* sp. nov.?
(Pl. 1, Fig. 4a, b)

MATERIAL: A fragmentary specimen, half of a phragmocone from ammonite level 2: 020212-3(3-8).

DESCRIPTION: A relatively evolute and depressed dactylioceratid with broad-ovate to coronate whorl cross-section and only weakly convex to flat venter. On the last preserved whorl, the ribbing consists of coarse, relatively distant and irregularly fibulate (looped) primaries, mostly ending into strong and sharp ventrolateral tubercles (spines?). Usually 3 to 4 fine and sharp ventral ribs arise from the tubercles.

DISCUSSION: From known species of *Peronoceras*, the present specimen differs by relatively coarse primaries and very fine and dense ribbing on the venter. The coarse ribbing on the flank is somehow reminiscent of *P. subarmatum* (YOUNG & BIRD) as figured in HOWARTH (1978, pl. 4, fig. 4a).

STRATIGRAPHIC RANGE: Middle Toarcian (Bifrons Zone).

*Nodicoeloceras* cf. *crassoides* (SIMPSON 1855)
(Pl. 1, Fig. 5a, b)

cf. 1855. *Ammonites crassoides*; SIMPSON, p. 55.
cf. 1978. *Nodicoeloceras crassoides* (SIMPSON 1855); HOWARTH, p. 256, pl. 2, figs 1, 4, 5; pl. 3, fig. 1 [with synonymy].

MATERIAL: Half of a poorly preserved specimen from ammonite level 2 (020216-1-7).

DESCRIPTION: Moderately evolute dactylioceratid with broad-ovate whorl cross-section. The ribbing is coarse and distant. On the last preserved whorl the simple primaries end at ventrolateral tubercles (spines?) and mostly trifurcate on the venter. On the crushed inner whorls, large ventrolateral spines are developed.

DISCUSSION: With regard to the coarse ribbing and the relatively broad whorl cross-section, the present specimen can be compared with *N. crassoides* (SIMPSON) as figured by HOWARTH (1978, especially the specimen on pl. 2, fig. 5a, b).

STRATIGRAPHIC RANGE: Lower Toarcian.

Superfamily Hildoceratacеae HYATT 1867
Family Hildoceratidae HYATT 1867
Subfamily Harpoceratinae NEUMAYR 1875

*Harpoceras* sp. ex gr. *H. falciferum* (J. SOWERBY 1820)/
*H. soloniacense* (LISSAJOUS 1906)
(Pl. 1, Fig. 6a, b)

MATERIAL: One half of an internal mould with parts of the original shell preserved (020212-3-11) and 3 smaller inner whorls from ammonite level 2 (020216-1-10, 020212-3-5, -3-6).

Dimensions:

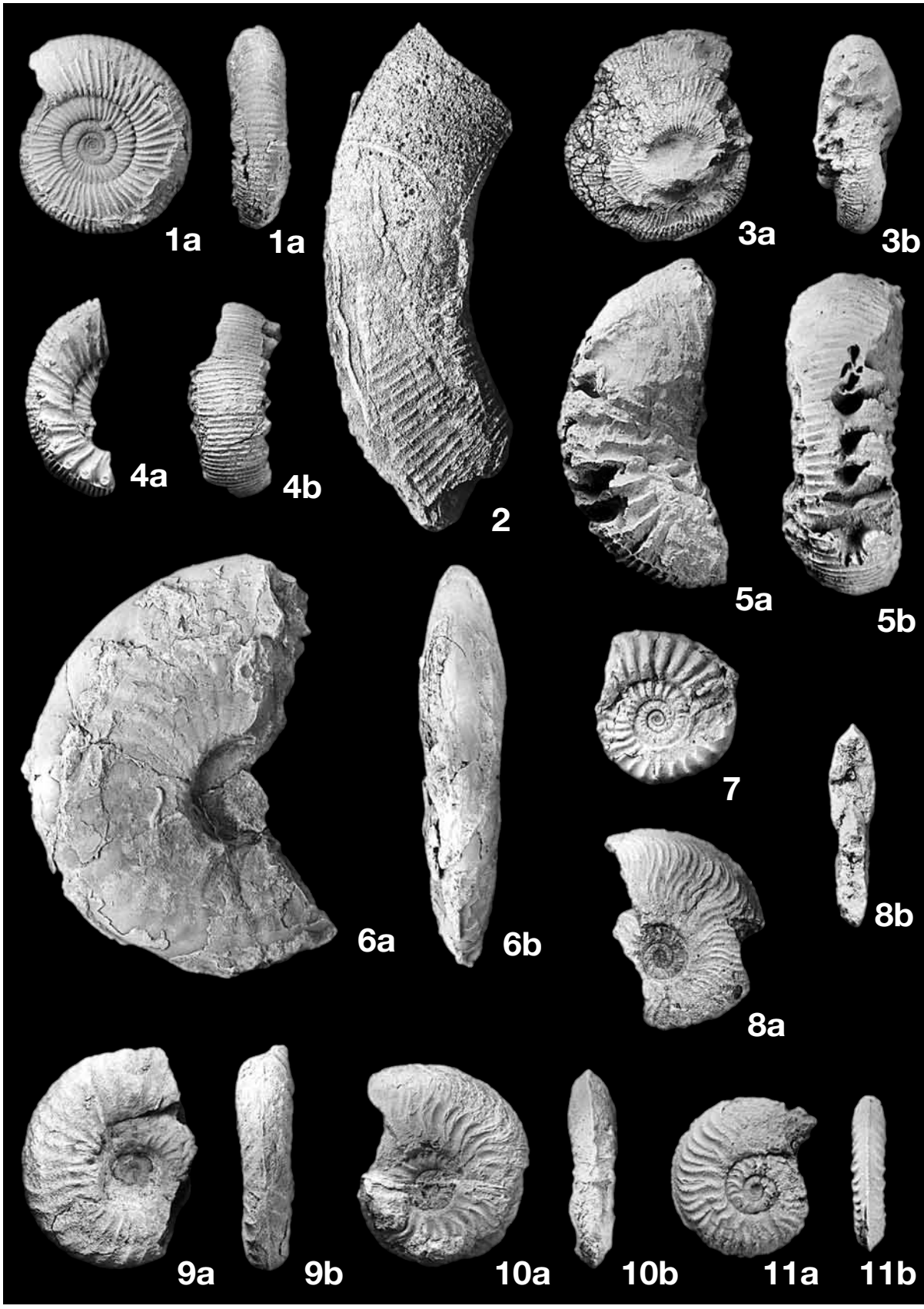
| specimen | D | U | H | W |
|---|---|---|---|---|
| 020212-3-11 | 73 | 24 | 45 | ~20 |

DESCRIPTION: Specimen -3-11 is a fully septate, moderately involute harpocertid with compressed, high-ovate whorl cross-section and relatively narrow and rounded venter. The umbilical margin is rather sharp with a vertical, undercut umbilical wall. The high and hollow keel is partly preserved on the shell. On the shell the ribs are simple and falcate, becoming broad and flat towards the outer part of the flank and projecting forward.

DISCUSSION: The specimens from Iran seem to fall somewhere into the range of variation of *H. falciferum* (J. SOWERBY) and *H. soloniacense* (LISSAJOUS). The

PLATE 1. Jurassic ammonites from the Lut Block, east-central Iran.

**1a, b** – *Dactylioceras* (*Orthodactylites*) *semicelatum* (SIMPSON 1843); **2** – *Dactylioceras* sp. ex gr. *D.* (*Orthodactylites*) *tenuicostatum* (YOUNG & BIRD 1822); **3a, b** – *Dactylioceras* sp. nov.; **4a, b** – *Peronoceras* sp. nov.?; **5a, b** – *Nodicoeloceras* cf. *crassoides* (SIMPSON 1855); **6a, b** – *Harpoceras* sp. ex gr. *H. falciferum* (J. SOWERBY 1820) / *H. soloniacense* (LISSAJOUS 1906); **7** – *Hildaites* sp. ex gr. *H. forte* (BUCKMAN 1921); **8a, b** – *Pleydellia* (*Walkericeras*) cf. *lugdunensis* ELMI, RULLEAU, GABILLY & MOUTERDE 1997 ; **9a, b** – *Dumortieria* cf. *explanata* BUCKMAN 1904; **10a, b** – *Leioceras costosum* (QUENSTEDT 1886); **11a, b** – *Leioceras paucicostatum* RIEBER 1963. All figures are natural size.


1a
1a
2
3a
3b
4a
4b
5a
5b
6a
6b
7
8a
8b
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10a
10b
11a
11b

coarse ribbing and the width of the umbilicus resmbles *H. soloniacense* as figured by HOWARTH (1992, pl. 21, fig. 2a, b).

STRATIGRAPHIC RANGE: Lower to lower Middle Toarcian (Falciferum/Bifrons zones). World-wide, except along the southern Tethys.

Subfamily Hildoceratinae HYATT 1867

*Hildaites* sp. ex gr. *H. forte* (BUCKMAN 1921)
(Pl. 1, Fig. 7)

MATERIAL: Two small specimens from ammonite level 2 (020216-1-1, -1-15).

Dimensions (in mm):

| specimen | D | U | H | W |
|---|---|---|---|---|
| O20216-1-15 | 24 | 42 | 35 | 33 |

DESCRIPTION: Evolute Hildoceratinae with a nearly quadrate whorl cross-section and a rather strong keel, bordered by shallow sulci. Ribs are simple, distant and slightly sinuous. They begin at the seam and are bullae-like raised at the ventro-lateral edge. On the umbilical wall the ribs are distinctly prorsiradiate, but become slightly rursiradiate on the flank.

DISCUSSION: The specimen shows similarities to the inner whorl of *H. forte* (BUCKMAN), figured by HOWARTH (1992, pl. 32, fig. 3). The coarse ribbing is somewhat reminiscent of *Orthildaites douvillei* (HAUG), figured by ELMI & *al.* (1997, pl. 9, figs 11-12) from the Serpentinum Zone. However, the ribbing of *O. douvillei* is not so straight as in our specimen.

STRATIGRAPHIC RANGE: Lower Toarcian (Serpentinum Zone?).

Subfamily Grammoceratinae BUCKMAN 1904

*Pleydellia (Walkericeras)* cf. *lugdunensis*
ELMI, RULLEAU, GABILLY & MOUTERDE 1997
(Pl. 1, Fig. 8a, b)

cf. 1997. *Pleydellia* (*Walkericeras*) *lugdunensis* nom. nov.; ELMI, RULLEAU, GABILLY & MOUTERDE, p. 35, fig. 5; pl. 11, fig. 19.

MATERIAL: 4 fragmentary specimens from ammonite level 4 (020212-4-4, -4-5; 020216-5-9, -5-12).

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-5-9 | 36 | 23 | 47 | 22 |

DESCRIPTION: The figured specimen (no. 020216-5-9) is a small, fully septate and relatively involute *Pleydellia* with compressed, high-ovate whorl cross section and a sharp keel. The umbilical margin is rather sharp and the umbilical wall oblique. The ribbing is relatively fine, falcate and slightly fasciculating on the inner part of the flank.

DICUSSION: Apart from the more acute whorl cross-section and finer ribbing, our specimens match *Pleydellia* (*Walkericeras*) *lugdunensis* nom. nov. of ELMI & *al.* (1997, 35, fig. 5; pl. 11, fig. 19).

STRATIGRAPHIC RANGE: Upper Toarcian (Aalensis Zone).

*Dumortieria* cf. *explanata* BUCKMAN 1904
(Pl. 1, Fig. 9a, b)

cf. 1904. *Dumortieria explanata* S. BUCKMAN; BUCKMAN, Suppl., p. 185, pl. 22, figs 28-30.
cf. 1985 *Dumortieria explanata* BUCKMAN; SEYED-EMAMI & NABAVI, p. 252, fig. 18a, b, 19a, b.

MATERIAL: 1 fully septate and abraded specimen from ammonite level 4: 020212-4-3.

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020212-4-3 | 38 | ~40 | ~35 | — |

DESCRIPTION: Moderately evolute *Dumortieria* with a rectangular to ovate whorl cross-section. The venter is slightly arched and possesses a low keel. The ribs are simple, distant, sharp and slightly sinuous, bending forward on the venter and ending at the keel.

DISCUSSION: Because of the poor preservation, the specimen is assigned to *D. explanata* with reservation.

STRATIGRAPHIC RANGE: Upper Toarcian (Pseudoradiosa Zone).

Family Graphoceratidae BUCKMAN 1905
Subfamily Leioceratinae SPATH 1936

*Leioceras* aff. *lineatum* BUCKMAN 1899
(Pl. 2, Fig. 1a, b)

aff. 1899. *Lioceras lineatum*; BUCKMAN, p. 40, pl. 8, figs 1-3.
aff. 1987. *Leioceras lineatum* BUCKMAN, 1899 (M); GOY & URETA, p. 222, pl. 2, figs 1-5, pl. 3, figs 1-6; text-figs 3-5. [with synonymy]

MATERIAL: 4 specimens from ammonite level 4: 020216-5(5-4, 5-5, 5-7, 5-8).

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-5-4 | 61 | 22 | 43 | — |

DESCRIPTION: About one-third of specimen -5-4 is the body whorl, beginning at about D = 55 mm. It is an involute *Leioceras* with a high-ovate, lanceolate whorl cross-section. The umbilical shoulder is rounded, the umbilical wall oblique. At the beginning of the body chamber, a slight egression of the last whorl is indicated. The sharp keel continues on the body chamber. No distinct ventrolateral shoulders are developed. On the shell the costation consists of fine, dense, falcoid and fasciculating striae, beginning at the umbilical seam and continuing onto the keel. On the internal mould the ribbing is relatively fine and falcoid.

DISCUSSION: The Iranian specimens belong with certainty to the morphotype group of *Leioceras opalinum – L. lineatum*. Compared to the holotpe of *L. lineatum* (BUCKMAN 1899, pl. 8, figs 1-3) and the specimens figured by GOY & URETA (1987), our specimens are slightly more involute.

STRATIGRAPHIC RANGE: Lower Aalenian (Opalinum Zone).

### *Leioceras paucicostatum* RIEBER 1963
(Pl. 1, Fig. 11a, b)

1963. *Leioceras paucicostatum* n. sp.; RIEBER, p. 35, pl. 2, figs 3-5, 8-9.
1967. *Leioceras* cf. *paucicostatum* RIEBER 1963; SEYED-EMAMI, p. 53, pl. 1, fig. 15.
1987. *Leioceras paucicostatum* RIEBER, 1963; GOY & URETA, p. 232, pl. 5, fig. 8.

MATERIAL: Three internal moulds from ammonite level 4: 020216-5(5-14, 5-17, 5-19).

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-5-19 | 27 | 37 | 37 | ~24 |

DESCRIPTION: Relatively evolute *Leioceras* with a sharp keel, shallow umbilicus and coarse ribbing.

DISCUSSION: With regard to the coarse ribbing, the relatively wide umbilicus and the small size, our specimens match well *L. paucicostatum* (RIEBER 1963, p. 35). The phragmocone of our figured specimen ends at D = 23 mm. Thus, *L. paucicostatum* may be considered as the micrococh form of members of the coarsely ribbed *L. costosum* group.

STRATIGRAPHIC RANGE: Lower Aalenian (Opalinum Zone).

### *Leioceras costosum* (QUENSTEDT 1886)
(Pl. 1, Fig. 10a, b; Pl. 2, Fig. 2a, b)

1886. *Ammonites opalinus costosus*; QUENSTEDT, p. 447, pl. 55, figs 5, 20, 21.
1963. *Leioceras costosum* (QUENSTEDT, 1886); RIEBER, p. 32.
1967. *Leioceras costosum* (QUENSTEDT); SEYED-EMAMI, p. 49, pl. 1, fig. 21; pl. 7, figs 6-7.
1987. *Leioceras* cf. *costosum* (QUENSTEDT), 1886; GOY & URETA, p. 232, pl. 5, figs 9-11.

MATERIAL: Four internal moulds from ammonite level 4: 020216-5(5-15, 5-16, 5-18, 5-20)

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-5-20 | 32 | 30 | 46 | ~25 |
| 020216-5-18 | 34 | 32 | 44 | ~26 |

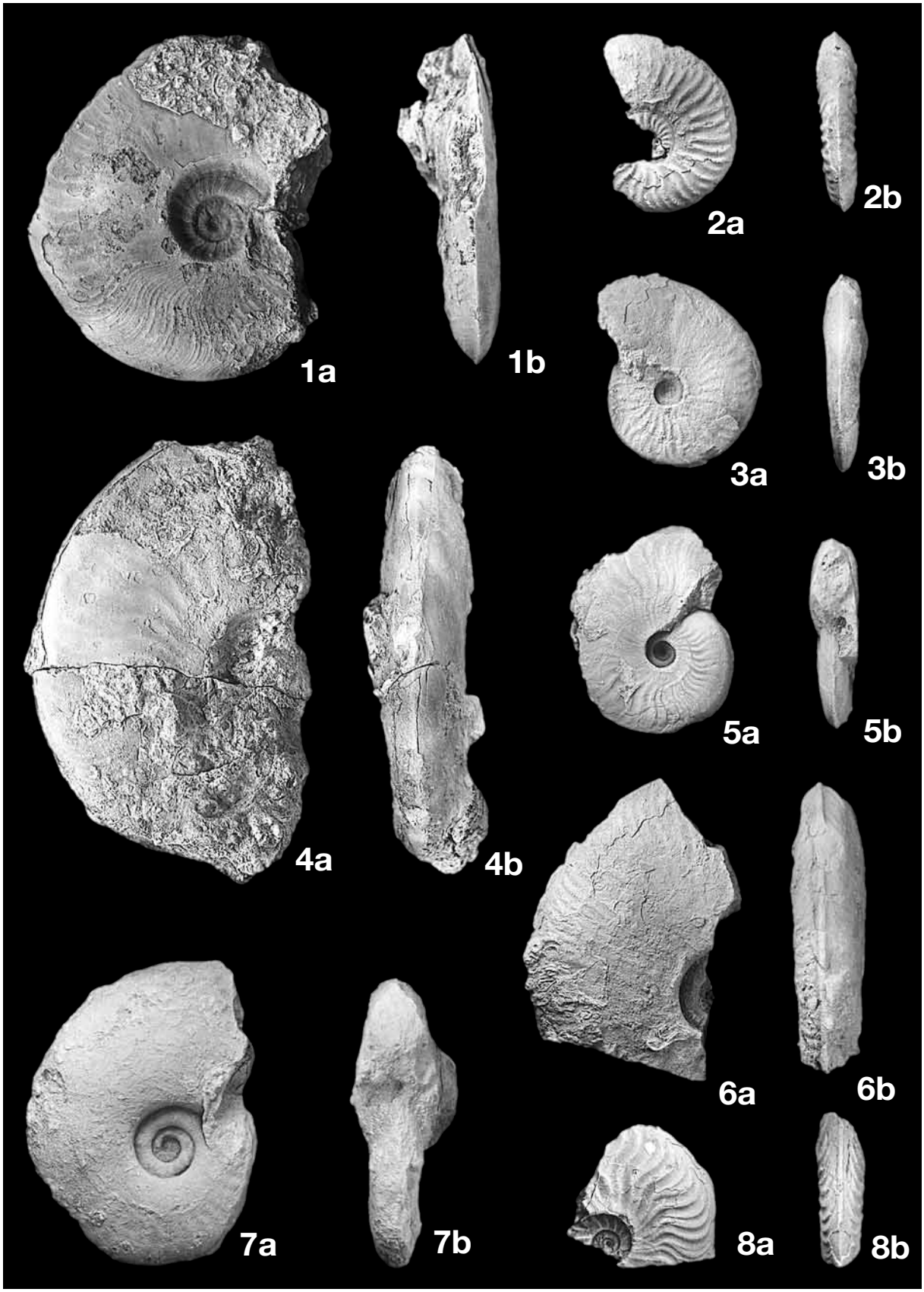
DESCRIPTION: Moderately evolute and coarsely ribbed *Leioceras* with bifurcating ribs, lanceolate whorl cross-section and a very sharp keel. The umbilicus is shallow with an oblique umbilical wall.

DISCUSSION: See SEYED-EMAMI (1967, p. 49) and GOY & URETA (1987, p. 232).

STRATIGRAPHIC RANGE: Lower Aalenian (Opalinum Zone).

### *Leioceras* aff. *comptum* (REINECKE 1818)
(Pl. 2, Figs 3a, b, 5a, b)

aff. 1818. *Nautilus comptus*; REINECKE, p. 57, pl. 1, figs 5, 6.
aff. 1987. *Leioceras comptum* (REINECKE), 1818; GOY & URETA, p. 226, pl. 4, figs 1-8; pl. 5, fig. 1-7; text-figs 6-7.


1a
1b
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
7a
7b
8a
8b

aff. 1993. *Leioceras comptum* (REINECKE, 1818); SEYED-EMAMI & *al*., p. 17, pl. 2, figs 1, 2.

MATERIAL: 3 small specimens from ammonite level 4 (020216-5-1, -5-2, -5-3).

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-5-2 | 33 | 17 | 50 | ~25 |
| 020216-5-1 | 36 | 17 | 50 | ~25 |

DESCRIPTION: Extremely involute and compressed *Leioceras* with a high-ovate, lanceolate whorl cross-section. The umbilical margin is sharp, the umbilical wall vertical. The keel is high and sharp, bordered by inconspicuous ventrolateral shoulders. The ribbing on the shell (specimen 5-1) consists of fine, falcoid and fasciculating striae, but on the internal mould (specimen 5-2) there are fine and rather dense falcoid ribs.

DISCUSSION: Our specimens are extremely involute and finely ribbed varieties of the *L. comptum* morphotype group. A very similar specimen is *L. comptum* figured by GOY & URETA (1987, pl. 5, fig. 1). Although the suture line is not visible, regarding the small size, our specimens may be considered as microconchs of *L. comptum*.

STRATIGRAPHIC RANGE: Lower Aalenian (Opalinum Zone).

Subfamily Graphoceratinae BUCKMAN 1905

*Brasilia* sp. ex gr. *B. bradfordensis* (BUCKMAN 1887)
(Pl. 2, Fig. 4a, b)

MATERIAL: 1 fragment from ammonite level 5 (020216-5-6).

DESCRIPTION AND DISCUSSION: The fragmentary specimen has a diameter of 80 mm. It is a relatively involute *Brasilia* with a high-ovate and fastigate whorl cross-section, a rather sharp umbilical margin, a steep umbilical wall, and a strongly falcate ribbing. For comparisons see SEYED-EMAMI & *al.* (1993, p. 21).

STRATIGRAPHIC RANGE: Middle Aalenian (Bradfordensis Zone).

*Graphoceras* sp. ex gr. *G. concavum* (J. SOWERBY 1815)
(Pl. 2, Fig. 8a, b)

MATERIAL: 2 fragmentary specimens from ammonite level 5: 020216-5-11, -5-21.

DESCRIPTION AND DISCUSSION: Relatively involute and compressed *Graphoceras* with high-ovate whorl cross-section and a high, sharp keel on the venter. The umbilical margin is sharp and slightly raised, the umbilical wall is vertical. The ribbing is strongly falcate, irregular, simple or bifurcating.

The fragmentary specimens compare well with the morphotype group of *G. concavum*. A rather similar specimen has been figured by CONTINI (1969, pl. 21, figs 5-6).

STRATIGRAPHIC RANGE: Upper Aalenian (Concavum Zone).

*Graphoceras* (*Ludwigella*) sp. ex gr. *G.* (*L.*) *cornu*
(BUCKMAN 1881)

MATERIAL: 6 fragmentary specimens from ammonite level 5: 020212-4-1; 020216-5-22, -5-23, -5-24.

DISCUSSION: With regard to the strong falcate ribbing and the fastigate venter, the very fragmentary specimens can be compared to the group of *G.* (*L.*) *cornu* as figured by CONTINI (1969, pl. 22, figs 13-15, 17).

STRATIGRAPHIC RANGE: Upper Aalenian.

Family Hammatoceratidae BUCKMAN 1887
Subfamily Hammatoceratinae BUCKMAN 1887

*Hammatoceras* sp.
(Pl. 3, Fig. 1)

MATERIAL: 1 fragmentary phragmocone from ammonite level 3: 020216-3.

DESCRIPTION: The large, fully septate and very evolute *Hammatoceras* has a broad, slightly higher than wide, triangular to ovate whorl cross-section and a high hollow keel. The umbilical margin is rounded with a flat, vertical

PLATE 2. Jurassic ammonites from the Lut Block, east-central Iran

**1a, b** – *Leioceras* aff. *lineatum* BUCKMAN 1899; **2a, b** – *Leioceras costosum* (QUENSTEDT 1886); **3a, b** – *Leioceras* aff. *comptum* (REINECKE 1818); **4a, b** – *Brasilia* sp. ex gr. *B. bradfordensis* (BUCKMAN 1881); **5a, b** – *Leioceras* aff. *comptum* (REINECKE 1818); **6a, b** – *Planammatoceras (Pseudaptetoceras)* aff. *klimakomphalum* (VACEK 1886); **7a, b** – *Sonninia* sp.; **8a, b** – *Graphoceras* sp. ex gr. *G. concavum* (J. SOWERBY 1815). All figures are natural size

umbilical wall. The ribbing is coarse, consisting of short, blunt and slightly prorsiradiate primaries, beginning at the umbilical margin and terminating at rounded nodes at around the inner third of the flank. Usually two slightly prorsiradiate and curved secondaries start from the nodes, with few intercalatory ribs, all ending at the keel.

DISCUSSION: Our specimen shows some similarities (evolute form and the general style of ribbing) to representatives of the genus *Crestaites*, erected by RULLEAU & *al*. (2001, p. 76) for evolute, compressed hammatoceratids of the Pseudoradiosa Zone. In *Crestaites*, the primaries bifurcate without nodes. However, our specimen shows well developed nodes at the point of bifurcation, and we, thus, keep it in *Hammatoceras*. A rather similar taxon is *H.* aff. *victorii* BONARELLI, described by SEYED-EMAMI (1967, p. 74, pl. 9, fig. 60) from the Badamu Formation of the Kerman area (southeast Central Iran).

STRATIGRAPHIC RANGE: Upper Toarcian (upper Dispansum or Pseudoradiosa zones?).

*Planammatoceras (Pseudaptetoceras)* aff. *klimakomphalum* (VACEK 1886)
(Pl. 2, Fig. 6a, b)

aff. 1886. *Harpoceras klimakomphalum* n. sp.; VACEK, p. 81, pl. 8, figs 16, 17.
aff. 1982. *Planammatoceras* (*Pseudaptetoceras*) *klimakomphalum* (VACEK); WESTERMANN & RICCARDI, p. 20, text-fig. 4C-E. [photographic reproduction of the lectotype]
1987. *Planammatoceras* (*Pseudaptetoceras*) aff. *klimakomphalum* (VACEK); SEYED-EMAMI, p. 379, pl. 4, fig. 1a, b.

MATERIAL: One-fourth of a fully septate internal mould from ammonite level 5: 020216-5-25.

DISCUSSION: The present specimen corresponds fully to specimens of the species described from the Badamu Formation of the Kerman area (SEYED-EMAMI 1967) and the Shemshak Formation of the Alborz Mountains (SEYED-EMAMI 1987). For detailed description and discussion see SEYED-EMAMI (1987, p. 380).

STRATIGRAPHIC RANGE: Upper Aalenian, co-occurring with *Graphoceras.*

Family Sonniniidae BUCKMAN 1892

*Sonninia* sp.
(Pl. 2, Fig. 7a, b)

MATERIAL: 2 eroded phragmocones from ammonite level 6: 020216-7-2, -7-5.

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-7-2 | 52 | 25 | 48 | - |

DESCRIPTION: Relatively involute *Sonninia* with triangular-ovate whorl cross-section, ventrolateral shoulders and a hollow keel. The umbilical margin is rounded, the umbilical wall vertical. Due to the erosion the ribbing is not clearly shown. Specimen -7-2 shows faint ribbing at the beginning of the last preserved whorl, but the rest seems to be smooth. The suture line is complex. Because of the poor preservation, no specific determination is possible.

STRATIGRAPHIC RANGE: Ammonite level 6 (Text-fig. 2), together with *Witchellia* ex gr. *laeviuscula* (J. DE C. SOWERBY) from the Lower Bajocian (Laeviuscula Zone).

*Witchellia* sp. ex gr. *W. laeviuscula*
(J. DE C. SOWERBY 1824)
(Pl. 3, Fig. 2)

MATERIAL: Two eroded phragmocones from ammonite level 6: 020216-7(7-1, 7-3).

Dimensions:

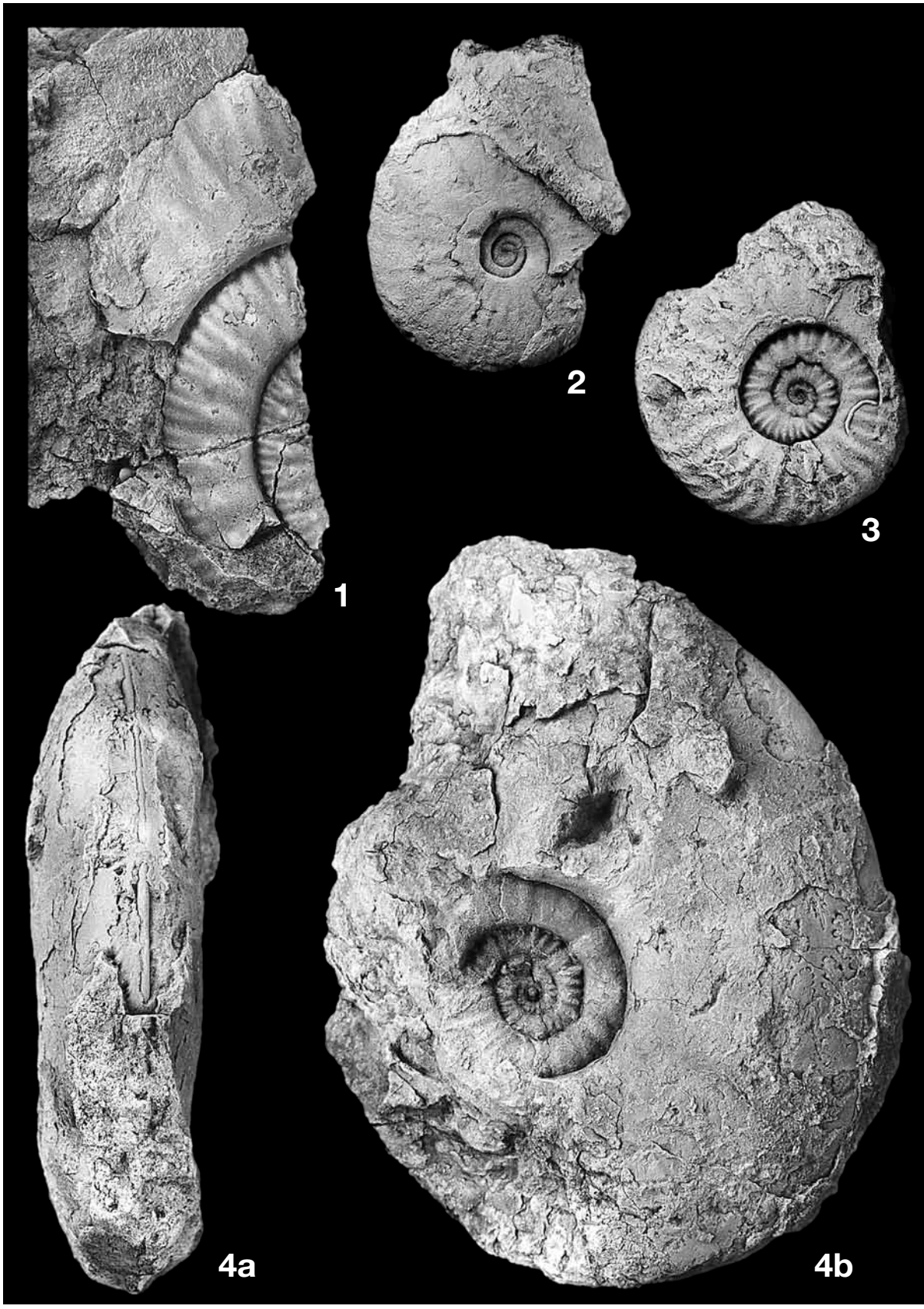
| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-7-3 | 48 | 18 | 48 | ~30 |
| lectotype | 68 | 18 | 48 | 29 |

(WESTERMANN 1969, see below)

DESCRIPTION: Relatively involute and compressed *Witchellia* with high-ovate whorl section. The umbilical margin is rounded, the umbilical wall steep. The ribbing is faint (partly because of abrasion) and consists of slightly prorsiradiate and irregularly fasciculating primaries on the inner half of the flank, slightly curving forward on the outer part of the flank. The venter is narrow and slightly rounded. The keel has been eroded away.

PLATE 3. Jurassic ammonites from the Lut Block, east-central Iran

**1** – *Hammatoceras* sp.; **2** – *Witchellia* sp. ex gr. *W. laeviuscula* (J. DE C. SOWERBY 1824); **3** – *Witchellia platymorpha* BUCKMAN 1925; **4a, b** – *Witchellia platymorpha* BUCKMAN 1925. All figures are natural size


1
2
3
4a
4b

DISCUSSION: The bigger specimen (figured on Pl. 3, fig. 2) matches the lectotype of *W. laeviuscula* (J. DE C. SOWERBY), described and figured by WESTERMANN (1969, p. 108, text-fig. 35). The dimensions of our specimen also fully correspond to those of the lectotype (see above). Similar specimens have been figured by BUCKMAN (1927, pl. 745), SEYED-EMAMI (1967, pl. 12, fig. 3), and FERNANDEZ-LOPEZ (1985, p. 70, fig. 8a; pl. 7, fig. 2). Concerning the relationship to *W. platymorpha* BUCKMAN and *W. sutneri* (BRANCO) see WESTERMANN (1969, p. 108) and the description of *W. platymorha* in this paper.

STRATIGRAPHIC RANGE: Lower Bajocian (Laeviuscula Zone).

*Witchellia platymorpha* BUCKMAN 1925
(Pl. 3, Fig. 3, Figs 4a, b)

1925. *Witchellia platymorpha*, S. BUCKMAN, 1925; BUCKMAN, pl. 580.

MATERIAL: 2 phragmocones from ammonite level 6: 020216-7-4, -7-6.

Dimensions:

| specimen | D | U | H | W |
|---|---|---|---|---|
| 020216-7-4 | 46 | 37 | 39 | ~32 |
| 020216-7-6 | 130 | ~24 | ~45 | — |

DESCRIPTION: The smaller specimen (-7-4) is a relatively evolute internal mould with subrectangular to ovate whorl section and bisulcate-tricarinate venter. The hollow keel has come off. The umbilical margin is rounded, the umbilical wall steep to vertical. The ribbing on the inner whorl is rather irregular, slightly rursiradiate, simple or fasciculating pair-wise at the umbilicus. Some primaries are swollen and bear small tubercles at the umbilical seam. On the outer preserved whorl the primaries are elongated-swollen and alternatingly bifurcate about the mid-flank. On the outer third of the flank the ribs project forward, terminating at the ventral sulci.

The larger specimen (-7-6) is a fully septate internal mould. It is relatively involute with a high-ovate whorl cross-section. The greatest thickness is about the mid-flank, converging towards the venter and the umbilicus. The venter is moderately broad and tabulate, the hollow keel has come off. The umbilical margin is rounded, the umbilical wall steep to vertical. The ribbing on the inner whorls corresponds fully to that of the smaller specimen (-7-4). Likewise, the umbilicus is wider on the inner whorls. The ribbing on the last preserved whorl consists only of faint and distant undulations.

DISCUSSION: The larger specimen (-7-6) matches fully the illustration and dimensions of the holotye of *W. platymorpha* BUCKMAN (1925, pl. 580). However, the smaller specimen (-7-4), although less coarsely ribbed, shows similarities to the holotype of *W. sutneri* (BRANCO), refigured by WESTERMANN (1969, text-fig. 34). From this point of view the specimen looks like *W. sutneri*, figured by DORN (1935, pl. 3, fig. 6). Another very similar species is *W. sutneroides* WESTERMANN (1969, p. 116, pl. 28, fig. 1a-c). WESTERMANN (1969, p. 110) discussed the great resemblance between the four species: *W. platymorpha* BUCKMAN, *W. laeviuscula* (SOWERBY), *W. sutneri* (BRANCO), and *W. sutneroides* (WESTERMANN) and was inclined to consider *W. platymorpha* as a variant of *W. laeviuscula*. *Witchellia* aff. *sutneri* from the Shotori Mountains (Tabas Block, see Text-fig. 1) (SEYED-EMAMI & *al.* 2000, p. 260) also is more coarsely ribbed.

STRATIGRAPHIC RANGE: Lower Bajocian (Laeviuscula Zone).

## DISCUSSION

About 800 m of marine upper Lower to lower Middle Jurassic strata crop out at Kuh-e-Shisui in the northern Lut Block (Text-figs 1, 2). The lower part of the succession consists of several hundred metres of thick-bedded quartzitic sandstones alternating, towards the upper part, with thick-bedded oolitic limestones. These are followed by about 350 m of pale yellow-green silty marls with intercalations of yellowish to violet calcareous sandstones, containing Early Toarcian to Early Bajocian ammonites. The underlying and overlying strata are covered by sand dunes or Tertiary volcanic rocks. The succession, although lithologically rather different, corresponds in age to the Badamu Formation (Toarcian-Early Bajocian, Text-fig. 3) of east-central Iran (SEYED-EMAMI 1967, 1971), which signifies a long-lasting marine ingression within the predominantly continental sediments of the Shemshak Group (SEYED-EMAMI & *al.* 2001). The Early Toarcian is a time of world-wide sea-level rise (HALLAM 2001), culminating in Central and North Iran in the Late Toarcian and Aalenian (SEYED-EMAMI 1987).

The low diversity and in part poorly preserved ammonite fauna, comprising the families and subfamilies Dactylioceratidae, Harpoceratinae, Hildoceratinae, Grammoceratinae, Leioceratinae, Graphoceratinae, Hammatoceratinae and Sonniniidae, is mostly concentrated within six levels (Text-figs 2, 3). The faunas of ammonite levels 2, 4 and 5 mostly comprise loose speci-

mens collected from thin rock units up to three metres in thickness. Those of levels 1, 3 and 6 were collected *in situ* from individual beds.

Ammonite level 1 yielded only a few and poorly preserved specimens.

Ammonite level 2 contains taxa corresponding to the Lower to lower Middle Toarcian Tenuicostatum, Falciferum and Bifrons zones (collections 020216-1; 020212-3):

*Dactylioceras* (*Orthodactylites*) *semicelatum* (SIMPSON)
*Dactylioceras* sp. ex gr. *D.* (*O.*) *tenuicostatum* (YOUNG & BIRD)
*Dactylioceras* sp. nov.
*Peronoceras* sp. nov.?
*Nodicoeloceras* cf. *crassoides* (SIMPSON)
*Harpoceras* sp. ex gr. *H. falciferum* (J. SOWERBY) / *H. soloniacense* (LISSAJOUS)
*Hildaites* sp. ex gr. *H. forte* (BUCKMAN)

Ammonite level 3 (Upper Toarcian: Dispansum or Pseudoradiosa Zone?); collection 020216-3:

*Hammatoceras* sp.

Ammonite level 4 (Upper Toarcian: Pseudoradiosa/ Aalensis zones; Lower Aalenian: Opalinum Zone); collections 020216-5; 020212-4:

*Dumortieria* cf. *explanata* BUCKMAN
*Pleydellia (Walkericeras)* cf. *lugdunensis* ELMI, RULLEAU, GABILLY & MOUTERDE
*Leioceras* aff. *lineatum* BUCKMAN

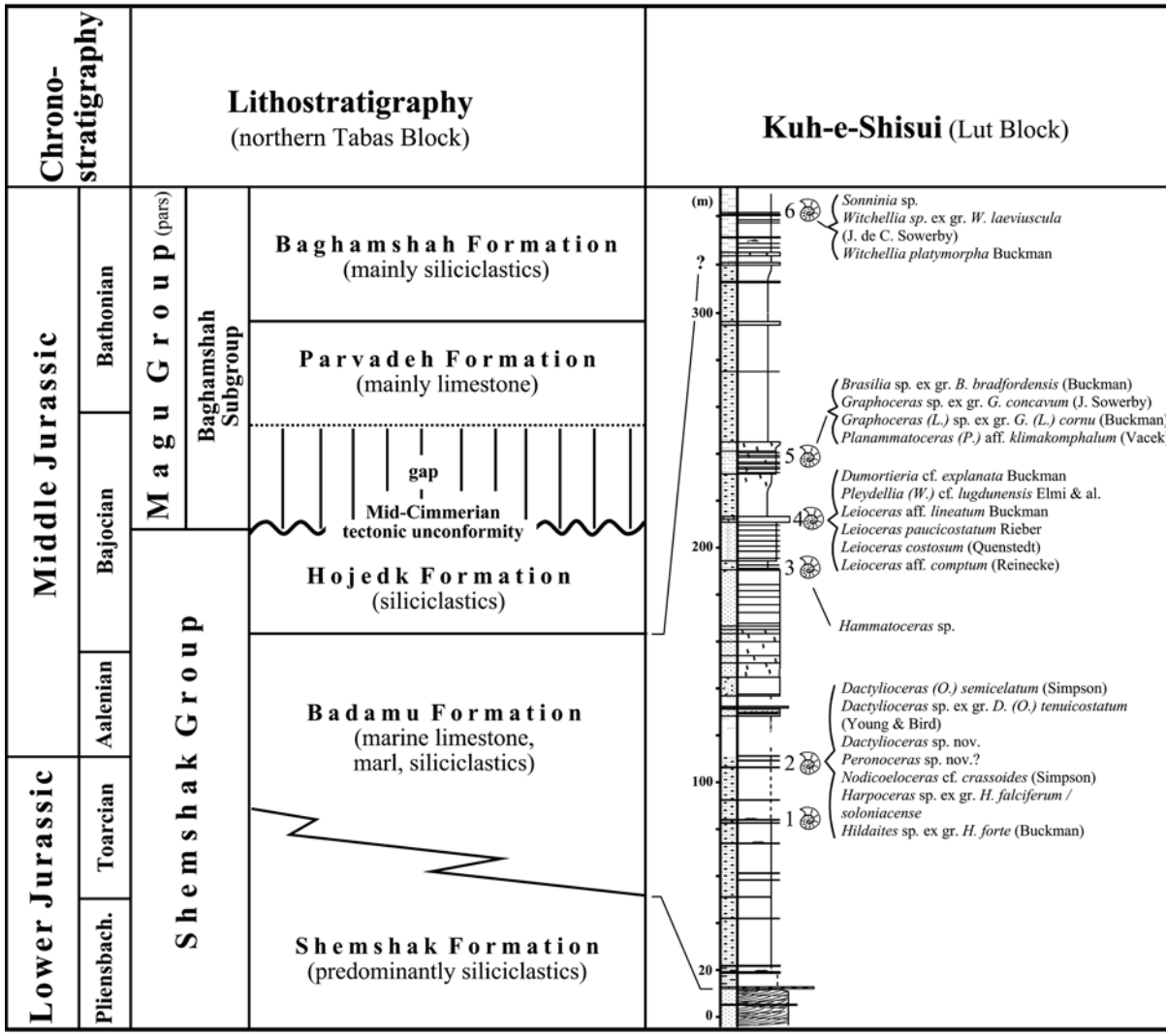



Fig. 3. Proposed correlation of the Kuh-e-Shisui section with the standard succession of the northern Tabas Block (cf. SEYED-EMAMI & *al.* 2001; WILMSEN & *al.* 2003)

*Leioceras paucicostatum* RIEBER
*Leioceras costosum* (QUENSTEDT)
*Leioceras* aff. *comptum* (REINECKE)

Ammonite level 5 (Upper Aalenian: Bradfordensis/ Concavum zones); collections 020216-5; 020212-4:
*Brasilia* sp. ex gr. *B. bradfordensis* (BUCKMAN)
*Graphoceras* sp. ex gr. *G. concavum* (J. SOWERBY)
*Graphoceras* (*Ludwigella*) sp. ex gr. *G.* (*L.*) *cornu* (BUCKMAN)
*Planammatoceras* (*Pseudaptetoceras*) aff. *klimakomphalum* (VACEK)

Ammonite level 6 (Lower Bajocian: Laeviuscula Zone); collection 020216-7:
*Sonninia* sp.
*Witchellia sp*. ex gr. *W. laeviuscula* (J. DE C. SOWERBY)
*Witchellia platymorpha* BUCKMAN

The ammonite fauna from the northern Lut Block, although far less abundant and diverse, corresponds fully to that of the Badamu Formation of the Kerman-Ravar region (SEYED-EMAMI 1967, 1971; SEYED-EMAMI & *al.* 1993). Worth noting are the Lower Toarcian Harpoceratinae and Hildoceratinae, which are well represented in the upper part of the Shemshak Formation of the Alborz Mountains (REPIN 1987) and which have not yet been reported from the Badamu Formation of east-central Iran. Palaeobiogeographically, the ammonite fauna of the northern Lut Block is similar to that of age-equivalent strata from North Iran and other areas of Central Iran, and is closely related to faunas from northwestern Europe (SEYED-EMAMI 1987, 1988; SEYED-EMAMI & *al.* 2001; MOUTERDE & ELMI 1991) but lacking Lytoceratidae and Phylloceratidae.

The presence of similar and analogous lithostratigraphic units during the Jurassic within the northern Lut Block and the northern Tabas Block indicates that the two areas were closely connected to each other, at least until the end of the Jurassic.

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