Substantiation of the Barremian/Aptian boundary

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This paper focuses on the Barremian/Aptian boundary in the Trans-Caspian area. Results of a stratigraphical study of the uppermost Barremian and the lower Aptian succession in the Trans-Caspian area are presented. The bed-by-bed description of three sections — Keldzhe, Tekedzhik and Utuludzha — is given as well as detailed lithologic columns. Five ammonite zones are known in the studied stratigraphic interval — the Turkmeniceras turkmenicum, Deshayesites tuarkyricus, D. weissi, D. deshayesi, and Dufrenoya furcata zones. These zones are correlated with those of Europe. The Barremian/Aptian boundary in the Trans-Caspian area should be drawn at the base of the D. tuarkyricus Zone. It corresponds to the layers with the first occurrences of *Deshayesites*, *Prodeshayesites* and *Paradeshayesites* in Europe. It is proposed here to situate the boundary stratotype in the Utuludzha section, where the beds containing zonal representatives of the T. turkmenicum and D. tuarkyricus Zones are almost adjacent.

Contents

Introduction

Beginning with the work of William Smith, the founder of the biostratigraphic method, assemblages of organic remains have been the major criterion for differentiating a biostratigraphic unit from adjacent divisions. A. d'Orbigny, the creator of the Jurassic and Cretaceous stages, contributed to a large measure to this idea. He believed that stages were separated from each other by sharp boundaries, which reflected disastrous events in geological history. According to these ideas, the assemblage of fossils of every stage would correspond to steps of complete rejuvenation of the organic world and would principally be different from those lying above and below.

Geological practice, however, showed that there were sections through more continuous deposits containing organic remains intermediate between those typical of the stages that occur above and below. In the majority of the cases these intermediate parts were omitted from the first stratigraphic scales; they considerably complicated the subdivision of the sections and in particular their interregional correlation. At the same time it turned out that a fossil assemblage is not only limited in time, but also discrete in space, frequently showing intricate interrelations with assemblages developed in neighbouring regions or in adjacent facial belts. Nevertheless, palaeontological criteria are accepted as a basis for determining corresponding intervals between a section and a given stage stratotype or standard zone. Age relationships among neighbouring strata depend on their position in the evolutionary order of index fossils.

Localities where biostratigraphic units of adjacent stages occur in immediate contact (or in close proximity) and display a gradual qualitative change in the composition of the fossils, have been found in the Trans-Caspian area in the last few decades.

History of the Barremian/Aptian boundary

For a long time the Barremian/Aptian boundary was not hard to establish. Both stages were defined in the same area — in southeast France. From the very beginning they differed in the composition of the ammonite species. True, long ago, species that these stages had in common were recorded in the boundary beds in France (Kilian, 1887) and Germany (Stolley, 1908). Stolley's investigations even compelled Spath (1924) to lower the lower boundary of the Aptian Stage in the northern regions of Western Europe and to include uppermost Barremian beds into it. This suggestion, however, was not folowed.

Descriptions of the stratotype sections of the Barremian and Aptian stages were published in 1965. Above the beds yielding *Heteroceras astieri* and *Leptoceras puzosianum* a palaeontologically undefined interval has been established beginning at the entry of the ammonite *Pseudohaploceras matheroni* (Busnardo, 1965). The Barremian/Aptian boundary has been drawn at the first occurrence of *Pseudohaploceras matheroni*. Representatives of *Deshayesites*, such as *D. deshayesi* and *D. consobrinus,* have been recorded much higher. In the lower Aptian stratotype near La Bédoule and Cassis a 3-4 m thick horizon, the so-called transition beds yielding unidentifiable remains of ammonites of the genus '*Heteroceras*', has been distinguished above limestones of Urgonian facies (Fabre-Taxi et al., 1965). The Barremian/Aptian boundary has been drawn at the top of these beds. Ammonites identified by Roch (1927) as '*Parahoplites*' *weissi* and '*P.*' *consobrinus* were recorded above these beds. But among the forms from southeast France identified as *D. weissi*, only one specimen (Kilian & Reboul, 1915, pl. 6, fig. 2) is close to the German species, whereas the others can most likely be assigned to *D. evolvens*. Recently Delanoy (1991, 1995) confirmed this supposition.

Thus from the stratotype sections only a rough idea can be obtained of the biostratigraphic characteristics of the Barremian/Aptian 'boundary' as a limit where *Heteroceras* and *Leptoceras* become extinct and *Pseudohaploceras* and *Deshayesites* emerge (editors' note: but see Ropolo et al., this volume). Classic sections of Western Europe (Casey, 1961; Kemper, 1971) unambiguously showed that the Aptian Stage has to begin with the appearance of typical Aptian ammonites, first of all of the genus *Deshayesites* sensu lato, i.e. including *Prodeshayesites* and *Paradeshayesites* (distinguished by some palaeontologists as independent genera) (see also Rawson, 1983).

A precise level for the Barremian/Aptian boundary — a surface separating fossil associations characteristic of either one or the other stage — can be observed in the southeast of the Trans-Caspian area, in the mountainous regions of the Tuarkyr, Bolshoi and Maly Balkhans and in the West Kopet Dagh. Throughout these regions a close succession of ammonite assemblages can be observed, which permits the distinction of a uniform vertical series of biozones from undeniably Barremian to undoubtedly Aptian age:

Lower Aptian	Dufrenoya furcata Zone
	Deshayesites deshayesi Zone
	Deshayesites weissi Zone
	Deshayesites tuarkyricus Zone
Upper Barremian	Turkmeniceras turkmenicum Zone
(uppermost part)	Beds with *Imerites* and *Colchidites*

The same succession of units has been recorded in each region in facially similar deposits. In these areas the Barremian/Aptian boundary beds form part of the terrigenous grey bed formation (Tashliev & Tovbina, 1992), and boundaries between biozones can rather be recognized through the distribution of fossils than through changes in lithology. At the same time the differences in facies between the Maly Balkhan and the West Kopet Dagh on the one hand and the more western regions on the other, have hardly any effect on the succession of biostratigraphic units, which remains the same. These facts suggest that the succession of ammonites and other fossil groups rather depend on evolution than on local migrations due to changes in habitat.

Description of the sections

Keldzhe and Tekedzhik sections

The Keldzhe and Tekedzhik sections situated in the south of the Tuarkyr region (Fig. 1) are here proposed as reference sections for the boundary strata of the Barremian and Aptian stages. The Tuarkyr region comprises a system of gentle folds composed of Mesozoic and Paleogene rocks striking northwest to southeast.

A brachyform fold, the core of which is exposed in the piedmont area of the Keldzhe Range, is situated in the south of the region. The core is composed of red-coloured lagoonal-continental deposits of Hauterivian age (Kazandzhaburun Formation). Its flanks are formed by Hauterivian to Albian strata. The well-preserved northeastern slope of the fold is represented by the Tekedzhik Range, which can be traced over a long distance along the anticline and displays a perfect bed-by-bed exposure of Aptian and Albian deposits.

The reference sections are at a distance of 35 km south of the Geokdere aul and 7 km southeast of the Gobekadzhy Wells. The Barremian/Aptian boundary beds are exposed on the west and east margins of a large valley developed on Barremian and Aptian silty-clayey rocks; the valley separates the slopes of the Keldzhe and the Tekedzhik. The monoclinal ridges of the Tekedzhik upland are composed of upper Aptian strata. There is hardly any tectonic dislocation in the locality where the sections were compiled providing a continuous bed-by-bed record of the lower Aptian ammonite zones.

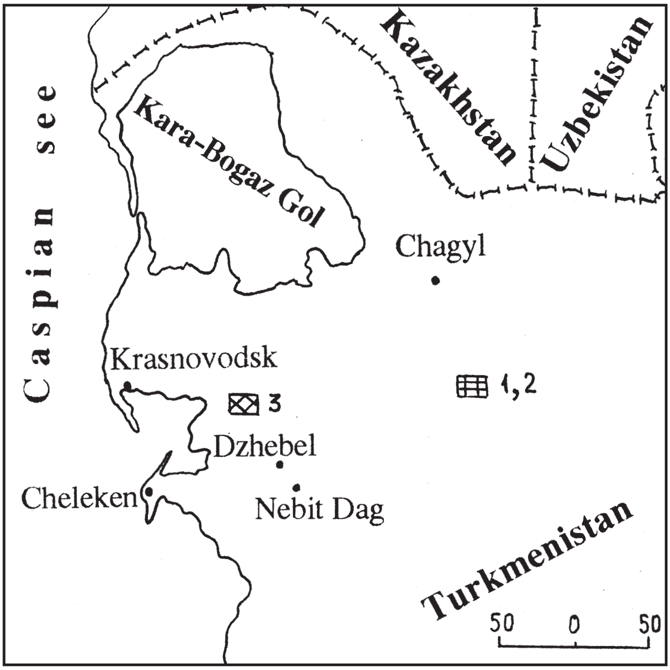

Fig. 1. Map with the locations of the sections studied; 1: Tekedzhik section; 2: Keldzhe section; 3: Utuludzha section.

These sections were first mentioned in Luppov's papers (1932, 1936). Based on the descriptions of the sections and their fossil content, he was the first to distinguish Aptian deposits in this region and he subdivided them into several ammonite horizons. In the lower Aptian two horizons were distinguished: a lower horizon with *Deshayesites deshayesi*, *D. consobrinoides*, *D. kiliani*, and an upper horizon with *Dufrenoya* aff. *dufrenoyi*, *Cheloniceras* cf. *crassum*. More recently T.N. Bogdanova and E.Ya. Yakhnin studied these deposits in detail under the leadership of Luppov and constructed a zonal chart of the Aptian Stage, which was improved by Bogdanova (1978). The upper Barremian deposits of the Keldzhe Range were studied by V.A. Prozorovsky.

Keldzhe Range (northeast slope) (Fig. 2)
Barremian

Description of the Barremian deposits begins with the terrigenous grey bed formation. These deposits occur at the top of the carbonate formation with washouts. The carbonate formation consists of thin-laminated clayey-carbonatic coquina. Its top is a rough surface. Abundant shells of the brachiopod *Belbekella* sp., and large foraminifera *Orbitolina* spp. are present. The upper 20 cm of the shell rock is composed of slightly argillaceous thin-platy limestones crammed with oriented shells of the gastropod *Pseudonerinea ornata*. They are distinguished as 'the beds with *P. ornata*', which can be traced throughout the Tuarkyr area, and represent a perfect reference horizon established by Luppov.

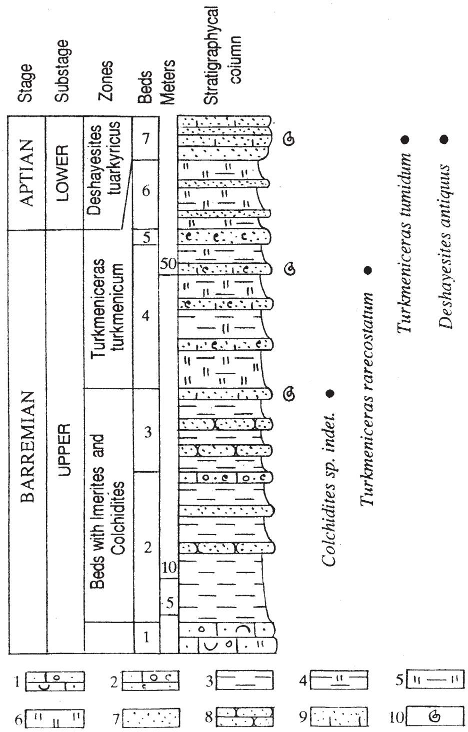

Fig. 2. Keldzhe section; 1: arenaceous oolitic limestone; 2: arenaceous oolitic-detrital limestone; 3: clay; 4: silty clay; 5: clayey siltstone; 6: siltstone; 7: friable sandstone; 8: hard sandstone; 9: calcareous sandstone; 10: beds with ammonites.

Bed 1. Composite lenticular alternation of obliquely laminated arenaceous oolitic limestones, coquina and carbonate mudstone; thickness 3.7 m. Abundant colonial and solitairy scleractinians, brachiopods (*Cyclothyris* sp.), bivalves (*Dentoperna subricordeana*), echinoids (*Epiaster* sp.), etc. were found.

Beds with *Imerites* and *Colchidites*

Bed 2: Alternation of grey compact clay with conchoidal fracture and beds (up to 0.5 m) of loose and hard fine-grained sandstones; thickness 20 m. At the top there is a bed of yellowish-greenish-grey arenaceous oolitic-detrital limestone. Shells of the bivalve *Sphaera corrugata* are recorded.

Bed 3: Thin alternation of bluish-grey clay and hard grey sandstones; thickness 11 m. At the top there is a layer of calcareous sandstone with rare *Colchidites* and bivalves.

Turkmeniceras turkmenicum Zone

Bed 4: Alternation of clayey siltstones and silty clays and interbeds of hard calcareous detrital sandstones; thickness 19 m. *Turkmeniceras rarecostatum*, abundant *Epiaster toxasteroides* and *Lamellaerhynchia geokderensis*, *L. adducta*, *L. bertheloti*, *Cyclothyris sayni*, *Sellithyris coxwellensis* occur in the upper part of the bed.

Bed 5: Grey sandstones with small crushed shells and detritus; thickness 2 m.

Bed 6. Clayey siltstones with thin sandstone interbeds; thickness 8.8 m.

Lower Aptian

Deshayesites tuarkyricus Zone

Bed 7: Calcareous platy sandstones alternating with friable sandstones; thickness 6 m. *Deshayesites antiquus*, *D. tumidum*, *Leionucula transcaspia*, *Epiaster toxasteroides*.

Tekedzhik Range (Fig. 3)

Upper Barremian

Turkmeniceras turkmenicum Zone

Bed 1: Greenish-grey, lenticular, obliquely laminated, oolitic-detrital sandstone with rare *Turkmeniceras* sp. indet., *'Nautilus'* sp.; thickness 0.5 m.

Bed 2: Greenish-grey clayey siltstones with small lenses of sandstones; thickness 2.1 m.

Bed 3: Arenaceous, oolitic-detrital, obliquely laminated limestones lie on the clayey siltstones of bed 2 with a sharp contact; thickness 0.5 m. *Turkmeniceras* sp., *Plicatula carteroni*, *'Exogyra'* sp., *Septifer lineatus*, *Iotrigonia* sp., *Lamellaerhynchia bertheloti*, *L. geokderensis*.

Bed 4: Friable sandstones alternate with hard massive ones containing rows of arenaceous concretions; thickness 4.5 m.

Bed 5: Platy, obliquely laminated, oolitic-detrital arenaceous limestones and is overlying bed 4 with a sharp contact. Laminae dip 50-60°, angle of dip of the bed is up to 20°; thickness 0.5-0.7 m. *Turkmeniceras turkmenicum* (Fig. 5f-g), *T. turkmenicum longicostatum*, *T. geokderense* (Fig. 5j-k), *T. multicostatum*, *T. rarecostatum*, *T. tumidum*, *Turkmeniceras* sp., *Hemihoplites (Matheronites) turkmenicus*, *H. (M.) ridzewskyi*, *H. (M.)* ex gr. *ukensis*, *Leionucula ovata*, *Camptonectes cottaldinus*, *Acesta longa*, *Modiolus aequalis*, *M. bipartitus*, *Tankredia khamperi*, *Unicardium vectense*, *Protocardia subhillana*, *Ptychomya robinaldina*, *Corbula carinata*, *C. striatula*, *Cyclothyris aptiensis*, *C. gibbsiana*, *Lamellaerhynchia bertheloti* (abundant shells), *L. geokderensis* (abundant shells), *L. adducta*, *Sellithyris sella*, *S. coxwellensis*, *Epiaster toxasteroides*, *Holaster benstedi*.

Bed 6: Grey, fine-grained, oolitic-glauconitic, calcareous sandstones; thickness 10 m. Oolitic-detrital sandstones with thin cross-bedding and small ripples in the upper part of the bed. Rare *Gervillaria* sp., *'Exogyra'* sp. and *Epiaster* sp.

Lower Aptian

Deshayesites tuarkyricus Zone

Bed 7: Dark-grey, silty clays with interbeds of dark, almost black clay; thickness 9.5 m. A horizon of large concretions composed of grey calcareous siltstone occurs in the basal part of the bed. The concretions contain *Deshayesites tuarkyricus*, *D. oglanlensis*, *D. antiquus*, *D.* aff. *antiquus, D. luppovi*, *Pseudohaploceras ramosum* (Fig. 7j-l), *Leionucula ovata*, *L. transcaspia, 'Falcimytilus' lanceolatus, Quadratotrigonia* cf. *nodosa, Astarte striatocostata, Tankredia khamperi, Protocardia subhillana, Dosinimeria parva, Corbula carinata, C. gaultina, C. striatula, Laternula gurgitis, Lamellaerhynchia marullensis, L. bertheloti, Epiaster toxasteroides.*

Bed 8: A layer of oolitic sandstone with scattered, rather small (up to 3-4 cm),

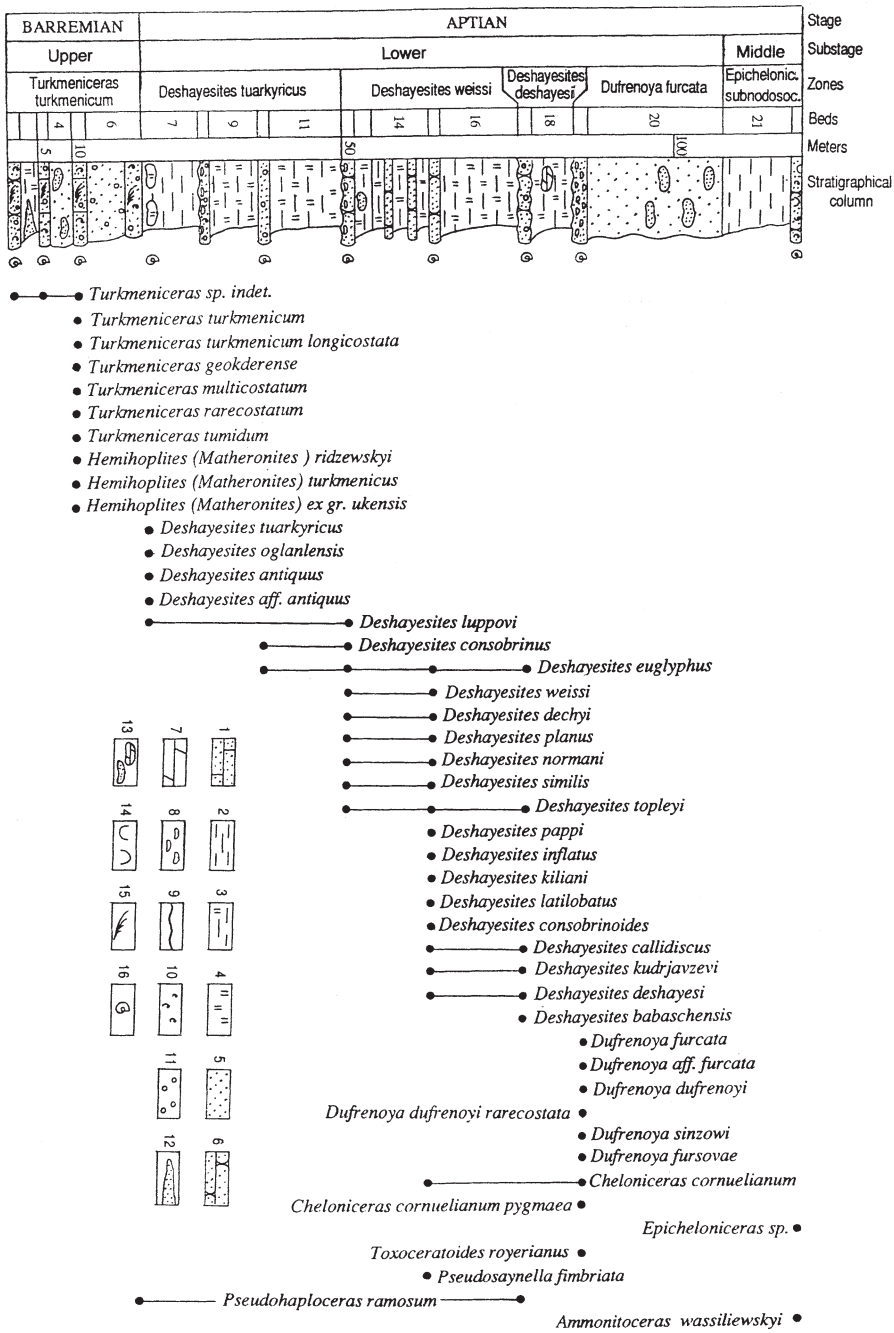

Fig. 3. Tekedzhik section; 1: sandy limestone; 2: clay; 3: silty clay; 4: siltstone; 5: friable sandstone; 6: hard sandstone; 7: marl; 8: pebbles; 9: unconformity; 10: detritus; 12: lenses; 13: concretions; 14: shells of large bivalves; 15: cross-bedding; 16: beds with ammonites.

rounded clay pebbles overlies the subjacent layer with a sharp contact; thickness 0.3-0.5 m. The bed contains accumulations of detritus. *Nucula subcancellata*, *Leionucula ovata*, *L. transcaspia*, *L. woodsi*, *Arca dupiniana*, *Cucullaea nana*, *Isoarca* sp., *Anomia laevigata*, *Modiolus bipartitus*, *Pterotrigonia vectiana*, *Astarte* aff. *striatocostata*, *Tankredia khamperi*, *Protocardia* cf. *subhillana*, *Pharus warburtoni*, *Corbula striatula*, *Lamellaerhynchia geokderensis*, *Epiaster toxasteroides*.

Bed 9: Dark-grey, spotted-banded, silty clays, locally with vague wave-like horizontal bedding due to the alternation of thin clay and silt beds; thickness 8.3 m.

Bed 10: Sandstones similar to bed 5; thickness 0.3-0.5 m. *Deshayesites consobrinus*, *D. euglyphus*, *Leionucula ovata*, *Quadratotrigonia kudakhurtensis*, *Lamellaerhynchia bertheloti*, *Epiaster toxasteroides*.

Bed 11: Dark-grey silty clays with thin spotted-banded structure grading into friable yellowish-gray silts at the top of the bed; thickness 12 m.

Deshayesites weissi Zone.

Bed 12: Calcareous sandstones with scattered small clayey pebbles, some of which are covered by glauconitic-ferruginous film, overlies bed 11 with sharp irregular contact; thickness 0.2-0.3 m. *Deshayesites weissi, D. dechyi, D. consobrinus, D. planus, D. normani, D. euglyphus, D. topleyi, D. luppuvi, D. similis, Leionucula transcaspia, Arca dupiniana, Cucullaea* ex gr. *consobrina, C. glabrae, C. nana, Gervillaria alaeformis, Chlamys archiacianus, Pseudolimea royeriana, Plicatula asperrima, Ceratostreon tuberculiferum, Modiolus aequalis, M. bipartitus, Litschkovitrigonia* aff. *media, Quadratotrigonia* ex gr. *nodosa, Astarte disparilis, A. obovata, Cardita fenestrata, Protocardia subhillana.*

Bed 13: Clayey siltstones with abundant arenaceous-calcareous concretions of various shapes and sizes; thickness 2.7 m.

Bed 14: Dark-grey silty clays with interbeds of dark clay and two layers (0.15 to 0.30 m) of platy calcareous sandstones; thickness 8.9 m.

Bed 15: Calcareous fine-grained sandstones with abundant fossils; thickness 0.4 m. *Deshayesites weissi*, *D. dechyi*, *D. pappi*, *D. callidiscus* (Fig. 10e-f), *D. kiliani*, *D. normani*, *D. latilobatus* (Fig. 10a-b), *D. planus* (Fig. 8j), *D. euglyphus* (Fig. 8d-f), *D. topleyi* (Fig. 9i), *D. consobrinoides*, *D. kudrjavzevi*, *D. deshayesi*, *D. similis* (Fig. 9a-b), *D. inflatus*, *Pseudosaynella fimbriata* (Fig. 12j), *Cheloniceras cornuelianum* (Fig. 12k), *Leionucula ovata*, *Barbatia aptiensis*, *Cucullaea forbesi, C. gabrielis*, *Grammatodon carinatus*, *G. securis*, *Gervillaria alaeformis*, *Modiolus aequalis*, *M.* cf. *reversus*, *Astarte disparilis, Arctica saussuri, Protocardia* ex gr. *subhillana, Epiaster toxasteroides.*

Bed 16: Dark-grey clayey siltstones; thickness 12.2 m. Two layers (from 0.2 to 0.3 m) of firm calcareous silstones occur at a distance of 4 m and 8 m from the basement.

Deshayesites deshayesi Zone

Bed 17: Calcareous oolitic, fine-grained sandstones with abundant fossils of which the casts are often crushed and covered by worm tracks. In the bed there are many concretions of firm arenaceous limestone of various shapes — from flat to spheroidal (with diameters from 8 to 10 cm). The boundaries of the bed are sharp and uneven; thickness 0.5 m. *Deshayesites callidiscus*, *D. euglyphus*, *D. topleyi*, *D. kudrjavzevi* (Fig. 11a), *D. deshayesi* (Fig. 11b), *D. babaschensis*, *Pseudohaploceras ramosum*, *P.* sp., *Leionucula ovata*, *Grammatodon carinatus*, *G. securis*, *Plicatula carteroni*, *P. inflata*, *P. placunea*, *Gryphaeostrea arduennensis*, *Quadratotrigonia* ex gr. *nodosa karakaschi*, *Pterotrigonia* aff. *vectiana*, *Cardita fenestrata*, *Cardium* sp., *Sulcirhynchia hythensis, Sellithyris coxwellensis.*

Bed 18. Dark-gray clayey siltstones with a few marlstone concretions up to 0.3 m; thickness 6.5 m.

Dufrenoya furcata Zone

Bed 19: A conglomerate layer crammed with well-rounded arenaceous-calcareous pebbles from 1 to 2 cm in diameter overlies the underlying clay with a sharp, but irregular contact; thickness 0.2 m. Stylolites and tracks of boring shells are recorded on the majority of the pebbles. *Dufrenoya furcata* (Fig. 12d-e), *D.* aff. *furcata*, *D. dufrenoyi* (Fig. 12a-b), *D. dufrenoyi rarecostata*, *D. sinzovi*, *D.* ex gr. *sinzovi*, *D. fursovae*, *Cheloniceras c. cornuelianum*, *Ch. cornuelianum pygmaea*, *Toxoceratoides royerianus* (Fig. 12n-o), *Aetostreon latissimum*, *'Falcimytilus' lanceolatus*.

Bed 20: Silty, fine-grained yellowish-grey sandstones; thickness 25.8 m. Four horizons of large flattened concretions of calcareous sandstone (diameter of the concretions is up to 2-3 m, height is up to 1 m) occur in the upper part of the bed.

Middle Aptian

Epicheloniceras subnodosocostatum Zone

Bed 21: Dark-grey, almost black, silty clays with a layer (0.1 m) of platy calcareous siltstone in the lower part of the bed; thickness 14.5 m.

Bed 22: Fine-grained calcareous sandstones crammed with shells of large oysters and other bivalves overlie the clays with a sharp contact; thickness 0.4-0.5 m. *Epicheloniceras* sp., *Ammonitoceras (Caspianites)* sp., *Leionucula rostrata*, *Chlamys* ex gr. *goldfussi*, *Aetostreon latissimum*, *Rhynchostreon subsinuatum*, *Modiolus* ex gr. *ligeriensis*, *Cyclothyris parvirostris*, *Sellithyris upwarensis*, *Epiaster* cf. *prior*, *Holaster prestensis*.

Utuludzha section

In the Tekedzhik section the last occurrence of *Turkmeniceras* and the first occurrence of *Deshayesites* are separated by a siltstone layer of 6 m thickness. Therefore it is reasonable to give the description of another section from the Bolshoi Balkhan Ridge, not far from the Utuludzha Wells, where the last occurrences of the Barremian and first occurrences of the Aptian ammonites are close together. The stratotype of the Deshayesites tuarkyricus Zone has been chosen in this section (Bogdanova, 1983) (Fig. 4).

Upper Barremian

Beds with *Imerites* and *Colchidites*

Bed 1: Organogenic detrital, oolitic, irregularly platy limestones with only weakly expressed cross-bedding; thickness 1.7 m. Rare *Colchidites* sp. indet. have been found.

Bed 2: Dark siltstone not well exposed; thickness 10.7 m.

Bed 3: Gray, calcareous, oolitic, glauconitic, cross-laminated sandstones; thickness 1.2 m. At the top occur lenses of oolitic-detrital limestone with flat pebbles derived from the underlying siltstones. The concretions are covered with a greenish glauconitic film showing traces of boring organisms.

Fig. 4. Utuludzha section; 1: limestone; 2: sandy limestone; 3: clay; 4: silty clay; 5: clayey siltstone; 6: siltstone; 7: sandy siltstone; 8: sandstone; 9: calcareous sandstone; 10: hard sandstone; 11: pebbles; 12: phosphorite; 13: unconformity; 14: lenses; 15: concretions; 16: cross-bedding; 17: beds with ammonites; 18: detritus; 19: oolite; 20: Dufrenoya furcata Zone.

Turkmeniceras turkmenicum Zone

Bed 4: Dark-grey, arenaceous, detrital siltstones; thickness 0.6 m.

Bed 5: Grey fine-grained calcareous sandstones; thickness 0.4 m. *Leionucula transcaspia*, *Camptonectes cottaldinus*, *Tankredia khamperi*, *Epiaster toxasteroides* (abundant).

Bed 6: Grey, friable, fine-grained sandstones with lenses of coarse-grained calcareous sandstones; thickness 1.5 m.

Bed 7: Almost black, fragmental silty clays grading upward into detrital clayey siltstones; thickness 10 m.

Bed 8: Siltstones grading into slightly calcareous, lumpy, fine-grained sandstones; thickness 4 m. In the middle of the bed are thin beds of hard arenaceous limestones with abundant echinoids. *Turkmeniceras* ex gr. *geokderense*, *Hemihoplites (Matheronites) ridzewskyi* (Fig. 5d-e), *Epiaster toxasteroides*, *Toxaster collignii*.

Lower Aptian

Deshayesites tuarkyricus Zone

Bed 9: Dense, calcareous, oolitic-detrital sandstone crammed with large shells of bivalves (*Cucullaea*, *Gervillaria*, *Gervilella*, *Sphaera*); thickness 1 m. It overlies bed 8 with a sharp contact. At the base of the bed occur abundant flattened and elongated oval pebbles of whitish oolitic sandstones covered with greenish glauconitic incrustations. Traces of boring shells and traces of adhered oysters are recorded on the pebbles. *Deshayesites oglanlensis*, *D. antiquus* (Fig. 6e), *D.* aff. *antiquus*, *Cucullaea forbesi*, *C. gabrielis*, *Gervillaria alaeformis*, *Sphaera corrugata*, *Epiaster toxasteroides.*

Bed 10: Dark silty clays; thickness 11.5 m.

Bed 11: Calcareous, oolitic, glauconitic, greenish-grey sandstones with lenses of dense sandstone containing scattered detritus; thickness 2.2 m.

Bed 12: Dark-grey clayey siltstones; thickness 7.3 m.

Bed 13: Greenish-grey, calcareous, oolitic, glauconitic sandstone containing pellets of the underlying siltstones and shelly detritus; thickness 0.8 m. Fossils abundant: *Deshayesites luppovi*, *Leionucula planata*, *Cucullaea gabrielis*, *C. fittoni*, *C. cornueliana*, *Gervilella sublanceolata*, *Gervillaria alaeformis*, *Neithea neocomiensis*, *Ctenoides undatus*, *Plicatula placunea*, *Aetostreon latissimum*, *Opis* ex gr. *neocomiensis*, *Tankredia khamperi*, *Unicardium vectense*, *Sulcirhynchia hythensis*.

Bed 14: Dark (with a greenish hue) friable siltstones have been uncovered in the lower part of the interval; thickness 20 m.

Bed 15: Greenish-gray, friable, calcareous, oolitic, glauconitic sandstones with lenses (5 to 8 cm thick) of hard calcareous sandstone with thin cross-bedding; thickness 3.2 m.

Bed 16: Three layers (0.3 m each) of calcareous, oolitic, glauconitic sandstones with accumulations of fine well-rounded detritus and with very thin cross-bedding. These layers are intercalated with friable, oolitic, greenish-grey sandstones; thickness 1.1 m.

Bed 17: Massive yellowish-grey sandstones with lenses of calcareous cross-bedded sandstone with scattered detritus; thickness 5 m.

Bed 18: Dense, calcareous, oolitic, grey sandstones with scattered detritus and rare *Deshayesites tuarkyricus*; thickness 3 m.

Deshayesites weissi Zone

Bed 19: Sandstones similar to bed 18 with remains of ammonites, bivalves, echinoids, etc.; thickness 1.5 m. *Deshayesites planus*, *D. gracilis*, *D. luppovi*, *Leionucula planata*, *L. transcaspia*, *Cucullaea forbesi*, *C. fittoni*, *Epiaster toxasteroides*.

Bed 20: Almost black, sticky, silty clays; thickness 8 m. Rows of small (up to 0.3-0.4) concretions of dense, grey, calcareous, glauconitic sandstones yielding abundant fauna are recorded in the upper part of the bed. *Deshayesites weissi*, *D. planus*, *D. consobrinoides, D. consobrinus*, *D. dechyi* (Fig. 8h), *D. euglyphus*, *D. deshayesi*, *D. inflatus*, *D. levigatus*, *D. pappi* (Fig. 9c-e), *D. babaschensis* (Fig. 11c-d), *Phyllopachyceras baborense* (Fig. 8k-l), *Protetragonites karakaschi*, *Leionucula planata*, *Aptolinter aptiensis*, *Grammatodon securis*, *Tankredia khamperi*, *Epiaster toxasteroides*.

Bed 21: Friable siltstones with lenses of grey, fine-grained, calcareous sandstones; thickness 0.8-1 m. Septarian concretions with accumulations of small shelly detritus and glauconite grains occur in the bed. *Deshayesites callidiscus*, *D. consobrinoides*, *D. dechyi*, *D. deshayesi, D. kiliani*, *D. topleyi*, *D. weissi*, *D. kudrjavzevi*, *D. levigatus*, *D. luppovi, D. pappi*, *D. similis*, *Cucullaea forbesi*, *C.* ex gr. *fittoni*, *Tankredia khamperi*, *Tellina carteroni*.

Bed 22: Yellowish-greenish, fine-grained, glauconitic sandstones (almost sands); thickness 7.5 m.

Bed 23: Gray, friable, mealy sandstones with lenses (up to 1-1.5 m) of dense calcareous sandstones containing abundant fauna; thickness 1.2 m. *Deshayesites weissi* (Fig. 8b-c), *D. callidiscus*, *D. inflatus*, *D. planus*, *D. levigatus*, *Leionucula transcaspia*, *Cucullaea glabrae*, *C. gabrielis*, *C. forbesi*, *Gervilella sublanceolata*, *Plicatula carteroni*, *Unicardium vectense*, *Epiaster toxasteroides*.

Bed 24: Yellowish-grey, fine-grained, very friable sandstones (almost sands); thickness 11 m.

Deshayesites deshayesi Zone

Bed 25: Conglomerate with abundant pebbles of hard calcareous sandstone; thickness 0.3 m. The spherical and oval pebbles have diameters from 0.5 to 2 cm. The matrix consists of fine-grained calcareous sandstones. *Deshayesites* sp. indet. (rounded), *Cucullaea* cf. *cornueliana*, *Plicatula carteroni*, *Lucina pissum*.

Bed 26: Yellowish-grey, friable, fine-grained sandstones with lenses of calcareous sandstones, which form horizons that can be traced over a long distance along the strike; thickness 8.5 m.

Bed 27: Greenish-grey, calcareous, glauconitic sandstones; thickness 1 m. Accumulations of shells of ammonites, bivalves and brachiopods occur as lenses: *Deshayesites callidiscus*, *D. consobrinoides* (Fig. 10c, d), *D. dechyi*, *D. normani debilis* (Fig. 8i), *D. kudrjavzevi*, *D. levigatus* (Fig. 10g-h), *Pseudosaynella bicurvata* (Fig. 11g-h), *Cucullaea gabrielis, C. cornueliana*, *C. robinaldina*, *C.* cf. *forbesi*, *Gervillaria alaeformis*, *Isognomon ricordeanus*, *Neithea neocomiensis*, *N. irinae, Ctenoides undatum*, *Aetostreon latissimum*, *Plicatula placunea*, *P. gurgitis, Modiolus aequalis*, *Lucina pissum*, *L.* cf. *dupiniana*, *Tankredia khamperi*, *Cardium* sp. nov., *Sulcirhynchia hythensis*.

Bed 28: Greenish-grey, friable sandstones, becoming calcareous at the top of the bed; thickness 0.7 m. Fauna is poorly preserved: *Deshayesites dechyi*, *Toxoceratoides royerianus*, *Plicatula gurgitis*, *Cardium* sp. nov.

Bed 29: Friable, dark-grey siltstones with shells of *Deshayesites* spp. indet.; thickness 1.5 m.

Dufrenoya furcata Zone

Bed 30: The siltstones of bed 29 are overlain by gray, fine-grained, calcareous sandstones with a distinct contact, but without traces of washout; thickness 1.2 m. At the top of the bed occur gravel lenses (up to 1.5 cm) containing rare subangular pebbles of denser glauconitic sandstone with phosphate grains. The lenses yielded *Dufrenoya dufrenoyi* (Fig. 12c), *D.* ex gr. *sinzovi*, *D. fursovae*, *Cheloniceras cornuelianum*, *Aucellina* sp. (ex gr. *caucasica*), *Epiaster fourtaeui*.

Middle Aptian

Epicheloniceras subnodosocostatum Zone

Bed 31: Dark (almost black), silty, detrital clays with lens-shaped interbeds of grey calcareous sandstones; thickness 8.5 m.

The first ammonites of this zone, viz. *Epicheloniceras subnodosocostatum*, *Ep. tschernyschewi* (Fig. 12l-m), etc., are recorded at a distance of c. 35-40 m above the base of this bed. The boundary between the lower and middle Aptian is, however, drawn at the base of this bed on acount of the correlation with other sections in the Trans-Caspian and Mangyshlak, in which biostratigraphically substantiated deposits of the E. subnodosocostatum Zone begin with black clays, frequently with septarian concretions (Mangyshlak) or marls (Kopet Dagh).

Biostratigraphy

Beds with *Imerites* and *Colchidites*

These beds constitute the lowest biostratigraphic unit considered. They occur in the southern Tuarkyr region (from the Kyzylkyr Mountain in the north to the Keldzhe and Tekedzhik ranges in the south), in the east of the Kubadag Ridge, within the western Oglanly Range of the Bolshoi Balkhan Ridge, in the southern piedmont area of the Maly Balkhan Ridge and in the Kopet Dagh, as far as the town of Ashkhabad. In the majority of the sections this biozone occurs in the lower part of the terrigenous gray bed formation, which is separated from the top of the Neocomian carbonate formation by a more or less thick rock sequence without ammonites. An exception is the sections in the western Maly Balkhan, where the first ammonites occur at the base of the terrigenous formation.

Within the terrigenous gray bed formation, ammonites are irregularly distributed. They are commonly confined to the carbonatic-terrigenous coquina interbeds and are less frequent in the clayey-silty rocks. In some sections they are abundant and rather uniformly distributed. Characteristic fossils are ammonites of the family Heteroceratidae, such as the genera *Imerites*, *Paraimerites*, *Colchidites*, and less frequently *Heteroceras*.

The distribution of ammonite genera and species in these beds in some sections of Kopet Dagh and Maly Balkhan displays certain features: the overwhelming majority of the species of *Colchidites* and *Imerites* is concentrated in the major upper part of these beds, whereas the lower part yields only *Imerites giraudi* with related species and *Heteroceras* (*Argvetites*) sp. On this basis Tovbina (1963) distinguished two independent faunal horizons within these beds: a lower one with *Imerites giraudi* and an upper one, with *Colchidites nicortsmindensis* (now = *C. ratshensis*). The lower horizon possibly corresponds to the Georgian Zone of *Imerites giraudi*, whereas the species composition of the upper horizon corresponds to the ammonite assemblage of the highest Barremian zone in Georgia, the Colchidites securiformis Zone.

Turkmeniceras turkmenicum Zone

This zone occurs within the same area as the underlying beds. In the Keldzhe and Tekedzhik reference sections and in the majority of the other sections, the latest ammonite occurrences in the beds with *Imerites* and *Colchidites* and the first occurrences of ammonites in the Turkmeniceras turkmenicum Zone are separated by a more or less thick stratigraphic interval without ammonites. However, in certain outcrops of the Bolshoi Balkhan (near Oglanly) and Kopet Dagh (Sekizkhan, Chalsu and Pyrnuar sections), the boundaries of the biostratigraphic units adjoin.

The Turkmeniceras turkmenicum Zone can be distinguished from the underlying deposits by its ammonite assemblage. In this zone the Heteroceratidae are replaced by the genus Turkmeniceras, represented by the following species: *T. turkmenicum*, *T. turkmenicum longicostata*, *T. multicostatum*, *T. geokderense*, *T. rarecostatum*, *T. tumidum*, *T. tovbinae*. Associated with them are representatives of the subgenus *Hemihoplites (Matheronites)*, such as the local species *H. (M.) turkmenicus* and *H. (M.) brevicostatus*, the North Caucasian species *H. (M.) ridzewskyi* and a form similar to the Bulgarian species *H. (M.) ukensis*. All these species are confined to this zone; they do not occur in the underlying, nor in the overlying beds.

Deshayesites tuarkyricus Zone

The ammonite assemblage of this Zone is composed of the following species: *D. tuarkyricus*, *D. oglanlensis*, *D. weissiformis*, *D. antiquus*, *D. consobrinus*, *D. euglyphus*, *D. luppovi*, *D. planicostatus*, *Pseudohaploceras ramosum*. The first two are the guide fossils. *D. tuarkyricus* occurs throughout the Trans-Caspian area and is represented by abundant specimens, which serves as the basis for choosing this species as the zonal index. *D. oglanlensis* is frequently recorded in Kubadag and Bolshoi Balkhan, less frequently in Kopet Dag, and quite rarely and only in the southern regions in Tuarkyr. *D. euglyphus* and *D. consobrinus* are also found in higher beds (therefore, they are not guide fossils); however, they permit correlating the biozone with the lower Aptian deposits of southeastern France, southern England, the Volga area, the Caucasus and other regions. *D. antiquus* is stratigraphically very important. Morphological features of the suture line of this species allow to consider it as one of the early representatives of the genus *Deshayesites*, which in the evolutionary series is very close to *Turkmeniceras*. Therefore, the deposits in which it occurs, are the earliest Aptian layers. *D. antiquus* has three umbilical lobes, as do most species of *Deshayesites*. However, lobe U3 is located on the umbilical border, similar to *Turkmeniceras*. At the same time, this zone contains evolutionary 'advanced' *Deshayesites*, which has a more complicate incision in the same saddle in which the fourth umbilical lobe develops. The formula of their suture line is $ELU_1U_3U_4{:}U_2I$.

The lower boundary of the zone and of the stage is drawn between the disappearance of *Turkmeniceras* and *Hemihoplites (Matheronites)* and the appearance of *Deshayesites*. In the stratotype section of the zone (Bolshoi Balkhan, Utuludzha Well) the beds with Barremian ammonites are separated by a one metre thick layer of glauconitic sandstone from the beds with Aptian ammonites, which allows drawing the Barremian/Aptian boundary with great precision.

Deshayesites weissi Zone

This zone is noted for its richer and more diverse ammonite assemblage, which contains many species known from Western Europe. The guide fossils belong to the genus *Deshayesites*. The lower boundary of the zone is drawn at the disappearance of the species *D. tuarkyricus*, *D. oglanlensis* and *D. weissiformis*, and the appearance of *D. weissi*, *D. planus*, *D. normani*, *D. callidiscus*, and *D. similis*. Besides *Deshayesites* this zone contains species of the genera *Phyllopachyceras*, *Protetragonites*, *Eulythoceras* (?), *Ancyloceras*, *Pseudohaploceras*, *Sanmartinoceras*, *Aconeceras*, *Pseudosaynella* and *Cheloniceras*. Representatives of the Cheloniceratidae firstly appear in this zone in the Trans-Caspian area. *Procheloniceras* has not been found in this zone, nor in underlying deposits.

Deshayesites deshayesi Zone

The fossil assemblage of this zone is much poorer as compared to the weissi Zone. This is partly due to an extensive regional erosion of strata deposited during this time in the Trans-Caspian area. *Deshayesites* still furnish the guide fossils for this zone. Generally it is characterized by *D. deshayesi*, *D. babaschensis*, *D. consobrinoides*, *D. dechyi*, *D. callidiscus*, *D. levigatus*, *Cheloniceras cornuelianum* and *Leptotetragonites* (?) sp. The Deshayesites deshayesi Zone in the Trans-Caspian area is not interpreted to represent the entire range of the index species, but only that part that does not yield species characteristic of the Weissi Zone. Presumably due to erosion of the upper part of this zone, the English species of *Deshayesites* that occur in the upper part of the English Deshayesites deshayesi Zone have not been found. They represent a morphologically transitional stage between *Deshayesites* and *Dufrenoya*: *D. vectensis*, *D. wiltshirei*, *D. geniculatus*.

Dufrenoya furcata Zone

There is a significant change in the ammonite assemblage at the boundary of the D. deshayesi and D. furcata zones. *Deshayesites* disappears and *Dufrenoya* becomes widespread. It is mainly represented by published species, only two of the nine species are new: *Dufrenoya furcata*, *D.* aff. *furcata*, *D. dufrenoyi*, *D. subfurcata*, *D. lurensis*, *D. scalata*, *D. sinzovi*, *D. fursovae*. Less frequent are the species of *Burckhardtites*, another genus of the Deshayesitidae, which up to now has not been known outside Mexico. Besides, species of the genera *Cheloniceras*, *Toxoceratoides* and

Aconeceras, whose stratigraphic range is longer than the zone, have been recorded.

Very typical for this zone are *Cheloniceras cornuelianum* and *Ch. seminodosum*. The presence of these species in the beds with *Dufrenoya* is one of the arguments for assigning the Furcata Zone to the lower Aptian. However, it should be mentioned that in one of the sections of Tuarkyr, this zone also yields *Gargasiceras gargasense*, the species that generally characterizes the middle Aptian.

Epicheloniceras subnodosocostatum Zone

This zone is characterized by an abrupt transition of the early Aptian ammonite assemblage into the middle Aptian one: *Epicheloniceras*, *Caspianites*, *Pseudoaustraliceras*, *Luppovia*, *Salfeldiella*, *Tetragonites*, *Jauberticeras* and others.

Where should the Barremian/Aptian boundary be drawn?

The ammonite succession, listed under section 2, contains assemblages whose position is determined; and there are also assemblages whose assignment to the Barremian or Aptian is debatable.

Indisputable is the inclusion of the lower part of the beds with *Imerites* and *Colchidites* into the Barremian. This is the unit with *I. giraudi*, a species that was first described from the upper Barremian in southeast France and is one of the characteristic representatives of this unit.

Also indisputable are the D. weissi and D. deshayesi Zones in the Trans-Caspian area, which are characterized by ammonite assemblages typical of the lower Aptian. The ranges of the ammonites enable a reliable correlation of the deposits in the Trans-Caspian area with the strata in the lower part of the Aptian (Bogdanova, 1978). As to the deposits between the indisputable biozones, their position is more or less debatable.

The horizon with *Colchidites rashensis*, which makes up the upper part of beds with *Imerites* and *Colchidites*, is regarded as Barremian, firstly because in the Trans-Caspian area it occurs stratigraphically below the beds with *Deshayesites*, which are clearly Aptian, and secondly because *Colchidites* belongs to the Heteroceratidae, which is a typical Barremian family. Kotetishvili (1970) and Kakabadze (1971, 1981) provided grounds for the correlation of the beds with *Imerites* and *Colchidites* in the Trans-Caspian area with the upper part of the Barremian in Georgia. At present *Colchidites* is recorded on many continents of the globe. In Eurasia: Turkey (Pelin & Thieuloy, 1975), France (Arnaud-Vanneau et al., 1976), Roumania (Avram, 1983, 1988), Bulgaria (Stoikova, 1986); in South Africa, in Zululand (Klinger, 1976), in South America, in Argentina (Aguirre-Urreta & Klinger, 1986), in Colombia (Kakabadze & Thieuloy, 1991). It should be mentioned, that these authors do not discuss the Barremian/Aptian boundary; however, they cast no doubt on ascribing the deposits with *Colchidites* to the Barremian. The Martelites sarasini Zone (in the first version of the chart of Hoedemaeker & Bulot, 1990, it was called Colchidites securiformis Zone) crowns the Barremian stage of the ammonite scale of the Mediterranean (Hoedemaeker et al., 1993).

As has already been mentioned the Deshayesites tuarkyricus Zone is characterized by a specific ammonite assemblage mainly consisting of new species, which makes its precise dating difficult. However, these species belong to the genus *Deshayesites*, which characterizes the lower Aptian and is unknown from the Barremian. This indicates an early Aptian age. This is confirmed by the presence of *D. consobrinus*, described from the lower Aptian of France. On account of its stratigraphic position, the Tuarkyricus Zone may be correlated with the lowest Aptian Prodeshayesites fissicostatus Zone in England and the Prodeshayesites tenuicostatus-Paradeshayesites laeviusculus Zone of Germany, although the species composition in Turkmenia entirely differs from the English and German zones (Bogdanova, 1983). [Editors' note: the Tuarkyricus Zone is now recognized in France too: Delanoy, 1995; Ropolo et al., this volume]

The problem of the stratigraphic position of the T. turkmenicum Zone is very complicated, because the majority of the species of the zonal assemblage is endemic, preventing a reliable correlation with any Barremian or Aptian assemblage outside the Trans-Caspian area.

The following three aspects of the problem should be discussed here. The first aspect is historical. Luppov (1936), the first who found the given assemblage in Turkmenia, assigned it to the Barremian. He then erroneously identified the ammonites of the genus *Turkmeniceras* (unknown at that time) as *Pseudothurmannia*. Tovbina (1963), who introduced the genus *Turkmeniceras*, rectified this error. She also assigned the deposits with these ammonites to the Barremian, but on the basis of their stratigraphic position below the appearance of *Deshayesites* in the section (Luppov at al., 1960).

The second aspect is evolutionary, for Tovbina revealed the rather close phylogenetic relationship between *Turkmeniceras* and *Deshayesites*, though she indicated a number of differences in their ontogeny. Assuming that *Turkmeniceras* was an immediate ancestor of *Deshayesites*, which is supported by stratigraphic relations, Tovbina considered it possible to include the former in the family of the Deshayesitidae (Tovbina, 1963, p. 100). At the same time several features typical of both *Turkmeniceras* and *Colchidites* were recorded. As a consequence the evolution of ammonites in the series *Colchidites* — *Turkmeniceras* — *Deshayesites* was outlined. In the Trans-Caspian sections the following evolutionary sequence could be followed: (1) A decrease of the helical stage (*Colchidites*), followed by (2) the entire reduction of the helix, the gradual atrophy of the crioceratid coiling and the appearance of involution of the whorls (*Turkmeniceras*) (Bogdanova, 1971). Finally (3) the crioceratid coiling disappears completely and the incision of the suture line in the umbilical part of the shell gradually increases (*Deshayesites*).

Tovbina's idea that *Turkmeniceras* had originated from *Colchidites* was critisized. Casey (1964) and Wiedmann (1966) phylogenetically connected *Turkmeniceras* with Hemihoplitidae. Their idea is worth considering, for it is based on the connection of monospiral *Turkmeniceras* with monospiral *Hemihoplites* instead of with heterospiral *Colchidites*. The qualitative leap from *Colchidites* with a helical stage to the planispiral whorls of *Turkmeniceras* was so great that in the series Heteroceradidae — Deshayesitidae, *Turkmeniceras* is closer to the latter. For this reason *Turkmeniceras* was included in the Deshayesitidae by S.Z. Tovbina but with an interrogation mark. This interpretation is in our opinion still appropriate. Species of *Turkmeniceras* with an umbilical perforation are similar to the species of *Hemihoplites* that have the same structure in the two initial whorls of the spiral. But hemihoplitids have been studied insufficiently and it is still too early to regard them as the direct ancestor of *Turkmeniceras* and of the Deshayesitidae.

Taking the interpretation of Tovbina and Bogdanova as evidence for the relationship of the above-mentioned ammonite genera, Mikhailova (1970, 1983) confidently includes *Turkmeniceras* in the family of the Deshayesitidae, and accepting the primacy of step-by-step evolution of index fossils in defining boundaries of stages, she establishes the base of the Aptian at the first occurrence of Deshayesitidae, i.e. at the base of the T. turkmenicum Zone. She was supported by Egoyan, Glasunova, Mordvilko, and Mirzoev, and this viewpoint was accepted by the Cretaceous Commission at ISC (Anonymus, 1981).

So, the position of *Turkmeniceras* in the system of Early Cretaceous Ammonitina cannot be considered as final.

The third, stratigraphic, aspect consists of the following: 1. The Deshayesites tuarkyricus Zone is rather confidently correlated with biozones at the base of the Aptian in England and Germany. 2. The ammonite assemblage of the Turkmeniceras turkmenicum Zone contains the North Caucasian species *H. (Matheronites) ridzewskyi*. The latter was long thought to be the index species of the lowest zone of the Aptian in the North Caucasus, since, according to Renngarten and Mordvilko, it occurred in the same beds as *Deshayesites*. Close inspection of the published materials, however, showed that most remains of hemihoplitids are confined to a condensed layer overlying with an erosional unconformity the Barremian deposits. It permitted Bogdanova (1971) to assume that *Matheronites* and *Deshayesites* occured at different stratigraphic levels and that the beds with *H. (Matheronites)* in the Caucasus were older than those with *Deshayesites*, and that they could stratigraphically correspond to the *T. turkmenicum* Zone. Later, after Kakabadze (1981) had closely examined the ammonite assemblages around the Barremian/Aptian boundary in complete sections in the North Caucasus, he arrived at the conclusion that it was reasonable to distinguish an independent biozone, the H. (Matheronites) ridzewskyi Zone. Moreover he provided grounds for its stratigraphic correlation with the T. turkmenicum Zone of the Trans-Caspian area. He proposed a binary name for it, the *H. (Matheronites) ridzewskyi — Turkmeniceras turkmenicum* Zone, and suggested that the Barremian should end with it. The assignment of the zone to the Barremian is supported by the fact that in recent publications concerning the Barremian/Aptian boundary deposits in Europe, South America and Africa, representatives of *Hemihoplites* are recorded only in the Barremian and never in the Aptian. All biostratigraphers dealing with Lower Cretaceous stratigraphy rightly agree with this correlation. But Mikhailova and Egoyan insist on placing the given unit under the same binary name at the base of the Aptian stage.

In this way the evolutionary and biostratigraphic infor-mation discussed above does not permit an unambiguous solution of the problem. Using this information as a basis, we can only state that the Trans-Caspian sections provide the most complete succession of ammonite assemblages, and therefore the Barremian/Aptian boundary should be drawn there.

The stratigraphic standard of a unit of the general stratigraphic scale (GSS) (Prozorovsky, 1995) or its boundaries must meet several require-ments. These require-ments were formulated by Arkell (1946), who called them 'a reasonable compromise'. The latter could be achieved by three criteria: priority (this is already determined), suitability and convenience. By suitability is meant the extension of the stratigraphic unit or its correlation potential. In the assemblages of the T. turkmenicum and D. tuarkyricus Zones endemic species are prevalent, and in the former even the genus is almost unknown beyond the Trans-Caspian area. At the same time the typical lower Aptian *Deshayesites* is widespread in the Caucasus, in the Europian territory of Russia, in Western Europe and in South America. *D. consobrinus* is also rather widespread for instance in Germany and South England. Hence the lower boundary of the D. tuarkyricus Zone is much more suitable as the base of the stage then the base of the T. turkmenicum Zone. [The occurrence of the more widely known species *H. (M.) ridzewskyi* is also of little importance, since its horizontal distibution is smaller than that of the species of *Deshayesites*.]

By the term 'convenience' Arkell (1946) meant the recognizability of a biozone or a boundary. In our case this is the degree of difference between the systematic characteristics of *Colchidites*, *Turkmeniceras* and *Deshayesites*. Although *Turkmeniceras* differs greatly from *Colchidites* (they belong to different families), the former is not identical to the early forms of *Deshayesites*. Tovbina (1963) had a reason to assign them to the Deshayesitidae only with a question mark, and she called for further study of their systematic relations.

Conclusions

Two of the three principle criteria for evaluating chronostratigraphic boundaries, the priority and the suitability, suggest that the Barremian/Aptian boundary should correspond to the first occurrence of representatives of the genera *Deshayesites*, *Prodeshayesites* and *Paradeshayesites*. This is the base of the Deshayesites tuarkyricus Zone in the Trans-Caspian area. The Turkmeniceras turkmenicum Zone completes the Barremian.

We propose to situate the boundary stratotype of the Aptian Stage in the Utuludzha section (Fig. 4) in the Oglanly Range of the Bolshoi Balkhan, where beds containing the zonal species of both zones are almost contiguous. A similar pattern can be observed at the eastern slope of the Maly Balkhan, but fossils are generally less well preserved there than in the Bolshoi Balkhan.

The '2nd Workshop of the Lower Cretaceous Cephalopod Team of IGCP-Project 262: Tethyan Cretaceous Correlation' placed the Trans-Caspian Turkmeniceras turkmenicum Zone into the scale as a horizon with *Hemihoplites ridzewskyi* (= the Turkmeniceras turkmenicum Zone) (Hoedemaeker et al., 1993) at the top of the Barremian. We offer this paper as a confirmation of the stratigraphic position of this stratigraphic unit.

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Plate 1

Fig. a-c. *Turkmeniceras turkmenicum* Tovbina, 1962; Tuarkyr, Gobekadzhi, T. turkmenicum Zone.

Fig. d-e. *Hemihoplites (Matheronites) ridzewskyi* (Karakasch, 1897); Bolshoi Balkhan, Utuludzha, T. turkmenicum Zone.

Fig. f-g. *Turkmeniceras turkmenicum* Tovbina, 1962; Tuarkyr, Tekedzhik, T. turkmenicum Zone; g: × 20.

Fig. h. *Hemihoplites (Matheronites) brevicostatus* Bogdanova, 1971; Tuarkyr, Gobekadzhi, T. turkmenicum Zone.

Fig. i. *Turkmeniceras turkmenicum longicostatum* Tovbina, 1963; Tuarkyr, Gobekadzhi, T. turkmenicum Zone.

Fig. j-l. *Turkmeniceras geokderense* Tovbina, 1962; j-k: Tuarkyr, Tekedzhik, T. turkmenicum Zone; l: × 20; Tuarkyr, Gobekadzhi, T. turkmenicum Zone.

Fig. m. *Holaster benstedi* Forbes, 1846; Tuarkyr, Tekedzhik, T. turkmenicum Zone.

Fig. n-p. *Epiaster toxasteroides* Poretzkaja & Lobatscheva, 1967; Tuarkyr, Tekedzhik, T. turkmenicum Zone.


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Plate 2

Fig. a-b. *Turkmeniceras tumidum* Bogdanova, 1971; Tuarkyr, Gobekadzhi, T. turkmenicum Zone.

Fig. c-d. *Turkmeniceras rarecostatum* Bogdanova, 1971; Tuarkyr, Tekedzhik, T. turkmenicum Zone.

Fig. e. *Deshayesites antiquus* Bogdanova, 1983; Bolshoi Balkhan, Utuludzha, D. tuarkyricus Zone.

Fig. f-g. *Deshayesites* aff. *antiquus* Bogdanova, 1983; Tuarkyr, Lauzan, D. tuarkyricus Zone.

Fig. h-k. *Lamellaerhynchia bertheloti* (Kilian, 1907); Tuarkyr, Tekedzhik, T. turkmenicum Zone.

Fig. l-o. *Lamellaerhynchia geokderensis* (Moisseev, in Weber, 1944); Tuarkyr, Tekedzhik, T. turkmenicum Zone.

Fig. p-t. *Cyclothyris aptiensis* Smirnova, 1972; Tuarkyr, Tekedzhik, T. turkmenicum Zone.

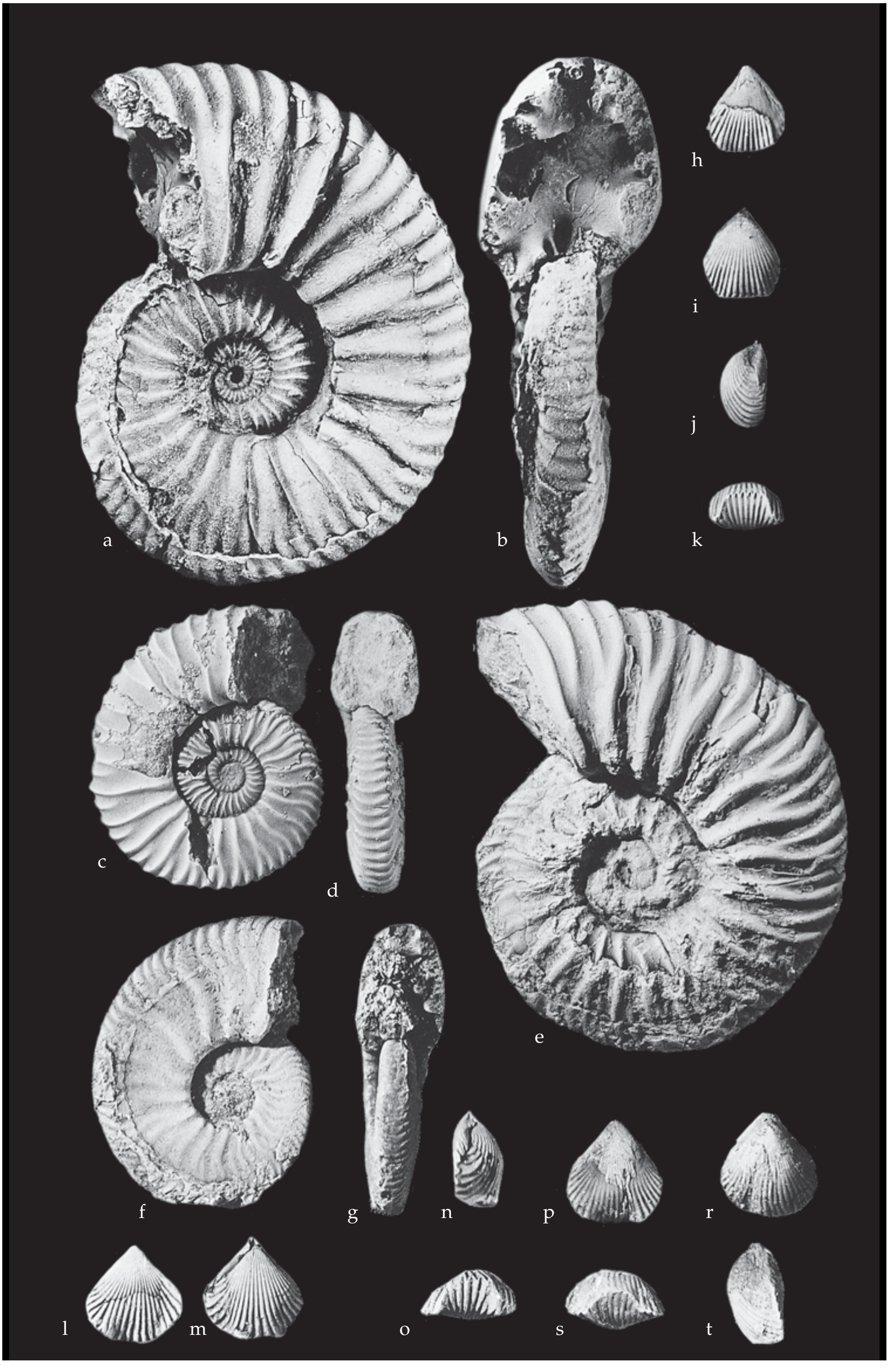
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Plate 3

Fig. a-c. *Deshayesites tuarkyricus* Bogdanova, 1983; Tuarkyr, Lauzan, D. tuarkyricus Zone.

Fig. d-e. *Deshayesites oglanlensis* Bogdanova, 1983; Bolshoi Balkhan, Oglanly, D. tuarkyricus Zone.

Fig. f. *Deshayesites luppovi* Bogdanova, 1983; Tuarkyr, Gobekadzhi, D. weissi Zone.

Fig. g-i. *Deshayesites consobrinus* (d'Orbigny, 1841); Bolshoi Balkhan, Bordzhakly, D. weissi Zone.

Fig. j-l. *Pseudohaploceras ramosum* Bogdanova, 1991; Tuarkyr, Tekedzhik, D. tuarkyricus Zone.

Fig. m-p. *Lamellaerhynchia bertheloti* (Kilian, 1907); Tuarkyr, Mirisynkyr, D. tuarkyricus Zone.

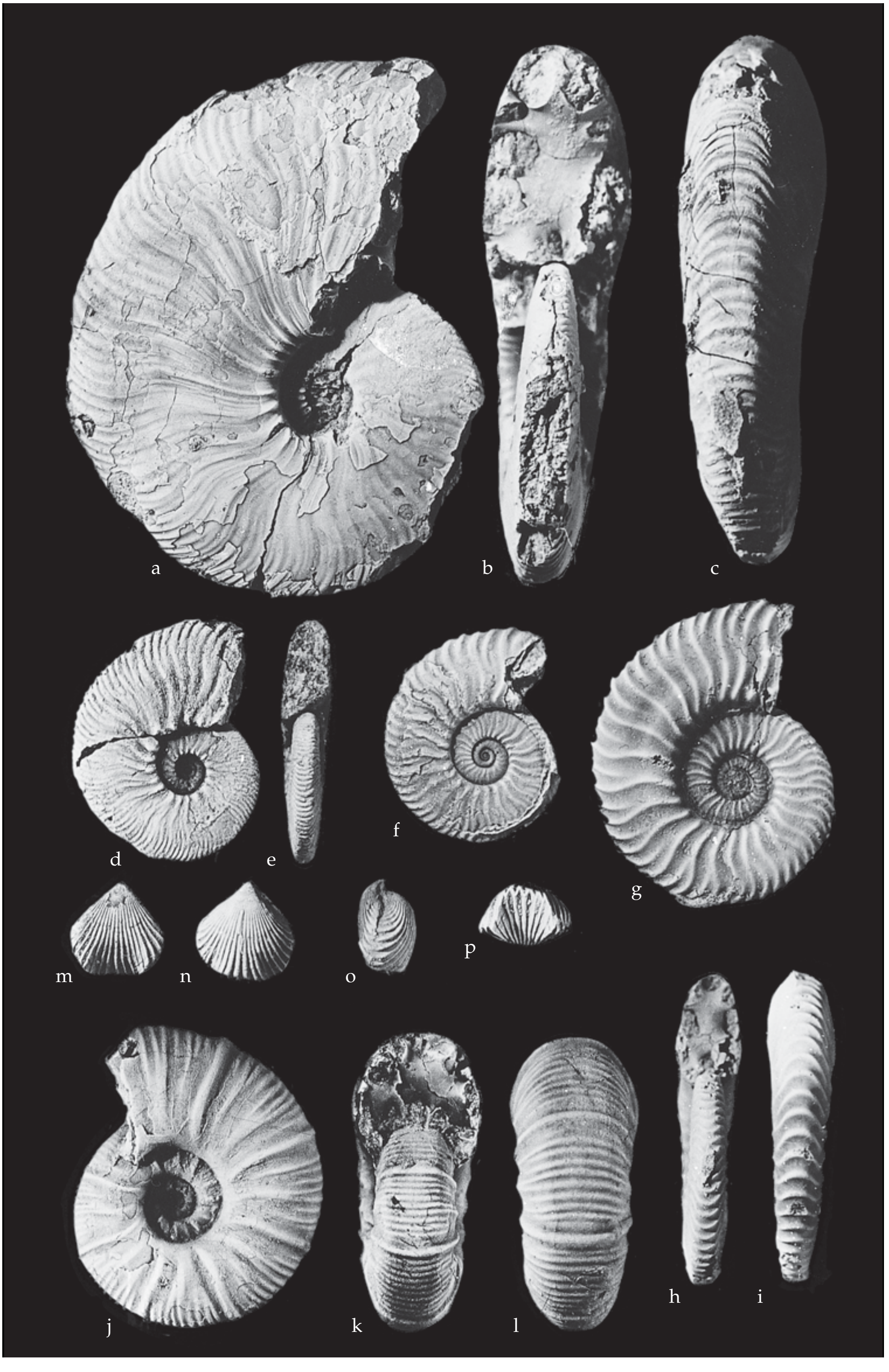
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Plate 4

Fig. a. *Deshayesites euglyphus* Casey, 1964; Bolshoi Balkhan, Kirov aul, D. weissi Zone.

Fig. b-c. *Deshayesites weissi* (Neumayr & Uhlig, 1881); Bolshoi Balkhan, Utuludzha, D. weissi Zone.

Fig. d-f. *Deshayesites euglyphus* Casey, 1964; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. g. *Deshayesites planus* Casey, 1964; Bolshoi Balkhan, Bordzhakly, D. weissi Zone.

Fig. h. *Deshayesites dechyi* (Papp, 1907); Bolshoi Balkhan, Utuludzha, D. weissi Zone.

Fig. i. *Deshayesites normani debilis* Casey, 1964; Bolshoi Balkhan, Utuludzha, D. deshayesi Zone.

Fig. j. *Deshayesites planus* Casy, 1964; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. k-l. *Phyllopachyceras baborense* (Coquand, 1880), Bolshoi Balkhan, Utuludzha, D. weissi Zone.

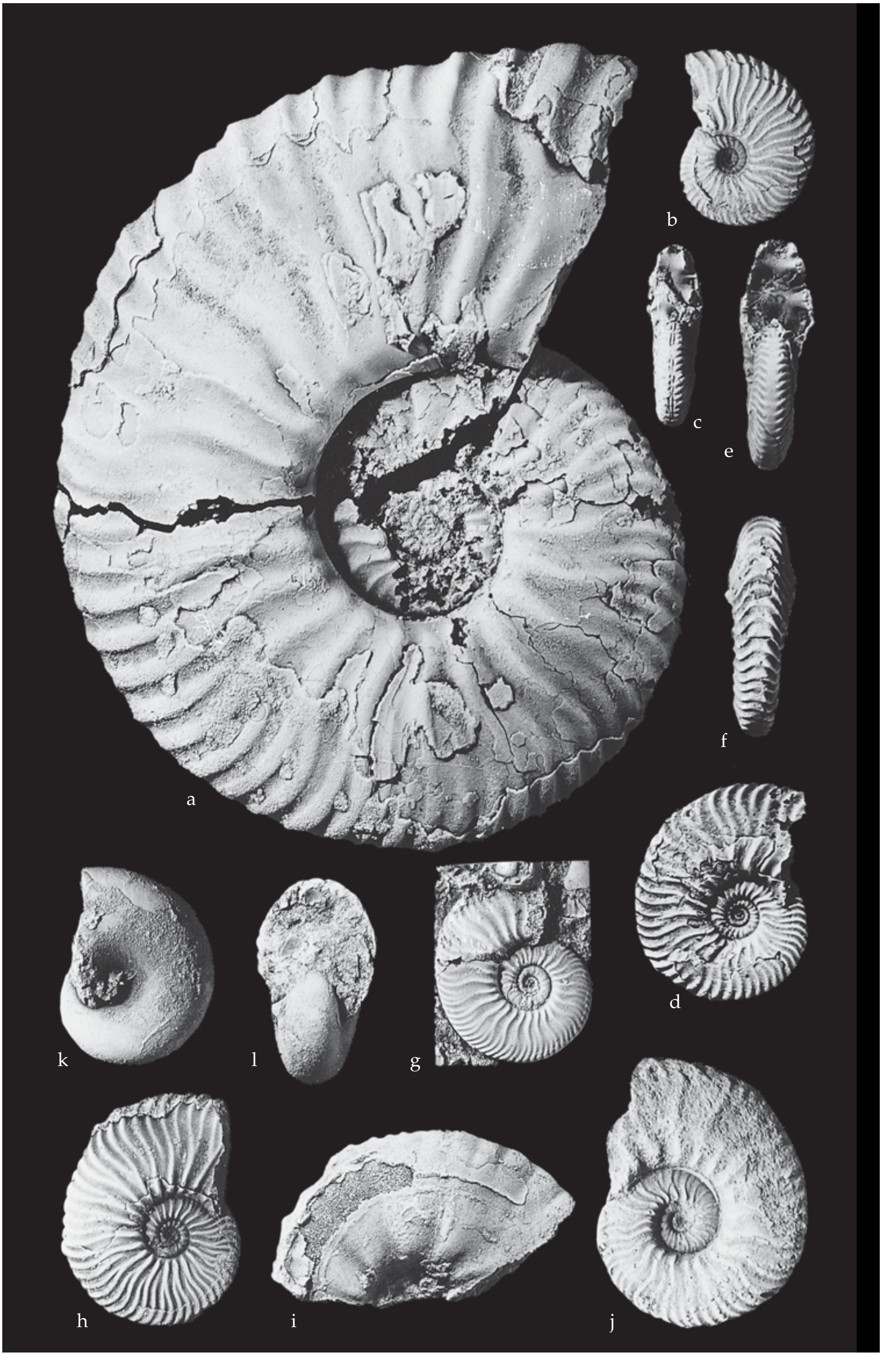
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Plate 5

Fig. a-b. *Deshayesites similis* Bogdanova, 1991; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. c-e. *Deshayesites pappi* Bogdanova, 1991; Bolshoi Balkhan, Utuludzha, D. weissi Zone.

Fig. f-h. *Deshayesites inflatus* Bogdanova, nom. nud.; Tuarkyr, Gobekadzhi, D. weissi Zone.

Fig. i. *Deshayesites topleyi* Spath, 1930; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. j-k. *Epiaster toxasteroides* Poretzkaja & Lobatscheva, 1967; Tuarkyr, Tekedzhik, D. deshayesi Zone.

Fig. l-o. *Sellithyris coxvellensis* Middlemiss, 1959; Tuarkyr, Gobekadzhi, D. tuarkyricus Zone.


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Plate 6

Fig. a-b. *Deshayesites latilobatus* (Sinzow, 1909); Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. c-d. *Deshayesites consobrinoides* (Sinzow, 1898), Bolshoi Balkhan, Utuludzha, D. deshayesi Zone.

Fig. e-f. *Deshayesites callidiscus* Casey, 1964; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. g-h. *Deshayesites levigatus* Bogdanova, 1991; Bolshoi Balkhan, Utuludzha, D. deshayesi Zone.

Plate 7

Fig. a. *Deshayesites kudrjavzevi* Mikhailova, 1958; Tuarkyr, Tekedzhik, D. deshayesi Zone.

Fig. b, e-f. *Deshayesites deshayesi* (d'Orbigny, 1841); b: Tuarkyr, Tekedzhik, D. deshayesi Zone; e-f: Tuarkyr, Lauzan, D. deshayesi Zone.

Fig. c-d. *Deshayesites babaschensis* Bogdanova, 1977; Bolshoi Balkhan, Utuludzha, D. weissi Zone.

Fig. g-h. *Pseudosaynella bicurvata* (Michelin, 1838); Bolshoi Balkhan, Utuludzha, D. deshayesi Zone.

Fig. i-k. *Sulcirhynchia hythensis* Owen, 1956; Bolshoi Balkhan, Utuludzha, D. weissi Zone.


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Plate 8

Fig. a-c. *Dufrenoya dufrenoyi* (d'Orbigny, 1841); a-b: Tuarkyr, Tekedzhik, D. furcata Zone; c: Bolshoi Balkhan, Utuludzha, D. furcata Zone.

Fig. d-e. *Dufrenoya furcata* (Sowerby, in Fitton, 1836); Tuarkyr, Tekedzhik, D. furcata Zone.

Fig. f, h-i. *Dufrenoya sinzovi* Luppov, 1949; Bolshoi Balkhan, Oglanly, D. furcata Zone.

Fig. g. *Dufrenoya fursovae* Bogdanova, 1991; Bolshoi Balkhan, Oglanly, D. furcata Zone.

Fig. j. *Pseudosaynella fimbriata* Imlay, 1945; Tuarkyr, Tekedzhik, D. weissi Zone.

Fig. k. *Cheloniceras cornuelianum* (d'Orbigny, 1841); Tuarkyr, Tekedzhik, D. furcata Zone.

Fig. l-m. *Epicheloniceras tschernyschewi* (Sinzow, 1906); Bolshoi, Balkhan, Utuludzha, E. subnodosocostatum Zone.

Fig. n-o. *Toxoceratoides royerianus* (d'Orbigny, 1842); Tuarkyr, Tekedzhik, D. furcata Zone.

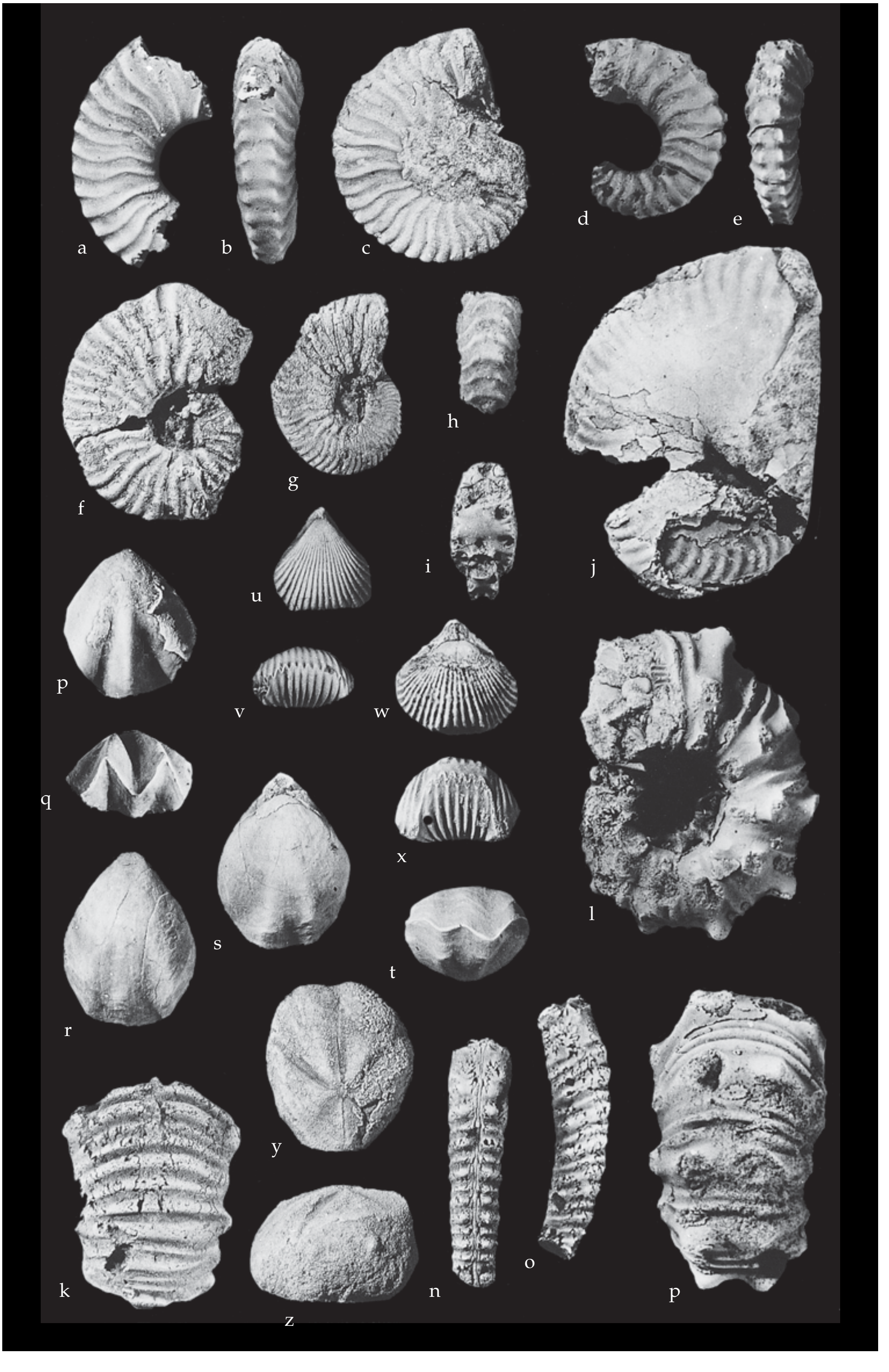
Fig. p-q. *Sellithyris upwarensis* (Walker, 1870), Kopet Dagh, Chalsu, E. subnodosocostatum Zone.

Fig. r-t. *Sellithyris jachnini* Lobatscheva, 1977; Tuarkyr, Doungra, E. subnodosocostatum Zone.

Fig. u-v. *Cyclothyris tuarkyrica* Lobatscheva, 1974; Tuarkyr, Doungra, E. subnodosocostatum Zone.

Fig. w-x. *Cyclothyris parvirostris* (Sowerby, in Fitton, 1836), Bolshoi Balkhan, Oglanly, E. subnodosocostatum Zone.

Fig. y-z. *Epiaster* aff. *prior* Lambert, 1902; Bolshoi Balkhan, Utuludzha, D. furcata Zone.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