JURASSIC AMMONITES FROM JEBEL TUWAIQ, CENTRAL ARABIA

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WITH STRATIGRAPHICAL INTRODUCTION

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[Plates 15 to 31]

CONTENTS

PART I. STRATIGRAPHICAL INTRODUCTION

By R. A. Bramkamp and M. Steineke

PART II. THE AMMONITE FAUNAS FROM JEBEL TUWAIQ

By W. J. Arkell, F.R.S.

The Jurassic system as developed along a strike of some 500 miles in the Jebel Tuwaiq, central Saudi Arabia (Nejd), is described and divided into formations, of which the names are here published for the first time, with a synopsis of their lithology and fossil contents. Apart from small collections, including only one ammonite species, made on camel journeys by H. St J. B. Philby, nothing was hitherto known of these formations; their age (except for the Middle Callovian date given by the ammonite), and the existence of most of them, were unknown until the area began to be mapped and explored geologically about 1940 by geologists of the Arabian American Oil Company, whose results are here summarized.

The total thickness of marine Jurassic rocks described exceeds 1000 m., all of it in neritic facies. This sequence is divided, in ascending order, into Marrat, Dhruma, Tuwaiq Mountain, Hanifa, Jubaila and Riyadh formations, above which follows the Cretaceous system. Below the marine Marrat is the Minjur Sandstone (315 m.), of 'continental' facies, with only obscure plant remains, which possibly corresponds to the supposedly Rhaetic-Lower Lias plant-bearing Kohlan Sandstones of the Yemen. The underlying Jilh formation of Saudi Arabia contains marine Middle Triassic fossils near the top.

Collections of ammonites establish the presence of marine Jurassic stages from Lower Toarcian (Lower Marrat) to Lower Kimeridgian (Jubaila); the Riyadh has not yet yielded ammonites at outcrop.

The ammonites described are of extraordinary interest from the points of view of palaeogeography, correlation, phylogeny and systematics. While most of the faunas contain just enough links with other parts of the world to establish broad correlations, many are entirely new, or confined, outside Arabia, to Sinai. In the Toarcian there was faunal continuity with Madagascar and Baluchistan, in the Bajocian only with Sinai, from the Middle Bathonian onwards with western Europe.

Most of the commonest cosmopolitan genera are missing from central Arabia, where there lived a succession of highly peculiar forms characterized at several successive horizons by unstable suture-lines. It has been found necessary to make eight new genera, besides three already named but hitherto not found outside Sinai, Madagascar and Baluchistan, although employing a taxonomic scale so large that some palaeontologists will consider it old-fashioned. This is believed, however, to be more useful at this stage of our knowledge than a proliferation of generic names based on inadequate material; for the area from which the collections were made is about equal to that of all the Jurassic outcrops of England.

The paper concludes with a discussion of problems of evolution, speciation, correlation, and palaeogeography raised by the material.

In an appendix are described relevant Bajocian ammonites from Sinai, with a hitherto unpublished section of the strata.

PART I. STRATIGRAPHICAL INTRODUCTION

By R. A. Bramkamp and M. Steineke*

1. General geology of Nejd

The crystalline rock nucleus or shield which comprises roughly the western third of the Arabian peninsula is bordered on the east and the north-east by a nearly parallel sequence of sedimentary formations dipping gently away from the margin of the pre-Cambrian core. This arrangement has laid out the formations in successive broad curved bands, which because of alternation in degree of resistance to erosion are expressed in the terrain by long and inward-facing cuestas and broad strips of lowland. The main sand belts which are a characteristic feature of Nejd lie parallel to, and just west of, the bases of the main escarpments, doubtless reflecting the influence of the topography on prevailing ground-winds.

Jebel Tuwaiq, which has furnished most of the ammonites here described, is the largest and most continuous of these cuestas, maintaining essentially the same topographic characteristics from Mundafan in the south (lat. 18° 35′ N., 45° 25′ E.), northward through a gentle curve to beyond Zilfi, where it passes beneath Nefud Es Sbilla (26° 30′ N., 44° 50′ E.), a total distance of over 925 km. (578 miles). This continuity reflects the persistence and relative uniformity of a dense coral-bearing limestone unit (described below as the Tuwaiq Mountain Limestone) whose resistance to erosion has been the main support of the upland. Its west-facing escarpment maintains a surprisingly straight trace, with major indentations only where the few large wadis cut the upland from west to east.

Through much of Jebel Tuwaiq, the capping Tuwaiq Mountain Limestone forms a vertical cliff facing to the west, below which are steep slopes of softer rocks studded with slid blocks and intermittently masked by partially cemented scree (plate 31). To a varying

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extent, stratigraphically lower hard units support promontories and benches at the base of the main escarpment. Only one of these, the Dhibi Limestone member, has any topographic importance, but between latitudes 22° 10′ and 24° 20′ N. this unit supports the face of Jebel Tuwaiq up to an elevation nearly equalling that of the Tuwaiq Mountain Limestone escarpment, which, however, maintains its continuity on the east.

Differential relief on the west face of Jebel Tuwaiq is over 500 m. in the central portion, diminishing to the north by gradual decrease in elevation of the crest (from heights of over 1000 m. down to about 700 m.), and to the south by gradual rise in the elevation of the western plains.

The eastern slope of the cuesta of Jebel Tuwaiq is fundamentally an upland surface sloping 5 to 8 m. to the kilometre to the east and north-east, dissected to a varying extent by a complex pattern of steep-walled, V-shaped or flat-bottomed wadis. This upland surface, which locally is well preserved in large patches, is characterized by low relief with only a few relatively low rounded hills and escarpments expressing the more resistant rock units (such as the Jubaila Limestone). The incised wadi pattern tends to be rather simply dendritic, with obvious portions of many drainage systems and larger wadis beheaded by the Tuwaiq escarpment. Younger beds are gradually added from west to east on the upland surface, for in general the dip of the rocks varies from 10 to 18 m. to the kilometre as compared with 5 to 8 m. for the surface. Thus the eastern slope is a near, rather than a real, dip-slope. The wadis cutting the upland surface in general discharge more or less at grade on to the plains, or into north-south wadis just east of the dip-slope.

The lowlands and plains on both sides of the Tuwaiq upland in the main are cut, rather than depositional, surfaces and carry only scant superficial deposits (aside from recent wind-blown sand). Thin scums of gravel of various types mantle considerable areas, but even on the outwash slopes of the Tuwaiq where these are expected to be at a maximum, outcrops of underlying rocks peep through with persistent frequency, and the deposits can only locally be more than a metre or two in maximum thickness. The commonest exception is in certain low areas where gypsum and relatively recent silts have apparently reached two or three times this thickness. West of the Tuwaiqs the plains and low-lying country fit particularly well into the definition of pediplane, with a fine development of this as the contact between the sedimentary rocks and the basement is approached. The passage across this contact between these radically different rock-types often has no topographic expression, being detected only by the nature of the inconspicuous outcrops exposed in the cut surface. The wide development of erosional rather than depositional surfaces is of practical importance in enabling even the softest members of the stratigraphic sequence to be worked out between the major highlands. The outcrops of the Jilh formation, for example, are mainly low rises in plains of this type, with only two appreciable escarpments a few tens of metres high.

Data are not yet available for deciphering the obviously interesting later history of the Jebel Tuwaiq and its surroundings. Unusual types of capture shown by now incised wadis, minor reversals in grade of one or two major wadis, the contrast between the characteristics of the upland surface and the one or more relatively subdued erosional surfaces, strong local development of surface enrichment in calcium carbonate, karst features on the upland surface, and many others attest to an eventful, although possibly relatively

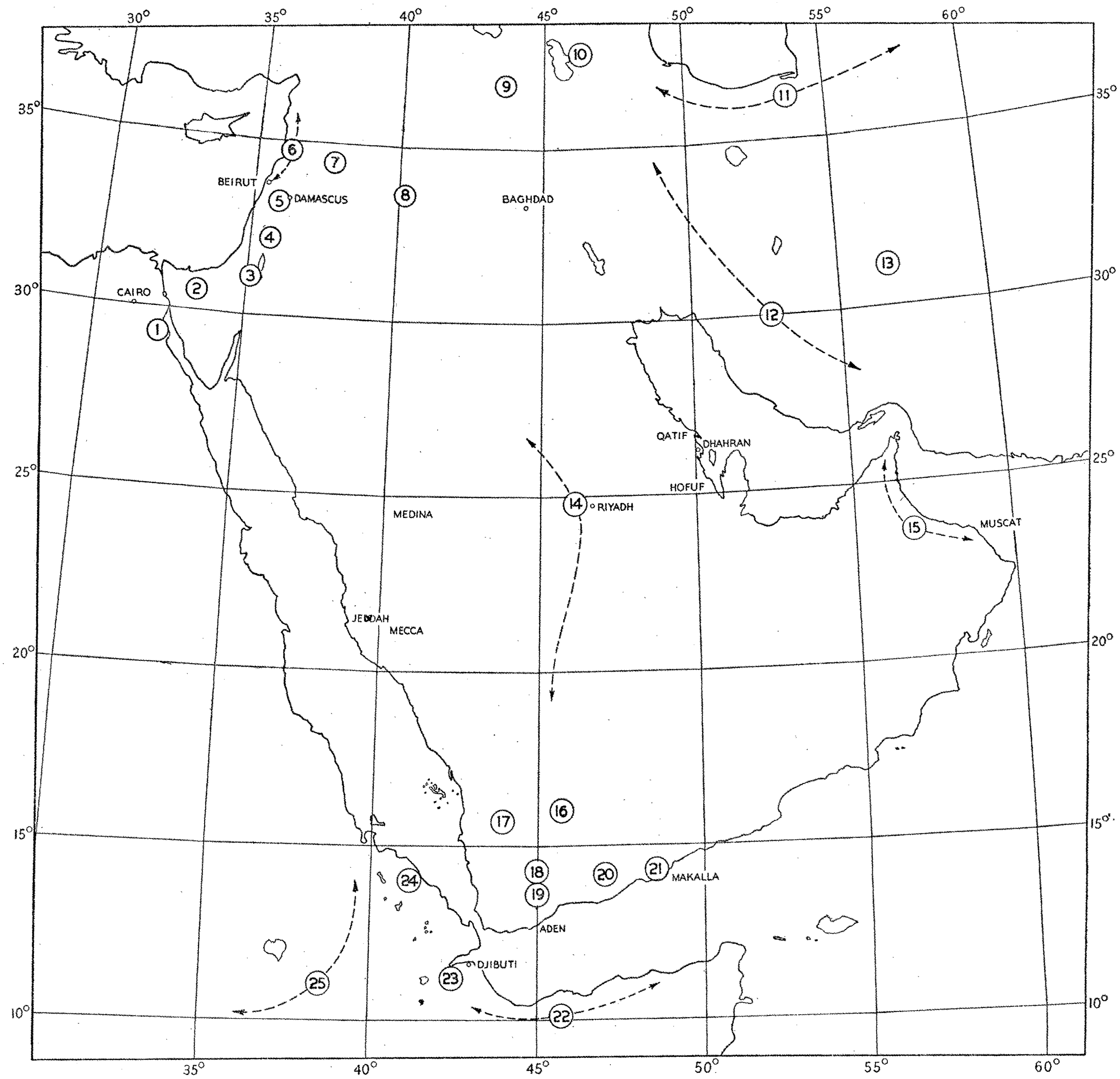

FIGURE 1. Sketch-map of Arabia and surrounding district, showing position of Jebel Tuwaiq and other Jurassic outcrops (1–25).

List of numbered Jurassic outcrops

1. Khashm el Galala and Ras el Abd (Sadek 1926; Carpentier & Farag 1948; Farag 1948).
2. Gebel Maghara (H. Douvillé 1916, 1925; Moon & Sadek 1921).
3. Kurnub anticline (Blake 1935).
4. Nahr es Zerka or Yabbok (Cox 1925; Avnimelech 1945).
5. Mount Hermon (Dubertret 1941–3).
6. Jebel Ansaria (Dubertret 1941–3).
7. Near Bassiri (Dubertret 1941–3).
8. Qara depression (Dubertret 1941–3).
9. Jebel Gara, near Amadia, Kurdistan.
10. Lake Urmia, Azerbaijan.
11. Elburz mountains.
12. Zagros mountains.
13. Central Iranian plateau.
14. Jebel Tuwaiq.
15. Oman (Lees 1928; Kühn 1929; Davis 1950).
16. Alam Aswad ridge of Philby (Cox 1938).
17. Amran, Yemen (Lamare 1930, 1936; Basse 1930).
18. } Hinterland of Aden (Tipper 1910; New-
19. } ton & Crick 1908).
20. Hinterland of Shugra (Stefanini 1925; von Wissmann 1943).
21. Makalla (Little 1925; Stefanini 1925).
22. British Somaliland (Gregory 1925; Spath, Cox, Muir-Wood and others 1935).
23. French Somaliland.
24. Eritrea.
25. North-west Ethiopia (Tigrai and Shoa).

subdued, history. The evidence in general also points to considerable age for some of these events, probably extending back into the middle of the Tertiary. Undoubtedly the structural stability of Nejd and its present extreme aridity have been instrumental in preserving these many traces of its later history.

2. Stratigraphy of the Lower and Middle Mesozoic rocks

The following is a tabulated summary of the pre-Cretaceous formations from which ammonites have been collected. All but the Minjur Sandstone were originally proposed and defined by M. Steineke some ten years ago, and have since been tested by field mapping and stratigraphic work by the writers and other Arabian American Oil Company geologists. The names and definitions, however, are here published for the first time. Some of the more important fossils other than ammonites have been identified by R. A. Bramkamp, whose determinations are added (see also §4, p. 251).

TABULATION OF FORMATIONS

(Cretaceous above)

Riyadh group, including in upper part the Hith Anhydrite. No ammonites found. Not studied in the present memoir.

Jubaila Limestone. Thickness at type locality about 110 m. (of which only the lower 75 m. exposed in the type section, the remainder being exposed in Wadi Hanifa between Jubaila and Riyadh). Cream to tan dense limestone, mainly microcrystalline; a number of hard, massive, partly conglomeratic, brown oolite layers, and a few thin softer oolite lenses. Forms a subsidiary escarpment on the dip-slope of Jebel Tuwaiq with little change in lithology or topographic expression.

Base. At top of major brown coral-bearing oolite of the Hanifa commonly at a prominent colour-change.

Top. At change from dense limestones below to softer dolomite and limestone. This is usually so involved in solution alterations on the old upland surface that it is rarely seen satisfactorily.

Type locality. Along Wadi Hanifa from the town of Jubaila (24° 53·2′ N., 46° 26·7′ E.) to a point about 12 km. west.

Fossils. *Perisphinctes jubailensis*, *Perisphinctes* large species of group of *P. progeron* von Ammon, *Ceromyopsis somaliensis* Weir, *Pholadomya protei* (Brongniart).

Hanifa Formation. Thickness at type locality 101 m. Cream to tan, relatively soft, chalky limestones with limited amounts of interbedded marl and tan clay-shale; several prominent brown oolite units in middle and upper portions, with a particularly prominent one at the top. Colonial corals common at several horizons in middle and upper portions, often in position of growth, but reefs have not been seen. There is little lateral variation along the strike.

Base. At contact between massive, coral-bearing Tuwaiq Mountain Limestone below and marls and soft limestones of Hanifa above.

Top. At top of the highest of the coral-bearing oolite beds.

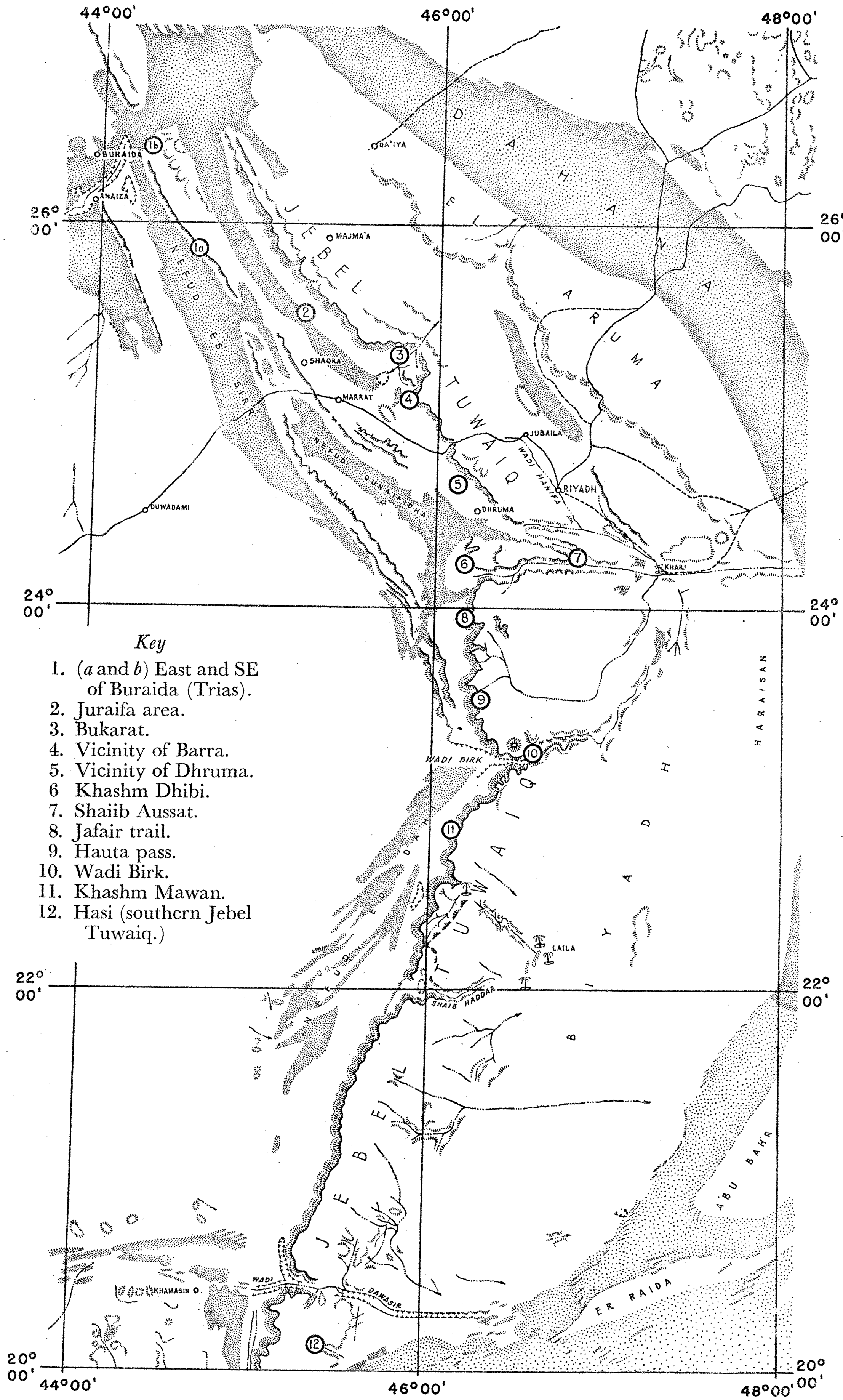

FIGURE 2. Map of Jebel Tuwaiq. The numbers 1 to 12 in circles refer to the districts under which localities are arranged in the list, pp. 252–256.

Type locality. Jebel Bakkain in Wadi Hanifa, extending east along the north side of the wadi for a distance of about 8 km. (24° 57·4′ N., 46° 12·8′ E. to 24° 55·2′ E., 46° 17·2′ E.).

Fossils. *Somalirhynchia africana* probably var. *mesoloba* Muir-Wood, *Modiolus imbricatus* (J. Sow.), *Lopha solitaria* (J. de C. Sow.), *Gryphaea balli* (Stefanini), *Exyogyra nana* (J. Sow.), *Chlamys macfadyeni* Cox, *Mactromya aequalis* Ag., *Ceromyopsis somaliensis* Weir, *Pholadomya protei* (Brongniart).

Tuwaiq Mountain Limestone. Thickness at type section 215 m. (calculated). Mainly cream, dense, microcrystalline and lithographic limestone with interbedded less dense but similar limestones; a few thin oolitic and detrital layers in upper part. Basal 35 to 40 m. soft and chalky, with limited amounts of interbedded oolite and abundant small fragmental organic remains. Colonial corals are common at a number of horizons and irregularly distributed through the upper and middle portions of the unit, often in position of growth, locally silicified. Reefs are lacking except for a few small ones in a limited area in Wadi Ammariya, north-west of Riyadh. The middle two-thirds of the unit exposed in headlands form vertical cliffs, resulting in a spectacular escarpment (plate 31). The whole formation is surprisingly persistent all along the outcrop.

Base. At contact of limestones above with underlying olive-green clay shales at top of Dhruma.

Top. See under Hanifa formation.

Type locality. Along the Riyadh-Jeddah road in Haisiyan Pass between 24° 51′ N., 46° 05′ E. and 24° 55′ N., 46° 12′ E.

Fossils. *Erymnoceras* and *Pachyceras* spp. in lower part. *Musculus somaliensis* Cox, *Eligmus rollandi* Douvillé and var. *jabbokensis* Cox, *Lopha solitaria* (J. de C. Sow.), *Gryphaea balli* (Stefanini), *Exogyra nana* (J. Sow.), *Chlamys curvivarians* Dietrich, *Ch. macfadyeni* Cox, *Ceratomya* cf. *plicata* (Ag.), *Ceromyopsis arabica* Cox, *Pholadomya aubryi* Douvillé, *Homomya inornata* J. de C. Sow.

Dhruma Formation. Thickness at type locality 383 m.

Base. At top of golden-weathering limestone unit of Upper Marrat.

Top. See under Tuwaiq Mountain Limestone.

Type locality. Series of overlapping measured sections from Khashm Dhibi (24° 12·4′ N., 46° 07·5′ E.) to Khashm Madhurd (24° 19·0′ N., 46° 19·6′ E.).

Upper Dhruma (86 m.)

10. Calcareous, partly olive, clay shale interbedded with white chalky limestone; fossils common in lower part, rare in upper part; *Gryphaea costellata* Douvillé in lowest 20 m. (65 m.).

9. Cream limestone with subordinate shale and many fossils (21 m.). *Fossils* of lower limestone unit: '*Terebratula*' cf. *superstes* Douvillé, *Eudesia cardium* (Lam.), *E. cardioides* Douvillé, *Gryphaea costellata* Douvillé, *Eligmus rollandi* Douvillé and var. *jabbokensis* Cox, *Mactromya aequalis* Ag., *Pholadomya lirata* (J. Sow.), *Ph. aubryi* Douvillé, *Homomya inornata* (J. de C. Sow.).

Middle Dhruma (170 m.). Divided into four units:

8. *Dhrumaites* Zone. Cream to tan limestones, mainly soft, with subordinate marl and shale and several prominent brown oolite beds. *Dhrumaites* in upper part (56 m.).

7. *Micromphalites* Zone. Cream soft limestones capped by a bed of hard oolite (33 m.). In lower two-thirds the *Micromphalites* fauna, with *Daghanirhynchia* cf. *daghaniensis* Muir-Wood, *Gryphaea costellata* Douvillé, *Lopha solitaria* (J. de C. Sow.), *Eligmus rollandi* Douvillé, *Bakevellia waltoni* (Lycett), *Pholadomya lirata* (J. Sow.), *Homomya* cf. *gibbosa* (J. Sow.).

6. *Tulites* Zone. Cream compact limestone with several thin oolite beds in upper part (37 m.). *Tulites* spp., *Arcomytilus somaliensis* Cox, *Modiolus* (*Inoperna*) *plicatus* (J. Sow.), *Eligmus rollandi* Douvillé, *Chlamys curvivarians* Dietrich, *Pholadomya lirata* (J. Sow.), *Homomya* cf. *gibbosa* (J. Sow.).

5. *Thambites* Zone. Cream to tan soft limestones, often oolitic especially near the top (44 m.). *Thambites* spp., *Bramkampia steinekei*, perisphinctids indet., *Eudesia cardium* (Lamarck), *Eligmus rollandi* Douvillé and var. *jabbokensis* Cox, *E. polytypus* (Eudes-Deslongchamps), *Chlamys curvivarians* Dietrich, *Homomya* cf. *gibbosa* (J. Sow.).

Lower Dhruma (127 m.). Also divided into four units:

4. Dhibi Limestone. Cream, dense, lithographic limestone, which caps a prominent escarpment through much of its outcrop, passing down into softer, partly oolitic limestone with interbedded shale below (38 m.). *Ermoceras* spp., *Thamboceras mirabile*, *Stephanoceras arabicum*, etc., also *Eudesia cardium* (Lam.), *Eligmus rollandi* Douvillé, *E. polytypus* (Eudes-Deslongchamps), *Lopha solitaria* (J. de C. Sow.).

3. Olive green and golden brown, slightly gypsiferous shale, with a few thin chalky limestone layers; fossils scarce, none identified (22 m.).

2. Interbedded white and cream, mainly chalky limestone and golden brown, slightly gypsiferous clay-shale; several thin hard limestone layers in lower part; fossils rare (36 m.) *Dorsetensia*, a single fragment.

1. *Dorsetensia* Zone. Clay-shale, green to olive in part varicoloured, with several thin layers of oolite and fine sandstone in upper part; locally several metres of bedded gypsum at base (31 m.). *Dorsetensia arabica*, main horizon.

Marrat Formation. Thickness at type locality 111 m.

Base. At contact of marine limestone and dolomites above with underlying varicoloured sandstones of the Minjur below.

Top. See under Dhruma formation.

Type locality. In Jebel Kumait, a hill immediately north-west of the town of Marrat (25° 04·5′ N., 45° 28·6′ E.) and in escarpment 5 km. S. 70° W. of town of Marrat. Limited supplemental data on uppermost beds near 25° 01·5′ N., 45° 33′ E.

Upper Marrat (21 m.). Golden brown to tan-weathering, light grey, dense limestone with several beds of oolite; locally common limonitic ooliths; small amounts of tan clay-shale near base. *Hildaites*, *Nejdia*.

Middle Marrat (56 m.). Dark brick-red, in part silty, shale, with a few thin light green layers; a zone of ripple-marked, silty, fine quartz sandstone in upper part; one thin layer of limestone as in Upper Marrat 2 m. below top. No fossils.

Lower Marrat (34 m.). Yellowish tan to grey, compact limestone and dolomite of varying hardness, with subordinate tan sandy shale and buff, fine to medium-grained quartz sandstone in lower part; locally with a soft, chalky, fossiliferous zone at top. *Bouleiceras* spp., *Protogrammoceras madagascariense* (Thevenin), many *Spiriferina*, *Stomechinus*, *Pecten ambongoensis* Thevenin, at or near top (plate 31).

Northward from the type area the upper and lower limestone units converge; southward the limestones thin and finally disappear, until the whole formation is represented only by a brick-red sandstone.

MINJUR SANDSTONE. Thickness at type locality 315 m. Buff, massive, commonly cross-bedded, fine to coarse quartz sandstone with a few layers containing abundant small quartz pebbles; locally calcareous, weathering to give small spherical concretionary masses; several irregular zones of red, purple and blue-grey varicoloured shale, sandy shale and shaly sand; somewhat strong development of black to brown ironstone as thin platy layers or concretionary masses, often containing moulds of fossil wood at several horizons. Weathering has caused locally much iron-enrichment, with result that conspicuous erosional remnants with black, quartzitic, strongly ferruginous capping layers are usually scattered along the outcrop. The only changes along the outcrop are moderate changes of thickness.

Base. At contact between sandstones of type described and resistant marine brown sandy oolitic quartz sandstone bed at top of the Jilh.

Top. At base of the first marine beds of the Marrat.

Type locality. From the east end of the dip-slope of the top of the Jilh formation (23° 33′ E., 46° 08′ E.) extending up to the base of the Marrat in the face of Khashm Minjur (23° 35′ E., 46° 10·4′ E.).

JILH FORMATION (Triassic). Thickness at type locality about 326 m.

Base. At contact between soft, poorly exposed sandstone and green shale of Jilh above, and thick red shales (suspected to be Permian) below.

Top. See under Minjur Sandstone.

Type locality. Across the Jilh El'Ishahr (a low escarpment near Nefud Qunaifidha) between 24° 03·7′ N., 45° 45·5′ E. and 24° 12·9′ N., 45° 52·2′ E.

Upper Jilh (185 m.). Divided into two units:

5. Fine to medium-grained quartz sandstone and green to purple silts and shales; several prominent layers of yellow to golden-brown, hard, slabby, in part sandy, dense, finely crystalline limestone; capped by a hard layer of sandy oolite and oolitic sand; in the limestones, especially the uppermost layer, rare casts of marine fossils. From between 45 and 55 m. below the top about forty fragments and nuclei of Middle Triassic ammonites and *Myophoria* spp. etc., collected on the Marrat-Buraida road, 11·8 km. from Er Rukaiya, 30·7 km. N. 76½° E. of Buraida (67 m.).

4. Grey to buff and white, fine to coarse quartz sandstone, with in places numerous small spherical concretions; mainly massive and strongly cross-bedded in upper part, with much interbedded green, olive, yellow and red silt and shale in the lower half; several thin ironstone layers, occasionally showing moulds of fossil wood; two thin limestone layers just below the middle (118 m.).

Lower Jilh (141 m.). Divided into three units:

3. Limestones, varying from grey and chalky to yellow-brown, slabby, dense, with interbedded fine quartz sandstone and marl; rare poorly preserved marine fossils (36 m.).

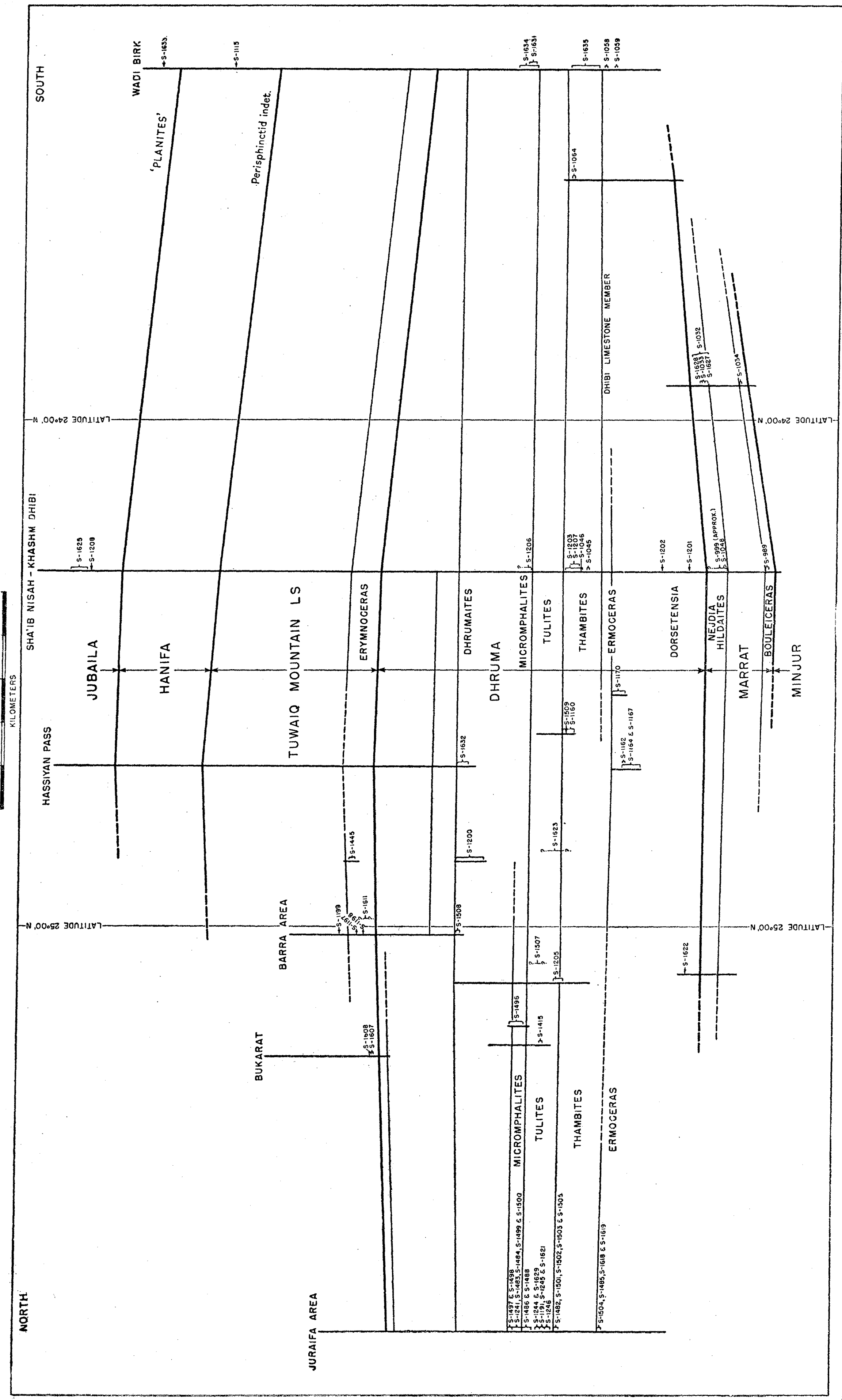

FIGURE 3. Stratigraphic levels of ammonite collections, central Jebel Tuwaiq, Saudi Arabia. (Aramco registration numbers as listed in Part I, §5, pp. 252–256.)

2. Green shale, in part gypsiferous, with a few thin, hard, limestone layers; rare poorly preserved marine fossils and a few (amphibian?) bone fragments (25 m.).

1. Quartz sandstone, grey to buff and reddish, fine to medium-grained, locally ferruginous, locally with many small spherical concretions, and light to dark green shale, in about equal amounts. Basal portion poorly exposed, probably mainly sandstone (about 80 m.).

3. Stratigraphic positions of ammonites

The relative stratigraphic positions of the ammonites collected are shown by Aramco numbers in the diagrammatic horizontal section along the strike (figure 3).

The best sequence of Lower Dhruma and Marrat faunas occurs south-west of Riyadh. Middle Dhruma ammonites are best represented near Juraifa, north-west of Riyadh. In the higher formations ammonites are much scarcer, probably as the result of unfavourable facies.

Because of the many new elements in the ammonite faunas, special care has been taken to determine their stratigraphic levels objectively from field evidence. The fine exposures in Nejd, and the systematic, gradual nature of lateral changes in the sediments, made it possible to establish the levels of most of the collections with considerable precision—usually within 2 or 3 m. over stretches of about 100 km. Long-distance correlation, although not of quite this accuracy, approaches it. This has been achieved by a combination of bed-tracing and matching details of lithologic sequence at sufficiently small intervals to detect and eliminate facies changes.

The best exposed and most thoroughly studied sequence is roughly between latitudes 24 and 25° N., and this has been taken as the standard sequence. Collections from between 23 and 24° N. can be tied in with about the accuracy mentioned above. Unfortunately, the unusually fine Middle Dhruma sequence near Juraifa is separated from that to the south by a considerable area concealed by plains, outwash and sand, and here field-work has so far failed to give an independent sequence of stratigraphic correlations based solely on lithologic criteria. The parallel is close enough, however, to leave no doubt of correlations between the two areas to the nearest 10 to 15 m. vertically when palaeontological evidence is included.

4. Fossils other than ammonites

The ammonites are the first group of fossils to be systematically studied, and the formations have been dated relative to the standard time-scale almost solely on their evidence. Other Mollusca, with numerous brachiopods, echinoids, corals, sponges, etc., are well represented, both with the ammonites and at numerous other horizons. When they can be studied they will doubtless throw new light on the age of such parts of the sequence as have no ammonites, and on the Arabian Jurassic system in general.

Meanwhile, only preliminary work having been done on these other groups (although large collections have been made), we cannot attempt to give complete fossil lists. In the tabulated stratigraphic sequence (§2, pp. 245–251), only some of the most abundant or most important species have been inserted, when it has been possible to identify them by means of published figures. Already, however, some interesting points emerge: notably, the much greater degree to which the lamellibranchs correspond with European species than do the ammonites; and the surprisingly long range of many lamellibranchs. For instance, *Eligmus rollandi* Douvillé and a *Lopha* like *L. solitaria* (Sow.) range from the Lower Dhruma (Bajocian) to the Tuwaiq Mountain Limestone (Middle Callovian); *Pholadomya lirata* (Sow.) and other Myacea range from at least as low as the Middle Bathonian up to the Middle Callovian; more suprising, brachiopods indistinguishable from *Eudesia cardium* as figured by H. Douvillé from Gebel Maghara occur not only (as there) in the Upper Bathonian but also in the early-Upper or possibly even late-Middle Bajocian. *Gryphaea costellata* (Douvillé), on the other hand, seems to be a better horizon-marker, for it has been found only in the Upper Dhruma and the *Micromphalites* Zone of the Middle Dhruma (Upper and Middle Bathonian). In Sinai and Algeria it seems to be also exclusively Bathonian, but in Somaliland it occurs in beds, the Lower Bihen Limestone without ammonites, which have been dated primarily on their brachiopods as Callovian (Muir-Wood 1935). The molluscan fauna of the lower Bihen Limestone of Somaliland would be accepted without comment if it had come from the Upper Dhruma.

Another Somaliland fossil of interest found in Nejd is *Somalirhynchia africana* Weir, which with several of its varieties characterizes the Lower and Middle Hanifa. Various Mollusca found in the Upper Bihen Limestone and Gadohleh Shale of Somaliland also occur in the Hanifa.

5. List of localities

The following list includes all the localities where ammonites described or recorded in this memoir were found, with identifications of the ammonites added. Nearly all the localities from which H. St J. B. Philby collected fossils have been revisited and placed stratigraphically, and some are included in the list. He has kindly (1951) supplied supplementary notes on his collections. His discovery of *Erymnoceras* at Haisiya is especially remarkable in view of the rarity of ammonites in this part of the succession. His collections confirm our own conclusion that *Gryphaea costellata* Douvillé does not extend up into the Callovian.

LIST OF LOCALITIES

(For key map see figure 2)

Juraifa area

Locality number

1 Dhruma formation: *Ermoceras* fauna (25° 31·2′ N., 45° 11·4′ E.). 86 m. below the *Micromphalites* clay, 7·0 km. S. 78° W. of Juraifa. Aramco S-1504. *Ermoceras* sp. indet.

2 Dhruma formation: *Ermoceras* fauna (25° 30·1′ N., 45° 13·6′ E.). Purple-red ammonite bed 88 to 90 m. below the *Micromphalites* clay, 4·5 km. S. 47½° W. of Juraifa. Aramco S-1618. *Ermoceras splendens*, *E. runcinatum*, *E. aulacostephanus*, *E. elegans*, *E. strigatum*, *Thamboceras mirabile*, *Nautilus* sp.

3 Dhruma formation: *Ermoceras* fauna (25° 30·1′ N., 45° 13·6′ E.), 86 to 88 m. below the *Micromphalites* clay, 4·5 km. S. 47½° W. of Juraifa. Aramco S-1619. *Ermoceras* spp. indet., *Thamboceras mirabile*.

4 Dhruma formation: *Ermoceras* fauna (25° 22·5′ N., 45° 20·8′ E.). Limonitic cast bed approximately 86 to 87 m. below *Micromphalites* clay, 19·1 km. S. 27¼° E. of Juraifa. Aramco S-1485. *Ermoceras runcinatum*, *E. magnificum*, *Ermoceras* aff. *mogharense*, *E. coronatoides*, *Stephanoceras arabicum*, ? *Teloceras* nucleus.

Locality number

5 Dhruma formation: *Thambites* fauna (25° 32·0′ N., 45° 11·9′ E.), 36·4 to 41·4 m. below the *Micromphalites* clay, 6·2 km. N. 86° W. of Juraifa. Aramco S-1482. *Thambites planus*.

6 Dhruma formation: *Thambites* fauna (25° 32·3′ N., 45° 11·5′ E.). 36·4 to 43·8 m. below the *Micromphalites* clay, 7·0 km. N. 82° W. of Juraifa. Aramco S-1501. *Thambites planus* in red limestone.

7 Dhruma formation: *Thambites* fauna (25° 31·8′ N., 45° 13·3′ E.). 39·4 to 40·4 m. below the *Micromphalites* clay, 3·8 km. N. 89° W. of Juraifa. Aramco S-1503. *Thambites planus*, fragments of perisphinctids.

8 Dhruma formation: *Thambites* fauna (25° 32·0′ N., 45° 12·5′ E.). 39·4 to 40·4 m. below the *Micromphalites* clay, 5·25 km. N. 85° W. of Juraifa. Aramco S-1505. *Bramkampia steinekei*, *Thambites planus* (giant specimen).

9 Dhruma formation: *Thambites* fauna (25° 31·8′ N., 45° 13·3′ E.). 36·4 to 38·4 m. below the *Micromphalites* clay, 3·8 km. N. 89° W. of Juraifa. Aramco S-1502.

10 Dhruma formation: *Tulites* fauna (25° 32·5′ N., 45° 11·9′ E.). 26·8 to 33·6 m. below the *Micromphalites* clay, 6·35 km. N. 78½° W. of Juraifa. Aramco S-1246. *Tulites* sp., nucleus.

11 Dhruma formation: *Tulites* fauna (25° 32·5′ N., 45° 11·9′ E). 20·7 to 26·8 m. below the *Micromphalites* clay, 6·35 km. N. 78½° W. of Juraifa. Aramco S-1245.

12 Dhruma formation: *Tulites* fauna (25° 33·5′ N., 45° 10·9′ E.). 20·7 to 21·7 m. below the *Micromphalites* clay, 8·4 km. N. 68° W. of Juraifa. Aramco S-1191 and 1621. *Tulites arabicus*, *T. tuwaiqensis*, *T. erymnoides*.

13 Dhruma formation: *Tulites* fauna (25° 33·5′ N., 45° 10·9′ E.). 15·7 to 20·7 m. below the *Micromphalites* clay, 8·4 km. N. 68° W. of Juraifa. Aramco S-1244 to S-1629. *Tulites arabicus*.

14 Dhruma formation: *Tulites* fauna (25° 25·5′ N., 45° 21·3′ E.). 3 to 11 m. below the *Micromphalites* clay, 14·9 km. S. 39° E. of Juraifa. Aramco S-1488. N.g. indet.

15 Dhruma formation: *Tulites* fauna (25° 25·5′ N., 45° 21·3′ E.). 0 to 3 m. below the *Micromphalites* clay, 14·9 km. S. 39° E. of Juraifa. Aramco S-1486. N.g. indet., as at locality 25.

16 Dhruma formation: *Micromphalites* fauna (25° 33·3′ N., 45° 12·5′ E.). 0 to 2 m. above the base of the *Micromphalites* clay, 5·9 km. N. 62° W. of Juraifa. Aramco S-1483 and 1500. *M. clydocromphalus* (best material), *M. elegans*, *M. intermedius*.

17 Dhruma formation: *Micromphalites* fauna (25° 33·3′ N., 45° 12·5′ E.). 0 to 9·4 m. above the base of the *Micromphalites* clay, 5·9 km. N. 62° W. of Juraifa. Aramco S-1241. *Micromphalites* cf. *busqueti*, *M. elegans*, *M. clydocromphalus*.

18 Dhruma formation: *Micromphalites* fauna (25° 33·3′ N., 45° 12·5′ E.). 6·7 to 9·4 m. above the base of the *Micromphalites* clay, 5·9 km. N. 62° W. of Juraifa. Aramco S-1484 and S-1499. *Micromphalites* cf. *busqueti*, *M. elegans*, *M. intermedius*, *M. clydocromphalus*, *M. vertebralis*, *Strungia arabica*.

19 Dhruma formation: *Micromphalites* fauna (25° 33·5′ N., 45° 12·6′ E.). 11·7 to 13·0 m. above the base of the *Micromphalites* clay, 6·0 km. N. 58° W. of Juraifa. Aramco S-1497. *Micromphalites* sp.? (field identification).

20 Dhruma formation: *Micromphalites* fauna (25° 33·5′ N., 45° 12·6′ E.). 13·0 to 16·3 m. above the base of the *Micomphalites* clay, 6·0 km. N. 58° W. of Juraifa. Aramco S-1498. *Micromphalites* cf. *busqueti* (best material), *M. elegans*, *M. clydocromphalus*.

Bukarat area

21 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 18·6′ N., 45° 45·9′ E.). 60·5 to 62·5 m. below the top of the lower coral-bearing unit, 1·0 km. due south of Jebel Bakarat. Aramco S-1607. *Erymnoceras* cf. *philbyi*.

22 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 18·6′ N., 45° 45·9′ E.). 59·3 m. below the top of the lower coral-bearing unit at the same locality as the preceding. Aramco S-1608. *Erymnoceras* aff. *triplicatum*.

Barra area

23 Dhruma formation: *Dorsetensia* fauna (24° 57·6′ N., 45° 41·5′ E.). Weak limestone layer 18·2 m. above the base of the Dhruma, and about 5·0 m. below capping sandstone in a low escarpment, 18·4 km. N. 73½° W. of Barra. Aramco S-1622. *Dorsetensia arabica*, *Dorsetensia* cf. *liostraca*.

Locality number

24 Dhruma formation: *Tulites* fauna (25° 04·0′ N., 45° 44·2′ E.). Between 0 and 13 m. below top of promontory (estimated between 30 and 43 m. below equivalent of base of *Micromphalites* fauna), 13·5 km. S. 83½° W. of Khashm Hisan. Aramco S-1205. *Tulites erymnoides*.

25 Dhruma formation: *Tulites* fauna (25° 01·7′ N., 45° 46·9′ E.). Exact level not determined but a few metres below the *Micromphalites* fauna, 10·7 km. S. 56¾° W. of Khashm Hisan. Aramco S-1507. *Tulites erymnoides* and n.g. indet. as at locality 15.

26 Dhruma formation: *Tulites* fauna (25° 11·0′ N., 45° 39·2′ E.). Between 13·2 and 17·3 m. below capping layer in low escarpment (15·2 to 19·3 m. below the *Micromphalites* fauna), 24·8 km. N. 62° W. of Khashm Hisan. Aramco S-1415. *Tulites tuwaiqensis* (crushed).

27 Dhruma formation: *Micromphalites* fauna (about 25° 10′ N., 45° 42·5′ E.). Between 3·7 and 20·6 m. above base of exposures (3·7 to 20·6 m. above the base of the *Micromphalites* fauna) in isolated hill, about 18·0 km. N. 60° W. of Khashm Hisan. Aramco S-1496. *M. clydocromphalus*, *Micromphalites* cf. *busqueti*, in pink limestone.

28 Dhruma formation: Probably *Tulites* fauna (24° 52·7′ N., 45° 53·9′ E.). Loose material on the 25 m. slope of a small promontory, 1·0 km. south-east of Uwainid. Exact stratigraphic level not determined, probably falling within the *Tulites*-bearing part of the sequence. Aramco S-1623. Perisphinctid nucleus indet.

29 Dhruma formation: *Dhrumaites* fauna (25° 02·6′ N., 45° 50·0′ E.). Derived from upper 5·3 m. of beds below the strongly bench-forming brown oolite unit (roughly 80 to 85 m. above the base of the *Micromphalites* fauna) in a promontory 5·6 km. S. 41° W. of Khashm Hisan. Aramco S-1508. *Dhrumaites cardioceratoides*.

30 Dhruma formation: *Dhrumaites* fauna (24° 54·3′ N., 45° 57·4′ E.). Derived from between 0 and 30 m. below brown strongly bench-forming oolite (roughly 55 to 85 m. above the base of the *Micromphalites* fauna) in promontory 3·3 km. S. 36° W. of Khashm Balaidiya. Aramco S-1200. *Dhrumaites cardioceratoides*.

31 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 02·4′ N., 45° 53·1′ E.). 15·6 m. above the base of the Tuwaiq Mountain limestone on the south-western corner of Khashm et Turab. Aramco S-1198. *E. philbyi*.

32 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 02·4′ N., 45° 53·1′ E.). 22·4 m. above the base of the Tuwaiq Mountain limestone at same locality as the preceding. Aramco S-1197. *Erymnoceras* cf. *philbyi*, *Pachyceras* cf. *schloenbachi*.

33 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 02·4′ N., 45° 53·1′ E.). About 43·4 m. above the base of the Tuwaiq Mountain limestone at the same locality as the preceding. Aramco S-1199. *Erymnoceras* cf. *jarryi*.

34 Tuwaiq Mountain limestone: *Erymnoceras* fauna (24° 50·5′ N., 45° 02·1′ E.). Between 30 and 35 m. above the base of the Tuwaiq Mountain limestone in the outlier at Khashm Balaidiya. Aramco S-1445. *Subgrossouvria*? nucleus.

35 Tuwaiq Mountain limestone: *Erymnoceras* fauna (25° 02·5′ N., 45° 40·4′ E.). Lower Tuwaiq Mountain limestone (exact level not determined), 24·2 km. N. 54° W. of Barra. Aramco S-1611. *Erymnoceras* cf. *philbyi*.

Dhruma area

36 Dhruma formation: *Ermoceras* fauna (24° 40·1′ N., 46° 03·0′ E.). Weathered-out fossils on the slope, derived from 0 to 19·7 m. below the top of the escarpment (calculated about 13 to 32 m. below the top of the Dhibi limestone member), 10·5 km. N. 53° W. of the northern corner of the town of Dhruma. Aramco S-1164. *Thamboceras mirabile*.

37 Dhruma formation: *Ermoceras* fauna (24° 39·3′ N., 46° 03·3′ E.). Weathered-out fossils on the slope derived from 0 to 20 m. below the top of the escarpment (calculated about 13 to 33 m. below the top of the Dhibi limestone member), 9·0 km. N. 58¼° W. of the northern corner of the town of Dhruma. Aramco S-1167. *Ermoceras reineckeoides*, *Stephanoceras arabicum*.

38 Dhruma formation: *Ermoceras* fauna (24° 40·1′ N., 46° 03·0′ E.). Fossils in place 11·7 to 14·3 m. below the top of the escarpment (calculated about 25 to 27½ m. below the top of the Dhibi limestone member, 10·5 km. N. 53° W. of the northern corner of the town of Dhruma. Aramco S-1162. *Ermoceras reineckeoides*, *E. runcinatum*, *E. magnificum*, *E. elegans*, *E. coronatoides*.

Locality number

39 Dhruma formation: *Ermoceras* fauna (24° 33·3′ N., 46° 08·1′ E.). Weathered-out fossils from the slope of escarpment covering 0 to 14 m. below its top (calculated about 13 to 27 m. below the top of the Dhibi limestone member), 6·3 km. S. 02½° E. of the northern corner of the town of Dhruma. Aramco S-1170. *Ermoceras* aff. *mogharense*, *Ermoceras* cf. *splendens*, *E. elegans*, *Teloceras* cf. *labrum*.

40 Dhruma formation: *Thambites* fauna (24° 38·2′ N., 46° 07·5′ E.). Derived from 0 to 10 m. below the top of a small hill (calculated 30 to 40 m. above the top of the Dhibi limestone member), 3·2 km. N. 11° W. of the town of Dhruma. Aramco S-1160. *Thambites* sp.

41 Dhruma formation: *Thambites* fauna (24° 38·2′ N., 46° 07·5′ E.). At the same locality as preceding, but on top of the hill (calculated 40 m. above the top of the Dhibi limestome member). Aramco S-1509. *Thambites* sp.

42 Dhruma formation: *Dhrumaites* fauna (24° 43·1′ N., 46° 08·1′ E.). Weathered out on slope, and potentially derived from 0 to 12 m. below prominent bench-forming brown oolite (calculated 153 to 166 m. above the top of the Dhibi limestone member), 11·9 km. N. 01½° E. of the town of Dhruma. Aramco S-1632. *Dhrumaites*, young specimen.

Khashm Dhibi area (Dhruma quadrangle)

43 Marrat formation: *Bouleiceras* fauna (24° 09·3′ N., 45° 09·4′ E.). Upper 3·0 m. of lower Marrat limestone in exposures 3·4 km. S. 67° W. of Ain Bukhara. Aramco S-989. *Bouleiceras elegans*, *Protogrammoceras madagascariense*.

44 Marrat formation: *Hildaites* fauna (24° 12·1′ N., 46° 07·2′ E.). 0·4 to 3·4 m. above the base of the upper Marrat limestone, 7·9 km. N. 57¼° W. of Ain Bukhara. Aramco S-1043. *Hildaites sanderi*.

45 Marrat formation: *Hildaites* fauna (24° 10·0′ N., 46° 13·9′ E.). Upper Marrat limestone member, exact stratigraphic level not determined), 4·35 km. S. 89½° E. of Ain Bukhara. Aramco S-999. *Hildaites*? sp. indet.

46 Dhruma formation: *Dorsetensia* fauna (24° 17·5′ N., 46° 08·3′ E.). 21·2 m. above the Marrat-Dhruma contact, 14·8 km. N. 20° W. of Ain Bukhara. Aramco S-1201. *Dorsetensia arabica* (main collection).

47 Dhruma formation: *Dorsetensia* fauna (24° 18·4′ N., 46° 09·6′ E.). 52·7 m. above the Marrat-Dhruma contact 15·6 km. N. 11° W. of Ain Bukhara. Aramco S-1202. *Dorsetensia* cf. *arabica* (single fragment).

48 Dhruma formation: *Thambites* fauna (24° 11·3′ N., 46° 16·1′ E.). Between 14·5 and 16·5 m. above the top of the Dhibi limestone member, in a section 8·4 km. N. 73½° E. of Ain Bukhara. Aramco S-1045. *Thambites avus*, *Thambites oxynotus*? (fragment).

49 Dhruma formation: *Thambites* fauna (24° 11·3′ N., 46° 16·1′ E.). 24·8 m. above the top of the Dhibi limestone member at the same locality as the preceding. Aramco S-1046. *Thambites oxynotus*, *Clydoniceras pseudodiscus*.

50 Dhruma formation: *Thambites* fauna (24° 21·6′ N., 46° 12·8′ E.). Between 25 and 35 m. above the top of the Dhibi limestone member, 21·4 km. N. 56½° E. of Ain Bukhara. Aramco S-1207. *Thambites planus*.

51 Dhruma formation: *Thambites* fauna (24° 19·8′ N., 46° 15·0′ E.). Two specimens 21·0 and 39·0 m. above the top of the Dhibi limestone member, 19·4 km. N. 20° E. of Ain Bukhara. Aramco S-1203. *Thambites planus*.

52 Dhruma formation: *Micromphalites* fauna (24° 19·5′ N., 46° 14·9′ E.). Fossils loose on surface between 81 and 86 m. above the top of the Dhibi limestone member on the upland above and 500 m. south of the preceding locality, 18·8 km. N. 21¼° E. of Ain Bukhara. Aramco S-1206. *Micromphalites* cf. *busqueti*.

Sha'ib Aussat

53 Jubaila limestone (24° 15·8′ N., 46° 44·5′ E.). 36 m. above the Jubaila-Hanifa contact, on north-eastern spur to the west of the meander at its junction with Sha'ib Nisah, 16·8 km. S. 32° W. of the town of Hair. Aramco S-1208.

54 Jubaila limestone (24° 15·5′ N., 46° 45·7′ E.). Between 40 and 60 m. above the Jubaila-Hanifa contact, on the southern side of the meander, about 2 km. S. 75° E. of the preceding locality. Aramco S-1625. *Perisphinctes* aff. *progeron*.

Jafair trail

Locality number

55 Marrat formation: *Bouleiceras* fauna (23° 56·6′ N., 46° 11·0′ E.). Upper 4·4 m. of lower limestone member of the Marrat (immediately below middle red shale unit) around southern base of the isolated *jebel* 24·8 km. S. 01° W. of Ain Bukhara. Aramco S-1034. *Bouleiceras nitescens*, *B. elegans*, *B. arabicum*, *B. marraticum*, *Protogrammoceras madagascariense*.

56 Marrat formation: *Hildaites* fauna (23° 56·6′ N., 46° 11·0′ E.). 4 to 7 m. above the base of the upper Marrat limestone at the same locality as the preceding. Aramco S-1627. *Hildaites sanderi*.

57 Marrat formation: *Nejdia* fauna (23° 56·6′ N., 46° 11·0′ E.). 8 to 9·3 m. above the base of the upper Marrat limestone at the same locality as the preceding. Aramco S-1033. *Nejdia bramkampi*, *N. furnishi*.

58 Marrat formation: *Nejdia* fauna (23° 56·6′ N., 46° 11·0′ E.). 2·0 m. above the top of the interval of the preceding locality, at the same locality. Aramco S-1628. *Nejdia* sp. fragment.

59 Marrat formation: Upper limestone (23° 56·6′ N., 46° 11·0′ E.). Unplaced material derived from 0 to 14·3 m. above the base of the upper Marrat limestone, at the same locality as the preceding. Aramco S-1032. *Hildaites sanderi*.

Hauta Pass

60 Dhruma formation: *Thambites* fauna (23° 31·0′ N., 46° 16·4′ E.). Between 31·6 and 34·3 m. above the top of the Dhibi limestone member, on the south side of the opening in Jebel Tuwaiq 38·8 km. N. 40° W. of Ain Bukra. Aramco S-1064. *Clydoniceras pseudodiscus* and single-keeled oxycones, indet.

Wadi Birk (Birk quadrangle)

61 Dhruma formation: *Ermoceras* fauna (23° 12·8′ N., 46° 25·8′ E.). Between 14·6 and 15·6 m. below the top of the Dhibi limestone member, 9·9 km. S. 68° W. of Ain Bukra (Wadi Birk). Aramco S-1058. *Normannites* cf. *orbignyi*.

62 Dhruma formation: *Ermoceras* fauna (23° 12·8′ N., 46° 25·8′ E.). Between 2·4 and 5·1 m. below the top of the Dhibi limestone at the same locality as preceding. Aramco S-1059. *Ermoceras runcinatum*, *Stephanoceras* cf. *psilacanthus*, *Teloceras* cf. *labrum*.

63 Dhruma formation: *Thambites* fauna (23° 11·0′ N., 46° 26·7′ E.). Between 4 and 35·4 m. above the top of the Dhibi limestone, on the south side of Wadi Birk, 10·3 km. S. 45° W. of Ain Bukra. Aramco S-1635. *Clydoniceras pseudodiscus*.

64 Dhruma formation: *Micromphalites* fauna (23° 12·7′ N., 46° 29·5′ E.). On surface 83·6 m. above the top of the Dhibi limestone (4 m. above base of *Gryphaea costellata* beds), 4·7 km. S. 34° W. of Ain Bukra (Wadi Birk). Nature of exposures preclude this specimen having been derived from more than a few metres stratigraphically above the level listed. Aramco S-1631. *Micromphalites* cf. *clydocromphalus*, juv.

65 Dhruma formation: *Micromphalites* fauna (23° 20·8′ N., 46° 29·2′ E.). About 85 m. above the top of the Dhibi limestone on the west side of the east fork of Wadi Baidhan (a tributary of Wadi Birk), 11·3 km. N. 16° W. of Ain Bukra. Aramco S-1634. *Micromphalites pustuliferus*.

66 Hanifa formation (23° 16·8′ N., 46° 38·7′ E.). 52·7 m. above the top of the Tuwaiq Mountain limestone, 13·0 km. N. 86½° E. of Ain Bukra (Wadi Birk). Aramco S-1115. *Perisphinctes* cf. *africanus* (indet.).

67 Jubaila limestone (23° 16·3′ N., 46° 45·7′ E.). Approximately 20 m. above the Jubaila-Hanifa contact on the north side of Wadi Birk, 5·5 km. S. 69° W. of Ghadir el Haid. Aramco S-1633. *Perisphinctes jubailensis*, *Lithacoceras*?

Khashm Mawan

68 Dhruma formation: Faunal level uncertain (22° 50·0′ N., 46° 07·2′ E.). Found on slope, with potential derivation from some level between 40 m. below and 62·7 m. above the Dhibi limestone member, 2·7 km. N. 63° E. of Khashm Mawan. Aramco S-1630. *Ermoceras coronatiforme*.

Southern Jebel Tuwaiq

69. Jubaila limestone (20° 08·2′ N., 45° 25·1′ E.). 9·5 m. below the base of the capping dolomite layer (exact equivalence with northern Jubaila section is not known, but the locality is equivalent to a relatively low level in the Jubaila), 9·5 km. west of Ain Hasi, Awairidh, southern Jebel Tuwaiq. Aramco S-1190. *Perisphinctes* cf. *jubailensis*.

PART II. THE AMMONITE FAUNAS FROM JEBEL TUWAIQ

By W. J. Arkell, F.R.S.

1. Introduction

In the foregoing modest account of the geology of the interior of Arabia, Dr Bramkamp gives little indication of the achievement it represents. Since the establishment of the Arabian-American Oil Co. in 1935 at Dhahran on the coast of the Persian Gulf, he, at first with his former chief M. Steineke, and their colleagues, have mapped and explored hundreds of square miles of unknown country, where the geological map previously was guess-work. By careful collecting and accurate stratigraphy, working always at least 300 miles from their base at Dhahran, they have unravelled a series of geological formations and systems extending along a strike of over 500 miles. It is no exaggeration to say that the palaeontological treasures that they have brought out of the interior of this vast country, some of which the Company has given permission to be published here, in the field of Mesozoic invertebrate palaeontology rank in importance and novelty with anything discovered in the first scientific opening up of any other sub-continent.

In the interior of Arabia, secluded before the motor age behind waterless tracts of sand, there lay all unknown a succession of Palaeozoic and Mesozoic systems teeming with marine fossils. The system most fully developed and the principal element forming the landscape is the Jurassic. The world palaeogeographic maps made by Neumayr in 1885 show the whole of Arabia as land throughout the Jurassic. Since then Upper Jurassic marine fossils have been recorded from a number of places near the coast: near Aden in the first decade of the present century, and later at intervals along the Gulf of Aden to Oman and in the Yemen.

The first knowledge of Jurassic rocks in the interior resulted from camel journeys in 1917 and 1918 by H. St J. B. Philby, who brought back to the British Museum fossils from Jebel Tuwaiq. The collections made on these earliest journeys were described by Newton (1921) and considered to be Lower Kimeridgian, but they included no identifiable ammonite. Another collection made by Philby 14 years later, at the Haisiya Pass, north-west of Riyadh, contained ammonites of the genus *Erymnoceras* (see plate 29, figure 2), and enabled all the lots to be dated as Callovian (Cox 1933).

On the strength of plant-bearing sandstones found in the Yemen, assigned on palaeobotanical evidence tentatively to the Lias (Carpentier & Farag 1948), and directly overlain by Upper Jurassic marine limestones, Lamare in 1936 in his coloured geological map of Arabia showed an outcrop of Lias all along the foot of the Jebel Tuwaiq. This appears to have been purely conjectural, however, and at the time when the Arabian-American Oil Company's geologists began their work the only Jurassic stage known to exist in the Tuwaiq was the Callovian (Upper Jurassic). This memoir illustrates the discovery of a whole series of Lower, Middle and Upper Jurassic formations, in neritic facies. Trias and Permian were found farther west (see Steineke 1947, p. 120).

The ammonite faunas of the Lower and Middle Jurassic contain such peculiar elements that they raise numerous important questions of evolution, classification, correlation and

palaeogeography. It has been a privilege to work on the collections made by Dr Bramkamp and his colleagues. I am deeply indebted to him for the opportunity to do so and for his stimulating collaboration during the last three years, and also to him and to the Directors of Aramco for a visit in January 1951, to the outcrops of the Jebel Tuwaiq and opportunities to collect from all the formations of the Jurassic, as well as for permission to publish this memoir.

All figured specimens have been deposited in the Sedgwick Museum, Cambridge, where the palaeontological work on the ammonites has been done. Their registered numbers, prefaced by SM., are quoted in the explanations of the plates and text-figures. The rest of the material will be deposited in the United States National Museum.

Stage-names and zones are used in accordance with the scheme for a standard European scale for the Jurassic (Arkell 1946*a*).

I am indebted to Mr A. G. Brighton, Curator of the Sedgwick Museum, for help in numerous ways and for identifying the *Stomechinus* of the *Bouleiceras* bed. The photographs were taken by Mr Albert Barlow at the Sedgwick Museum, with a few exceptions taken at Aramco headquarters in Arabia.

2. Jurassic rocks in other parts of Arabia

Marine Upper Jurassic rocks are known from a number of places in and round the southern corner of Arabia, ranging from the Yemen, by Aden and its hinterland to the coast of the Gulf of Aden at Makalla. The principal localities are shown on the sketch-map, figure 1, p. 244.

In the Yemen the Jurassic rocks, including the plant-bearing Kohlan Sandstone at the base, are about 2000 ft. thick and rest on the crystalline basement complex. They are overlain in turn by Nubian Sandstone (about 700 ft.) and the Aden lavas (1000 ft.) (Lamare 1930, p. 52). From locality 17 near Amran, about 50 km. north-west of Sanaa, the capital, Lamare obtained and Basse (1930) described a Lower Kimeridgian fauna including *Balanocidaris glandifera* (*Cidaris glandarius*), which is common in Syria and the Carpathians (Krumbeck 1905), and three perisphinctids of doubtful identity but evidently Lower Kimeridgian age. This fauna came from some 220 m. of beds (numbers 6, 8 and 10 of the Amran Series, as Mme Basse has kindly confirmed in lit. 1949) in the upper half of the Yemen Jurassics, leaving below about 370 m., or 1200 ft., still undated by fossils other than plants (Lamare 1930, p. 52). About 130 miles east of Amran, at a ridge called 'Alam Aswad (16 on figure 1), Philby collected Mollusca which Cox (1938) identified as of similar date, but no ammonites were found.

At 18 and 19 on figure 1, respectively 100 and 50 miles north of Aden, limestone yielded fragmentary perisphinctids which were figured by Newton & Crick (1908) and Tipper (1910), and they were correctly dated by Crick to the Lower and Middle Kimeridgian.

On the coast near Makalla (21 on figure 1), 300 miles east-north-east of Aden, Little (1925) found about 150 m. of limestone, shales and an oil-shale with *Posidonia*, aptychi and other fossils, including fragmentary perisphinctids, resting upon an eroded surface of the crystalline basement complex. Stefanini (1925) identified the ammonites with 'Lusitanian' species. The three fragments of which he published photographs all belong to Lower Kimeridgian forms, of about the Pseudomutabilis Zone of Europe. (I identify Stefanini's pl. xxvii, fig. 1 as *Torquatisphinctes* aff. *beyrichi* (Futterer), fig. 2 as ?*Katroliceras* sp. indet., fig. 3 as *Lithacoceras* aff. *stenocyclus* Schneid, 1914, pl. i, fig. 2, non Fontannes.) These Lower Kimeridgian beds are overlain unconformably by a band of Lower Cretaceous Limestone, on which follows up to 500 m. of Nubian Sandstone.

From between Aden and Makalla, in the hinterland of Shugra (20 on figure 1), about 60 miles from Aden, Dacqué (in Stefanini 1925, p. 194) identified 'badly preserved internal whorls of *Parkinsonia* or perhaps *Perisphinctes* of the group of *P. funatus*, and shells of *Posidonia* closely allied to *P. alpina*', which he interpreted as Callovian. Since these fossils have not been figured and cannot now be traced, judgement must be reserved; but Stefanini pointed out that *Posidonia* also occurs at Makalla in the Kimeridgian. An *Idoceras* such as the Somali species *I. farquharsoni* Spath (1935, p. 213, pl. xxiv) could account for a record of *Parkinsonia*.

The only other Jurassic rocks known in Arabia are in the eastern peninsula of Oman, where they are in a different facies and have yielded very few identifiable fossils. On the Upper Triassic Elphinstone Beds, which are about 500 ft. thick, and contain *Myophoria* and other Triassic fossils, there follows conformably the Musandam Limestone, nearly 5000 ft. thick, which probably represents the whole, or a large part, of the Jurassic (Lees 1928). It is of shallow-water facies throughout, and some bands contain many sections of fossils, totally recrystallized, among which uppermost Oxfordian or Lower Kimeridgian corals have been recognized (Kühn 1929). In marl bands near the top are fossils of Barremian age. South of Ruus al Jibal are transitional Tithonian-Neocomian beds with radiolarite cherts (Lees 1928; Davis 1950).

3. Systematic description and discussion

3·1. *Ammonites of the Lower Marrat Formation*

The single ammonite horizon in the Lower Marrat Formation is only a foot or two thick, but it contains in abundance some of the same ammonites, lamellibranchs and brachiopods as the main (lower) *Bouleiceras* bed of Madagascar, namely: *Bouleiceras nitescens* Thevenin, *Protogrammoceras madagascariense* (Thevenin), *Spiriferina rostrata* var. *madagascariensis* Thevenin, and *Pecten ambongoensis* Thevenin. The two localities are 3000 miles apart, on the same meridian, and there are no known intervening occurrences.

Most of the material has been collected from the escarpment near the Jafair Trail (locality 55, plate 31), but some also (weathering out on a flat surface) in Khashm Dhibi area (locality 43). The horizon is extremely rich in *Spiriferina*, *Pecten*, *Stomechinus* and small horn corals.

Superfamily Harpocerataceae Wedekind, 1917

Family Hildoceratidae Hyatt, 1867

Subfamily Bouleiceratinae Arkell, 1950

Genus **BOULEICERAS** Thevenin, 1906

Type species by monotypy *Bouleiceras nitescens* Thevenin, 1906.

Thevenin placed this remarkable genus in the Harpoceratidae (now the superfamily Harpocerataceae), and pointed out the resemblance in the suture to some small '*Harpoceras*' figured by Meneghini from the Ammonitico rosso of Lombardy and the Central Apennines. *H. pectinatum* Meneghini (1881, p. 7, pl. i, figs. 2*c*, *d*) in particular shows smooth rounded saddles without accessory lobes, but Meneghini pointed out that the sutures of this specimen are different on the two sides (cf. fig. 2*e*).

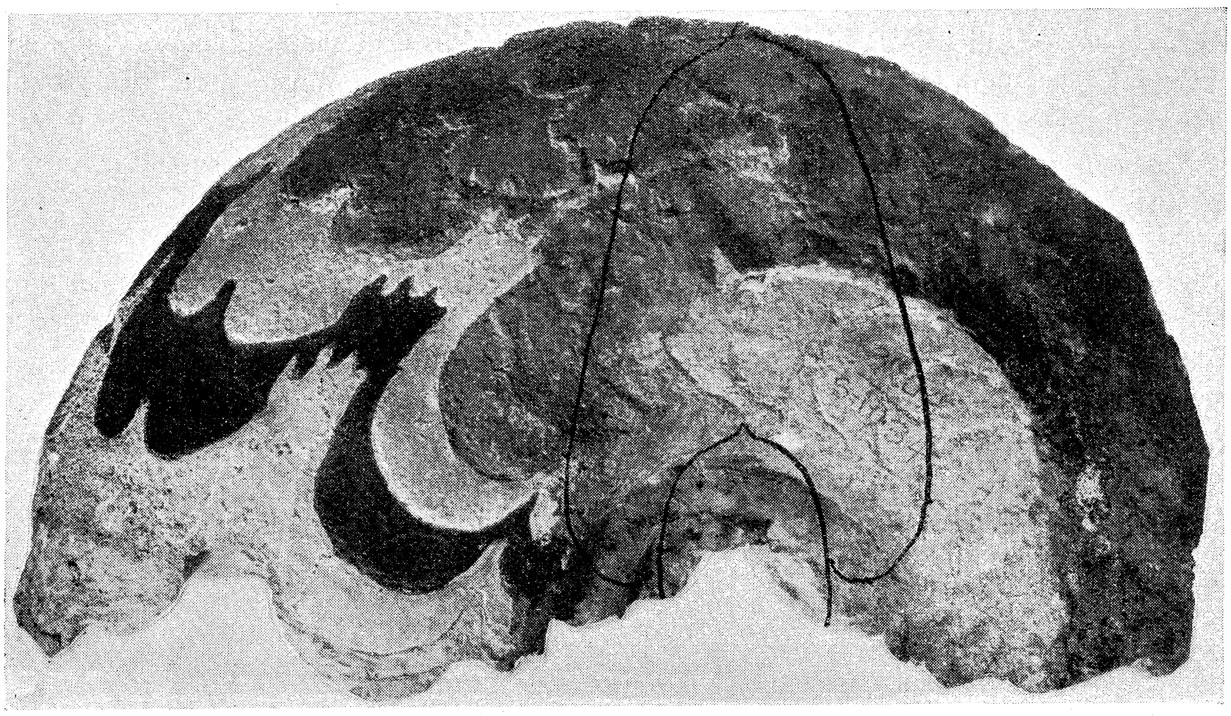

FIGURE 4. *Bouleiceras nitescens* Thevenin. Locality 55. Natural size. SM. F 10805.

A much more striking resemblance, however, is found in the Upper Toarcian genus *Paroniceras* Bonarelli, 1893. *P. helveticum* Renz (1925, pl. iv, fig. 1) from Bavaria has a suture almost identical with that of *Bouleiceras*, but lacks keel and ribs. In *Paroniceras buckmani* Bonarelli (Renz, 1923, pl. xii, fig. 4), however, there is a keel and sagittate whorl-section, so that the resemblance is almost complete.

Buckman (1894*a*, p. 357) united *Paroniceras* with *Cymbites* and placed it in the Arietitidae. The other closely allied Toarcian genus *Frechiella* Prinz, 1904, was also placed, with a query, in the Arietitidae by Buckman (1911, vol. i, pl. xxiii *b*), following Prinz. Later, however, Buckman (1919, vol. ii, p. xv) separated *Cymbites*, *Paroniceras*, *Frechiella* and ?*Hudlestonia* as a new family Cymbitidae. Renz (1925) continued to link *Paroniceras* with Lower Lias genera, regarding it as a subgenus of the Sinemurian *Agassiceras* Hyatt (family Arietitidae). Ceratitic sutures do indeed occur in another Sinemurian Arietitid genus *Hypasteroceras* Spath, 1923, based on *Asteroceras*? *ceratiticum* Fucini (1903, p. 148, pl. xxxiv, figs. 1, 2), of the subfamily Asteroceratinae.

It is unlikely that *Paroniceras* and *Bouleiceras* are directly related to any of these Sinemurian genera. Like the simplified sphaerocone shape of *Cymbites*, ceratitic sutures seem to be a form of degeneration likely to occur at any time or place in any stock. There can be no doubt that Thevenin was right in assigning *Bouleiceras* to the Harpocerataceae.

To a recapitulationist, the spinous nucleus of *Bouleiceras* proclaims descent from Polymorphitidae such as *Platypleuroceras* and *Acanthopleuroceras*, or even direct from Eoderoceratidae. But nuclei that do not differ radically are found in some forms of *Hildoceras*: e.g. Wright 1878–86, pl. lxi, figs. 1, 2 (Bifrons Zone, Toarcian), and the immediate ancestors were presumably some form of Domerian *Seguenziceras*, such as Geyer 1893, pl. i, figs. 18, 19, in which the ribs are occasionally flared and show an incipient tendency to join at the umbilical margin. *Bouleiceras arabicum* (see below), on the other hand, with its single (inner) discontinuous row of tubercles, would not be generically separable, but for the sutures, from *Chartronia* Buckman (1898, p. xvi) (including *Denckmannia* Buckman, and *Lillia* Bayle, 1878, non Boie, 1844), of the Phymatoceratinae (see especially Merla 1933, pl. i, figs. 5–10).

Bouleiceras, *Paroniceras*, *Frechiella* Prinz, *Achilleia* Renz and *Leukadiella* Renz may be convergent offshoots or end-forms of several different genera in different subfamilies, but at present it is impossible to distribute them with confidence among existing subfamilies, and so the purposes of truth and systematic convenience are better served by keeping them together as a separate subfamily of Hildoceratidae (Arkell 1950).

Bouleiceras nitescens Thevenin, plate 15, figure 5; text-figure 4

Bouleiceras nitescens Thevenin 1906, p. 171, figs. 1–3.
Bouleiceras nitescens Thevenin 1908, p. 13, pl. ii, figs. 6 (lectotype), 11.
Bouleiceras nitescens Haug 1910, *Traité de Géologie*, vol. ii, p. 995, fig. 308.

The Madagascan types. Thevenin designated no type specimen, but he figured two examples in 1906, half natural size, and mentioned that he had before him about fifty good examples. According to the Rules of Nomenclature all these fifty rank as syntypes, from which a lectotype may be chosen. There is no indication that either of the two specimens figured in 1906 as reduced drawings are the same as any of those well figured photographically and natural size in 1908 (pl. ii). From Thevenin's description of 1908 it is evident that he regarded figs. 1–8 of his pl. ii as typical, figs. 9–12 as variations, fig. 13 as perhaps a variety, and fig. 14 as a monstrosity. I therefore designate as lectotype of *Bouleiceras nitescens* Thevenin's 1908, pl. ii, figs. 6*a*, *b*, the figure reproduced in Haug's *Traité*. The other figures illustrate at least three forms that require specific names if the genus *Bouleiceras* is to be in scale with other genera. The Madagascan species then become:

B. nitescens Thevenin, pl. ii, figs. 6, 7, 11?.

B. elegans n.sp., holotype pl. ii, fig. 8, with finer, more persistent secondary ribs, and with feebler tubercles. To this probably belongs also fig. 10.

B. tumidum n.sp., holotype pl. ii, fig. 9, more tumid, more involute, with stronger inner tubercles.

B. rectum n.sp., holotype pl. ii, fig. 12, with straight and very rursiradiate ribs and flat whorl-sides.

Arabian material. Localities 55 and 43. Out of fifty-four specimens, mainly fragments, from Jebel Tuwaiq, only some of the smallest nuclei and the largest specimens, 104 and 165 mm. in diameter while wholly septate, can be assigned to *B. nitescens* with confidence. The rest are too large to show ribs or tubercles, but the presumption is that most belong to *B. arabicum*.

Other occurrences. All the Madagascan species have bituberculate nuclei, like the Arabian nucleus shown in plate 15, figure 9. A Baluchistan specimen 37 mm. in diameter, from Las Bela State, collected by Dr A. Allison for the Burmah Oil Co. in 1939, is coarsely bituberculate and seems to belong to *B. tumidum*. A larger specimen in the Cook Collection, British Museum Nat. Hist. (C. 40704), from Kelat, Baluchistan, is rather less than half a whorl in desert-weathered limestone similar to the Arabian specimens. The sutures have almost semicircular saddles, resembling Thevenin's pl. ii, fig. 10; but Thevenin pointed out the extraordinary variation and unreliability for systematic purposes of the sutures, which will be dealt with under *B. arabicum*.

The *Bouleiceras* aff. *nitescens* recorded with Toarcian ammonites in Algeria by Deleau (1941; 1948, pl. ii) seems to be *Leukadiella* cf. *ionica* Renz. (See p. 294.)

Bouleiceras arabicum n.sp., plate 15, figures 6, 8, 13, 14

Material. Six fragmentary inner whorls and probably up to about forty fragments of septate middle whorls. Localities 55 and 43.

Description. Resembling *Bouleiceras elegans*, from which middle and outer whorls may be indistinguishable, but the inner whorls differing by having only a single (inner) row of distant lateral tubercles and a more tabulate venter. The inner whorls are strongly reminiscent of some *Chartronia* (including *Denckmannia*) (see Merla 1933, pl. i, figs. 6–10). There is considerable variation in the strength and spacing of the ribs and in thickness of whorl-section, which, if more nearly complete material can be found, may lead to recognition of several species and foundation of a new genus.

Variation of suture-line. The remarkable variation in the suture-line of *Bouleiceras nitescens* was shown by Thevenin (1908). There is a similar but somewhat different range of variation among the Arabian material, most of which probably belongs to *B. arabicum*. So far no correlation is apparent between variations of suture-line and differences of form and ornament.

The first lateral lobe may be either symmetrical (plate 15, figures 4, 12) or asymmetrical (plate 15, figure 1; text-figure 5, nos. 1, 2), and either narrow and pointed (text-figure 5, nos. 3, 4) or wide and blunt (plate 15, figure 1; text-figure 5, nos. 6, 9), with every gradation between. Its extremity may be two-, three-, four- or five-pronged. The normal seems to be the four-pronged lobe (text-figure 5, nos. 1, 2, 3, 10), from the outer side of which a fifth prong or tine may arise, as in *Clydoniceras* (plate 15, fig. 4; text-figure 5, nos. 6, 7) and may become bigger than the others (plate 15, figure 1). More rarely a lobe with three subequal main tines buds off a fourth and fifth on both sides (plate 15, figure 12). Three-pronged lobes are rarer (plate 15, figure 14; text-figure 5, no. 4) and only one two-pronged specimen is known (plate 15, figure 3; text-figure 5, no. 8). The general shape of the lobe also varies from thick-based (plate 15, figure 3) to necked and bud-shaped (plate 15, figure 2).

The second lateral lobe is usually single-pointed, but sometimes is forked (plate 15, figures 2, 12). Sometimes the forking is incipient (text-figure 5, no. 3). Occasionally one, more rarely two, auxiliaries are developed (text-figure 5, nos. 4, 5, 7, 9).

Spacing of the suture-lines varies much, and independently of normal approximation in the adult (text-figure 5, no. 7).

Bouleiceras marraticum n.sp., plate 15, figure 10

Material. Two nuclei, locality 55.

Description. Whorls stout, with a single row of inner lateral tubercles, more closely spaced than in *Bouleiceras arabicum*, from each of which forks a pair of strong, widely splayed, distant V-shaped ribs.

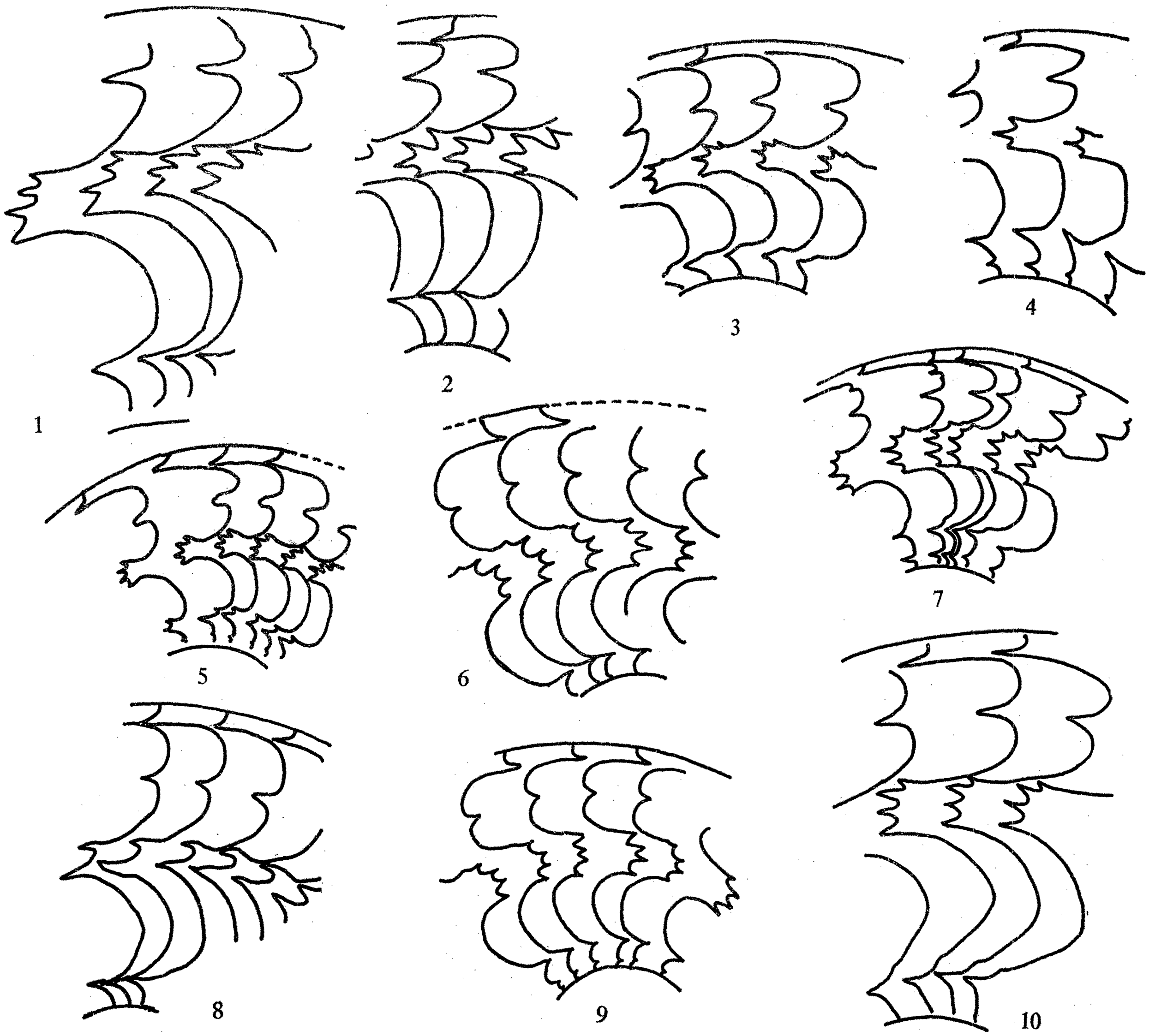

FIGURE 5. Suture-lines of *Bouleiceras* from Jebel Tuwaiq. (Drawn on enlarged photos subsequently bleached and reduced to natural size.) For explanation see p. 262. Nos. 1 to 4, SM. F 10807–10; 5, plate 15, figure 2, F 10661; 6, plate 15, figure 4, F 10663; 7, plate 18, figure 1, F 10691; 8, plate 15, figure 3, F 10662; 9, F 10811; 10, F 10812.

Remarks. Differs from *B. arabicum* in the fact that all, instead of only some, of the ribs spring from a tubercle; in the coarser, more distant ribs; in the more numerous tubercles; and in the stouter whorl. Thevenin's pl. ii, fig. 13, may belong to this species, if the (hidden) inner whorls are not bituberculate.

Bouleiceras elegans n.sp., plate 15, figures 9, 11

Bouleiceras nitescens Thevenin pars, 1908, pl. ii, fig. 8 (holotype).

Material. At least four specimens, localities 55 and 43.

Descriptive remarks. Of three small specimens with fine ribbing lost early, two show indistinctly but unmistakably bituberculate inner whorls and are referable to Thevenin's pl. ii, fig. 8, or an allied dwarf species. A larger specimen (locality 43), 104 mm. in diameter and with nearly half a whorl of body-chamber, seems to agree with the type, but the umbilicus is hidden by hard matrix.

Subfamily Hildoceratinae s.str.

Genus **PROTOGRAMMOCERAS** Spath 1913

Type species *Hildoceras bassanii* Fucini, designated by Spath 1919.

Protogrammoceras madagascariense (Thevenin), plate 16, figures 4 to 8; plate 17, figures 3, 4

Harpoceras (*Grammoceras*) *madagascariense* Thevenin 1908, p. 7, pl. i, fig. 7; pl. iii, figs. 2–5.
Harpoceras (*Grammoceras*) cf. *crassifalcatum* Dumortier, Thevenin 1908, p. 9, pl. i, fig. 8.

Material. Twenty-seven fragments, localities 55 and 43.

Remarks and affinities. This is also a common companion of *Bouleiceras nitescens* in the basal beds of Madagascar. Thevenin stated that in the curvature of its ribs it is intermediate between *Ammonites normanianus* d'Orb. of the Middle Lias and '*Leioceras*' of the Upper Lias, and since he placed *Harpoceras serpentinum* (Reinecke) in *Leioceras*, his statement would now read 'intermediate between *Protogrammoceras* of the Domerian and *Harpoceras* sensu stricto of the Toarcian'; which is an assessment that can still hardly be improved upon.

The closest match in the literature is still *Ammonites crassifalcatus* Dumortier (1874, p. 257, pl. lii, figs. 1, 2) from the Upper Toarcian of Verpillière in the Rhone basin. Thevenin identified his largest Madagascar fragment with Dumortier's species, but intermediate material from Arabia shows that the Madagascar fragment is merely the outer half-whorl of a full-grown *madagascariense*. Specific identity with the European form cannot be claimed in ignorance of the inner whorls of *crassifalcatus* (Dumortier says nothing of a bisulcate tricarinate venter) and in view of the considerably less simplified septal suture shown on Dumortier's figure. Thevenin himself, in fact, rightly pointed out that his specimen is more evolute than Dumortier's and might prove to be only a variety of *P. madagascariense*. It also reaches the unicarinate stage earlier than *A. crassifalcatus*.

The only other possible close comparisons for *Harpoceras madagascariense* are with the genus *Protogrammoceras* Spath (1913, p. 547). Even a similarly simple suture-line with rounded lobes is illustrated for *P. pantanellii* Fucini (1900, p. 27, fig. 27) and *P. semilaevis* Fucini (1900, p. 31, fig. 31). From this one might be inclined to infer a Domerian age for *madagascariense*, especially if like Thevenin one assumes the simplicity of the sutures to be primitive.

On the other hand, all the characters are just as closely matched among later Toarcian forms. The curve and general style of the ribbing are identical with those of the common *Harpoceras serpentinum* auct. (non Thevenin) of the Upper Lias; in side view the two are striking homoeomorphs. (By *H. serpentinum* is here meant the form figured by Wright 1878–86, pl. lviii; cf. also a more involute and finely ribbed but closely allied species figured by Buckman 1927, vol. vii, pl. dccxlii, as *H. concinnum.*) Further, the combination of tricarinate-bisulcate venter with simplified sutures is closely matched in Upper Lias Hildoceratinae. The pre-Spinatum Zone date of some of the allegedly Domerian Harpoceratids is open to question, as remarked below (p. 294); in particular, *Protogrammoceras celebratum* (Fucini) and several others have been found in Umbria in the Toarcian (Principi 1915, p. 451, pl. xvii, fig. 5).

3·2. *Ammonites of the Upper Marrat Formation*

In the same escarpment as the *Bouleiceras* bed on the Jafair Trail, but separated by the unfossiliferous Middle Marrat red shales, here 43·4 m. thick, two fossiliferous horizons occur near the base of the Upper Marrat. The first, 4 to 7 m. above the base, is characterized by a plain, smooth Hildoceratid (*Hildaites*) of obviously Toarcian age. The second horizon, 8 to 9·3 m. above the base, is rich in a remarkable new genus, *Nejdia*. Occasional *Nejdia* also occur 2 m. higher. The best specimen of *Hildaites* unfortunately was picked up loose from some part of the lowest 14·3 m. of the Upper Marrat at the same locality, but there can be no doubt about the horizon from which it came.

Family Hildoceratidae Hyatt, 1867

Subfamily Hildoceratinae s.str.

Genus **HILDAITES** Buckman, 1921

Type species by original designation *Hildaites subserpentinum* Buckman (1921, vol. iii, pl. ccxvii), Toarcian, England. (Subjective synonym *Hildoceratoides* Buckman, 1921.)

Hildaites sanderi n.sp., plate 16, figures 1, 2?, 3, 9, 10; plate 18, figure 2?

Material. One nearly complete septate specimen, locality 59; seventeen fragments, locality 56; two fragments, locality 44. [Better material received November 1951 indicates that some of these fragments represent a different species and perhaps a new genus (plate 16, figure 2, and plate 18, figure 2). *Note added in proof.*]

Description. The best specimen is 114 mm. in diameter and wholly septate. It is evolute, compressed, smooth except for feeble and irregular undulations, with unicarinate tabulate venter. Fragments at considerably larger diameters show that as usual the venter becomes less tabulate, with more sloping shoulders, before the body-chamber is reached. Fragments of small individuals show no ribbing at any stage.

Comparisons. At first I was inclined to identify this species with *Hildaites jolyi* Thevenin (1908, p. 10, pl. iii, fig. 1) from Madagascar, from beds presumed to be higher than the *Bouleiceras* beds. But fragments of small specimens found later are more involute and show no sign of the first simple and then bundled ribs of the inner whorls of *Hildaites jolyi*. *H. sanderi* seems to be smooth from a very early age, if not at all stages.

The sutures agree perfectly with those of *Hildaites* of the English Toarcian.

Named after Mr N. J. Sander of Aramco, who collected much material.

? Family HAMMATOCERATIDAE S. Buckman, 1887

? Subfamily PHYMATOCERATINAE Hyatt, 1900
(as 'Phymatoidae', family)

(synonym Hauginae S. Buckman, 1905)

Genus **NEJDIA** n.gen.

Type species *Nejdia bramkampi* n.

Diagnosis. Smooth, oxycone, involute, keeled ammonites with sagittate or lanceolate whorl-section, steep or undercut umbilical wall, rounded umbilical edge, and subceratitic sutures. The lobes are small, distant, short, bud-shaped, reaching but little beyond the radial line; the saddles are smooth, wide, shallow, with only minute distant serrations; but the suture-lines are subject to extraordinary variation.

Affinities. The placing of this unique genus is one of the many puzzles of the Arabian Jurassic. At first sight one thinks of Upper Cretaceous pseudoceratites such as *Tissotia* and *Lenticeras*. Next comes to mind *Staufenia* of the basal Murchisonae Zone in Germany; but the sutures have far more numerous elements than those of *Nejdia*. *Staufenia* (refigured Arkell 1951, p. 31) is, as Pompeckj pointed out in 1906, a degenerated Leioceratid. Another oxycone with degenerated sutures is *Hudlestonia* Buckman (1890, p. 225), which is, as Ernst (1923–5, p. 126) pointed out, 'merely an oxycone end-form' of one of the Grammoceratinae. According to Denckmann (1897, p. 22), *H. affinis* (Seebach), the type species, marks a horizon at the base of the Opalinum Zone, immediately above the Dispansum and Aalensis Subzones of the Jurense Zone. *Nejdia* differs from *Hudlestonia* in its much steeper or undercut umbilical wall, and in the position of greatest whorl-thickness nearer the umbilical margin. Moreover, the sutures of *Hudlestonia*, though degenerated in the *Clydoniceras* manner, have not the distant bud-like lobes of *Nejdia*.

The total absence of ribbing on *Nejdia* leaves very little guidance in seeking affinities, for the obvious extreme degeneration of the sutures means that they likewise afford little help; while the oxycone form also is *ex hypothesi* a trend that can recur in almost any group at any time. It is therefore admittedly a matter largely of personal predilection, influenced by the associated *Hildaites* with its time significance, that prompts me to regard *Nejdia* as a degenerated offshoot of the Phymatoceratinae, beside the genera *Esericeras* and *Whitbyiceras*. In form and loss of ribbing, some species of *Witchellia* provide an analogue in the Sonninidae (e.g. Buckman 1926, vol. vi, pl. dcxlii).

Whitbyiceras Buckman (1913, vol. ii, pl. lxxx) already shows beginning of involution and fading of ribs on the inner half of the whorl-sides. *Esericeras* Buckman (1920, vol. iii, pl. clxxxii) shows both tendencies carried further, but the sutures, though essentially the same as those of *Nejdia* in plan, are by no means degenerated. (For other *Esericeras* see Buckman 1890, pl. xxv, and *Esericeras gruneri* Dumortier sp., 1874, pl. xxxi, figs. 1, 2). An oxycone *Phymatoceras* with ribs becoming obsolescent is also known—*P. pauper* Buckman (1898, Suppl. pl. iii, figs. 7–9).

Some varieties of the suture of *Nejdia* echo some characteristics of *Bouleiceras*; and considering the marked resemblance of *Bouleiceras arabicum* to *Chartronia*, a close relationship between *Bouleiceras* and *Nejdia* is possible.

Nejdia bramkampi n.sp., plate 17, figures 5–7; plate 18, figures 3–6; text-figure 6

Material. Twenty-three specimens, all more or less fragmentary, locality 57; one fragment, locality 58, i.e. 2 m. higher than the main *Nejdia* bed, in the same cliff.

Description. See generic diagnosis. The smallest specimens found, 32 and 42 mm. in diameter, show that from the nucleus the shell is compressed, involute and completely smooth. The largest fragment has a whorl-height of 86 mm. while still septate and strongly keeled.

Variation of the suture-line. The commonest form of suture, regarded as typical, is as in the holotype (plate 17, figure 5). The lateral lobes are small, distant, bud-shaped, the auxiliaries small and irregular, two more prominent than the rest; the saddles are flatly

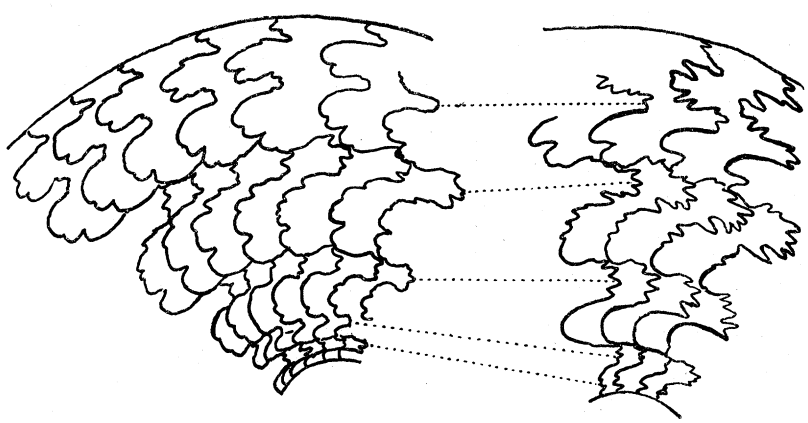

FIGURE 6. Suture-lines of typical *Nejdia bramkampi* (left) and *Nejdia furnishi* (right), showing development of adventitious lobe in *N. furnishi* in the first lateral saddle, and recession of last auxiliary lobe. (Reduction × 2/3).

curved, their ends conforming approximately to the radial line. The first lateral (sometimes called external) saddle is always divided by one accessory, which is sometimes almost as large as the second lateral. The second lateral saddle may be entire and semicircular (plate 17, figure 6) or straight-ended and minutely frilled (plate 17, figure 7), or very oblique, either with or without accessories (plate 18, figure 3*b*); the last variation recalls that normal in *Bouleiceras*.

The most remarkable variations are shown by the auxiliary lobes. Three of them may be enlarged to the same size as the second lateral, so that they form a continuous subequal series of four ceratitic lobes and saddles (plate 18, figure 3). On the specimen illustrated this occurs on only one side of the specimen, the auxiliaries on the other side, at the same diameter, being normal. Sometimes the auxiliary lobes are broader and blunter than the intervening saddles, so that lobes and saddles appear to be reversed (plate 17, figure 7). These sutural variations make an interesting comparison with the Bathonian *Clydoniceras* (Arkell 1951).

Comparisons. Differs from *Nejdia pseudogruneri* (Thevenin) in being more involute, with more lanceolate whorl-section.

Named after Dr R. A. Bramkamp, Chief Geologist of Aramco, who discovered the genus and found most of the material.

Nejdia furnishi n.sp., plate 17, figures 1, 2; text-figure 6

Material. Three large fragments, locality 57.

Description. In this the suture-line differs so radically from that of *Nejdia bramkampi* that specific importance must be attached to it. The chief difference is the extreme enlargement of the first accessory lobe, dividing the first lateral (sometimes called external) saddle, to form a five-branched, asymmetric, adventitious lobe, which may be even larger than the first lateral lobe. The second difference is the enlargement of one auxiliary lobe and recession of the others. The total effect of these two changes is to produce a suture-line comprising an evenly graded series of four lateral lobes.

Comparisons. Despite the striking differences pointed out, a link with *N. bramkampi* is seen in some specimens of that species which show a first accessory lobe almost as large as the second lateral and developing incipient branching (text-figure 6).

Named after Mr W. M. Furnish of Aramco, who collected much material on the occasion of my visit.

3·3. *Ammonites of the Lower Dhruma Formation*

The lowest subdivision of the Lower Dhruma Formation (31 m.) has so far yielded only one genus of ammonites, *Dorsetensia* Buckman. The next subdivision (58 m.) has yielded a single fragment of ?*Dorsetensia* in the lower part. The highest subdivision (38 m.), on the contrary, is extremely rich in ammonites. In the south and central parts of the Tuwaiq it is developed as a dense, hard, white limestone, the Dhibi Limestone, which caps a prominent escarpment for hundreds of miles. In the north, however, the limestone passes laterally into shales, clays and sandstones, with bands of ammonites and many other fossils.

The most conspicuous ammonites in this subdivision are many forms of the peculiar genus *Ermoceras* H. Douvillé, with which also occurs the equally peculiar *Thamboceras* H. Douvillé. These two genera were first described in 1916 from Gebel Maghara (or Moghara) in northern Sinai, and hitherto they have been found nowhere else in the world. With them, but much more rarely, occur several Stephanoceratidae which provide links with the highest Middle and lowest Upper Bajocian of Europe and elsewhere.

In the main area near Dhruma the ammonites occur as casts in cream-coloured compact Dhibi Limestone (localities 36 to 39). Several species of *Ermoceras* are here by far the dominant ammonites, and there is a single species each of *Stephanoceras*, *Teloceras* and *Thamboceras*, all from different localities. No sequence could be made out, but at the richest locality (38) all came from between 25 and $27\frac{1}{2}$ m. from the top. At locality 39 the *Teloceras* was between 13 and 27 m. from the top, and at locality 37 the *Stephanoceras* was between 13 and 33 m. from the top.

Farther south, in Wadi Birk (localities 61, 62), a harder, mottled brownish and red compact limestone yielded *Stephanoceras*, *Teloceras* and one species of *Ermoceras* 2·4 to 5·1 m. below the top, and a poorly preserved *Normannites*? 14·6 to 15·6 m. below the top.

In the Juraifa area in the north, where the Dhibi Limestone has passed into shales, clays and sandstones, the preservation is very different, and it is hard to be sure of exact equivalence, either stratigraphically or palaeontologically. At locality 4 the ammonites, as small yellow-brown limonitic casts, weather out of a clay with numerous horn corals, *Eligmus*, and well-preserved brachiopods of many kinds. There are inner whorls, in perfect preservation, of various *Ermoceras* and *Stephanoceras*. Comparison with the large specimens from near Dhruma is difficult.

At locality 2 a low cliff of shales is followed by a thin purplish red band of oolite, a few inches thick, in which are crowds of small to medium-sized *Ermoceras* in great variety but not closely comparable with those of the other localities. Here too are splendidly preserved *Eligmus*, *Coelastarte* and other shells. *Thamboceras* was obtained from this bed, and again about 2 m. higher up (also with *Ermoceras*). The purple oolite at locality 2 is thought to be probably a few metres lower in the sequence than the clays of locality 4; but it will be difficult to establish this, since large alluvial flats intervene between the low benches in which the fossils occur.

Superfamily HARPOCERATACEAE Wedekind, 1917

Family SONNINIDAE Buckman, 1892

Genus **DORSETENSIA** Buckman, 1892

Type species by original designation *Ammonites edouardianus* d'Orbigny, Middle Bajocian, France.

Dorsetensia arabica n.sp., plate 19, figures 3 to 12

?*Dorsetensia* cf. *edouardiana* Spath, 1930*a*, p. 32, pl. i, fig. 5.

Material. Nine nuclei and fragments of nuclei up to a diameter of 22 mm. and whorl-height of 9 mm.; eighteen larger fragments of all sizes up to a whorl-height of 73 mm., all wholly septate; locality 46. Also one fragment, which is doubtfully identical, from locality 47. Also ten fragments of varying size from locality 23 (all casts).

Description and comparisons. The nuclei are all strongly ribbed and closely resemble nuclei from the Humphriesianum Zone of Dorset figured by Buckman (1892, pl. lii, figs. 11, 18, 21–24) as *Dorsetensia edouardiana* (d'Orbigny), but not the true *edouardiana* of d'Orbigny, which, according to Haug (1893, p. 318), is *D. pulchra* Buckman. Buckman's types are in the Sedgwick Museum and bear close comparison. Some of the larger Arabian fragments show portions of their nuclei, which are identical with the detached nuclei, thus proving that as in the European *Dorsetensia*, the whorls become smooth after about 30 to 40 mm. diameter.

The smooth outer whorl fragments show some variation in whorl-shape and strength of carina, and considerable variation in sutural details. None is so compressed as *D. subtecta* Buckman or so involute as *D. tecta* Buckman or *D. liostraca* Buckman (1892, pls. liv, lvi), and from locality 46 there are none of the group with smooth nuclei like *D. liostraca* and *D. complanata* Buckman (1892, pl. liii). When more material is known it is likely that as many species will be recognizable amongst the Arabian material as amongst the European.

There is good agreement so far as it goes with the Mombasa fragment figured by Spath (1930*a*, pl. i, fig. 5). Spath's reference of this to the Upper Bajocian, followed by Weir, was presumably only a slip, for he assigned it to the Humphriesianum or Sauzei Zone, which are, of course, Middle Bajocian.

Dorsetensia cf. **liostraca** Buckman

cf. *Dorsetensia liostraca* Buckman, 1892, p. 310, pl. liii, figs. 11–16.

Material. One fragment, locality 23.

Remarks. A single fragment agrees closely with the original (Sedgwick Museum, no. J. 6259) of Buckman's pl. liii, figs. 15, 16. It is the same size, almost smooth, compressed, with tall sharp keel.

Superfamily Stephanocerataceae Perrin Smith, 1913

Family Stephanoceratidae Neumayr, 1875

Genus **STEPHANOCERAS** Waagen, 1869

Lectotype species *Ammonites humphriesianus* J. de C. Sowerby, designated by Buckman 1898. Objective synonym *Stepheoceras* Buckman. Subjective synonyms *Kreterostephanus* and *Mollistephanus* Buckman, *Grahamites* Kilian & Reboul, *Brodiaeia* Roché.

Stephanoceras cf. **psilacanthus** Wermbter, plate 19, figure 1

Ammonites humphriesianus d'Orbigny, 1846, p. 398, pl. 134 only, figs. 1, 2 (holotype) (non Sowerby).
Stephanoceras psilacanthus Wermbter, 1891, p. 270.
S. cosmopoliticum Möricke, 1894, p. 20.
Coeloceras humphriesi H. Douvillé, 1916, p. 25, pl. i, figs. 6–8, 10.
Cadomites cosmopoliticus Fallot & Blanchet, 1923, p. 151, pl. xi, fig. 10.
Kreterostephanus kreter Buckman, 1927, vol. vii, pl. dcclv.

Material. One specimen, locality 62.

Remarks. The single specimen 66 mm. in diameter is badly preserved and has a distinct ventral groove like all the other Stephanoceratid material from Arabia, but it compares well with specimens from Dorset in the Sedgwick Museum which are typically representative of the world-wide *Stephanoceras* '*cosmopoliticum*' of Möricke (an apt name, unfortunately a junior objective synonym of *S. psilacanthus* Wermbter, both names being based on d'Orbigny's pl. 134). The fragment figured by H. Douvillé (fig. 6) from Sinai has rather longer and less distant primary ribs, but he too considered it identical with type material from the Oolithe ferrugineuse of Normandy.

S. psilacanthus has been figured from the Bajocian of England, France, Spain and Chile, and recorded from Mexico and Morocco. Gillet's figure (1937, p. 82, pl. v, fig. 8) of a specimen, said to be from the Sauzei Zone of Alsace-Lorraine, is not quite the same in several details.

According to Buckman (1930, vol. vii, p. 34) the horizon of the species in Dorset is the Blagdeni Subzone of the Humphriesianum Zone; Brigadier G. Bomford has collected it *in situ* in the 'Red Conglomerate' of Burton Bradstock, Dorset. Typical specimens in the Sedgwick Museum (nos. J 20162–3) come from Miller's Quarry, Sherborne, Dorset.

Stephanoceras arabicum n.sp., plate 20, figures 4–7

Coeloceras humphriesi H. Douvillé, 1916, pl. i, fig. 9 only.
cf. *Cadomites gignouxi* Roché, 1939, p. 196, pl. iii, fig. 1.

Material. The largest specimen is 35 mm. in diameter and wholly septate. The coiling is involute, the whorl-section subcircular but slightly thicker than high, the whorl enlarging rapidly. Ribbing is as in the *humphriesianum* group but differing by lack of tubercles; primaries prorsiradiate, secondaries rapidly becoming rectiradiate, interrupted by a shallow, narrow groove on the venter.

Comparisons. The style of ribbing is that of some Sherborne specimens of the *humphriesianum* group (e.g. *Stephanoceras mollis* Buckman, *S. paululus* Buckman) in which there is no tuberculation, but *S. arabicum* is much more involute and has a groove on the venter. It is also distinguished by the same characters from the more involute *S. gignouxi* Roché (1939, p. 196, pl. iii, fig. 1), which is also non-tuberculate and comes nearest. I have no doubt that it was a specimen of *S. arabicum* that was figured in H. Douvillé's pl. i, fig. 9, from Sinai.

Buckman's figure (1927, vol. vii, pl. dccliv) of the holotype of *S. paululus* shows a groove on at least part of the venter.

The style of ribbing is closely comparable with the Caucasian form figured as *S. rectelobatum* Hauer by Neumayr & Uhlig (1892, pl. v, fig. 5, pl. vi, fig. 2), but in that there is no ventral groove and the ribs on the nucleus are stronger and more distant; that it is not the same as *S. rectelobatum* Hauer is shown by the fact that the ribs (pl. vi, fig. 2) are still enlarging and becoming more distant although septation has not ceased.

Genus **TELOCERAS** Mascke, 1907

Type species by original designation *A. blagdeni* J. Sowerby, Inferior Oolite, Dorset (synonym *Blagdenia* Roché, 1939).

Teloceras cf. **labrum** Buckman, plate 21, figures 2, 11

cf. *Teloceras labrum* Buckman, 1922, vol. iv, pl. cccl, A, B.
?*Cadomites coronatus* Schlotheim sp., 1820 (non Bruguière, 1799), Roché, 1939, p. 208, pl. vi, fig. 8 (type refigured).

Material. One fragment, locality 39; another, locality 62; nucleus, locality 4?

Remarks. The fragments are too badly preserved for definite identification, but by their extremely depressed whorl and almost flat venter they seem typical *Teloceras*. It is possible, however, that with more material it may be found that this form is really more closely allied to *Ermoceras* than to *Teloceras*.

Roché retains '*Cadomites coronatus* Schlotheim' and '*C. labrus* Buckman' as two distinct species, but does not point out wherein they differ, and from his figure of Schlotheim's type it appears likely that *Teloceras labrum* Buckman is the valid name for this species which has given rise to a century of confusion owing to Schlotheim's name being a junior homonym of *Ammonites coronatus* Bruguière, 1799 (now *Erymnoceras*), and therefore not available.

The fragment from locality 62 has no groove on the venter; the other fragment is too worn to show whether or not it had a groove. Buckman's figure of the type shows a faintly defined ventral smooth band. According to Buckman the horizon in Dorset is Humphriesianum Zone, below Blagdeni, but above Humphriesianum Subzone s.str.

Genus **ERMOCERAS** H. Douvillé, 1916

Type species by original designation *Ermoceras mogharense* H. Douvillé, Bajocian, Sinai.

H. Douvillé placed this genus, on account of its marked ventral groove, in the Liassic family Schlotheimidae (an impossibility according to modern ideas of ammonite phylogeny), but he also remarked that 'it could be considered as a branch replacing *Garantiana*'; i.e. family Parkinsonidae, which also have a ventral groove. A similar mistake was made by his son R. Douvillé (1915, p. 19, pl. iii, fig. 3) when he placed in *Garantiana* a typical *Stephanoceras* s.str. close to *S. psilacanthus* Wermbter, solely on account of a ventral groove.* In this specimen the groove is so deep and looks so machine-made that it may be pathological. Another *Stephanoceras* s.str., on the strength of a much shallower ventral groove, has been figured from the Caucasus as *Reineckeia humilis* Zatvornitzki (1914, pl. xvii, figs. 13–17). This early-Upper Bajocian form is close to *Stephanoceras rectelobatum* (non Hauer) Neumayr & Uhlig, and to our *S. arabicum*, and can have as little to do with *Reineckeia* as R. Douvillé's form with *Garantiana*.

It appears that a ventral groove arose from time to time as a mutation in various Stephanocerataceae and Perisphinctaceae. In *Ermoceras* it became 'fixed' and a generic character, just as in *Garantiana*, *Reineckeia*, *Ebrayiceras*, etc. An intensification of the condition, perhaps pathological (as in R. Douvillé 1915, pl. iii, fig. 3), seems to occur frequently in the fine-ribbed *Ermoceras elegans* H. Douvillé, as shown in H. Douvillé 1916, pl. ii, fig. 4*b*, and in some Arabian specimens of the same species.

Another peculiarity of at least some species of *Ermoceras*, especially *E. mogharense*, the type species, is the presence of marked radial striations or growth-lines on the test, parallel to the ribbing. In the young of some species (but not others) this feature is very marked; see, for instance, the Gebel Maghara specimen in Cairo figured (twice natural size) in plate 30, figure 5. But in much of the Arabian material having the test perfectly preserved no growth-lines appear; while fine radial striation can sometimes be discerned on well-preserved specimens even of *Otoites* from the English Sauzei Zone.

The systematic position of *Ermoceras* is a problem for which no one hitherto has attempted a solution. Some species cannot be distinguished by any visible character from Callovian *Reineckeia*. Others seem to be transitional from *Teloceras*. Others are, at least in the young, hardly distinguishable from *Otoites*; but there is no sign of the peculiar coiling of *Otoites*, with contracted outer half-whorl and elaborate lappets. Others (of the group of *Ermoceras elegans*) are so finely ribbed that they suggest derivation from *Emileia*, but the degeneration of first-order into second-order ribbing and compression of the whorl make them unlike any Stephanoceratids, and, but for the sutures and ventral groove, they look at first sight more like a *Phylloceras*. Some of the most finely ribbed forms, at least in the young, have faint spiral strigation.

It is clear that *Ermoceras* represents a stock which in Arabia and Sinai, somewhere in the border-time between Middle and Upper Bajocian, experienced a burst of explosive evolution. Such a group of forms is always difficult to classify. The diversity of shape and ornament in material collected from a single bed is a systematist's despair. The obviously

* G. Steinmann, who originally figured and named the specimen in 1880, thought it a *Strenoceras* (then called *Cosmoceras subfurcatum*).

close affinity and contemporaneity of all the forms makes it essential to leave them all in one genus. At the same time, the conventions of modern classification require them to be divided into three subgenera. *Ermoceras* s.str. is intermediate between the extremes but has some peculiar features of its own.

TELERMOCERAS n.subg.

Type species *Coeloceras coronatoides* H. Douvillé.

Diagnosis. *Ermoceras* with depressed whorls, coarse secondary ribs, and deep, smooth, crater-like umbilicus surrounded by large nodes or spines; inner whorls resembling *Otoites*, middle and outer whorls resembling *Teloceras*, but sometimes simulating *Reineckeia*.

KOSMERMOCERAS n.subg.

Type species *Ermoceras runcinatum* n.

Diagnosis. *Ermoceras* with high, compressed whorls, fine sharp primary and secondary ribs, and more or less tabulate venter, with or without a row of tubercles or spines on the whorl-side; resembling various genera of the Kosmoceratidae, especially *Toricellites*, sometimes Reineckeidae.

Ermoceras (Telermoceras) coronatoides (H. Douvillé), plate 21, figures 1, 3 to 7, 12; text-figure 7

Coeloceras coronatoides H. Douvillé, 1916, p. 24, pl. 1, figs. 3–5.

Material. Six limonitic casts and a nucleus, locality 4; one specimen and two larger fragments in White Dhibi Limestone, locality 38.

Remarks. The Arabian material comprises specimens or fragments agreeing with all three of Douvillé's figures of Sinai specimens and fragments, and confirms his attribution of all three to one species. Douvillé remarked that the ventral groove might not be 'real' but due only to thickening of the (missing) test over the siphuncle, such as occurs in many perisphinctids. Such grooves do occasionally occur on casts of *Stephanoceras* (e.g. *S. paululus* Buckman, 1927, vol. vii, pl. dccliv) and also *Otoites* (SM. no. J 20141). The general resemblance of the holotype to *Ammonites coronatus* Schlotheim led Douvillé to assign it to '*Coeloceras*', by which he meant *Teloceras*. At first I was inclined to follow, but comparison with *Teloceras* from the Dorset Inferior Oolite leads to the conclusion that *coronatoides* is more closely related to *Ermoceras*, to other species of which there are perfect transitions at all stages of ontogeny. Three points which weigh most are: (1) the discovery, since Douvillé published, of the new Sinai and Arabian species described below as *E. splendens* (p. 274), which is intermediate between *coronatoides* and *E. deserti*, having all the characters of *coronatoides* except whorl-shape, which is typical of *Ermoceras* and could not be accommodated in *Teloceras*; (2) the discovery of material in Arabia showing the sutures, which are indistinguishable from those of other species of *Ermoceras* and much less complex than in any *Teloceras*; (3) the ventral groove, which occurs on all the mateıial and is exactly like the characteristic ventral groove of *Ermoceras*.

Although *E. coronatoides* is therefore better classified in *Ermoceras* with its Arabian associates than in *Teloceras*, the homoeomorphy is truly remarkable and probably derives from close relationship between the two genera.

Among the variable inner whorls are some with nuclei which suggest the possibility of a common origin with *Stephanoceras arabicum*.

Ermoceras (Telermoceras) coronatiforme n.sp., plate 19, figure 2

Material. The holotype, in brown limestone, locality 68.

Description and comparisons. A coarsely ribbed and strongly tuberculate form which in side view resembles *Ermoceras coronatoides*, but which has a much narrower and somewhat more arched venter and coarser and more distant secondary ribs. The suture is as in *E. coronatoides*. In some respects the species is intermediate between *E. coronatoides* and *E. mogharense*, but the ribs are much coarser than in *E. mogharense* and the secondaries shorter and not swung forward. The ventral groove is feeble but persistent.

Despite the resemblance in side view to *Teloceras*, not even the most coarsely ribbed and tuberculated *Teloceras*, such as *T. banksi* (Sow.), are at all comparable in ventral view. Resemblance to some Callovian *Erymnoceras* is much greater; and when a species of that genus develops a ventral groove (e.g. Jeannet 1951, pl. 40, fig. 13), the homoeomorphy with *Ermoceras* is almost perfect.

Ermoceras (Telermoceras) splendens n.sp., plate 23, figures 1, 2, 8; text-figure 7; also plate 30, figure 6

Material. Six well-preserved inner whorls and three fragments of middle whorls, from the purple-red band near Juraifa, locality 2; a doubtful fragment in Dhibi Limestone, locality 39.

Description. Early whorls rounded, depressed, *Otoites*-like, with umbilicus deep but its sides convex, its edge rounded. On the walls of the umbilicus are obsolescent rounded primary ribs, each ending in a large sharp tubercle. Secondary ribs strong, sharp, dense, mainly triplicate, interrupted by a strong ventral groove. Middle (and outer?) whorls similar, the primary ribs never quite fading, the tubercles large and (in the test) spinous.

Remarks. The late-middle whorls are shown by a specimen from Sinai figured on plate 30, figure 6, which is linked up with the holotype by intermediates. Differences from *Ermoceras coronatoides* are a higher, more arched whorl-section at all diameters, more rounded umbilical margin (less coronate shape), sharper and finer ribbing.

Ermoceras (Telermoceras) reineckeoides n.sp., plate 20, figures 8, 9; text-figure 7

Material. Two good specimens in Dhibi Limestone, localities 37, 38.

Description. Two identical specimens, both wholly septate and well preserved almost to the centre. The inner whorls, up to a diameter of about 40 to 50 mm., are very depressed and coronate, with broad rounded coarse-ribbed venter and a median lateral row of large spinous distant tubercles encircling the umbilicus. Later the whorl heightens and becomes eventually (while still septate) higher than wide, with the tubercles only one-third of the way up.

Remarks. In side view there is a remarkable resemblance to *Reineckeia nodosa* Till (1911, p. 4, pl. xix, figs. 4–6) of the Hungarian Callovian. Although that species at a comparable stage has a more inflated and circular whorl-section, when the holotype of the present species reached me ahead of other relevant evidence I identified it without much hesitation as *Reineckeia* aff. *nodosa* Till and of Callovian date.

Ermoceras (Ermoceras) aff. **mogharense** H. Douvillé, plate 20, figures 3, 10

cf. *Ermoceras mogharense* H. Douvillé, 1916, p. 19, pl. ii, figs. 5–9.

Material. One half-whorl in cream Dhibi Limestone, locality 39; another, yellow, limonitic, locality 4.

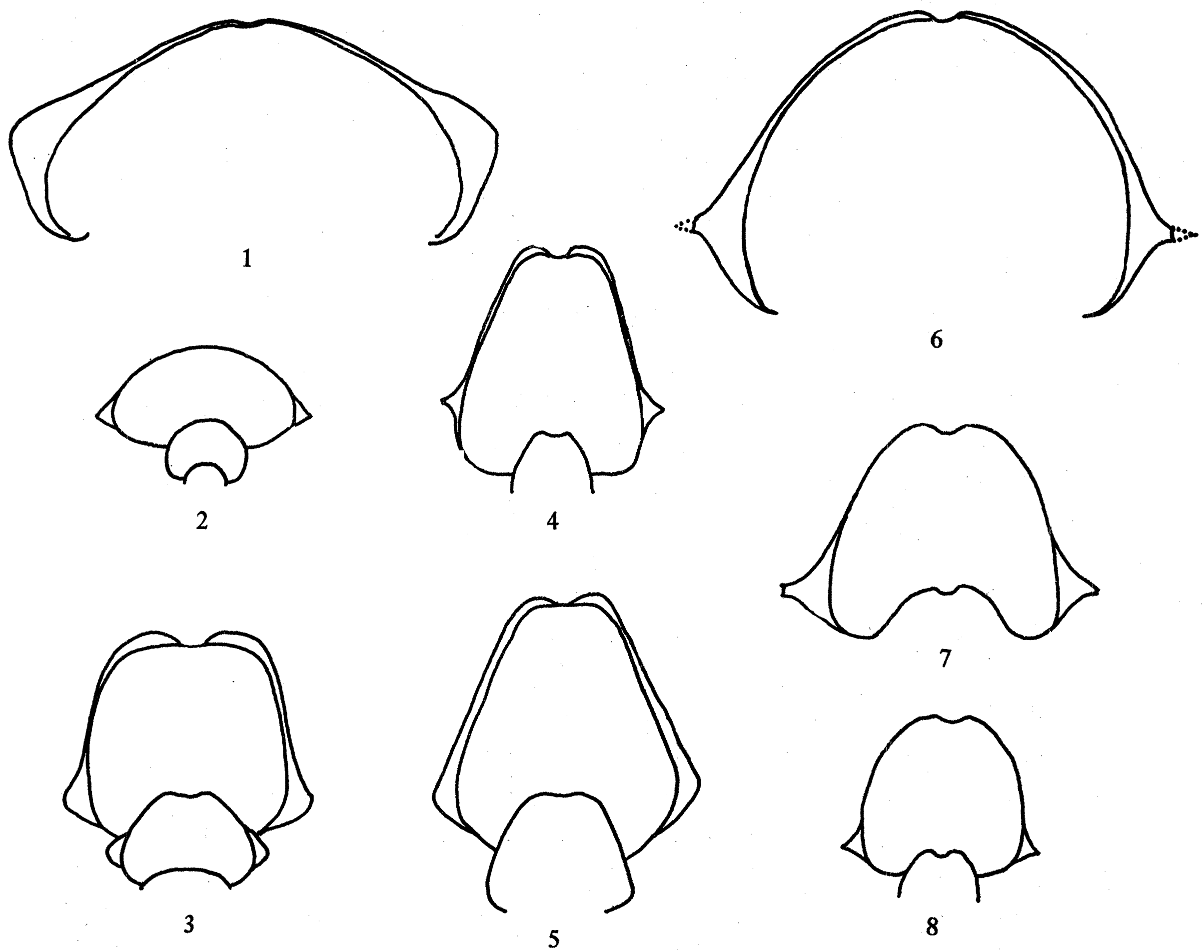

FIGURE 7. Whorl-sections of species of *Ermoceras*, natural size. 1, 2, *E. coronatoides* (from fragments, partly restored), locality 38; 3, *E. reineckeoides*, locality 37; 4, *E. runcinatum*, locality 2; 5, *E.* aff. *runcinatum*, locality 62; 6, *E. splendens*, Gebel Maghara, Sinai; 7, 8, *E. splendens*, locality 2 (no. 8 holotype).

Remarks. The holotype (Douvillé's pl. ii, fig. 9) seems to be distorted. The half-whorl from locality 39 is the same size as the holotype but agrees better with Douvillé's other figures in the side view. The venter has at first almost, and finally quite, lost the groove, as has the holotype. Nevertheless, none of the Arabian fragments is identical with Douvillé's figures or with a topotype sent me on loan from Washington. The true Sinai form has longer secondary ribs which have a tendency to form chevrons on the venter.

Ermoceras (Kosmermoceras) magnificum n.sp., plate 22, figures 1 to 4

Material. A large cast (holotype), a still larger fragment, and two smaller fragments, in creamy white Dhibi Limestone, locality 38; a well-preserved nucleus in yellow limonite, with test, locality 4.

Description. A giant species. The holotype is about 130 mm. in diameter and wholly septate. Inner whorls compressed, like those of *Ermoceras runcinatum,* but the ribbing more irregularly branched, with finer secondaries, which are rectiradiate instead of rursiradiate. On the middle whorls ribbing is somewhat like that of *E. deserti* Douvillé but finer and denser, especially the primaries. Later the primaries fade, and first the inner half, later two-thirds, of the whorl-sides becomes smooth. The whorl-section is high, elliptical, the venter narrow, with at first a well-marked groove, which disappears on later whorls. Coiling is involute for the genus.

Remarks. Inner whorls tempt identification with the Callovian '*Torricelliceras*' *torricellii* (Oppel) (Buckman, 1922, vol. iv, pl. ccxcii), but the outer whorls come to resemble a large *Seymourites.*

Ermoceras (Kosmermoceras) runcinatum n.sp., plate 20, figures 1, 2; plate 21, figures 8, 9, 10; plate 22, figures 8 to 11; text-figure 7

Material. Fifteen fragments of all sizes, purple-red band, locality 2; nine nuclei with test preserved, in limonitic preservation, locality 4; a cast in hard cream Dhibi Limestone, locality 38; another and four fragments in hard mottled red and brown limestone, locality 62.

Description. A high-whorled compressed form with dense sharp ribs. The primaries are sharp and distinct on inner whorls, but in some varieties fade on middle and outer whorls; at all stages they end in a small sharp tubercle just below the middle of the whorl-sides, later falling to a third of the way up the whorl-sides. From the tubercle the ribs bifurcate into sharp, wiry secondaries, which swing gently backwards. Venter narrow and tabulate, with wide, deep, smooth groove. Some outer whorls come to resemble *Ermoceras deserti* H. Douvillé, but the whorl-section is higher, narrower, more tabulate; and usually the primary ribs are less like enlarged bullae, more inclined to be represented only by the terminal tubercles, which are often discrete.

Remarks. As holotype is chosen one of the well-preserved inner whorls from the limonitic bed, locality 4. These link up with abundant but much less perfect fragments from the purple-red band, locality 2. The material from farther south (localities 38 and 62) is more sparse, very poorly preserved and doubtful. The fragment in plate 20, figure 2, may belong to a different species.

Compared with *E. magnificum,* the inner whorls have the ribbing sharper, stronger, more definitely biplicate from distinct bifurcation points, and the outer whorls retain the tubercles.

Ermoceras (Kosmermoceras) aulacostephanus n.sp., plate 22, figure 7

Material. One specimen, purple-red band, Juraifa, locality 2.

Description. Compressed, high-whorled, with narrow, tabulate venter, so much of which is occupied by the ventral groove that it could almost be described as concave. Primary ribs short, obscure, with irregular bullate tubercles; secondary ribs long, becoming sharper outwards. Umbilicus small.

Remarks. The specimen on which this species is based comes nearest of the Arabian material to the Sinai *Ermoceras inerme* Douvillé (1916, pl. ii, fig. 10).

Ermoceras (Kosmermoceras) elegans H. Douvillé, plate 22, figures 5, 6; plate 23, figures 3, 5, 7

Ermoceras elegans H. Douvillé, 1916, p. 18, pl. ii, figs. 3, 4.

Material. Four fragments in Dhibi Limestone, localities 38, 39; ten inner whorls from the purple-red band, locality 2.

Remarks. This species, at first sight so different from the others, is connected by *Ermoceras strigatum* to *E. splendens*. It differs from *E. strigatum* only in being more compressed and non-tuberculate. Both have the same fine and sharp secondary ribbing. Emphasis of the ventral groove varies greatly. In some it looks machine-made as in Douvillé's figure; in others it is much more vague.

Ermoceras (Kosmermoceras) strigatum n.sp., plate 23, figures 4, 6

Material. Five inner whorls from the purple-red band, locality 2.

Description. This nominal species is required for some *Phylloceras*-like inner whorls occurring in the purple-red band near Juraifa, associated with *Ermoceras splendens* and *E. elegans* and intermediate between them. The shape is that of *E. splendens*, much more globular, less compressed than *E. elegans*, and there is a row of tubercles on the umbilical margin as in *E. splendens*. But the ribbing is extremely fine and dense, as in *E. elegans*. Ribs and growth-lines merge on the nucleus, with an effect similar to that on parts of the Cairo specimen figured in plate 30, figure 5. Two specimens show minute longitudinal strigation.

Genus **NORMANNITES** Munier-Chalmas, 1892

Type species by original designation *Ammonites braikenridgii* d'Orbigny (1846, pl. 135, figs. 3, 4) non Sowerby. Subjective synonyms *Epalxites* Mascke, *Kanastephanus* and *Itinsaites* McLearn, 1927. See *Bull. Zool. Nomenclature*, 1951, vol. ii, parts 6–8, p. 222.

Normannites cf. **orbignyi** Buckman

Ammonites braikenridgii d'Orbigny, 1846, pl. 135, figs. 3, 4.
non *Coeloceras braikenridgii* H. Douvillé, 1916, p. 26, pl. i, figs. 11, 12.
Cadomites braikenridgii d'Orb. non Sow., Fallot & Blanchet, 1923, p. 162, pl. x, figs. 1–7; pl. xii, fig. 2.
Normannites orbignyi Buckman, 1927, vol. vii, pl. dccxxxiv.

Material. Two fragments, locality 61.

Remarks. The two fragments are intermediate in strength of ribbing between *Normannites orbignyi* and *N. latansatus* (Buckman, 1920, vol. iii, pl. clix), both from the Blagdeni beds of the Humphriesianum Zone of Dorset. The nearest comparison is with a Majorcan specimen figured by Fallot & Blanchet (1923, pl. xii, fig. 2), but the Arabian form was larger, for it is still septate at the maximum diameter of normal *N. orbignyi*. The nuclei figured from Sinai by H. Douvillé are too small for close comparison, but a complete specimen in Cairo figured here on plate 30, figure 4, proves that they belong to a miniature new species (see appendix, p. 309). Typical *Normannites* also occur in the Humphriesianum Zone in the Caucasus, Western Australia and western Canada.

Family Thamboceratidae n.

Genus **THAMBOCERAS** H. Douvillé, 1916

Type species by monotypy *Thamboceras mirum* H. Douvillé, Bajocian, Sinai.

This genus is still as great a puzzle as when H. Douvillé described it from Gebel Maghara 35 years ago. Attempts to fit it into Oppeliidae, Clydoniceratidae or Graphoceratidae, or any other Oppeliacean or Harpoceratacean family, all seem equally unnatural. Although Douvillé assigned it to the Amaltheidae and rightly pointed to the resemblance of its suture-line to that of *Oxynoticeras*, he remarked with considerable perspicacity that the characters of the suture could result merely from the oxycone shape, and that the real affinities may lie with *Ermoceras*, the concave venter of *Thamboceras* and the carinae on either side corresponding to the ventral groove flanked by raised rib-endings in *Ermoceras*. In fact, the smooth, compressed *E. inerme* Douvillé (1916, pl. ii, fig. 10) is so similar to *Thamboceras* that Douvillé's suggestion is the best working hypothesis yet put forward. Oxycones of Stephanoceratacean origin are familiar enough in the Upper Jurassic, where at times they were even dominant (e.g. *Cardioceras*, *Amoeboceras*, *Quenstedtoceras*), and they are known in the Lower Callovian (*Chamoussetia*), but except for this neglected suggestion of H. Douvillé's there appears to be no mention of them in the Middle Jurassic. Another analogue for *Thamboceras* on this hypothesis would be the smooth, discoidal *Kosmoceras* of the Jason Zone (subgenus *Gulielmites*), in which also there is a tabulate venter verging on concave owing to the raised rib-endings on either side, such as Douvillé pointed out in young *Ermoceras*.

Thamboceras mirabile n.sp., plate 19, figures 13, 14; plate 30, figure 9

Thamboceras mirum H. Douvillé, 1916, pars, p. 22, pl. ii, figs. 12*a*, *b* only.

Material. About half a whorl, in white Dhibi Limestone, locality 36; a fragment in the purple-red bed near Juraifa, locality 2; another about 2 m. higher, locality 4.

Description and remarks. Douvillé's fig. 11 is holotype of *Thamboceras mirum*, and he called his fig. 12 an involute variety. Judging by collections in Cairo the latter is the commoner at Gebel Maghara, and it alone has so far been found in Arabia. It is a distinct species by modern standards of discrimination and is here named *T. mirabile*, holotype to be the Maghara specimen figured on plate 30, figure 9 (Moon & Sadek Coll., Geol. Survey of Egypt, no. 16687). It is wholly septate, 37 mm. in diameter, with small umbilicus and the ribbing almost obsolete except near the periphery. There are several specimens in Cairo, one now in the collection of the Desert Institute at Heliopolis. I am indebted to Mr M. Attia, Director of the Geological Survey of Egypt, for allowing me to paint the suture-line. The suture is noticeably straight and simple, with small, distant lateral lobes and a straight series of six minute auxiliaries. Nuclei down to 10 mm. show the concave venter clearly and have smooth sides except for growth-lines. The specific differences from *T. mirum* are: smaller umbilicus, feebler primary ribs, secondaries less projected at periphery.

Distribution. At Gebel Maghara, according to Douvillé, *T. mirum* and *T. mirabile* occur in the same beds and at the same locality as *Ermoceras* spp. This is confirmed in Arabia.

3·4. *Ammonites of the Middle Dhruma Formation*

In the north, in the Juraifa area, no ammonites have been found for 45 m. above the highest bed with *Ermoceras* and *Thamboceras*. Then come the lowest ammonite-bearing strata of the Middle Dhruma, consisting of 7·5 m. of beds with double-keeled oxycones (*Thambites* n.gen.) obviously descended from *Thamboceras*, and accompanied (in the lowest metre) by a still more remarkable oxycone genus with highly specialized pseudoceratitic sutures (*Bramkampia* n.gen.). No other ammonites have been found above these for another 20 m., when white limestones of typical Great Oolite facies come in, yielding the European Middle Bathonian genus *Tulites*. Then, after another 3 m. without ammonites, follow shales and limestones (16 m.) with another European Bathonian genus, *Micromphalites*, in abundance at three levels.

Farther south, in the Dhruma and Khashm Dhibi areas and at Hauta Pass, various oxycones have been collected at levels 4, 8, 14·5 to 16·5 and 21 to 40 m. above the top of the Dhibi Limestone (which contains the *Ermoceras* fauna). The preservation varies widely. It is sometimes excellent, but more often so poor that it is impossible to tell whether the peripheries of the oxycones are double or single, and internal distortion has resulted in little being gained by sectioning or grinding. Several specimens, however, including some from the lowest levels (4, 8 and 37·5 m. above the Dhibi Limestones) have a single-keeled acute periphery and seem to be inseparable from *Clydoniceras*. The material so far available suggests that some forms of *Thambites* lost their ventral concavity at an early stage of development and became normal oxycones which, although existing contemporaneously with the double-keeled *Thambites*, cannot be separated generically from *Clydoniceras*.

Both at Khashm Dhibi (locality 52) and in Wadi Birk (locality 63), *Micromphalites* have been found at suitable distances above these oxycones, but the farthest south that *Tulites* have so far been found between them is the Barra area (see text-figure 2).

From the *Thambites* beds near Juraifa (locality 7) there are four small fragments of indeterminable perisphinctids, similar, so far as they go, to the Upper Bajocian *Leptosphinctes subdivisus* Buckman sp. (1920, vol. iii, pl. cxc), but inadequate for dating.

(*a*) ? Lower Bathonian

Family Thamboceratidae Arkell

Genus **THAMBITES** n.

Type species *Thambites planus* n.sp.

Diagnosis. Discoidal oxycones with minute or occluded umbilicus and extremely narrow, bicarinate, concave venter, resembling in form the Triassic *Sageceras*; ribbing obsolete; sutures degenerated, *Oxynoticeras*-like, with large prominent external lobe, its side branch or branches sometimes developed as an incipient adventitious lobe, the rest of the suture more or less reduced, as in *Thamboceras*.

Differences from *Thamboceras* are: larger, more prominent external lobe; absence of ribbing; still more minute umbilicus; and narrower venter, on which the two sharp keels are separated by a mere slit.

Thambites planus n.sp., plate 23, figure 11; plate 24, figures 1–6; text-figure 8

Material. Holotype and at least fifteen other fragments of all sizes, some with test intact, in red and brown mottled compact limestone, localities 6 and 7; two quarter whorls showing sutures clearly, in brown limestone, localities 5 and 40; two specimens showing sutures,

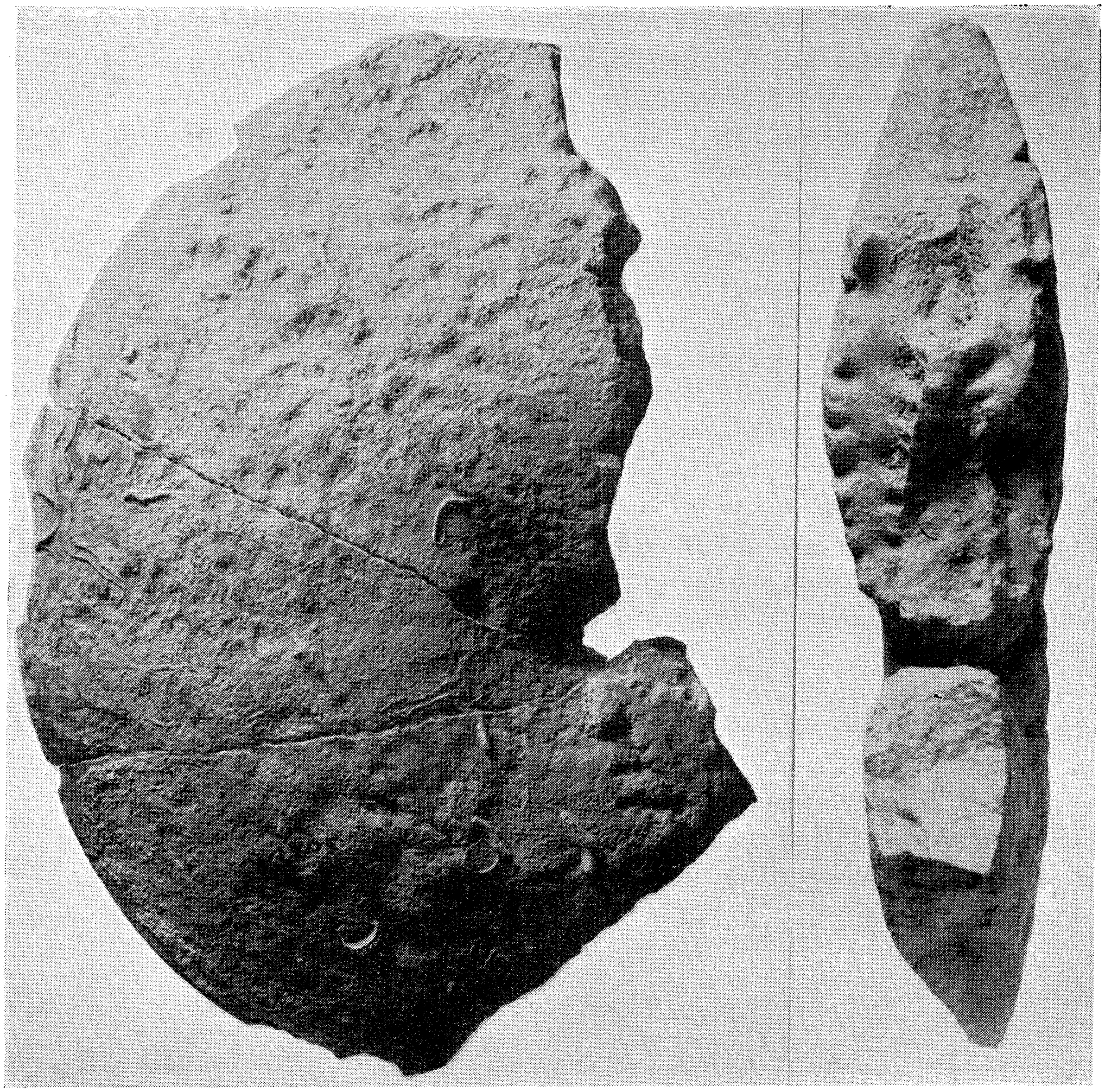

FIGURE 8. *Thambites planus* n.sp. Large specimen × 0·75. Locality 8. (Suture not decipherable in detail.) SM. F10806.

in buff limestone, locality 51; half a small specimen with test, locality 50; half a large specimen (diameter *ca.* 220 mm.), locality 8 (text-figure 8).

Description. As holotype is chosen a specimen (plate 24, figure 6) only 32 mm. in diameter, but it has the test intact, a clear umbilicus, and part of an adherent larger whorl and protruding inner whorl. Where the whorl first appears, at a diameter of 16·5 mm., there is already a narrow bicarinate concave venter, and other specimens show that this feature is retained at all diameters up to at least 200 mm. The width of the venter from 145 to 200 mm. is only 2 mm., but it is nevertheless concave.

The largest specimen (text-figure 8) is about 220 mm. in diameter and still septate. The full-grown ammonite, when complete with body-chamber, must have been a giant.

The whorl-sides are at first almost flat, the maximum thickness close to the umbilicus, which is small, with vertical walls, but its edge rounded although forming a right-angle. At large diameters the umbilicus widens gradually and considerably. There is no trace of ribbing or growth-lines. Sutures straight.

Remarks. By a fortunate peculiarity of preservation at localities 6 and 7, relics of internal sutures and septal-endings of outer whorls adhere to the outside of the test, and some of these penetrate into the bottom of the groove on the venter, proving that the venter is truly concave and does not merely appear so owing to falling away of the siphuncle or breakage of a hollow keel.

Thambites oxynotus n.sp., plate 21, figure 13

Material. One perfect specimen (holotype) in brownish limestone, locality 49; a fragment of a larger specimen, whorl-height 86 mm., still septate and double-keeled, locality 48.

Description. The holotype is a cast, 127 mm. in diameter and wholly septate. The whorl-sides are gently convex, the greatest thickness nearly central, the inner half sloping towards the umbilicus, which is minute. There is some faint vague ribbing in places on the outer half of the whorl-sides. The venter is very narrow and flattened (on the cast) to slightly concave. The suture-line is curved, convex forwards, the lobes small and narrow relative to its total length, except the external lobe, which is much enlarged, both long and wide, so that the lateral lobes reach far short of the radial line. If the separate fragment belongs to the same species, as would appear from the whorl-section, the species is septate and bicarinate to a diameter of at least 145 mm.

Comparisons. Differs from *Thambites planus* in its more rounded whorl-sides and curved suture-line. Until evidence for a post-Bajocian age was forthcoming I was prepared for this ammonite to turn out to be of Sinemurian or Lower Pliensbachian age, so close is the resemblance in form and suture-line to '*Kleistoxynoticeras*' *columellatum* Buckman (1925, vol. v, pl. dlxxvi) of the Jamesoni Zone. (This genus is apparently a synonym of *Metoxynoticeras* Spath, 1922.)

?**Thambites avus** n.sp., plate 24, figure 7

Material. One specimen, in cream limestone, locality 48.

Description. The holotype is a cast about 112 mm. in diameter and wholly septate. The venter is damaged all round, and sectioning has failed to reveal its shape, owing to internal distortion. The whorls are thicker than in the two preceding species, the greatest thickness near the umbilicus, which is minute. The suture-line is much less attenuated than in the other species, the lobes larger in proportion to its length; external lobe much elongated.

Remarks. The name alludes to the possibility that this species is on a line ancestral to *Clydoniceras*.

Genus **BRAMKAMPIA** n.

Type species *Bramkampia steinekei* n.

Diagnosis. Discoidal oxycones; periphery acute but its detail uncertain; perhaps with a narrow groove, perhaps with a hollow carina (the former regarded as the more likely). Ribbing obsolete. The distinctive feature is the suture-lines, which are extremely degenerated, the lobes irregular, digitate to candelabra-shaped as in such Cretaceous genera as *Engonoceras*, *Knemiceras* and *Lybicoceras*, the saddles approaching pseudoceratitic. Named after Dr R. A. Bramkamp, Chief Geologist of the Arabian American Oil Co.

Bramkampia steinekei, n.sp., plate 23, figures 9, 10

Material. Two large fragments, one about half complete, and a small fragment; from the lowest metre of the *Thambites* beds, near Juraifa, locality 8.

Description. The holotype is 111 mm. in diameter and wholly septate. The topotype was larger; whorl-height over 75 mm., still septate. No ribbing is present. The periphery is damaged all round all the material. One specimen shows a narrow concavity, but this could be caused by breakage of a hollow carina. Sectioning has failed to clear up the point, owing to internal distortion; no siphuncle can be detected. The sutures comprise an irregular series of digitate or candelabra-shaped lobes, the first and second laterals slightly divergent and separated by a large, smooth, semi-elliptical second lateral saddle. It is possible to interpret the first and second lateral lobes as the two prongs of a deeply cleft first lateral, but material available provides no means of judging this question.

Named after Mr M. Steineke, one-time Chief Geologist of the Arabian American Oil Co., who named the geological formations of the Arabian Jurassic system.

Family Clydoniceratidae Buckman, 1924

Genus **CLYDONICERAS** Blake, 1905

Type species by monotypy *Ammonites discus* J. Sowerby. See Arkell, 1951, pp. 30–40.

Clydoniceras pseudodiscus n.sp., plate 24, figure 8

Material. A cast, holotype, locality 60; three casts, locality 63; half a whorl (cast), locality 49; all in brown limestone.

Description. These specimens, varying in diameter from 75 to 160 mm., and all except the holotype wholly septate, are much worn, but all show at various sizes a single-edged acute venter, with no sign of a double keel or flattening. No signs of ribbing are discernible. The sutures are intermediate between those of *Thambites* and some species of *Clydoniceras*. In particular, the external lobe is reduced as in *Clydoniceras*, but still carries a large lateral branch as in *Thambites*.

Remarks. There is no essential difference between the sutures of *Clydoniceras pseudodiscus* and those of the earliest known English *Clydoniceras*, *C. tegularum* Arkell (1951, p. 42, pl. iv, fig. 7) from the Stonesfield Slates, and *C. hollandi* (Buckman) from the Bradford Clay (Arkell, 1951, p. 41, pl. i, fig. 5), but the detail has not the 'degenerated' digitate lobules so characteristic of the Upper Bathonian forms found in the Cornbrash (of which *C. discus*, is the commonest). Nevertheless, even the type variety of *C. discus* is not very different, except that it lacks the enlarged lateral branch of the external lobe (cf. Arkell 1951, pl. ii, fig. 1).

C. orientale (H. Douvillé) (1916, p. 40, pl. vi, fig. 1), from Gebel Maghara, Sinai, although incompletely known from a single fragment, has essentially digitate sutures and seems to belong to the Upper Bathonian group. It has not been recognized yet from Arabia.

In monographing the English Bathonian ammonites (Arkell 1951, pp. 30–32) it was insisted that the Clydoniceratidae are not aberrant Oppeliaceae, as supposed by most previous authors, but survivors of Harpocerataceae. The Arabian material, which had not then been worked out, and of which the horizon was at that time unknown, seems to indicate that Clydoniceratidae are derived from *Thambites* and the Bajocian *Thamboceras*, and that this was perhaps in turn derived from *Ermoceras*. If these inferences are correct, Clydoniceratidae must be regarded as Stephanocerataceae. The origin from Harpocerataceae nevertheless still holds, for Stephanocerataceae originated from Harpocerataceae by way of Hammatoceratidae and *Erycites*; this sufficiently accounts for the (doubtless reversionary) Harpoceratacean characters shown by Clydoniceratidae.

(*b*) MIDDLE BATHONIAN

Superfamily STEPHANOCERATACEAE Perrin Smith, 1913

Family TULITIDAE S. Buckman, 1921

Genus **TULITES** S. Buckman (1921, vol. iii, p. 44).

Type species by original designation *Tulites tula* Buckman (figured 1922, vol. iv, pl. cclxix). (Subjective synonyms *Tulophorites*, *Madarites*, *Sphaeromorphites* Buckman, 1921, vol. iii, p. 45.)

Tulites arabicus n.sp., plate 25, figures 5, 6, 7

Material. Eight specimens and fragments, localities 12, 13.

Description. A miniature species, probably 75 to 80 mm. in diameter when full grown. Inner whorls, up to about 40 mm. diameter, cadicone, with deep crater-like umbilicus, to which a row of tubercles forms a beaded edge. Venter broad, depressed, crossed by inconspicuous ribs which bifurcate from the tubercles. In profile the sides of the venter rise slightly towards the marginal tubercles. In the last stages, from 40 to 50 mm. onwards, ribs and tubercles disappear and the whorl rapidly heightens and contracts; the last quarter whorl is compressed and smooth but for growth-lines and obscure irregular paulostomes. Peristome not preserved. Sutures typical of *Tulites*, with the characteristic thick-based bifid second lateral lobe (plate 25, figure 7).

Comparisons. Inner whorls are hardly distinguishable from those of *Tulites cadus* Buckman (1922, vol. iv, pls. cclxviii, A–C); but that is a giant species which perhaps does not contract the body-chamber at any stage. The ontogeny of *T. arabicus* conforms more closely to that of other English species, especially the common *T. modiolaris* Wm. Smith sp. (= *T. madarus* Buckman sp., 1922, vol. iv, pl. cclxxi) as regards the inner whorls and *T. subcontractus* (Morris & Lycett) (Buckman, 1922, vol. iv, pl. cclxx) as regards the outer. The English species are at present undergoing revision. There is great difficulty in matching outer and inner whorls owing to the poor preservation and scarcity of material. It is certain, however, that none of the three Arabian species is conspecific with any of the English, or with any German material from Bavaria kindly loaned me by Professor L. Krumbeck of Erlangen.

Tulites tuwaiqensis n.sp., plate 25, figure 3

Material. Holotype, locality 12; also locality 26.

Description. The holotype is 68 mm. in diameter and might be full grown, but a crushed specimen which probably belongs to the same species is 102 mm. in diameter and still lacks a quarter of a whorl. The ontogenetic stages are as described for *Tulites arabicus*, but at least the middle whorls (the inner are unknown) are not nearly so depressed, not cadicone, but more sphaerocone. The umbilical edge is not so sharp, the venter much more arched, so that much of the ribbing is on the whorl-sides, instead of all on the venter. The few ribs visible are triplicate instead of biplicate. Ribbing fades at 40 to 45 mm. In both this and the holotype of *T. arabicus* compression of the body-chamber has probably been exaggerated by crushing.

Tulites erymnoides n.sp., plate 25, figures 1, 4

Material. Holotype, locality 25; also localities 12, 24.

Description. The holotype is 55 mm. in diameter and there is a nucleus 27 mm. in diameter. They belong to the same group of small and (for the genus) rather compressed species as the two foregoing, in form most resembling *Tulites subcontractus* and its allies. *T. erymnoides* differs from both the other Arabian and all the known English species, however, in its stronger and sharper and more persistent ribbing, which is strongly prorsiradiate and forms well-marked tubercles on the umbilical edge. The tubercles persist, though irregularly, at least half a whorl longer than in the other two species. Sutures unknown.

Remarks. The name of this species is suggested by its remarkable homoeomorphy with *Erymnoceras* of the Middle Callovian. In the absence of sutures it is impossible to give any reasons other than stratigraphical for placing these two specimens in *Tulites* rather than *Erymnoceras*.

Family Clydoniceratidae Buckman, 1924

Genus **MICROMPHALITES** Buckman, 1923

Type species by original designation *Ammonites micromphalus* Phillips, Middle Bathonian, Stonesfield Slates, Oxfordshire (see Arkell 1951, pp. 33, 45).

Micromphalites cf. **busqueti** (de Grossouvre), plate 27, figures 1–6; text-figure 9

Ammonites busqueti de Grossouvre, 1919, p. 412, pl. xiv, fig. 2.

Material. At least ten specimens plus nuclei, Juraifa area, localities 17, 18, 20; Barra area, one specimen in pink limestone, locality 27; Khashm Dhibi area, one fragment, locality 52.

Description. Inner whorls strongly ribbed all over the sides, with strong circum-umbilical bulge on which the primary ribs are incipiently tuberculate. On the middle whorls (for example in the holotype) the ribs coarsen on the ventro-lateral shoulders but fade towards the umbilicus, and by a diameter of 40 to 45 mm. the bulge becomes smooth. On the outer septate whorl the ribbing gradually dies away and the bulge becomes obsolete and by 100 to 110 mm. disappears, leaving the whorl-section *Clydoniceras*-like. The keel remains tall and the shoulders distinct throughout. The body-chamber is not known, but just before septation ceases the umbilicus suddenly becomes excentric, and remains of the umbilical seam of the body-chamber show that the tendency increases and then halts for the last half whorl. Septal sutures minutely crenulate, the lobes short. The largest specimen is 125 mm. in diameter and wholly septate.

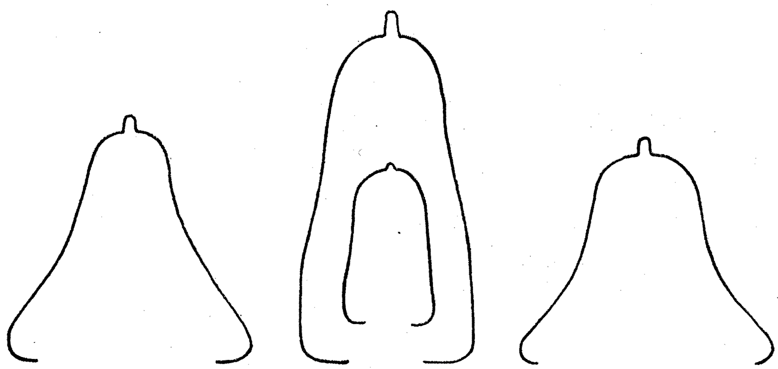

FIGURE 9. Whorl-sections of *Micromphalites*, natural size. Left, *M. elegans*; centre, *M. clydocromphalus*; right, *M.* cf. *busqueti*.

Comparisons. Fragments somewhat closely resemble *Micromphalites micromphalus* (Phillips) of the English Stonesfield Slates, but in that the inner whorls are more evolute and much more feebly ribbed, and the middle whorls have smaller and more numerous ribs, while there is no evidence that the size of the complete ammonite was nearly so great; also the umbilical bulge of the inner and middle whorls was probably less conspicuous (even when allowance is made for crushing of the Stonesfield material).

Judging by the anterior view of the holotype of *M. busqueti* the inner whorls might be almost unribbed, but this appearance may be due to preservation; de Grassouvre says nothing about it. However, without seeing type material of *Ammonites busqueti* it would be unwise to insist on specific identity, especially as at the type locality, Saint-Benin d'Azy, Nièvre, it is said to occur in a band of ferruginous oolite with many ammonites of Lower Bathonian date (de Grossouvre, 1919, p. 359). The Arabian species is well known from ample material and is compared to, rather than identified with, *Micromphalites busqueti* only because the French species is imperfectly known.

Micromphalites pustuliferus (H. Douvillé), plate 28, figure 1

Stringoceras pustuliferum H. Douvillé, 1916, p. 41, pl. vi, figs. 2, 3.

Material. One worn specimen, Wadi Birk, locality 65.

Remarks. The Arabian specimen is 64 mm. in diameter and wholly septate. Where the whorl first appears it is already larger than Douvillé's fig. 2 (lectotype now designated), but for about half a whorl it continues the same style of ornament, with enormous inner and outer tubercles joined by scarcely-perceptible wide, distant, V-shaped pairs of ribs, and tabulate keeled venter. The tubercles then gradually change to bullae and progressively diminish.

Micromphalites elegans n.sp., plate 26, figure 8; plate 28, figures 3, 4, 5, 8; text-figure 9

Material. Seven specimens plus nuclei, Juraifa area, localities 16, 17, 18, 20.

Description and comparisons. Resembles *Micromphalites* cf. *busqueti* but is more compressed in early and middle stages, with narrower and somewhat less square-shouldered venter, less prominent and smoother umbilical bulge, and finer ribbing, which (at least on the middle whorls) is more prorsiradiate towards the venter.

Micromphalites vertebralis n.sp., plate 28, figure 11

Material. One nucleus, locality 18.

Description and comparisons. Among many nuclei of *Micromphalites* in chocolate-coloured ironstone is one 18 mm. in diameter that cannot belong to any of the known species. It resembles a young *Vertebriceras* or *Sagitticeras*. At a diameter of 15 mm. the whorl-thickness is 12 mm., or 80 %. The umbilical walls are smooth and vertical, edged with a beading of small but prominent tubercles, from which spring coarse biplicate secondary ribs. The venter is wide and flatly arched, strongly keeled.

Micromphalites intermedius n.sp., plate 28, figures 6, 7, 9

Material. Three specimens, localities 16, 18, plus nuclei.

Description and comparisons. A moderate-sized species, in which the umbilicus begins to widen at a diameter of about 90 mm. The name *intermedius* is chosen because the whorls are thick and the outer ribbing strong, as in *Micromphalites micromphalus* and *M. busqueti*, but at all stages the circum-umbilical bulge is only slight; the species is therefore a link between *Micromphalites* s.str. and the subgenus *Clydomphalites*. The inner half of the whorl-sides also is unribbed, as in *Clydomphalites*.

Subgenus **CLYDOMPHALITES** n.

Type species *M.* (*C.*) *clydocromphalus* n.

Diagnosis. Discoidal *Micromphalites* without circum-umbilical bulge or nodes and with minute umbilicus, which suddenly opens out in the last whorl. The form is like that of *Clydoniceras*, but the suture-lines, ribbing, and keel are those of *Micromphalites*.

From the drawings it appears possible that a species of this genus may have been figured from Algeria as a cast of *Oraniceras hamyanense* Flamand (1911, p. 918, pl. vii, figs. 10*a*–*c* only); but the holotype of that species (and therefore the ultimate standard of reference for the genus) is Flamand's figs. 12*a*, *b* ('spécimen typique'), and the photographs since published by Roman (1930, p. 11, pl. viii, figs. 1, 3, 4, 6; 1933, p. 64, pl. ii, figs. 6–9) show that it is not congeneric with any of the Arabian material here described, though undoubtedly belonging to the Clydoniceratidae (Arkell, 1951, p. 33).

Micromphalites (Clydomphalites) clydocromphalus n.sp., plate 26, figures 1–7, 9; plate 28, figure 12; text-figure 9

Material. Sixteen specimens, locality 16; four specimens, locality 17; one specimen, locality 18; plus nuclei (Juraifa area); one fragment Barra area, locality 27; one specimen Wadi Birk, locality 64.

Description. The largest specimen (locality 16) is wholly septate and 100 mm. in diameter, with dimensions 0·57, 0·22, 0·04. The dimensions of another at 36 mm. are 0·585, 0·35, 0·085. The holotype is 79 mm. in diameter and wholly septate. At this diameter the umbilicus is only 3·5 mm. wide, but almost immediately afterwards it suddenly widens out, as shown by a scar of involution on both sides of the specimen, so that a whorl later the umbilicus was about 22 mm. wide and the previous whorl was only half overlapped. In this specimen (the holotype) excentrumbilication takes place at a considerably smaller size than in the largest specimen collected, but this is a matter of individual variation in ultimate size.

Ribbing on the inner whorls is confined to the outer third of the whorl-side and venter; gradually it becomes restricted to the venter and shoulders, and eventually, at a diameter of about 70 to 80 mm., it fades altogether, the whole shell becoming smooth as in *Clydoniceras*. The shouldered venter and tall keel of *Micromphalites* persist, however, and serve to identify even small smooth fragments.

Suture-lines are as variable as in *Clydoniceras*, the first lateral lobe pointed or blunt, trifid or multifid, but always narrow compared with the second lateral lobe, which is sometimes so spread-out and amorphous that the two adjacent saddles are practically confluent.

Superfamily Oppeliaceae Buckman, 1924

Family Oppeliidae Bonarelli, 1893

Genus **STRUNGIA** n.

Type species *Oppelia redlichi* Popovici-Hatzeg, 1905, p. 18, pl. xiii, fig. 1, Bathonian, Mt Strunga, Rumania.

Diagnosis. Compressed, involute Oppeliids, with fastigate venter becoming rounded on the adult; irregular feeble bundled ribs, which may crenulate the umbilical edge and may develop ventro-lateral tuberculation; the surface with minute longitudinal strigation.

Strungia arabica n.sp., plate 28, figure 2

Material. One specimen, in chocolate ironstone, locality 18.

Description. The holotype is 25 mm. in diameter. The umbilicus is narrow, its edge moderately angular, the venter fastigate but with the keel in places becoming more pronounced and perhaps elsewhere worn down. The whorl-sides are nearly flat and distinctly strigate, the ribbing irregularly bundled and only slightly falcoid, the primaries more prominent than in *Strungia redlichi*, the secondaries more effaced and not tuberculate. Sutures not visible.

Comparisons. This, the only recognizable Oppeliid from the Tuwaiq Bathonian, in the same chocolate matrix as some *Micromphalites*, is most nearly comparable, in form, style of ribbing and strigation, with *Oppelia redlichi* Popovici-Hatzeg, from Mt Strunga, Rumania. Loczy (1915, p. 341) assigned *O. redlichi* to the Callovian genus *Petitclercia* Rollier, 1909, of which the lectotype species is *Ammonites mirabilis* de Grossouvre (1891, p. 258, pl. ix, figs. 4, 5), designated by Rollier, 1913. This and the associated Callovian species figured by de Grossouvre, however, do not seem generically related to *Oppelia redlichi*, and *Petitclercia? hungarica* Loczy (1915, pl. iii, fig. 18) certainly is not. Spath (1928, pp. 90, 93) thought *Oppelia redlichi* might belong to Phlycticeratinae.

(*c*) Middle or Upper Bathonian

For about 70 m. above the *Micromphalites* beds of the Middle Dhruma no ammonites have been found, although other fossils are abundant. The only ammonites known from the 56 m. uppermost subdivision of the Middle Dhruma are giant *Clydoniceras*-like forms occasionally found near the top. These belong to a new genus. No ammonites are known from the Upper Dhruma.

Family Clydoniceratidae

Genus **DHRUMAITES** n.

Type species *Dhrumaites cardioceratoides* n.

Diagnosis. Giant oxycones with degenerated *Micromphalites*-like sutures.

Dhrumaites cardioceratoides n.sp., plate 25, figures 2, 8; text-figure 10

Material. Parts of two giant specimens, Barra area, localities 29, 30; inner whorls, Dhruma area, locality 42.

Description. The diameter of the holotype (allowing for damaged venter) is about 280 mm., and it is wholly septate. The whorl-height is about 145 mm. Another specimen, also wholly septate, has a whorl-height of 135 mm. The whorl-section is lanceolate at all stages, the outer whorls much like a large *Cardioceras* from the Lower or early-Upper Oxfordian. The outer third only of the whorl-sides shows feeble, blunt, close ribbing, swung only slightly forward. Inner whorls show feeble ribbing most nearly comparable to that of *Micromphalites micromphalus* (Phillips), without the strong forward swing of the ends on approaching the venter that occurs in all *Clydoniceras*. The sutures, visible only on the large outer whorls, resemble those of *Micromphalites*, especially in having a wide, amorphous, highly variable, often straggling second lateral lobe.

Comparison. The ribbing (feeble though it is) and the suture-lines, especially the second lateral lobe, leave no doubt that this genus is an oxycone derivative of *Micromphalites*, simulating *Clydoniceras* in form and in details of degeneration of the sutures, but parallel to it rather than directly related. The extremely sharp periphery, with no trace of shoulders, and the general variability of the details of the sutures, form a close parallel to *Clydoniceras*. There is even the same tendency in some specimens but not in others for the first lateral lobe to become forked as in *C. discus* var *hochstetteri*. (For abundant figures see Arkell 1951, pp. 33–40, pls. ii, iii.) Another peculiarity of *Clydoniceras* occurs in *Dhrumaites*: the inner (dorsal) edges of the first and second lateral lobes of successive sutures almost touch, forming two spiral lines of weakness; and the inner line has given way under rock-pressure, producing a false umbilicus.

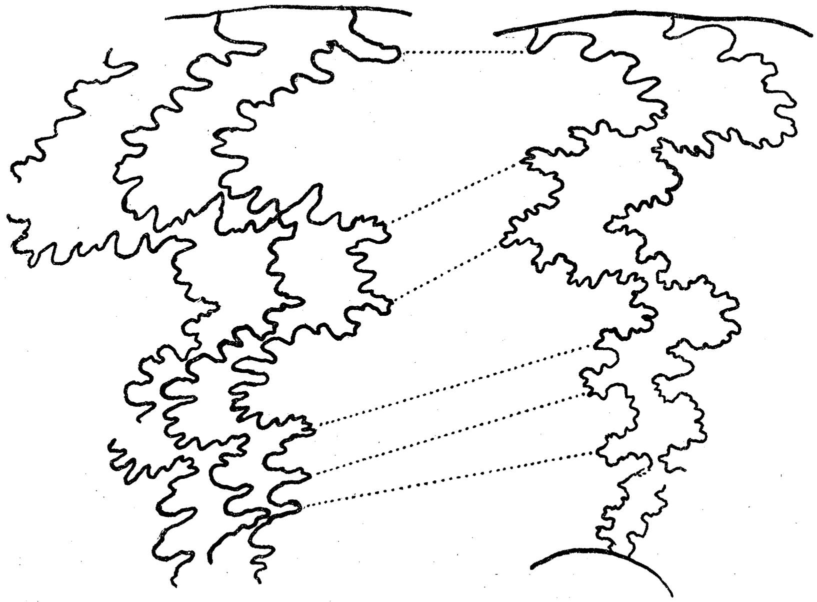

FIGURE 10. *Dhrumaites cardioceratoides* n.sp. Two suture-lines ×2/3 (drawn on photographs), the corresponding principal lobes connected by dotted lines. Left, specimen from locality 30, SM. F10765; right, holotype, locality 29, SM. F10771.

3·5. *Ammonites of the Tuwaiq Mountain Limestone*

The Tuwaiq Mountain Limestone, altogether about 215 m. thick at its type locality, consists of two very different parts: a soft, white or greenish grey chalky lower division, 35 to 40 m. thick or more, which passes up gradually into the main, much harder, coral-bearing limestones that form the high precipices of Jebel Tuwaiq (plate 31). So far ammonites have been found only in the chalky lower division, and they all belong to the two allied genera *Erymnoceras* (first discovered by Philby in 1932) and *Pachyceras*, denoting Middle Callovian.

Superfamily STEPHANOCERATACEAE Perrin Smith, 1913

Family PACHYCERATIDAE Buckman, 1918

Genus **ERYMNOCERAS** Hyatt, 1900

Type species by original designation *Ammonites coronatus* Bruguière, d'Orbigny.

The two principal earlier sources for this genus, by R. Douvillé (1912, pp. 28–33) and Roman (1930, pp. 170–175) (both using the erroneous name *Stepheoceras* Buckman, which is an objective synonym of the Bajocian *Stephanoceras* Waagen, 1869) has been superseded by the recent monograph by Jeannet (1951), who gives numerous figures based on 100 to 200 Swiss specimens. None of his figures, however, agrees specifically with the few Arabian examples available.

Erymnoceras philbyi n.sp., plate 29, figures 1–3

Material. Barra area, the holotype, locality 31, and fragments, localities 32, 35; Bakarat, locality 21.

Description and comparisons. The holotype is a nearly complete full-grown example 165 mm. in diameter, which takes to pieces to show inner whorls. At 150 mm. the dimensions are 0·36, 0·46, 0·37, and at 70 mm. 0·46, *ca.* 0·53, 0·35. The inner whorls show a style of ribbing and whorl-shape most like *Erymnoceras leuthardti* Jeannet (1951, p. 121, pls. 41–2), with its rather numerous and prorsiradiate secondaries, but the umbilical margin is tuberculated (not ribbed), as in the *coronatum* group. In side view the inner and middle whorls agree well enough with some varieties of *E. coronatum* as figured by Jeannet (especially his pl. 39, fig. 1), but at all stages *E. philbyi* has a much more arched venter. On the outer whorl it develops the coarse gerontic, biplicate, rounded ribbing, round whorl-section and slightly excentric coiling of the form figured by R. Douvillé (1912, p. 31, fig. 24). Unless Douvillé's figure is reduced, however, *E. philbyi* is much larger. This style of body-chamber is perhaps subgenerically distinct from the smooth style developed in *E. reginaldi* Morris sp. (refigured Arkell 1933, pl. xxxvi, fig. 1; and d'Orbigny 1848, pl. 169, fig. 3, reduced to one sixth).

Compared with *E. doliforme* Roman (for references and new figures see Jeannet 1951, p. 110, pl. 33), *E. philbyi* has a much less depressed, more arched venter, and more numerous ribs, which are more often triplicate than biplicate, and sometimes quadruplicate. Roman's version of *E. coronatum* (1930, p. 170, pl. xv, fig. 3) has a body-chamber of the same style as *E. philbyi*, but is much more compressed; so is *E. richei* Roman (1930, p. 172). *E. ajax* d'Orbigny sp. (Cottreau 1925, p. 2, pl. xxxv, figs. 12–15; =*Steph. coronatum* R. Douvillé pars, 1912, p. 30, figs. 21, 23 right) has a whorl-section more like *E. philbyi* but is much more involute, with blunter umbilical edge and blunter tubercles. *E. naltschikense* (Chickhachev) (1933, pl. ii, figs. 1, 1*a*) from the northern Caucasus is similar but more cadicone, with flatter venter and ribs that are regularly biplicate and much more prorsiradiate. *E. renardi* (Nikitin) (1882, p. 120, pl. iv, figs. 24*a*, *b*, the type from Elatma) is too compressed in the nucleus (Chickhachev, pl. ii, fig. 7) and also the ribbing is regularly biplicate and more strongly prorsiradiate. The Hungarian *E. triplicatum* (Till) (1911, p. 22, pl. ii, fig. 14; pl. iii, fig. 1) has a much more depressed whorl-section than *E. philbyi*, though similar in side view.

Philby's best *Erymnoceras* from near Haisiya, Jebel Tuwaiq, (Brit. Mus. Nat. Hist. C. 35960, Sha'ib Hassi) is obliquely crushed, but it and two nuclei (C. 35958–9, Sha'ib al Hish) all seem to belong to this species. Philby's best specimen is now figured for its historical interest (plate 29, figure 2).

Erymnoceras cf. **jarryi** (R. Douvillé), plate 29, figure 4

cf. *Pachyceras jarryi* R. Douvillé, 1912, p. 37, pl. vii, fig. 10 (holotype).

Material. One specimen, Barra area, locality 33.

Remarks. A distorted nucleus about 30 mm. in diameter shows intensely strong ribbing on the venter, as in Douvillé's figs. 10, 10*a*, the holotype. The Arabian specimen, however, is at an earlier stage of growth, more comparable with the type of *Erymnoceras villersense* (R. Douvillé), figs. 6, 6*a*, which it resembles in shape, but its ribbing is stronger. As to whether the inner whorls and nuclei figured as *E. jarryi* on the same plate (figs. 3–5, 7, 8) belong to the same species, Douvillé (p. 39) was himself convinced but admitted that others might not be; for which reason he designated fig. 10 holotype. These others are quite different from the Arabian specimen. The species with coronate inner whorls and a sharp and tuberculated umbilical edge were wrongly placed in *Pachyceras* by R. Douvillé.

For strength of ribbing at an early stage, the most closely comparable figure is the unnamed specimen from the northern Caucasus figured by Chickhachev, 1933, pl. ii, fig. 2; but he only gives one side view, no ventral view.

Erymnoceras aff. **triplicatum** (Till)

cf. *Stephanoceras triplicatum* Till, 1911, p. 22, pl. ii, fig. 14; pl. iii, fig. 1.

Material. A large fragment of a giant, Bakarat, locality 22.

Remarks. Our fragment, with a whorl-thickness of about 115 mm. and median vertical whorl-height from dorsum to venter of 27 mm. has a far more depressed whorl-section than any west European species except *Erymnoceras doliforme* Roman, but it differs from that in having the ribbing triplicate and subdued instead of strong and biplicate. In particular, the venter is nearly smooth except towards the sides. The only figured species to which this fragment of giant outer whorl could belong seems to be the Hungarian *E. triplicatum.*

Genus **PACHYCERAS** Bayle, 1878

Type species by monotypy *Ammonites lalandeanus* d'Orbigny (1848, pl. 175, figs. 1–3).

This Middle Callovian to Middle Oxfordian genus has been illustrated by R. Douvillé (1912), who, however, included in it several very different forms which ought to be separated. Thus *Pachyceras radiatum* R. Douvillé (1912, pl. ix, fig. 1) is, in my opinion, a *Quenstedtoceras*, a compressed species of the subgenus *Eboraciceras* Buckman, while *Pachyceras jarryi* R. Douvillé, with coronate nucleus, as remarked above, should be transferred to *Erymnoceras*. This leaves in *Pachyceras* s.str. (of Douvillé's species), only the compressed forms with planulate nuclei and smoothing ribs, which fade on the umbilical edge just where those of *Erymnoceras* become accentuated and tuberculated, namely, *Pachyceras lalandeanum* (d'Orbigny), *P. crassum* R. Douvillé, and the 'mutation' *romani* R. Douvillé. *Tornquistes*, the Oxfordian subgenus which reaches the Plicatilis Zone, has been discussed elsewhere (Arkell 1940, pp. lxxi, 215).

Pachyceras cf. **schloenbachi** (Roman), plate 30, figure 1

cf. *Stepheoceras schloenbachi* Roman, 1930, p. 173, pl. xiii, fig. 6 (lectotype now designated).

Material. One specimen, locality 32.

Remarks. A rather poorly preserved specimen, 52 mm. in diameter, differs from *Pachyceras lalandeanum* (d'Orbigny) at a comparable diameter (cf. R. Douvillé, 1912, pl. viii, figs. 2, 2*a*) by its slightly wider umbilicus and more slowly thickening whorl. In these respects it agrees better with Roman's figure of his *P. schloenbachi* (here designated lectotype, since Schloenbach's figure may represent a Quenstedtoceratid). Sudden contraction of the last quarter whorl of the Arabian specimen is almost certainly due to rock-distortion.

Two fragments figured by H. Douvillé (1916, p. 70, pl. viii, figs. 4, 5) as *Pachyceras* cf. *lalandei*, from the Oxfordian of Gebel Maghara, Sinai, could belong to the same species.

The specimens figured by Jeannet (1951, pl. 40, figs. 8, 10–12) as *Erymnoceras* cf. *schloenbachi* Roman are *Erymnoceras*.

3·6. *Ammonites of the Hanifa and Jubaila Formations*

Superfamily Perisphinctaceae Wedekind, 1917

Family Perisphinctidae Steinmann, 1890

The only ammonites so far found in these two formations are fragmentary and poorly preserved perisphinctids.

From the Hanifa formation (101 m. thick at its type locality) there is only one specimen, a very poor fragmentary and distorted cast from locality 66, Wadi Birk, in hard pink and white mottled limestone near the middle of the formation. It is moderately fine-ribbed, biplicate, constricted, round-whorled. Owing to a peculiar irregularity of the ventral ribbing I determined it at first as a Callovian *Grossouvria*, comparable with *G. leptoides* Till sp. (1911, p. 42, pl. v, figs. 1, 2). The irregularity, however, may be due to an injury during life, in which case a better match would be with an Upper Oxfordian *Kranaosphinctes* such as *Perisphinctes* (*K.*) *africanus* Dacqué (1910, p. 17, pl. iii, fig. 2) from Mombasa (Plicatilis Zone).

From the Jubaila Limestone (110 m. thick), near the middle of the formation, four fragmentary casts and impressions of large perisphinctids were obtained by the party during my visit in January 1951, from the side of the gorge of Sha'ib Aussat. None is identifiable specifically, but from the style of the ribbing, its fasciculate triplication and steady forward swing, and from the high, compressed whorls, I have no doubt that these belong to the Lower Kimeridgian group of *P. progeron* von Ammon and *P. eggeri* von Ammon (1875, pp. 180, 181, pl. i, fig. 2, pl. ii, fig. 2), with the figures of which the match is as nearly perfect as the material will allow. One or two of the larger fragments may represent parts of outer whorls of the species here described as *P. jubailensis* n. A similar large impression found with the latter in Wadi Birk (locality 67) has finer, denser secondaries and is more like a *Lithacoceras*.

Perisphinctes jubailensis n.sp., plate 29, figure 5; plate 30, figure 2

Material. One good cast, Wadi Birk, locality 67. Perhaps another from the southern Tuwaiq, locality 69.

Description. The holotype is 101 mm. in diameter, the dimensions at 100 mm. 0·39, 0·32, 0·33. Primary ribs number 28 to 29 at 100 mm. The ribs bifurcate obscurely a little way above the middle of the whorl-sides and from the region of furcation swing steadily forward over the shoulders and venter. Each pair is accompanied by an intercalatory which may or may not be obscurely joined to produce triplication. There is no fading on the venter. Sutures not visible.

Comparisons. The smaller specimen from locality 69 (many miles away) is more evolute but otherwise similar (plate 30, figure 2).

Both *Perisphinctes eggeri* and *P. progeron* von Ammon have much denser ribbing, but otherwise the resemblance is unmistakable. Other possible comparisons are all with perisphinctids of the same age: e.g. '*Ataxioceras* (*Decipia*)' *lautum* Schneid (1944, pl. viii, figs. 5, 6, 7), '*A.*' *discobolum* (Font.) Schneid (1944, pl. v, fig. 4), the former slightly more evolute and with a tendency to quadrifurcation of the ribbing, the latter with slightly finer ribbing.

These forms have sometimes been referred to the subgenus *Planites*, but since that name, if used, takes priority over *Perisphinctes*, an application to suppress it has been made to the International Commission, and accordingly the name *Perisphinctes* sensu lato is used here.

4. Correlation

Marrat formation

Lower Marrat (34 m.). The *Bouleiceras* fauna. *Bouleiceras nitescens* Thevenin et spp., *Protogrammoceras madagascariense* (Thevenin). This horizon clearly represents the lower *Bouleiceras* bed of Madagascar, which is there likewise the earliest Jurassic marine horizon. Thevenin in 1908 considered the age approximately between Domerian and Toarcian, but it has since usually been regarded as Toarcian (e.g. Barrabé, 1929, p. 88).

Correlation table

Formations	Ammonite faunas	European stages
Riyadh	nil	?
Jubaila	'*Planites*' fauna	Lower Kimeridgian
Hanifa	?	?
Tuwaiq Mt	Coral limestones	?
	Erymnoceras fauna	Middle Callovian
Upper Dhruma	?	Upper Bathonian ?
Middle Dhruma	*Dhrumaites* fauna *Micromphalites* fauna *Tulites* fauna	Middle (and Upper ?) Bathonian
	Thambites fauna	Lower Bathonian ?
Lower Dhruma	*Ermoceras* fauna	Early-Upper or late-Middle Bajocian
	Dorsetensia fauna	Middle Bajocian
Upper Marrat	*Nejdia* fauna	Early-Upper Toarcian
Middle Marrat	nil	?
Lower Marrat	*Bouleiceras* fauna	Lower Toarcian
Minjur	nil	?
Upper Jilh	*Paraceratites* fauna	Middle Triassic

In Madagascar the only ammonite recorded from the basal *Bouleiceras* bed which has not been found in Arabia is *Harpoceras* (*Hildoceras*) *inclytum* Fucini var. *madagascariense* Thevenin (1908, p. 11, pl. i, fig. 9). Fucini's Italian species, *inclytum* (1900, pl. xiii, figs. 1, 2), was referred to *Hildoceras* by both Fucini and Thevenin, but in neither ribbing, venter, nor sutures is it a true *Hildoceras*. Owing to its simple and not conspicuously projected ribs, unicarinate venter, and Domerian age, it would now be classed in the genus *Seguenziceras*, to the type of which, *S. algovianum* Oppel sp. (see e.g. Geyer, 1893, pl. i, figs. 7, 8), it bears much closer resemblance. But, as pointed out by Thevenin, his Madagascan 'variety' differs from the Italian *inclytum* by having a distinctly bisulcate venter, bifid (and more projected) ribs, and simpler sutures. These differences make it a true *Hildoceras* and point to a Toarcian age. Nothing like it has been figured from the Domerian.

In Baluchistan, on the Porali River, Tipper collected *Bouleiceras* at a lower level than *Harpoceras*, *Hildoceras*, *Dactylioceras* and '*Oxynoticeras*' (Holland 1909, p. 28), which seems to be an indubitably Toarcian fauna. Through the kindness of the Burmah Oil Co. and of Professor J. A. Douglas, two ammonites, one a *Bouleiceras*, and two fragments, collected in 1940 in Las Bela State, Baluchistan, came into my hands in May 1951. They are all in a peculiar ironstone and apparently from one bed, thus throwing welcome additional light on the age of *Bouleiceras*. All four are different species. Two are Harpoceratids or Hildoceratids with strongly tricarinate venters, the ribs only weakly projected at the shoulders. They could be identified with either *Protogrammoceras* or *Fuciniceras*, especially var. *brevispirata* Fucini (1900, pl. xii, fig. 4), and a coarser-ribbed form such as his pl. xi, fig. 7, which Fucini calls Middle Liassic. On the other hand, in Portugal, where the stratigraphical relations of the Pliensbachian and Toarcian are clear and the ammonite faunas have been collected *in situ* (Renz 1912; Meister 1914) an assemblage of these tricarinate Hildoceratids, including one recorded (wrongly) as *H. cornacaldense* Tausch, occurs above the Spinatum Zone (which contains abundant *Pleuroceras spinatum* Brug. sp.), and even above *Dactylioceras commune*. Two of the Baluchistan specimens, in fact, are indistinguishable from material figured from this bed (Renz 1912, p. 68) by Meister (1914, pl. xii, figs. 5, 7; pl. xiii, fig. 5). The fourth Baluchistan specimen is a fragment of a high-whorled, involute Harpoceratid with fine and dense falcoid ribbing and complex sutures. In side view it is apparently a *Polyplectus*, but it differs from the typical Upper Toarcian forms of that genus by its blunt though very narrow periphery and by a unicarinate, shouldered venter on the inner whorls. This is probably the form recorded and figured by Renz (1912, p. 68, pl. vi, fig. 3) as *P. discoides* from Portugal, where it is said to mark a special horizon under the Bifrons Zone.

Thus the evidence from Portugal indicates that the *Bouleiceras* fauna is Lower Toarcian, and it causes one to accept with reserve the supposedly Domerian date of some of the Hildoceratids figured by Fucini, which have been perhaps too hastily all assigned an early date. It seems clear from the *Dactylioceras* spp. figured by Fucini (1935, pls. viii, ix, x) that he did not always use 'Domerian' in the sense in which it is used in north-west Europe, to mean Spinatum and Margaritatus Zones, for these forms must surely be post-Spinatum Zone. In Umbria Principi (1915, pp. 451–452, pl. xvii) found two of Fucini's supposedly Domerian species, *Harpoceras celebratum* Fucini and *H. exiguum* Fucini, in unequivocal Toarcian beds with *Hildoceras bifrons*, *Polyplectus*, etc. Further stratigraphical work of this sort on the Italian Lias is badly needed.

Finally, at Gebel Nador, Oran, Algeria, Deleau (1941) has recorded *Bouleiceras* aff. *nitescens* in 10 m. of red marls associated with *Hildoceras bifrons*, *Hildoceras* cf. *semipolitum* Buck., *H. sublevisoni* Fucini var. *raricosta* Mitzopoulos, *Hildoceros* cf. *undicosta* Merla (the last very close to one of the Baluchistan specimens but more evolute), *Mercaticeras mercati* (Hauer), *Denckmannia erbaensis* (Hauer), *Polyplectus* cf. *discoides* (Zieten), *P. subplanatus* (Oppel), and *Coeloceras* cf. *crassum*. This is unquestionably a Lower to Middle Toarcian assemblage. Judging by the photographs, however, I do not believe the supposed *Bouleiceras* are correctly identified. *Bouleiceras*-like sutures are occasionally developed in the Mediterranean region by species of *Frechiella* as well as *Leukadiella* and *Paroniceras* (see e.g. Parisch & Viale, 1906, pl. vii, fig. 5). (See p. 262.)

Middle Marrat (56 m.). Unfossiliferous red shales.

Upper Marrat (21 m.). The *Hildaites* and *Nejdia* beds are so close together that they may be discussed as one fauna for the purpose of dating the early part of the Upper Marrat. The *Hildaites* indicates about the middle of the Toarcian, possibly Lower Toarcian at earliest. The only other known species of *Nejdia* outside Arabia, *N. pseudogruneri* Thevenin sp. (1908, p. 12, pl. i, fig. 5), occurs in the upper *Bouleiceras* beds of Madagascar with *Bouleiceras* sp., Thevenin's pl. ii, fig. 13 only, not in the main bed with *B. nitescens*, *B. elegans*, *B. tumidum*, and *B. rectum*. The morphological comparisons of the genus *Nejdia* discussed above (p. 266) suggest either the uppermost Lower Toarcian or lower part of the Upper Toarcian (Variabilis to Dispansum Subzones).

Dhruma Formation

Lower Dhruma, lower part (67 m.). *Dorsetensia*, the only genus of ammonites found in this subdivision, occurs abundantly 21·2 m. above the base at locality 46 and was found again by Dr Bramkamp when demonstrating the same horizon to me in January 1951 in another area, at locality 23, at 18·2 m. above the base. There is also a fragment from 52·7 m. above the base at locality 47.

In England *Dorsetensia* is confined to the Humphriesianum and Sauzei Zones, in which it is always accompanied by various Stephanoceratids. Near Mombasa (Spath, 1933, p. 815) it is likewise associated with *Stephanoceras*, but the material (kindly sent me on loan from the University of Glasgow) is too small for zonal dating. *Dorsetensia* and *Stephanoceras* have also been recorded together in the Himalayas of Tibet (Hayden, 1907, p. 33), and I owe to Dr R. W. Fairbridge a small collection of typical *Dorsetensia* with various Stephanoceratids from the famous occurrence of the Humphriesianum Zone near Geraldton in Western Australia, from which Buckman identified the genus (Crick 1894). A map showing this remarkable distribution has been published (Arkell 1949); the present occurrence was unknown when the map went to press, and should be added.

Notwithstanding the absence of the almost ubiquitous *Stephanoceras*, the Arabian *Dorsetensia* beds can be assigned with confidence to the Middle Bajocian.

Lower Dhruma, middle part (22 m.). No ammonites.

Lower Dhruma, upper part (38 m.). The *Ermoceras* fauna. *Ermoceras* and *Thamboceras* being unknown outside Arabia and Sinai, correlation depends on the associated genera. The only links with Europe or elsewhere yet found with the *Ermoceras* fauna in Arabia are the three Stephanoceratids, *Stephanoceras* cf. *psilacanthus* Wermbter, *Teloceras* cf. *labrum* Buckman, *Normannites* cf. *orbignyi* Buckman. All three indicate the Humphriesianum Zone, and more especially the highest subzone (Blagdeni). This fact and the absence of *Strenoceras*, *Garantiana*, or *Parkinsonia*, infallible indices of the Upper Bajocian all over the world, at first led me to assume the age of the *Ermoceras* fauna to be highest Middle Bajocian.

In Sinai there is considerably more evidence. H. Douvillé (1916, p. 9–10) recognized three subdivisions of his Bajocian, but recorded species of *Ermoceras* from both the highest and the lowest, so that for our purpose all three can be considered together. He made no suggestions as to correlation with any particular part of the Bajocian. Besides Arabian ammonites already discussed, and a few others not yet found in Arabia or anywhere else, Douvillé figured the following species from the Bajocian of Gebel Maghara, Sinai. I append notes on their stratigraphical range in Europe. (Beds 1, 2, 3, refer to Douvillé's lower, middle, and upper subdivisions.)

Holcophylloceras mediterraneum (Neumayr). Bed 3. Abundant and long-ranged from the Bathonian upwards, but has been recorded in south-east Europe from the Bajocian.

Calliphylloceras disputabile (Zittel). Bed 3. Widespread and abundant from the Bathonian upwards but not known earlier.

Lytoceras adeloides (Kudernatsch). Bed 3. Mainly Bathonian and Callovian.

Spiroceras bifurcatum (Quenstedt) (Douvillé, pl. iii, figs. 10–14). Bed 3. Special to the Subfurcatum and Garantiana Zones.

Lissoceras oolithicum (d'Orbigny). Bed 3. Commonest in the Upper Bajocian but possibly also occurs in the Middle in Dorset.

Oppelia cf. *subradiata* (Sow.). Bed 3. The nearest forms (though not identical) are those from the Garantiana Zone and Truellei bed of Dorset.

Oecotraustes angustus Douvillé. Bed 3. The earliest known forms of this group are from the Subfurcatum Zone.

Leptosphinctes cf. *tenuiplicatus* (Brauns) (Douvillé, pl. i, figs. 1, 2) (based on Schloenbach's pl. xxix, figs. 2*a*, 2*b* only). Bed 2. Special to the Upper Bajocian and not known earlier.

In addition, Douvillé recorded a *Cadomites* (pl. i, fig. 6) from bed 2, and *Stephanoceras arabicum* (pl. i, fig. 9) and *Normannites* sp. (pl. i, figs. 11, 12) from bed 3. He published no measurements or detailed succession.

In April 1942, geologists of the Standard Oil Company of Egypt measured a profile at Gebel Maghara and collected fossils from numbered beds. Through the kindness of Dr R. W. Imlay and the Smithsonian Institution, Washington, I have been sent on loan the ammonites from the Bajocian part of the column, and the unpublished detailed profile and records. (Appendix, p. 306.) These confirm Douvillé's succession in some respects, notably in the occurrence of *Leptosphinctes* cf. *tenuiplicatus* (as figured by Douvillé) with and also many metres below species of *Ermoceras*. Not all the forms figured by Douvillé are represented in the new collection, but it contains several new forms, including a new genus, unknown to Douvillé. These are described and figured in the appendix (p. 306).

Samples 21077 A–21083 (representing 148 m. of strata) with *Ermoceras* and *Magharina* can only be dated to Upper Bajocian failing evidence to the contrary, despite the absence of *Strenoceras*, *Garantiana*, and *Parkinsonia*. This leaves 115 m. for the Middle Bajocian down to sample 21074 which is Sauzei Zone, above the immense gap of 558 m. down to sample 21053 which seems to be Aalenian (Jurense or Murchisonae Zones). This conclusion is inconsistent with the evidence of the date of *Ermoceras* in Arabia, where the associated ammonites indicate late Middle Bajocian. Possibly the explanation is that the *Ermoceras* fauna lived in the interval between Middle and Upper Bajocian, which in many parts of Europe was a time of earth-movements and erosion, and is always indicated by a faunal break (non-sequence). This was the period of the Bajocian denudation of Buckman.

Fourtau (in Hume and others, 1921, p. 344) was certainly wrong to move the *Ermoceras* beds of Sinai up into the Bathonian. The only indicators of Bathonian are the two Phylloceratids and the *Lytoceras*, but members of those families are notoriously long-ranged. Everything else known from these beds in Sinai points to early-Upper Bajocian (pre-Parkinsoni Zone). In the same paper (Hume and others, 1921) the Bathonian *Oecotraustes subfuscus* and Callovian *Reineckeia anceps* and a *Quenstedtoceras* (impression) are recorded from Gebel Maghara. These records were apparently taken from Couyat-Barthoux & Douvillé's preliminary paper (1913, p. 267) where they were probably erroneous, for they were omitted by Douvillé in his monograph of 1916. It may be surmised that the *Oecotraustes* was that later figured as *O. angustus* H. Douvillé (1916, p. 15, pl. iii, fig. 6) and called Bajocian, and that the *Reineckeia anceps* was a Bajocian *Ermoceras*.

Middle Dhruma (*ca.* 170 m.). In the north, near Juraifa, the following succession was determined by Dr Bramkamp in units 5, 6, 7 (see above, p. 248):

(Top)

Micromphalites fauna	3·3 m. with *Micromphalites* cf. *busqueti*, *M. elegans*, *M. clydocromphalus*. 3·6 m. without ammonites. 7·4 m. with many *Micromphalites*, mainly preserved as chocolate-coloured casts: *Micromphalites* cf. *busqueti*, *M. elegans*, *M. clydocromphalus*, *M. intermedius*, *M. vertebralis*, *Strungia arabica*. 2·0 m. red clay, main *Micromphalites clydocromphalus* horizon; also *Micromphalites* cf. *busqueti*, *M. elegans*, *M. intermedius*.
	3·0 m. without ammonites.
Tulites fauna	12·0 m., mainly white limestones, with *Tulites arabicus*, *T. tuwaiqensis*, *T. erymnoides*. 20·0 m. without ammonites.
Thambites fauna	7·5 m. with *Thambites planus*, *Bramkampia steinekei*, and fragmentary Perisphinctaceae. 45 m. without ammonites.

(Base at top of the *Ermoceras* zone)

Thus these three units comprise three distinct successive ammonite zones, characterized by the genera *Thambites*, *Tulites* and *Micromphalites*. Finds in more southerly localities bear out this succession.

The *Thambites* fauna, being entirely new, cannot yet be dated, though by stratigraphical position presumably it is Lower Bathonian or between that and Upper Bajocian.

Tulites in Europe is essentially Middle Bathonian, and this seems likely to be its date in Arabia also, although the species are different.

Micromphalites in England is also Middle Bathonian; but the only English species, *M. micromphalus* (Phillips), occurs exclusively in the Stonesfield Slates, where it is associated with rare *Tulites* but is below the main *Tulites* horizon (see Arkell 1951, p. 45). In the Nièvre, on the other hand, the horizon of *Micromphalites busqueti* was stated to be the ferruginous oolite of Saint-Benin d'Azy, where it is associated with *Zigzagiceras*, *Morphoceras*, and other typical ammonites of the Lower Bathonian. If there was no mistake in recording the unique holotype of *M. busqueti* in France, and if it turns out on investigation to be identical with the Arabian species here compared to it, there is in Arabia an inversion of faunas. Rather than accept this conclusion it is better to assume provisionally that the unique holotype of *M. busqueti* really came from a higher bed than de Grossouvre supposed.

In the highest unit (8), the only ammonites found (all near the top) are the giant oxycones *Dhrumaites*. Being a new genus they cannot be dated *per se*, but since they resemble no known ammonite among the world-wide and richly fossiliferous Lower Callovian faunas, and fit best into the Bathonian family Clydoniceratidae, they are considered to be Upper Bathonian.

Upper Dhruma (86 m.). The lamellibranchs and brachiopods of the Upper Dhruma are of special interest. *Gryphaea costellata* Douvillé occurs in both subdivisions and is especially abundant about the middle. With it occur *Eligmus rollandi* Douvillé (with var. *jabbokensis* Cox), *Eudesia cardium* (Lam.), and *E. cardioides* Douvillé. This is the '*Eligmus* fauna' (Weir, 1929) of Sinai, Palestine, and Somaliland. Cox (1935, p. 149) has called *Gryphaea costellata* 'a reliable index-fossil of the uppermost Bathonian and Callovian', but the same cannot be said of *Eligmus rollandi*, since in Arabia it also occurs with the *Tulites*, *Thambites* and *Ermoceras* faunas. *Gryphaea costellata* begins in the *Micromphalites* fauna and ranges up to reach its maximum abundance in the Upper Dhruma, as Dr Bramkamp demonstrated to me in the field in several places many miles apart.

On the evidence from Arabia and Sinai there is no reason for dating the *Eudesia-Eligmus-G. costellata* beds to any stage but the Upper Bathonian. H. Douvillé, (1916, p. 39; 1925, p. 304) divided them between the Upper Bathonian and Lower Callovian, but the ground for that seems to have been his misinterpretation of *Micromphalites pustuliferus* as a Callovian *Phlycticeras*. This was the only ammonite obtained from the upper part, and it indicates a Bathonian date. Douvillé himself (1916, p. 39) had doubts, for he remarked that it 'could still belong to the Upper Bathonian.'

The only other ammonite from these *Eudesia-Eligmus* beds of Gebel Maghara figured by Douvillé is the Upper Bathonian *Clydoniceras orientale*, which unfortunately was not found *in situ*. Recognizing it to be Bathonian, Douvillé assumed that it came from an earlier horizon than *Micromphalites pustuliferus*, and therefore from the lower part of the beds.

In British Somaliland the brachiopods and corals associated with *Eligmus* are said to be of Callovian and later types, but no ammonites have been found. In Madagascar it occurs with Lower Callovian ammonites (Barrabé 1929, p. 115).

Tuwaiq Mountain Limestone (*ca.* 215 m.)

All the ammonites found have been in the lowest 40 to 50 m., the basal soft chalky beds. They comprise species of *Erymnoceras*, with *Pachyceras* and a nucleus of *Subgrossouvria*? These were the beds from which Philby obtained the first Jurassic fossils collected in Central Arabia, at the Haisiya Pass, the ammonites identified as *Erymnoceras* sp. by Spath (Cox 1933). The age of the fauna is Middle Callovian, corresponding to the Coronatum Zone of north-west Europe and the Anceps Zone elsewhere. *Erymnoceras* also occurs in Syria and the Caucasus, and limestones with *Pachyceras* are recorded at Gebel Maghara in Sinai, underlying fossiliferous Lower Oxfordian (and Upper Callovian?) marls (H. Douvillé, 1916, p. 70, pl. viii, figs. 4, 5; and 1925, p. 304).

Hanifa formation (101 m.)

Evidence of age is so far inadequate. The only ammonite fragment found compares perhaps best with *Perisphinctes africanus* Dacqué, a form from Mombasa, of Upper Oxfordian age (Plicatilis Zone).

Jubaila limestone (110 m.)

Perisphinctids found in the lower part of the formation and near the middle belong to the group of '*Planites*' *progeron* von Ammon and can be dated with some confidence to the lowest of Oppel's zones of the Kimeridgian, the Tenuilobatus Zone of central Europe (equivalent to the Mutabilis and perhaps Baylei Zones of north-west Europe). A possible *Lithacoceras* points to approximately the same date.

5. Palaeogeography

During the Jurassic period Egypt south of latitude 28° 40′ N., namely about the latitude of the Monastery of St Paul and the South Galala plateau, with central and south Sinai, formed part of a landmass which was continued eastwards across the Red Sea to include most of the area now occupied by crystalline rocks in western Arabia. In Sinai, Egypt, and the Sudan the crystalline basement complex is either bare or overlain directly by Nubian Sandstone, from which there has been obtained no evidence for any period between Palaeozoic (in the south-west Libyan Desert, the Egyptian Wadi Araba, Sinai and Central Nejd) and Cretaceous (see Arkell 1951 *a*). Such scanty evidence as there is for age points to the true Nubian Sandstone of Nubia being Cretaceous and probably Upper Cretaceous. It rests on a peneplaned surface of the Pre-Cambrian. (For recent discussions of the Nubian Sandstone see Beadnell 1927, pp. 136–8; Sandford 1935; Andrew 1937; Shukri & Said 1944–6.)

It was around the shores of this crystalline land-mass, the Arabo-Nubian shield or massif (figure 11), that were deposited the Jurassic rocks of North Galala on the west coast of the Gulf of Suez, Gebel Maghara in North Sinai, Gebel Kurnub and the Jordan valley in Palestine, and Jebel Tuwaiq in Arabia. The Yemen, Aden, and Hadramaut Jurassics were deposited in a shallow seaway communicating with those of Somaliland and Abyssinia, between the Arabo-Nubian massif and a second massif, the Arabo-Somali, which covered eastern Somaliland, Sokotra, and the coast of the Hadramaut (see Lees 1931, map, p. 267; and Picard 1939, map, p. 417). The gap in the Jurassic outcrops across northern Arabia, from the point, north-west of Riyadh, where the limestones of the Jebel Tuwaiq seem to wedge out under the Dahna, to the inliers near the Dead Sea and Jordan valley (a gap of at least 1000 km.; see Lamare's map, 1936), is presumably due to overlap by the Cretaceous Nubian Sandstone. Strong indications of this are given by the outcrop that crosses central Sinai, mapped and studied by Beadnell (1927). Here true Nubian Sandstone, like that seen overlying marine Oxfordian and Kimeridgian at Gebel Maghara, marine Bathonian at North Galala (Sadek 1926), and marine Carboniferous in the Egyptian Wadi Araba and west Sinai, rests on the peneplaned crystalline basement complex and is overlain disconformably by marine Cenomanian. In other words, the Arabo-Nubian massif of the Jurassic extends farther north than appears, and its fringing garland of epicontinental marine Jurassic sediments is hidden beneath the Cretaceous, which hereabouts has not been stripped off by denudation. How far it extended is a matter of conjecture; perhaps to the head of the Persian Gulf as suggested by Lees (1931, map, p. 267).

Marine Trias is known in the Araif-al-Naga dome close to the Sinai-Palestine frontier (Awad 1945) and in Transjordan (Cox 1932), and Dr Bramkamp and other Aramco geologists have now found it west of Jebel Tuwaiq. Whether the Triassic marginal transgression extended farther than any in the Jurassic, as suggested by Lees' map (1931), is doubtful, since the relative positions of the Triassic and Jurassic outcrops are as would be expected to result from denudation of a succession of marginal deposits shelving off a raised landmass.

Within the Jurassic, however, three main transgressive periods are noticeable. The first was Lower Toarcian and lasted till the Bajocian; the second was Bathonian; the third Upper Jurassic.

The first or Lower Toarcian transgression is known only in the Jebel Tuwaiq and is a new discovery. It is distinguished by the *Bouleiceras* and *Spiriferina* fauna. The occurrence of this fauna in Baluchistan and Madagascar, but not in Yemen, Somaliland, Abyssinia, or East Africa, proves an open seaway to the Jebel Tuwaiq round the east and north of the Arabo-Somali massif. Perhaps the fauna will be found one day in the intractable Musandam Limestone of Oman. If Deleau's record (1941) is correct, *Bouleiceras* was able to travel through the hidden outcrop north of the Great Nefud and across Syria and the eastern Mediterranean to Algeria. The possibility that this marine horizon exists under Gebel Maghara cannot be excluded. At least in the Bajocian there must have been direct connection along this route from Gebel Maghara to Jebel Tuwaiq, as is proved by the identical and highly peculiar ammonite fauna (*Ermoceras* and *Thamboceras*).

The Bathonian transgression was more widespread and its products are known in many places. It is only in the Jebel Tuwaiq and Gebel Maghara, however, that ammonites have been found. As in Europe, ammonites were rare in the Bathonian except at certain periods and in certain places. The more common facies was rapidly accumulated and abounds in brachiopods and lamellibranchs, many of them identical with or closely allied to European species. These beds are described from the foot of the North Galala plateau on the west coast of the Gulf of Suez (Sadek 1925, 1926; Farag 1948), from Gebel Maghara (H. Douvillé 1916; Moon & Sadek 1921), the Jordan valley (Cox 1925; Blake 1935; Avnimelech 1945), British Somaliland (Cox 1935; Muir-Wood 1935, and others; Weir 1929), Jubaland (Weir 1929; Venzo 1949) Kenya (Weir 1938), and Madagascar (Barrabé 1929). In several places they are the first definite marine Jurassic strata: this applies to Galala, the Jordan valley, Jubaland, S.W. Madagascar, parts of Tunisia, and Cutch.

The Bathonian transgression seems to have opened up a direct seaway from Central Arabia to Somaliland and Kenya, between the Arabo-Nubian and Arabo-Somali massifs. Such direct connexion across Central Arabia from Somaliland to Palestine was inferred for the Oxfordian by Dacqué (1909, pp. 170, 183–4), for the Upper Jurassic in general by Reck & Dietrich (1923, p. 189) and for the Bathonian by Gregory (1925, pp. 4, 7) and Weir (1929, p. 3). Lamare (1936, p. 51) called this seaway the trans-Erythraean trough. Spath (1933, p. 834) thought it 'an unnecessary assumption', but it has now been satisfactorily established, and it renders unnecessary his alternative assumption (rightly dismissed by Dacqué in 1909, p. 184) of a seaway across north-east Africa, i.e. over the Arabo-Nubian massif, or, as Hoppe thought (1922, pl. vi), through the Red Sea (see sketch-map, figure 11).

Finally, in the Upper Jurassic there was a further transgression. Dr Bramkamp's work shows that in Nejd it began with the Middle Callovian; but in many places it reached its

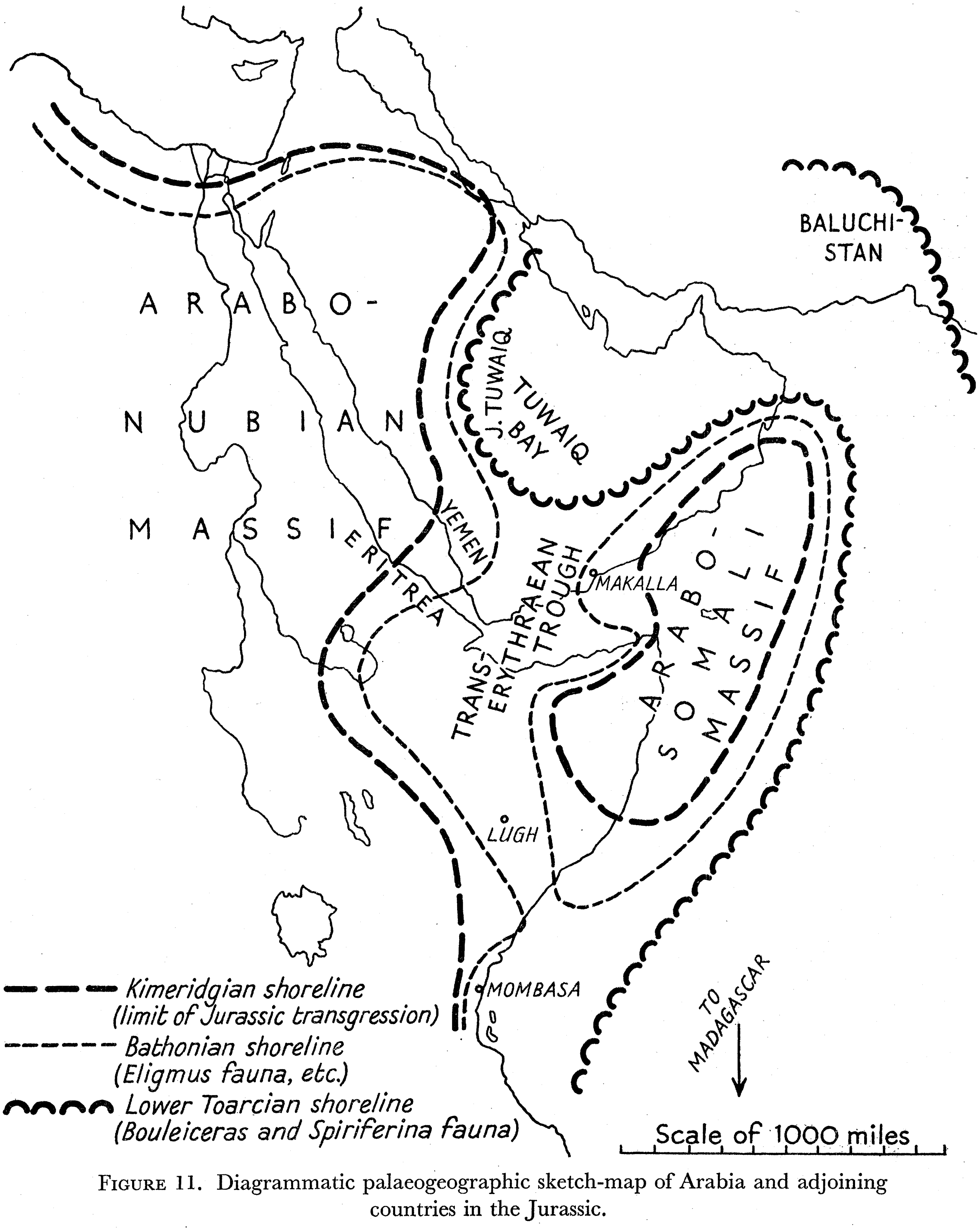

FIGURE 11. Diagrammatic palaeogeographic sketch-map of Arabia and adjoining countries in the Jurassic.

maximum in the Lower Kimeridgian. It widened the trans-Erythraean trough, spreading the first marine faunas (Lower Kimeridgian Amran Limestone) over the plant-bearing Kohlan Sandstones in the Yemen (Lamare 1930), and over the crystalline basement complex near Makalla (Little 1925). It the north, in Egypt, as shown in the sketch-map (figure 11), the Kimeridgian does not extend so far on to the massif as the Bathonian, but this may be due to Cretaceous tilting, erosion, and overstep; for in the Araif-al-Naga dome, near the Sinai-Palestine frontier, early-Cretaceous folding caused Cretaceous Nubian Sandstone to overstep unconformably on to Trias, in an area where it is probable that much of the Jurassic system formerly existed.

The conclusion that the Trans-Erythraean trough was first established in the Bathonian is at present inferential, since no Bathonian has yet been reported in southern Arabia. The Bathonian in British Somaliland, however, is thin, late, and hardly distinguishable from the Callovian, and its equivalents in southern Arabia may be still undetected, or may have been eroded during the Callovian movements. The presence of *Eligmus rollandi* and *Gryphaea costellata* at the base of the Bihendula marine section in British Somaliland demands that there must have been a direct connexion with Central Arabia as Weir inferred, even if very narrow and certainly shallow.

At all times the Jurassic Tuwaiq bay and Trans-Erythraean trough in Somaliland, Abyssinia and Jubaland were shallow neritic seas.

6. Evolution

Assuming, as we must, that the collections (although far from exhaustive) are representative of the principal assemblages present in the area, the Lower and Middle Jurassic ammonite faunas of central Arabia stand out as some of the most peculiar and interesting in the world. They qualify for this distinction almost as much by what is missing as by what is present.

Students of the Jurassic recognize certain ammonite faunas as of world-wide extent and great abundance, others as restricted in distribution and rare. There are degrees of abundance and extension, but the following faunas are the most notable and dominant, at least in the Old World:

(1) The Sinemurian Arietitidae and Oxynoticeratidae, which occur throughout Europe and in North Africa, Asia Minor, the Himalayas, in the Far East, North and South America, and Mexico.

(2) The Lower and Middle Toarcian Dactylioceratidae, which abound throughout Europe and North Africa and as far afield as East Central Asia, Japan, Indonesia, New Zealand, western Canada, and Oregon.

(3) The Middle Bajocian Stephanoceratidae, abundant from the north of Scotland to the Sahara, and from Spain through the Caucasus and South Russia to Tibet, the East Indies, and Western Australia, and from British Columbia to Peru.

(4) The Upper Bajocian Parkinsonidae (*Garantiana* and *Parkinsonia*), ubiquitous in Europe and extending through the Caucasus and Donetz Basin and North Persia (Elburz Mountains) to East Central Asia.

(5) The Lower Bathonian assemblage of the Zigzag Zone, comprising the genera

Morphoceras, *Zigzagiceras*, *Oxycerites* and others, which abound from southern England to Algeria and from western France to northern Persia and perhaps also occur in the East Indies.

(6) The Lower Callovian Macrocephalitidae of the Macrocephalus Zone (the first zone of the Upper Jurassic), which abound all over Europe and much of Asia, from Siberia to Georgia and India, and in East Africa, Madagascar, the East Indies, New Guinea, Alberta, and the Andes.

In Central Arabia a few Stephanoceratidae (no. 3) are all that has been found of these cosmopolitan faunas. Instead there is a succession of peculiar and recondite ammonites which are difficult to fit into the standard sequence and at first sight might have been collected on another planet.

The first marine Jurassic invasion brought, not one of the well-known Liassic assemblages, but the highly peculiar *Bouleiceras* of Madagascar and Baluchistan, with their attendant *Spiriferina*.

There follow two links (separated by a wide stratigraphical gap) with cosmopolitan faunas: first the genus *Hildaites* found in Europe and Japan; later the genus *Dorsetensia*, which has almost the same extension as *Stephanoceras*, from Europe to Western Australia and in East Africa. Both these genera, however, are represented in the Arabian collection only by new species or species otherwise peculiar to Madagascar, and the *Hildaites* is accompanied by the new genus *Nejdia*.

Then with only a trace of the cosmopolitan fauna familiar for the Bajocian comes the *Ermoceras* fauna hitherto known only in Sinai. With it in both Sinai and Arabia is the problematic genus *Thamboceras*, known nowhere else. S. S. Buckman would certainly have taken the view that this represents a new zone, missing from the standard European sequence.

Next on the scene in Arabia is not the Lower Bathonian Zigzag Zone assemblage, recorded along the north, in the Armenian borderlands (Julfa Gorge) and the Elburz mountains of north Persia, as well as in North Africa, but the entirely new *Thambites*, followed by rare genera of the Middle Bathonian, hitherto thought to be restricted to Europe, where they are local, often rare, and more often absent. For the Upper Bathonian there is only another new genus, *Dhrumaites*, unlike anything yet reported from other parts of the world.

Above the Upper Bathonian we should expect to find the cosmopolitan Lower Callovian faunas, especially the *Macrocephalites* of the Macrocephalus Zone, for they virtually encircle Arabia, running from Europe through the Caucasus into Baluchistan and Cutch, and abounding in the East Indies, in Madagascar, and East and North Africa. But there is no Lower Callovian ammonite in the collections from either Jebel Tuwaiq or Sinai. The next genera found are the much less widespread *Erymnoceras* and *Pachyceras* of the Middle Callovian.

Thus the ammonites of Central Arabia and Sinai are a selection of the less likely assemblages. Many have in common another characteristic besides this unexpectedness, namely, a tendency to possess degenerated suture-lines. Of the total number of known Jurassic genera with markedly pseudoceratitic or clydoniceratid suture lines, all the most remarkable, and a high proportion of the total, are represented in the collections from

Arabia and Sinai. The most remarkable of all are *Bouleiceras* and *Nejdia*, and in these assemblages there are no ammonites with normal sutures; even the externally typical-looking Harpocerataceae have degenerated sutures. Higher up there are the remarkable genera *Thambites* and *Bramkampia*, the latter with sutures like Cretaceous pseudoceratites. All these forms and some others, such as *Tulites*, show also a tendency to early loss of ribbing, resulting in a general smoothness.

In Europe, the Middle and Upper Bathonian ammonites with degenerated sutures (*Clydoniceras*), smooth whorls (*Clydoniceras, Tulites, Morrisiceras, Procerites*) and contracted body-chambers (*Tulites, Bullatimorphites* and others) are racially senescent (Arkell 1951, pp. 3–4). The Middle and Upper Bathonian was a period of gerontomorphosis, when the evolutionary forces were temporarily checked and turned in, as it were, upon the individual. No new and virile stocks arose at this time whose descendants would mould the shape of future faunas. The Middle and Upper Bathonian ammonites with their physical peculiarities were mostly the last of their lines, and they inhabited a restricted area. All this contrasts with the Bajocian and Lower Callovian, which were times of paedomorphosis, or evolutionary virility and enterprise, world-wide colonization by the race, and vigorous shell-formation by the individual.

Arabia, therefore, with Sinai, during the Lower and Middle Jurassic formed part of a region where the periods of ammonite colonization seem to have alternated with those in other regions. The normal invaders of most parts of the world were excluded; ammonites that are among the least conspicuous elsewhere entered and flourished, producing extraordinary aberrant forms. This curious fact suggests that Arabia formed part of a region which had a tectonic history opposite or complementary to that normal for the better-known sedimentary basins of the world in the Jurassic. Transgressions round the Arabo-Nubian massif and into the Tuwaiq bay perhaps coincided with regressions in the old classic regions of Europe and elsewhere.

The Middle East was a region also characterized by pseudoceratites in the Cretaceous. In fact all the Cretaceous ammonites so far collected by the geologists of the Arabian American Oil Co. in Central Arabia are pseudoceratites. Mr C. W. Wright has identified them with various genera ranging from Albian to Maestrichtian. The pseudoceratites of Egypt and Sinai belonging to these periods have long been known. Mme Basse (1940), in describing those of the Albian of Syria and the Lebanon, attributes their distribution to climatic causes. She regards them as inhabiting a narrow belt round the earth, corresponding to the Albian equator. But the supposed equatorial belt delineated (Basse 1940, maps pp. 464–465) is extremely narrow, and Mr Wright has pointed out that other groups of pseudoceratites are found far outside it in many parts of the world.

It is quite possible, even probable, that the Jurassic pseudoceratites and other peculiar ammonites here described from Jebel Tuwaiq represent tropical or equatorial faunas, but the absence of the cosmopolitan faunas cannot be accounted for by climatic factors. They occur in other parts of the world irrespective of latitude and in both hemispheres. It seems impossible to reconstruct a Jurassic equatorial zone that excludes them, even by taking full liberties with continental drift. Moreover, judging by the maximum distribution of coral reefs the equator in at least Upper Jurassic times seems to have passed through

Southern Europe, where the Arabian ammonite faunas are conspicuously absent and the normal European faunas are prevalent.

If the degenerated or gerontomorphic character of most of the Lower and Middle Jurassic ammonites that inhabited the Tuwaiq bay is their most conspicuous feature, no less interest attaches to the exceptions. An outstanding exception is the genus *Ermoceras*, which possesses all the vigour of sharp and varied ornamentation and variety of form, combined with numerical abundance, that characterize the Bajocian and Lower Callovian paedomorphic families Stephanoceratidae, Macrocephalitidae, etc., in other parts of the world. Origin of the numerous forms of *Ermoceras* by geographical speciation seems precluded by the continuity of their occurrence along more than 300 miles of outcrop in Arabia and their absence everywhere else but in Central Arabia and Sinai. The Tuwaiq bay and adjoining parts of the shelf sea surrounding this part of the Arabo-Nubian massif seem to have been the sole habitat of the genus; within it they all moved freely; outside it they did not migrate. We cannot assume geographical barriers within the area, so that speciation by physical isolation could take place. Rather the proliferation of forms and numbers seems to have been a spontaneous reaction to a diversified and favourable environment. This would seem to be, in fact, a typical case of explosive evolution in ammonites, such as those to which attention has been called by Schindewolf (1936) and Swinnerton (1938), and presumably to be explained by ecological and genetic speciation (cf. Huxley 1942, chapter 6).

Concerning comparable explosive radiation among the gastropods of south-east Europe during the Neogene, Wenz has made some apposite remarks (in Krejci-Graf & Wenz 1932, pp. 115–117), and I am indebted to Mr R. V. Melville for calling my attention to this analogy. Wenz points out that many striking forms of sculpture may be insignificant from the point of view of the anatomy of the animal as a whole; that however rich collected material may be it is almost impossible to dispose of sufficient quantity to obtain a fairly representative idea of the whole range of forms present in a bed over its whole area of occurrence; and that consequently it is misleading to erect upon such inadequate grounds an elaborate systematic hierarchy. The explosive deployment and equally sudden extinction of the aberrant family of limpet-like Valenciennidae from Limneid pond-snails, all within the geologically brief period of the Lower Pontic beds in the same region, provides another example of the possibilities of molluscan plasticity given the right conditions (e.g. Gorjanovic-Kramberger 1923).

There is a hint as to one possible mechanism of such phenomena in recent observations on butterflies. In isolated groups subject to fluctuation in numbers, variability is greatly enhanced during periods of increasing numbers. In a group observed over a period of 20 years 'an extraordinary outburst of variation took place while the numbers were rapidly increasing, and many of the more extreme aberrations were deformed' (Ford 1949, p. 312). Ford also observed that 'when the population became stabilized again at the new and high value, uniformity was restored, yet the constant form which was then established differed in appearance from that which existed before the outburst of variability'. Huxley (1942) has shown by a wealth of examples that isolation need not be geographical.

If it is a correct hypothesis that *Thamboceras* is connected by way of *Ermoceras inerme* with the *Stephanoceras*-like forms of *Ermoceras*, and if as appears certain *Thamboceras* gave rise to

Thambites and *Clydoniceras*, we have a good example of a cycle of evolution as envisaged by Schindewolf and others: an explosive phase producing numerous species of strongly ribbed and spinous *Ermoceras* (phase of paedomorphosis); then extinction of most of the experiments so produced; followed by a phase of gerontomorphosis in which only smooth oxycones with highly specialized sutures survived. An echo of the same process was repeated with the dominance of *Micromphalites*, with its wide range of forms and styles of ribbing, to be followed by its solitary, simple, smooth oxycone descendant *Dhrumaites*.

The Arabian material provides illuminating examples of the suddenness with which major transformations of characters can take place in the ammonites. A ventral groove which may arise as an occasional abnormal mutation in Stephanoceratidae in various parts of the world appears unannounced as a generic character in all the multitude of forms of Arabian *Ermoceras* and apparently is retained in the surviving oxycones after extinction of the normal forms. The pseudoceratitic sutures of *Nejdia* are particularly illuminating because they show that extreme modification of the whole suspensive part of the suture can occur suddenly and be repeated consistently on one side only of a single individual. Similar mutations, perhaps cumulative, may well account for equally sudden 'degeneration' of the entire suture-line and become fixed in a section of the population by some form of ecological isolation of a group of affected individuals. Our knowledge of the habits of ammonites and of the possibilities for the numerous subtle forms of ecological differentiation provided by the sea bed and the sea in a neritic environment are so rudimentary that we shall long remain in the recording stage and cannot yet aspire to complete explanations such as those attempted by the zoologists for ecological speciation among land faunas. That such speciation occurred cannot be doubted.

Appendix

New genera and species from the Ermoceras Beds of Gebel Maghara, Northern Sinai

A nomenclatural revision of most of the Bajocian ammonites from north Sinai figured by H. Douvillé in 1916 is given above on p. 296, but in addition at least one new genus and two new species are required for his figures. Another new genus and two new species are contained in a small collection from a complete measured section at Gebel Maghara made by geologists of the Standard Oil Company of Egypt in 1942. The geologists were H. W. Haight, K. D. White, E. J. Foley, F. Iskander, and S. Soliman, and I am indebted to Mr Paul Ruedemann for permission to publish. The material is now in the U.S. National Museum at Washington and has been loaned to me through the kindness of Dr R. W. Imlay and the Smithsonian Institution, who have given me permission to make use of it and to publish the relevant part of the measured section. The *Ermoceras* fauna is of special interest in connexion with the subject of this memoir. I am also indebted to Mr M. Attia and Mr G. W. Murray who kindly arranged for me to have photographs, reproduced here (plate 30), of some of the Sinai specimens in the Moon & Sadek collection belonging to the Geological Survey of Egypt, Cairo. For chronological evaluation, see above, p. 296.

Stratigraphical section, Gebel Maghara, Sinai

(Total thickness of Jurassic 1905 m. The author's determinations of ammonites added.)

(Top)

3 m. with *Clydoniceras* and *Oecotraustes* (sample 21089, not seen).

275 m. without ammonites.

1·5 m. with *Magharina* sp.B. and nucleus of Perisphinctid (sample 21083).

11·5 m. without ammonites.

2 m. with *Magharina magharensis* abundant, *Cadomites* cf. *deslongchampsi* (d'Orbigny), *Nannolytoceras* cf. *pygmaeum* (d'Orbigny) (sample 21082).

57 m. without ammonites.

0·3 m. with *Ermoceras mogharense* Douvillé, *Stephanoceras arabicum*, *Trimarginia sinaitica*, *Magharina* sp. C (sample 21081).

62·2 m. without ammonites.

13·5 m. with *Leptosphinctes* cf. *tenuiplicatus* (Brauns) (as figd. by Douvillé), *Ermoceras coronatoides* (Douvillé), *Ermoceras splendens*, *Oppelia* cf. *subradiata* (Sow.), *Normannites* sp. indet. (sample 21077A).

43 m. without ammonites.

13 m. with *Normannites*? sp. indet. (sample 21076).

39 m. without ammonites.

20 m. with *Normannites* cf. *braikenridgii* (J. Sowerby) (sample 21074).

558 m. (sic) without ammonites.

9 m. with a large crushed fragment resembling *Pseudogrammoceras* cf. *muelleri* (Denckmann)? (Jurense Zone), or *Sonninia* cf. *dominans* Buckman? (Murchisonae Zone) (sample 21053).

252 m. without ammonites, to base of section.

Descriptions

MAGHARINA n.gen.

Type species *Magharina magharensis* n.sp. Dwarf keeled oxycones with feeble ribbing and prominent growth-lines, simple sutures, and regular coiling.

Magharina magharensis n.sp., plate 30, figures 7, 8

Material. Twenty-nine specimens.

Horizon. 21082 (see above), with *Cadomites* cf. *deslongchampsi* (d'Orbigny) and *Nannolytoceras* cf. *pygmaeum* (d'Orbigny) (cf. Riche & Roman 1921, pl. vii, fig. 1, from the Zigzag Zone of Crussol). Presumed date Upper Bajocian.

Description. A miniature oxycone with feeble obsolescent fasciculate ribbing, fine but conspicuous and dense growth-lines, strong keel developing gradually on the last $1\frac{1}{2}$ whorls, and simple sutures having broad short lobes, the external lobe hardly differentiated. Maximum size 18 to 20 mm. About $\frac{3}{4}$ whorl of body-chamber. Aperture simple so far as known, but this point not certain. Coiling regular, with no ellipticity and no contraction of the body-chamber. The growth-lines pass over the keel to form delicate chevrons and very fine serrations.

Affinities. The systematic position is problematic, but the genus may perhaps best be placed in Haploceratidae, close to the Bajocian *Cadomoceras*. It differs, however, from *Cadomoceras* in its wide, blunt (instead of sharp, narrow) lobes, regular (instead of elliptic) coiling, and simple aperture. There is considerable resemblance to inner whorls of Oxfordian *Creniceras* and also to Oxfordian *Proscaphites* such as *P. richei* (de Loriol).

Magharina spp.

From horizon 21081, which is 57 m. below horizon 21082 (see above) there are four minute specimens which belong to a different species but are too small to be named or figured. From horizon 21083, which is 11·5 m. above horizon 21082, there is a single wholly septate specimen 10 mm. in diameter which resembles *Magharina* externally but has much less simplified sutures. More material is required of both these species.

TRIMARGINIA n.gen.

Type species *T. sinaitica* n.sp. Tricarinate oxycones with *Oppelia*-like ribbing and regular coiling.

Trimarginia sinaitica n.sp.

Oppelia (*Trimarginites*) *waterhousei* H. Douvillé, 1916, p. 16, pl. iii, figs. 7, 8.

Remarks. This remarkable form, well figured and described by Douvillé, cannot be congeneric with the Oxfordian *Trimarginites* and has no resemblance to *Ammonites waterhousei*, a Middle Bathonian *Oxycerites* described by Morris & Lycett, which has only one keel. It is presumably an Oppeliid, but is new for the Middle Jurassic. In the Washington collection there is a smaller specimen from horizon 21081 (see above), showing the trimarginate venter back to a diameter of 12 mm. and ornamented only with tertiary ribbing like that of *Oppelia* sensu stricto. A specimen at Cairo (Geol. Surv. Mus. no. 16657) is trimarginate to the end at 45 mm. and still septate.

Type. The specimen figured in Douvillé's pl. iii, fig. 7.

Horizon. Presumed Upper Bajocian. A specimen in the Geological Survey Museum, Cairo (no. 16657) is in the same ferruginous preservation as *Thamboceras mirabile* and *Normannites egyptiacus*.

Genus ERMOCERAS H. Douvillé

Ermoceras splendens Arkell (see above, p. 274), plate 30, figure 6

Material. One large specimen.

Horizon. 21077 A, associated with *Ermoceras coronatoides* (Douvillé), *Leptosphinctes* cf. *tenuiplicatus* (Brauns), *Oppelia* cf. *subradiata* (Sow.) and *Normannites* sp. Date presumed Upper Bajocian or uppermost Middle Bajocian, or between the two.

Description. The specimen is 96 mm. in diameter but is incomplete and may have been considerably larger. In form and ribbing it is intermediate between *Ermoceras deserti* Douvillé and *E. coronatoides* (Douvillé). The primary ribs are short but strong and distant, ending in large pointed tubercles on the cast, which represent spines on the test. From each tubercle spring three strong, straight secondary ribs, accompanied by an equal intercalatory in each interspace. The ribs are directed slightly forward and are interrupted by a well-marked ventral groove. The whorl-section is considerably more arched than in *E. coronatoides*, but otherwise the resemblance is close.

Remarks. The Sinai specimen is larger than any in the Arabian collections, but the purple-red band of Juraifa (locality 2) yields fragments intermediate between the Sinai specimen and the inner whorls common in the purple-red band (plate 23, figures 1, 2, 8).

Genus **NORMANNITES** Munier-Chalmas

Normannites egyptiacus n.sp., plate 30, figure 4

Coeloceras braikenridgei H. Douvillé, 1916, p. 26, pl. i, figs. 11, 12.

Description and remarks. This miniature species seems to be new and deserves a name. It is complete at a diameter of 18 to 20 mm., at which size the holotype has part of a broken lappet. The ribs are sharp and strong, regularly biplicate, with occasional simple ribs but no intercalatories, the secondaries widely splayed and inclined to be rursiradiate on the body-chamber. The ribbing shows no trace of interruption on the venter. The whorl-section is rounded.

Type. The specimen in the Geological Survey Museum, Cairo, no. 16685, here figured.

Date. Presumed Upper Bajocian. In same preservation as *Trimarginia sinaitica* and *Thamboceras mirabile*.

Normannites cf. **braikenridgii** (J. Sowerby), plate 30, figure 3

cf. *Otoites braikenridgii* (J. Sowerby) S. Buckman, 1913, ii, pl. lxxxi (holotype refigured).

Material. A perfectly preserved little specimen, 20 mm. in diameter, with test complete.

Horizon. 21074, presumably Middle Bajocian, Sauzei Zone.

Remarks. The specimen is too small for positive identification in the absence of type material at a comparable size, but so far as it goes it is indistinguishable from the holotype of the oft-quoted *Ammonites braikenridgii* Sow., refigured by Buckman (1913) and from a cast by Fallot & Blanchet (1923, pl. xiii, fig. 3), which came from the Sauzei Zone of Dundry Hill, Somerset. Buckman called it an *Otoites*, presumably because of the horizon, H. Douvillé (1916, p. 26) a *Coeloceras*, and Fallot & Blanchet a *Cadomites*; it is a typical *Normannites*.

Normannites densus (Buckman), *N. formosus* (Buckman), and *N. latansatus* (Buckman) (1920, pls. clii, cli, clix), from the Humphriesianum Zone of Dorset, are all less close; the two last have coronate nuclei. The specimens of *N. orbignyi* Buckman from Normandy and Spain (Fallot & Blanchet, 1923, pl. x) are nearer.

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Plate 15

Toarcian ammonites from the Bouleiceras bed, Lower Marrat formation.

Figures

1, 2, 3, 4. *Bouleiceras* sp. or spp., fragments, locality 55. SM. F 10660–3 (p. 261).

5*a*, *b*. *Bouleiceras nitescens* Thevenin, wholly septate; locality 55. SM. F 10664 (p. 261).

6. *Bouleiceras arabicum* n.sp., locality 55. SM. F 10665 (p. 262).

7. *Bouleiceras* n.sp. indet., locality 43. SM. F 10666.

8. *Bouleiceras arabicum* n.sp., locality 55. SM. F 10667 (p. 262).

9. *Bouleiceras elegans* n.sp., nucleus; locality 55. SM. F 10668 (p. 264).

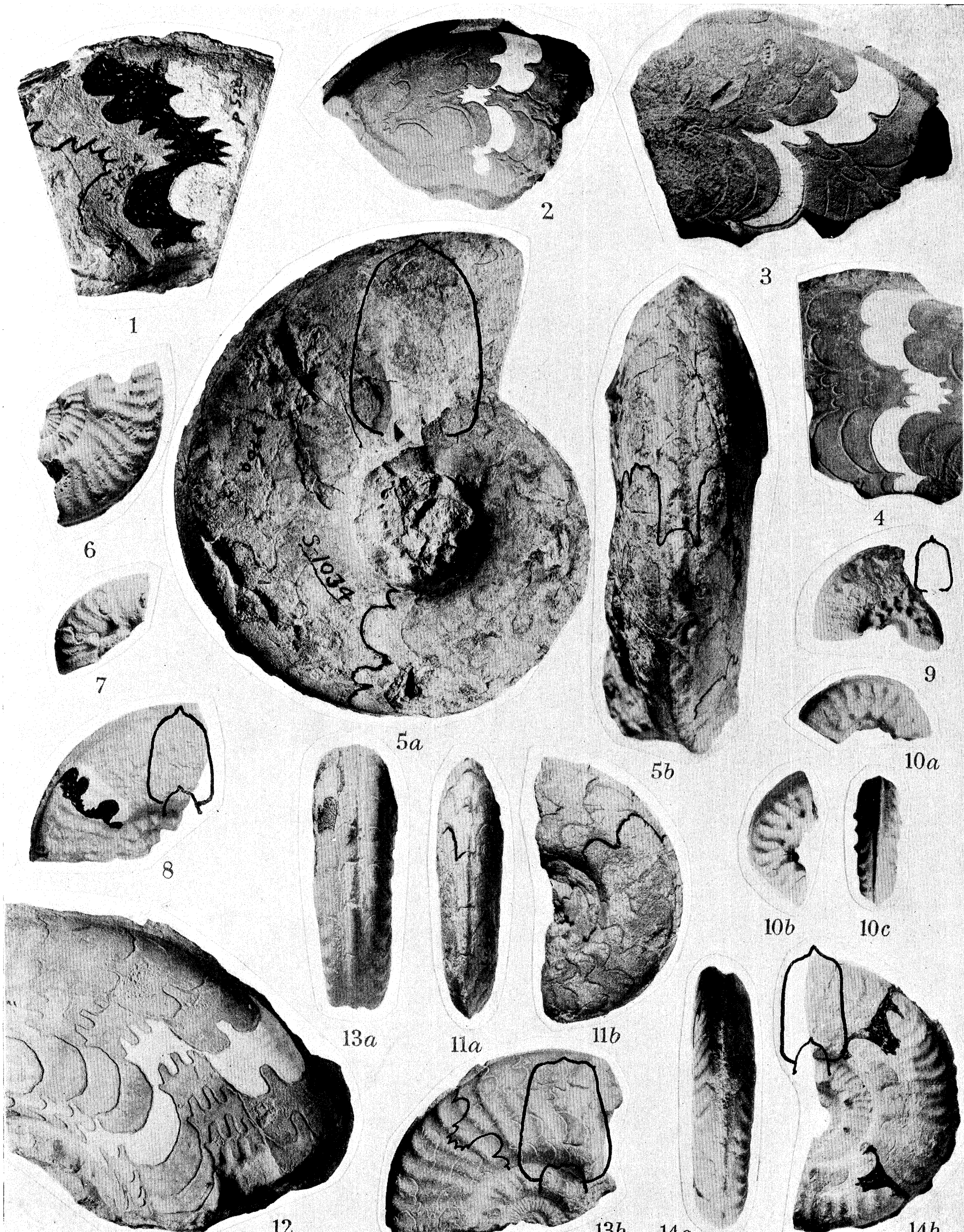
10*a*, *b*, *c*. *Bouleiceras marraticum* n.sp. Holotype, locality 55. SM. F 10669 (p. 263).

11*a*, *b*. *Bouleiceras elegans* n.sp., locality 55. SM. F 10670 (p. 264).

12. *Bouleiceras* sp., fragment, locality 55. SM. F 10671 (p. 262).

13*a*, *b*, 14*a*, *b*. *Bouleiceras arabicum* n.sp., locality 55. Figure 13 SM. F 10672; figure 14 holotype, SM. F 10673 (p. 262).

All figures natural size.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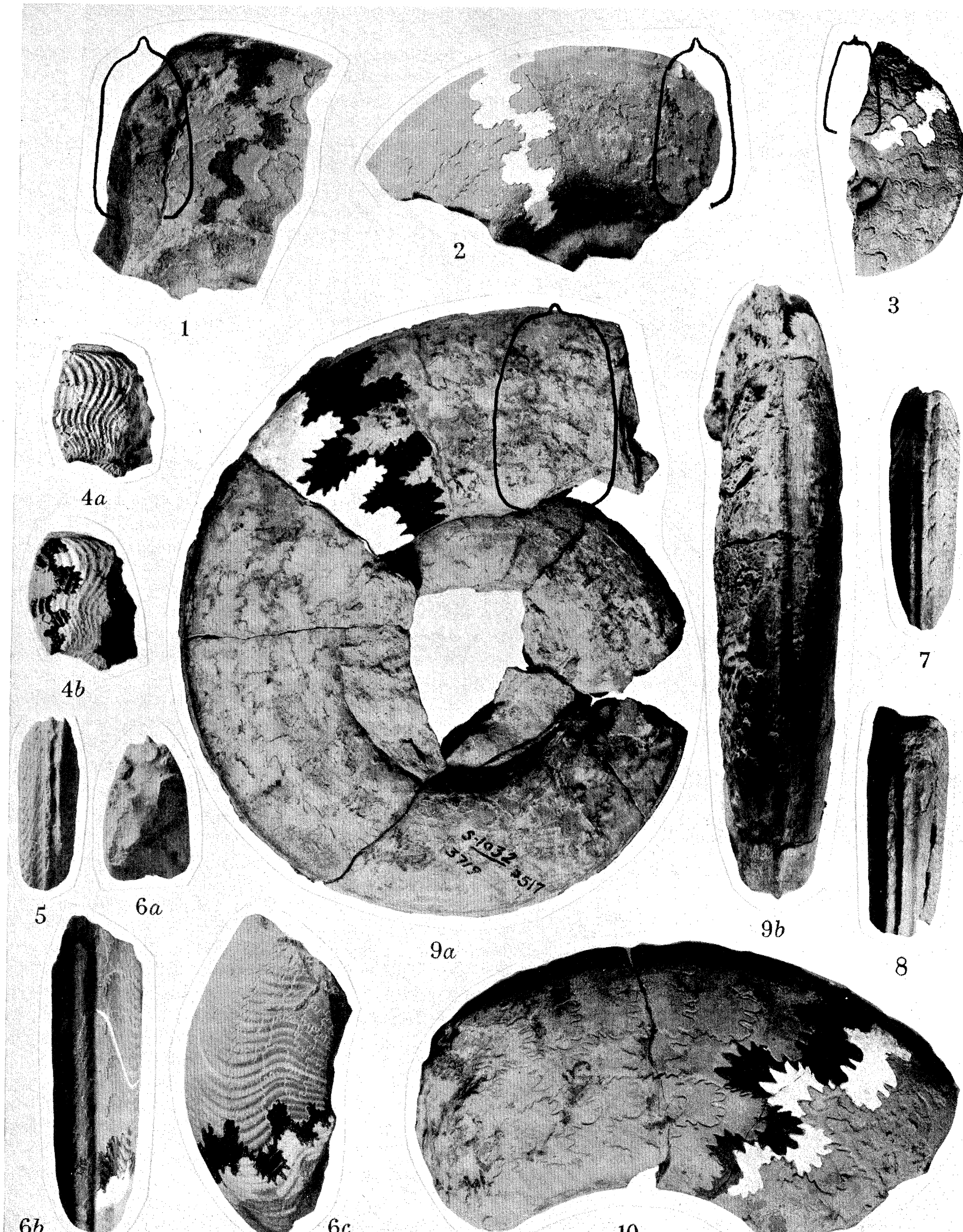
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Plate 16

Toarcian ammonites from the Marrat formation. (Figures 4 to 8 Lower Marrat, the rest Upper Marrat.)

Figures

1, 2. *Hildaites* sp?, fragments, locality 56. SM. F 10674–5 (p. 265).

3. Presumed inner whorls of *Hildaites sanderi*; loose, near locality 56. SM. F 10676 (p. 265).

4 to 8. *Protogrammoceras madagascariense* (Thevenin), fragments from the *Bouleiceras* bed, locality 55. SM. F 10677–10681 (p. 264).

9 *a*, *b*. *Hildaites sanderi* n.sp. Holotype, locality 59. SM. F 10682 (p. 265).

10. *Hildaites sanderi* n.sp., locality 56. SM. F 10683 (p. 265).

All figures natural size.

Plate 17

Toarcian ammonites from the Marrat formation. (Figures 3, 4, Lower Marrat, the rest Upper Marrat.)

Figures

1, 2. *Nejdia furnishi* n.sp., *Nejdia* bed, locality 57. Figure 1, SM. F 10684; figure 2, holotype, SM. F 10685 (p. 268).

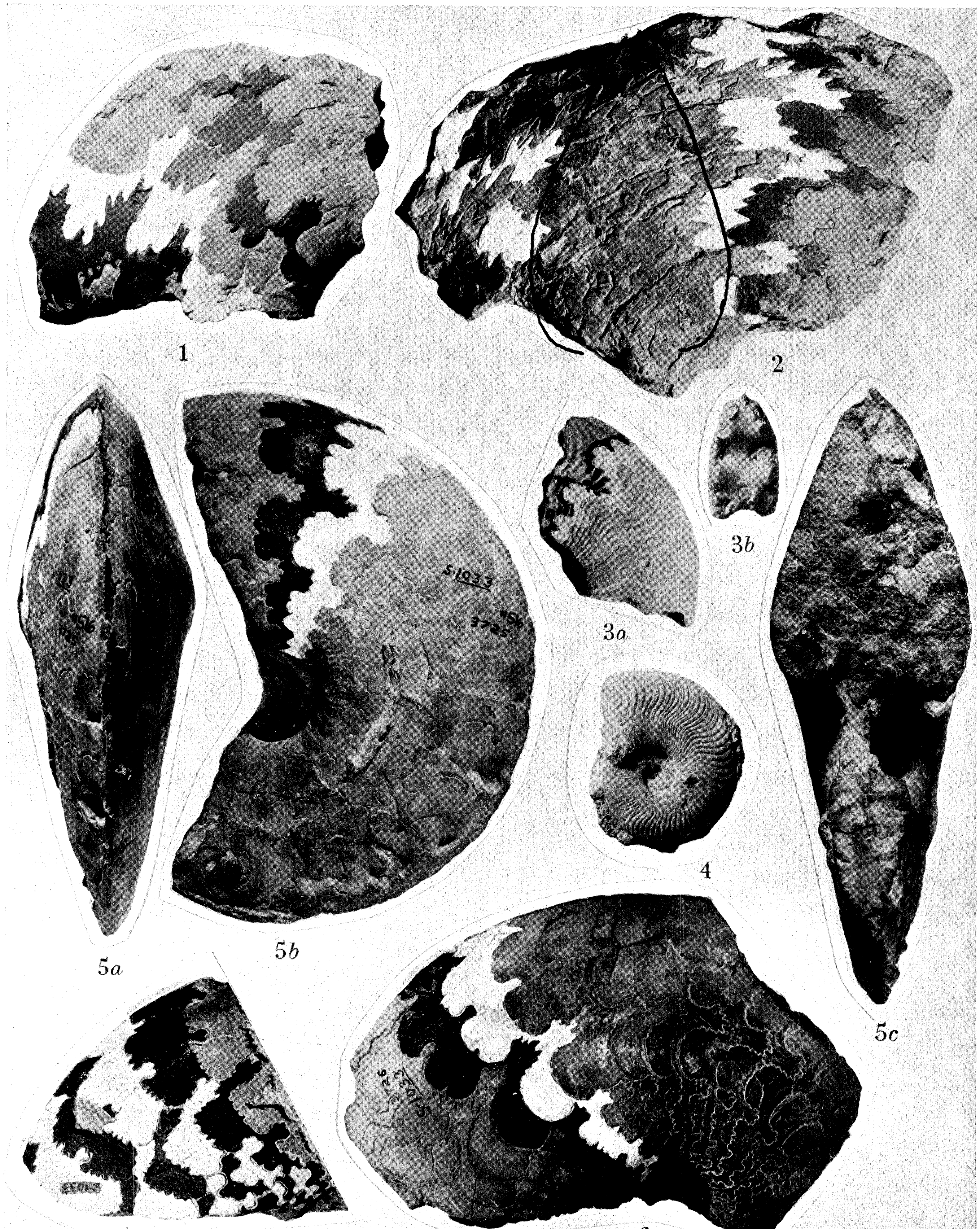
3*a*, *b*, 4. *Protogrammoceras madagascariense* (Thevenin). Bouleiceras bed, locality 55. SM. F 10686–7 (p. 264).

5*a*, *b*, *c*. *Nejdia bramkampi* n.sp. Holotype, Nejdia bed, locality 57. SM. F 10688 (p. 267).

6. *Nejdia bramkampi* n.sp., locality 57. SM. F 10689 (p. 267).

7. *Nejdia bramkampi* n.sp., locality 57; variety with minutely crenulate but straight-ended first and second lateral saddles. Note irregular and aberrant auxiliary lobes. SM. F 10690 (p. 267).

All figures natural size.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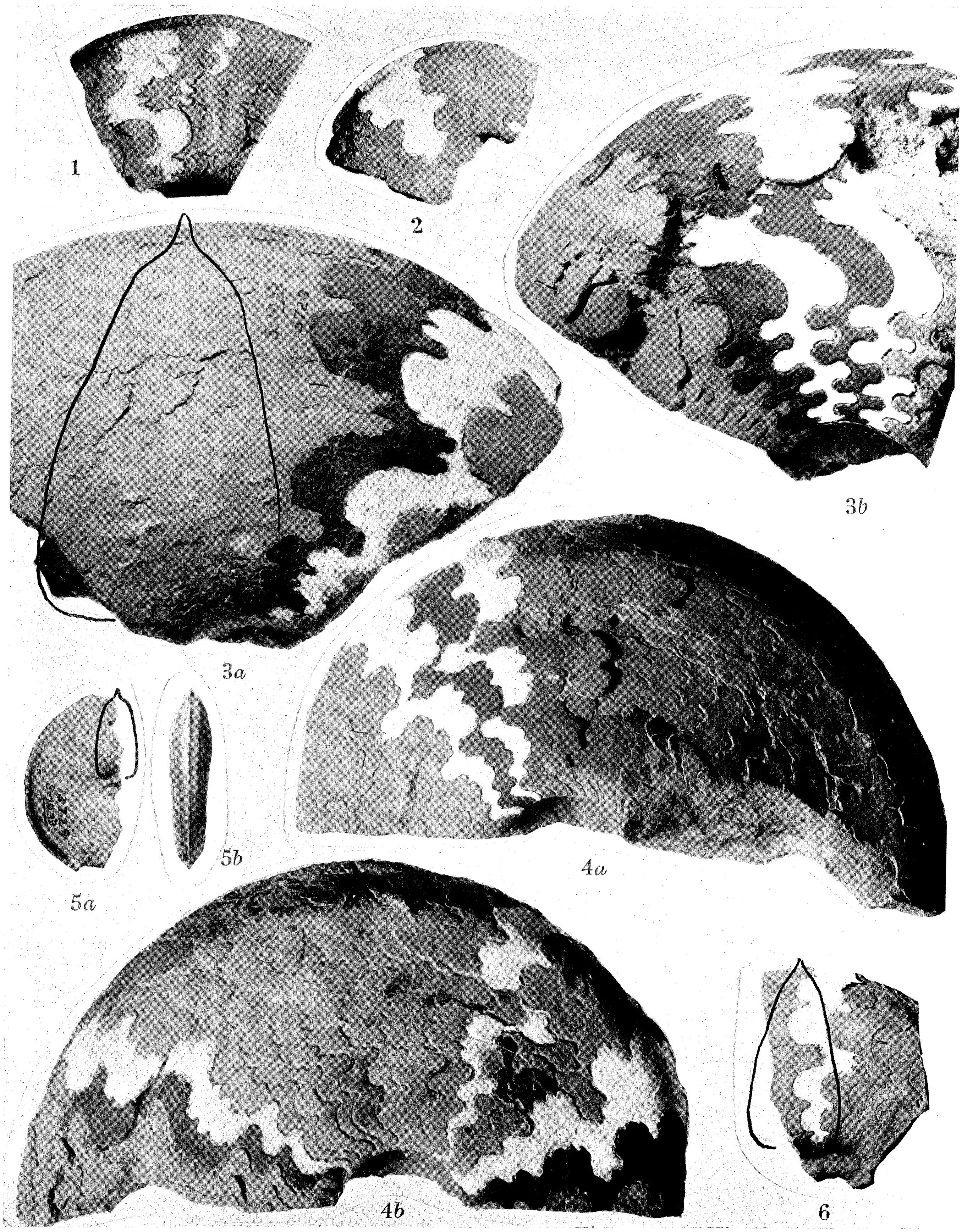
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Plate 18

Toarcian ammonites from the Marrat formation. (Figure 1 Lower Marrat, the rest Upper Marrat.)

Figures

1. *Bouleiceras* sp., locality 55. Fragment showing irregular spacing of suture-lines. SM. F 10691 (p. 262).

2. Fragment, n.gen.?, *Hildaites* bed, locality 56. SM. F 10692 (cf. plate 16, figure 2) (p. 265).

3 *a*, *b*. *Nejdia bramkampi* n.sp. Opposite sides of the same fragment, showing asymmetry and elongation of second lateral saddle (as in *Bouleiceras*) on both sides, and ceratitic suspensive lobe on one side only. Locality 57. SM. F 10693. (Cf. plate 17, figure 7) (p. 267).

4 *a*, *b*. *Nejdia bramkampi* n.sp. Opposite sides of the same specimen, showing different suture-lines on the two sides, especially in the suspensive lobe. Locality 57. SM. F 10694 (p. 267).

5 *a*, *b*. *Nejdia bramkampi* n.sp. Inner whorls from the Nejdia bed, locality 57. SM. F 10695 (p. 267).

6. *Nejdia bramkampi* n.sp. Intermediate growth stage. Nejdia bed, locality 57. SM. F 10696 (p. 267).

All figures natural size.

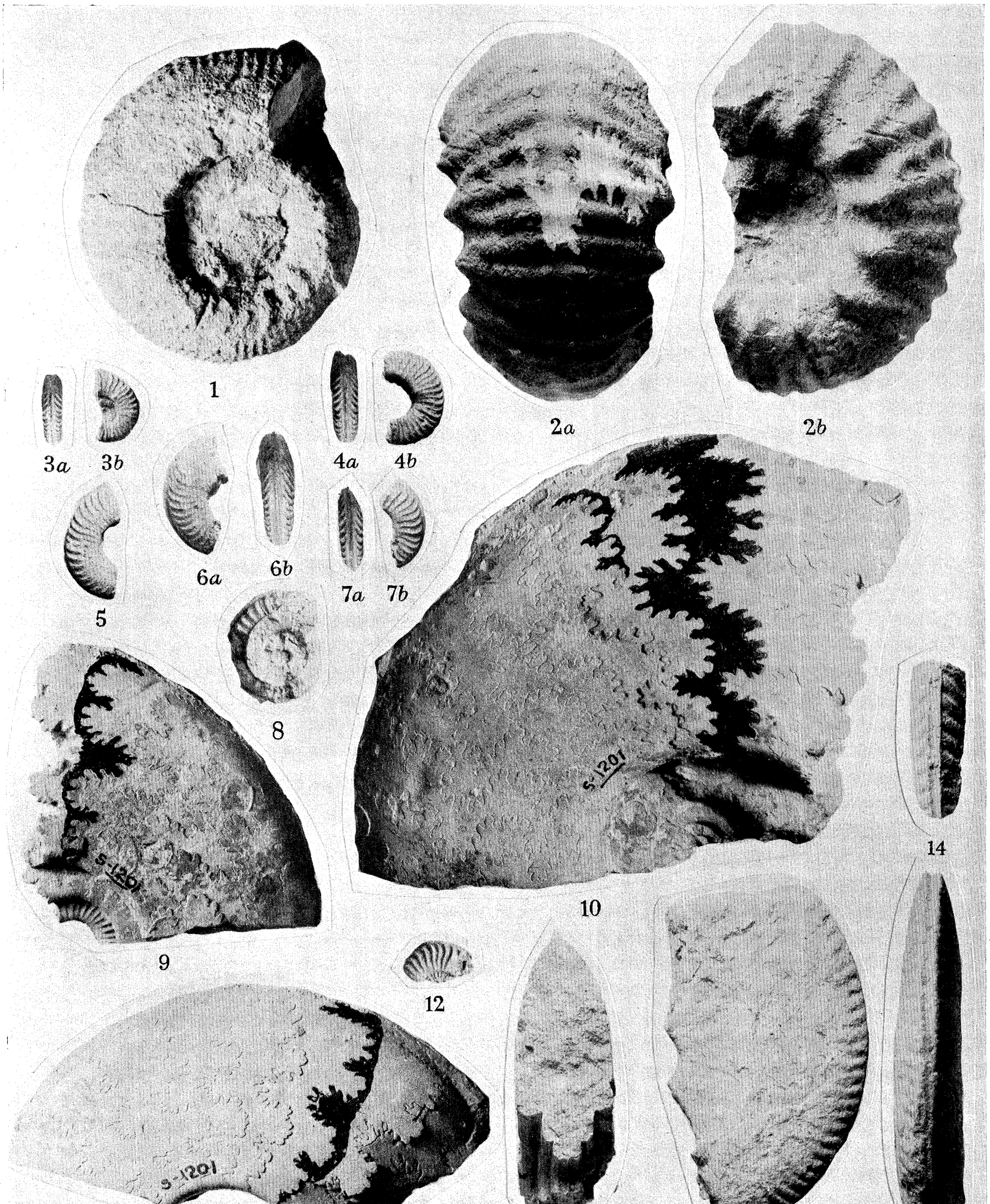
Plate 19

Bajocian ammonites from the Lower Dhruma formation.

Figures

1.	*Stephanoceras* cf. *psilacanthus* Wermbter, Dhibi Limestone, Wadi Birk, locality 62. SM. F 10697 (p. 270).
2 *a*, *b*.	*Ermoceras coronatiforme* n.sp., holotype, brown limestone. Khashm Mawan, locality 68. SM. F 10698 (p. 274).
3, 4, 5, 6, 7, 8.	*Dorsetensia arabica* n.sp., nuclei, Khasm Dhibi area, locality 46. SM. F 10699–10704 (p. 269).
9, 10, 11.	*Dorsetensia arabica* n.sp., fragments. Figure 10 holotype. Khashm Dhibi area, locality 46. Note ribbed nucleus in figure 9, resembling figures 7 and 12. SM. F 10705–7 (p. 269).
12.	*Dorsetensia arabica* n.sp., locality 46. SM. F 10708 (p. 269).
13 *a*, *b*.	*Thamboceras mirabile* n.sp., Dhibi Limestone, Dhruma area, locality 36. SM .F 10709 (p. 278).
14.	*Thamboceras mirabile* n.sp., fragment from the purple-red band near Juraifa, locality 2. SM. F 10710 (p. 278).

All figures natural size.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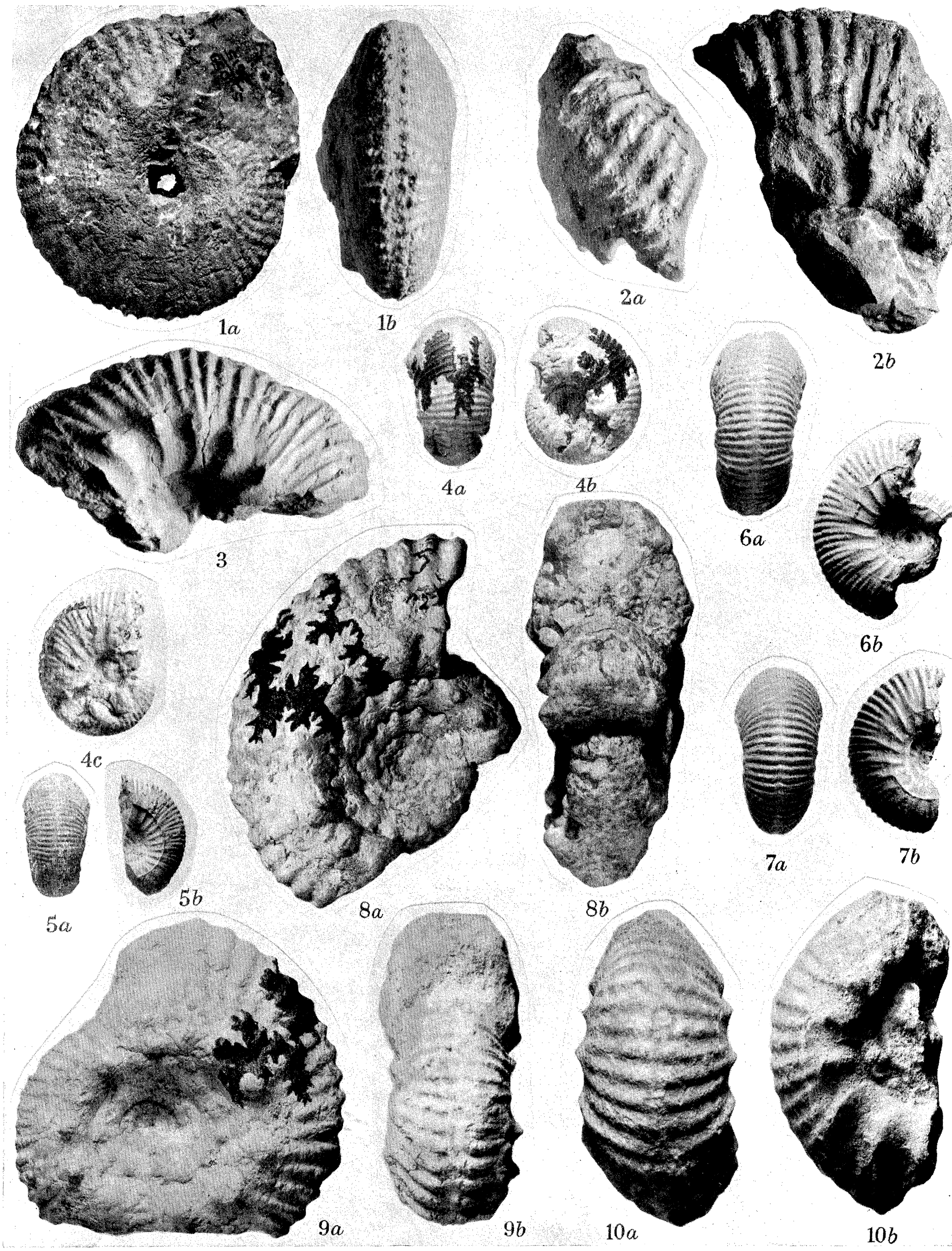
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Plate 20

Bajocian ammonites from the Ermoceras beds of the Lower Dhruma formation.

Figures

1, 2. *Ermoceras* cf. *runcinatum* n.sp., Dhibi Limestone, Wadi Birk, locality 62. (Tubercles worn off figure 1?). SM. F 10711–2 (p. 276).

3. *Ermoceras* aff. *mogharense* Douvillé, limonitic specimen with test, locality 4, near Juraifa. SM. F 10713 (p. 275).

4*a*, *b*, *c*. *Stephanoceras arabicum* n.sp., Dhibi Limestone, locality 37, near Dhruma. SM. F 10714 (p. 270).

5, 6, 7. *Stephanoceras arabicum* n.sp., limonitic specimens, locality 4, near Juraifa. Figure 5, SM. F 10715; figure 6 holotype, SM. F 10716; figure 7, SM. F 10717 (p. 270).

8, 9. *Ermoceras reineckeoides* n.sp. Dhibi Limestone, Dhruma area. Figure 8 holotype, locality 37, SM. F 10718; figure 9, locality 38, SM. F 10719 (p. 274).

10*a*, *b*. *Ermoceras* aff. *mogharense* Douvillé, cast, Dhibi Limestone, near Dhruma, locality 39. SM. F 10720 (p. 275).

All figures natural size.

Plate 21

Bajocian ammonites from the Lower Dhruma formation; and one (figure 13) Lower Bathonian? from the base of the Middle Dhruma.

Figures

1*a*, *b*. *Ermoceras coronatoides* (Douvillé), Dhibi Limestone, locality 38, near Dhruma. SM. F10721 (p. 273).

2*a*, *b*. *Teloceras* cf. *labrum* Buckman, Dhibi Limestone, locality 39, near Dhruma. SM. F10722 (p. 271).

3, 4, 5, 6, 7. *Ermoceras coronatoides* (Douvillé), limonitic specimens from the Juraifa area, locality 4. SM. F10723–7 (p. 273).

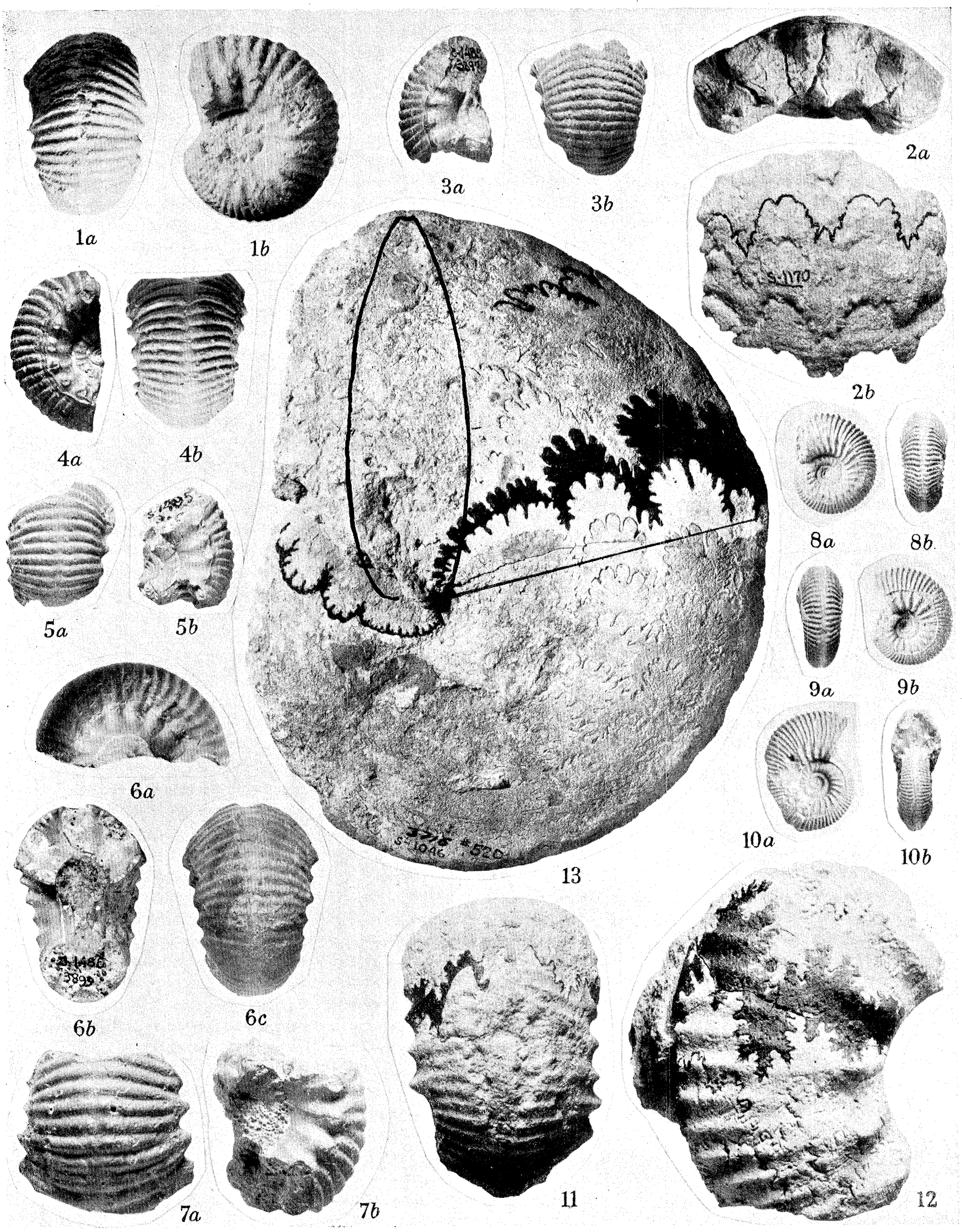
8, 9, 10. *Ermoceras runcinatum* n.sp., limonitic nuclei from the Juraifa area locality 4. SM. F10728–30 (p. 276).

11. *Teloceras* cf. *labrum* Buckman, Dhibi Limestone, Wadi Birk, locality 62. SM. F10731 (p. 271).

12. *Ermoceras coronatoides* (Douvillé), Dhibi Limestone, locality 38, near Dhruma. SM. F10732 (p. 273).

13. *Thambites oxynotus* n.sp. Holotype, Khashm Dhibi, locality 49. SM. F10733 (p. 281).

All figures natural size.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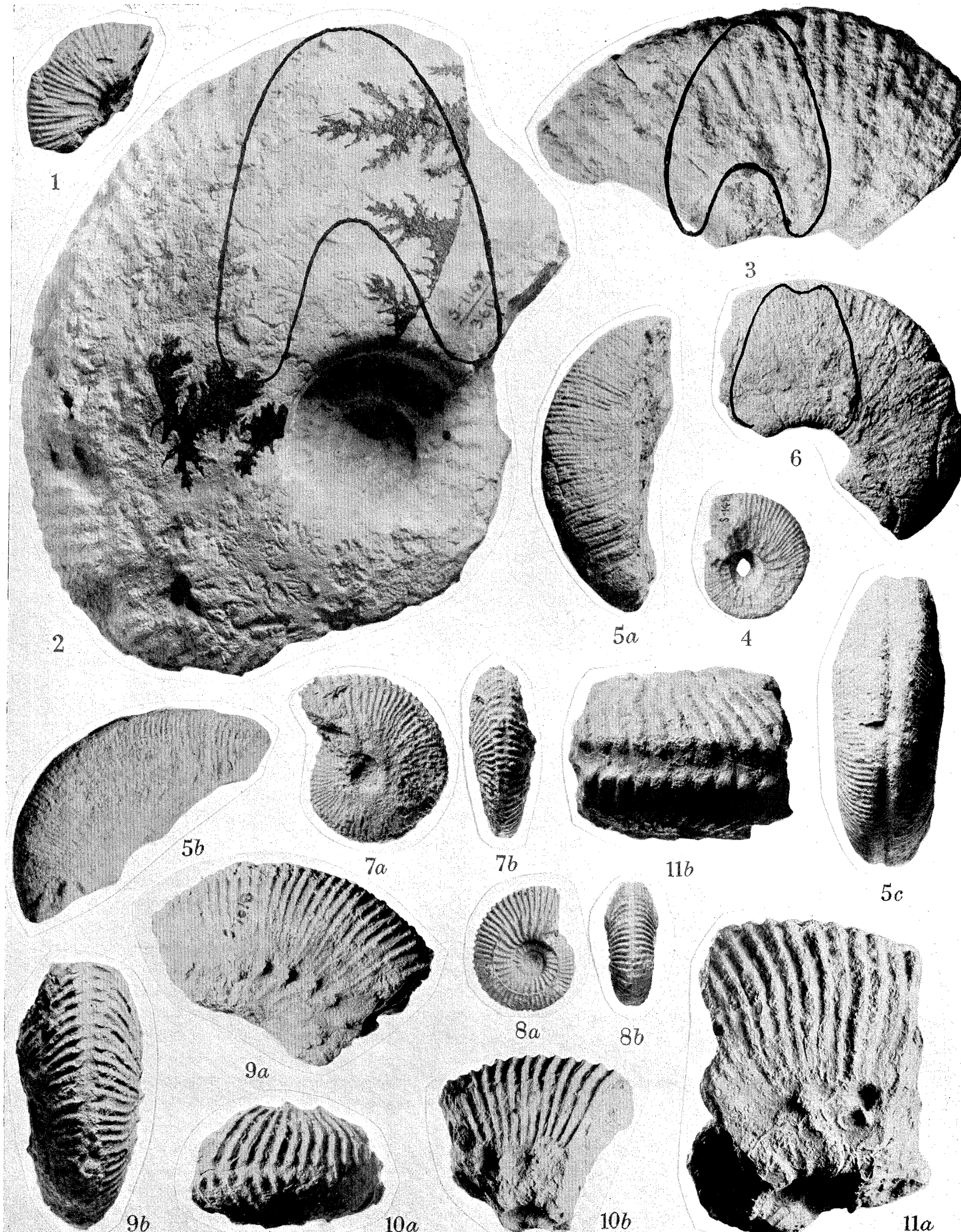
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Plate 22

Bajocian ammonites from the Lower Dhruma formation.

Figures

1, 2, 3. *Ermoceras magnificum* n.sp., Dhibi Limestone, near Dhruma, locality 38. SM. F 10734–6. Figure 2 holotype, SM. F 10735 (p. 275).

4. *Ermoceras magnificum* n.sp., limonitic specimen from the Juraifa area, locality 4. SM. F 10737 (p. 275).

5, 6. *Ermoceras elegans* (Douvillé), Dhibi Limestone, casts, locality 38. SM. F 10738–9 (p. 277).

7 *a*, *b*. *Ermoceras aulacostephanus* n.sp. Holotype, purple-red band, locality 2. SM. F 10740 (p. 276).

8 *a*, *b*. *Ermoceras runcinatum* n.sp. Holotype, limonitic inner whorls, locality 4. SM. F10741 (p. 276)

9, 10, 11. *Ermoceras runcinatum* n.sp. Fragments of middle and outer whorls, purple-red band, locality 2. SM. F 10742–4 (p. 276).

All figures natural size.

PLATE 23

Bajocian ammonites from the Lower Dhruma formation, and three oxycones (figures 9, 10, 11) from the base of the Middle Dhruma.

FIGURES

1, 2. *Ermoceras splendens* n.sp., from the purple-red band near Juraifa, locality 2. SM. F 10745–6 (p. 274).

3, 5, 7. *Ermoceras elegans* Douvillé, from the purple-red band near Juraifa, locality 2. SM. F 10747–9 (p. 277).

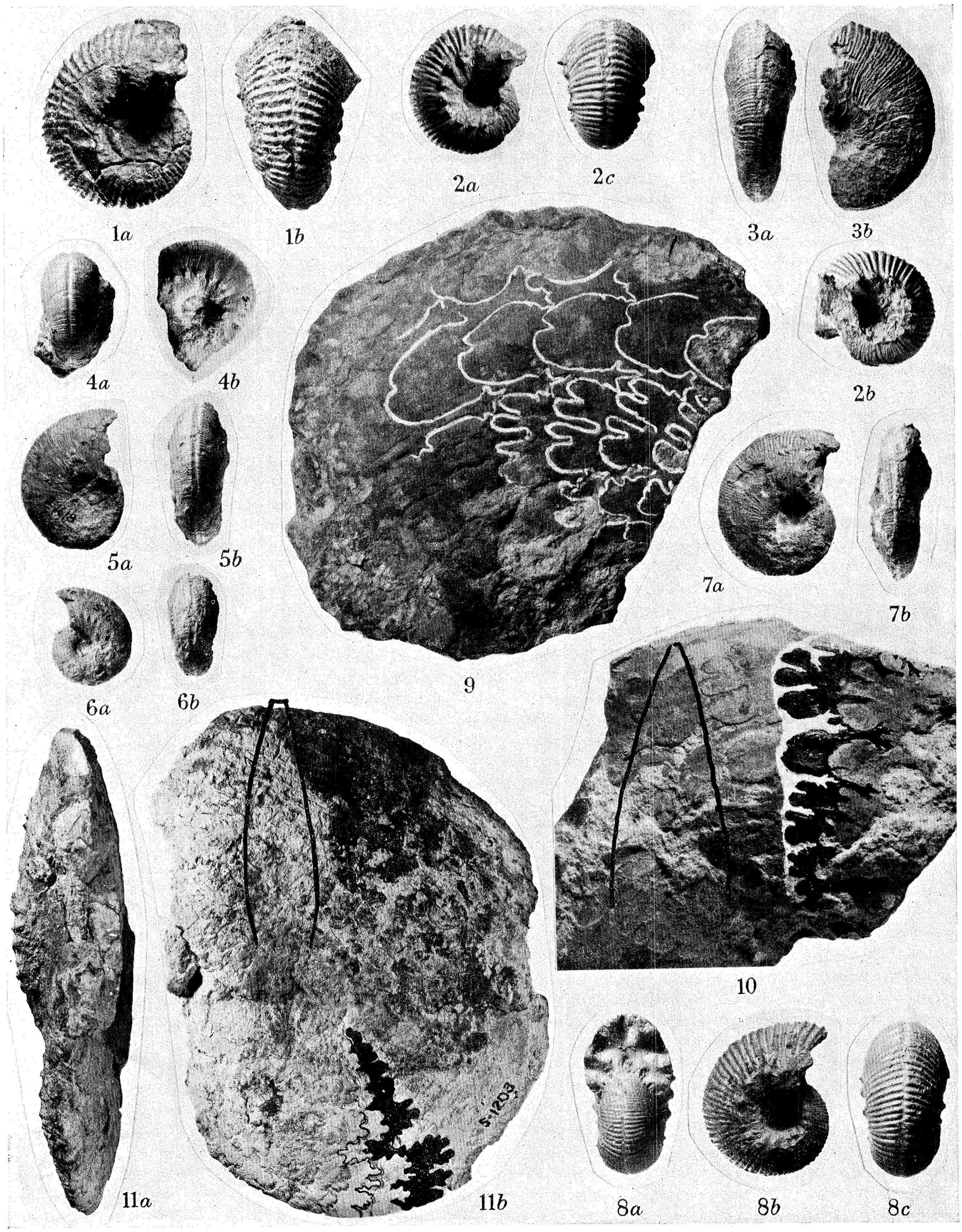
4, 6. *Ermoceras strigatum* n.sp., from the purple-red band near Juraifa, locality 2. Figure 4 holotype, SM. F 10750; figure 6 SM. F 10751 (p. 277).

8*a*, *b*, *c*. *Ermoceras splendens* n.sp. Holotype, purple-red band near Juraifa, locality 2. SM. F 10752 (p. 274).

9, 10. *Bramkampia steinekei* n.sp. *Thambites* beds, base of the Middle Dhruma formation near Juraifa, locality 8. Figure 9, SM. F 10753; figure 10 holotype, SM. F 10754 (p. 282).

11 *a*, *b*. *Thambites planus* n.sp. Medium-sized specimen $\times 0{\cdot}8$, Khashm Dhibi, locality 51. SM. F 10755 (p. 280).

All figures except 11 *a*, *b*, natural size.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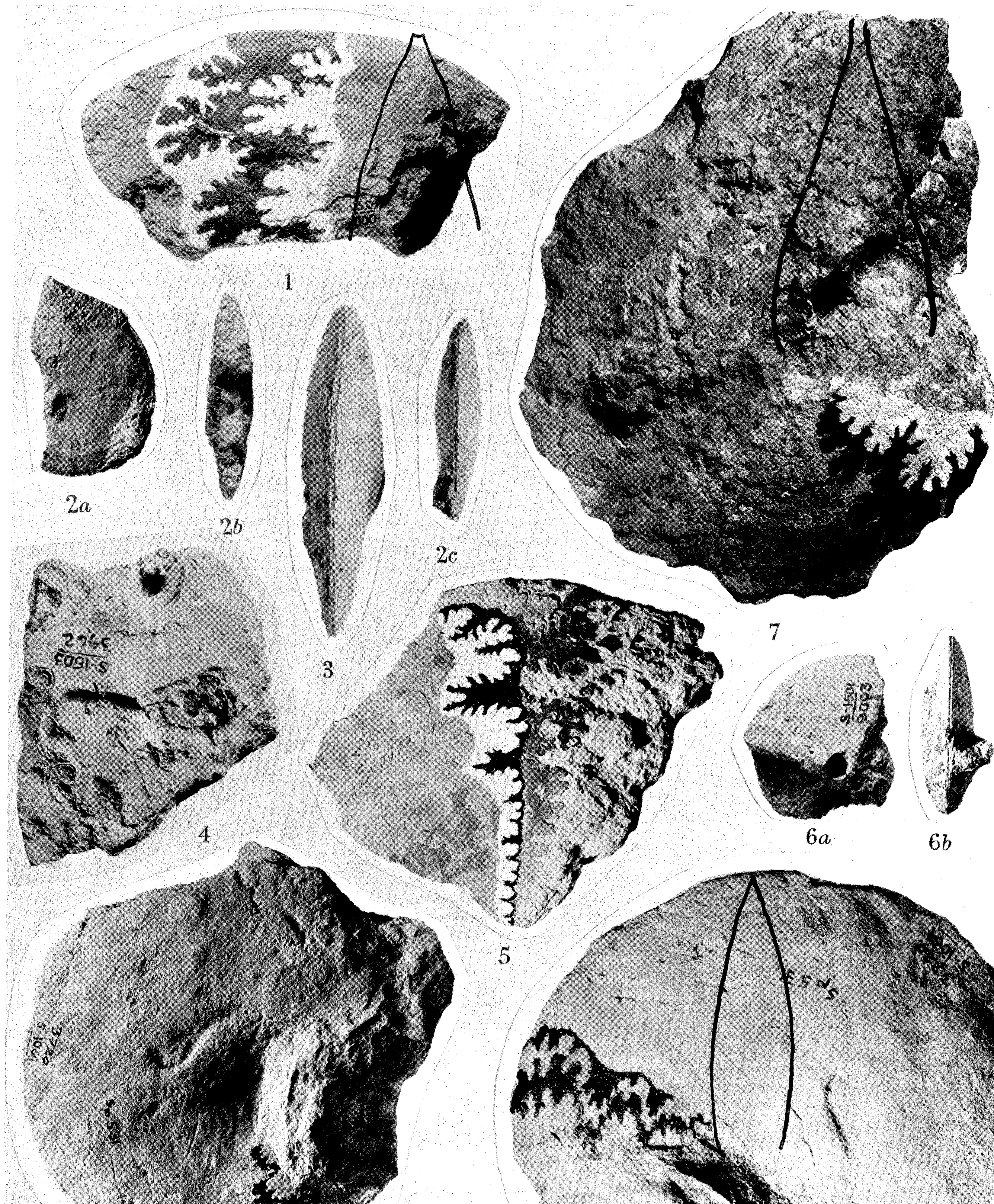
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Plate 24

Oxycones (Lower Bathonian?) from the base of the Middle Dhruma formation.

Figures

1. *Thambites planus* n.sp., detail of suture, showing adventitious branch of external lobe. Juraifa area, locality 6 (topotype). SM. F 10756 (p. 280).

2, 3. *Thambites planus* n.sp., inner whorls showing concave venter. Juraifa area, locality 7. SM. F 10757–8 (p. 280).

4. *Thambites planus* n.sp., fragment showing well-preserved umbilicus. Locality 7. SM. F 10759 (p. 280).

5. *Thambites planus* n.sp., fragment with complete external suture. Locality 7. SM. F 10760 (p. 280).

6*a*, *b*. *Thambites planus* n.sp. Holotype, Juraifa area, locality 6. SM. F 10761 (p. 280).

7. *Thambites avus* n.sp. Holotype, Khashm Dhibi, locality 48. SM. F 10762 (p. 281).

8*a*, *b*. *Clydoniceras pseudodiscus* n.sp. Holotype, Hauta Pass, locality 60. Figure 8*a*, reduced photo taken in Dhahran; figure 8*b*, part of same with more sutures inked, natural size. SM. F 10763 (p. 282).

All figures natural size, except figure 8*a*.

PLATE 25

Middle Bathonian ammonites from the Middle Dhruma formation.

FIGURES

1 *a*, *b*. *Tulites erymnoides* n.sp. Holotype, Barra area, locality 25. SM. F 10764 (p. 284).

2 *a*, *b*. *Dhrumaites cardioceratoides* n.sp. Interior of giant septate specimen from locality 30, of which the suture is shown in text-figure 10, p. 289. SM. F 10765 (p. 288).

3 *a*, *b*, *c*. *Tulites tuwaiqensis* n.sp. Holotype, Juraifa area, locality 12. SM. F 10766 (p. 284).

4 *a*, *b*. *Tulites erymnoides* n.sp. Barra area, locality 24. SM. F 10767 (p. 284).

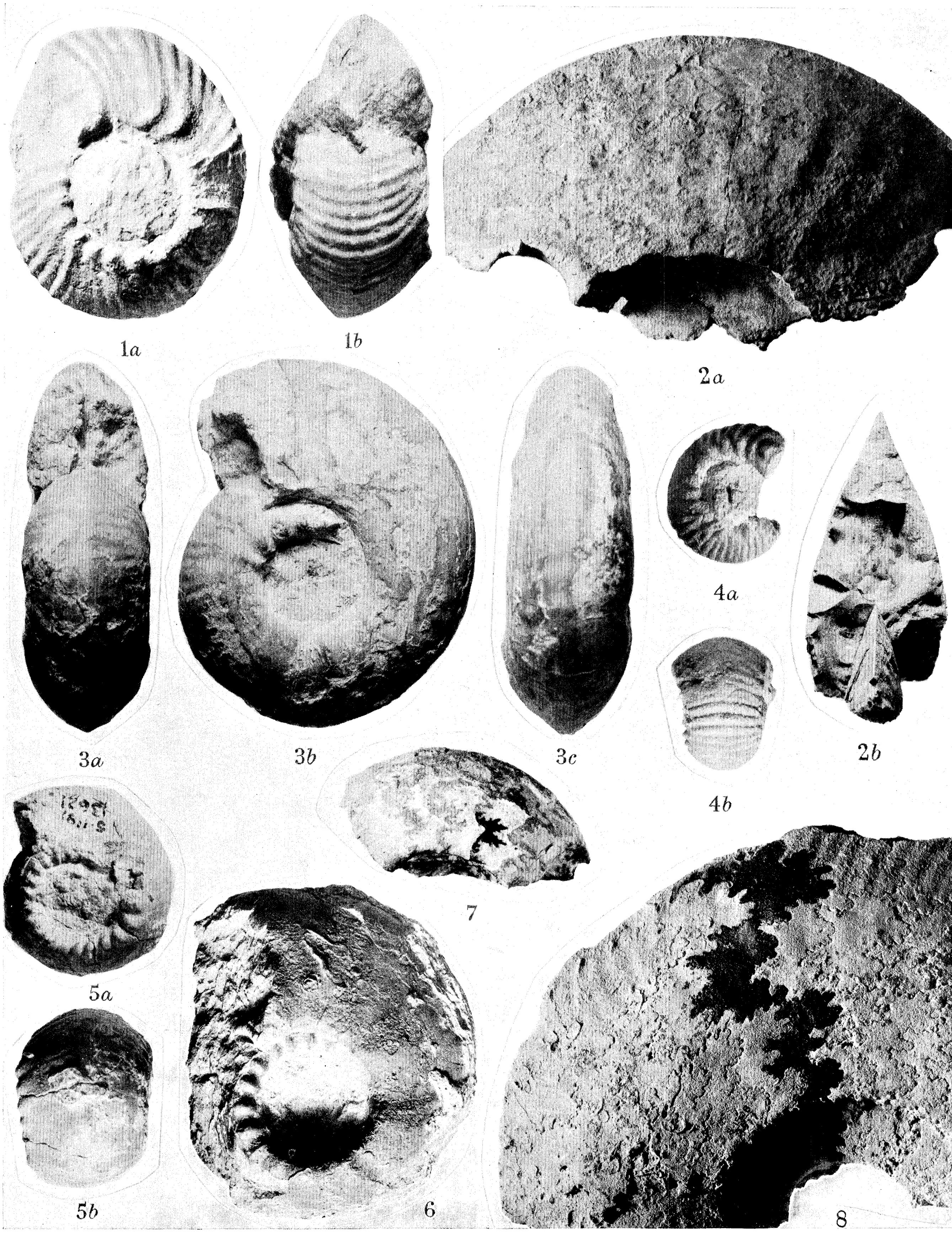
5 *a*, *b*. *Tulites arabicus* n.sp. Juraifa area, locality 12. SM. F 10768 (p. 283).

6. *Tulites arabicus* n.sp. Holotype, Juraifa area, locality 12. SM. F 10769 (p. 283).

7. *Tulites arabicus* n.sp. Fragment of topotype showing the cloven second lateral lobe, locality 12. SM. F 10770 (p. 283).

8. *Dhrumaites cardioceratoides* n.sp. Holotype, reduced $\times 0{\cdot}55$. Collapse along a longitudinal line of weakness formed by part of the second lateral lobe produces a false umbilicus. SM. F 10771 (p. 288).

All figures natural size, except figure 8.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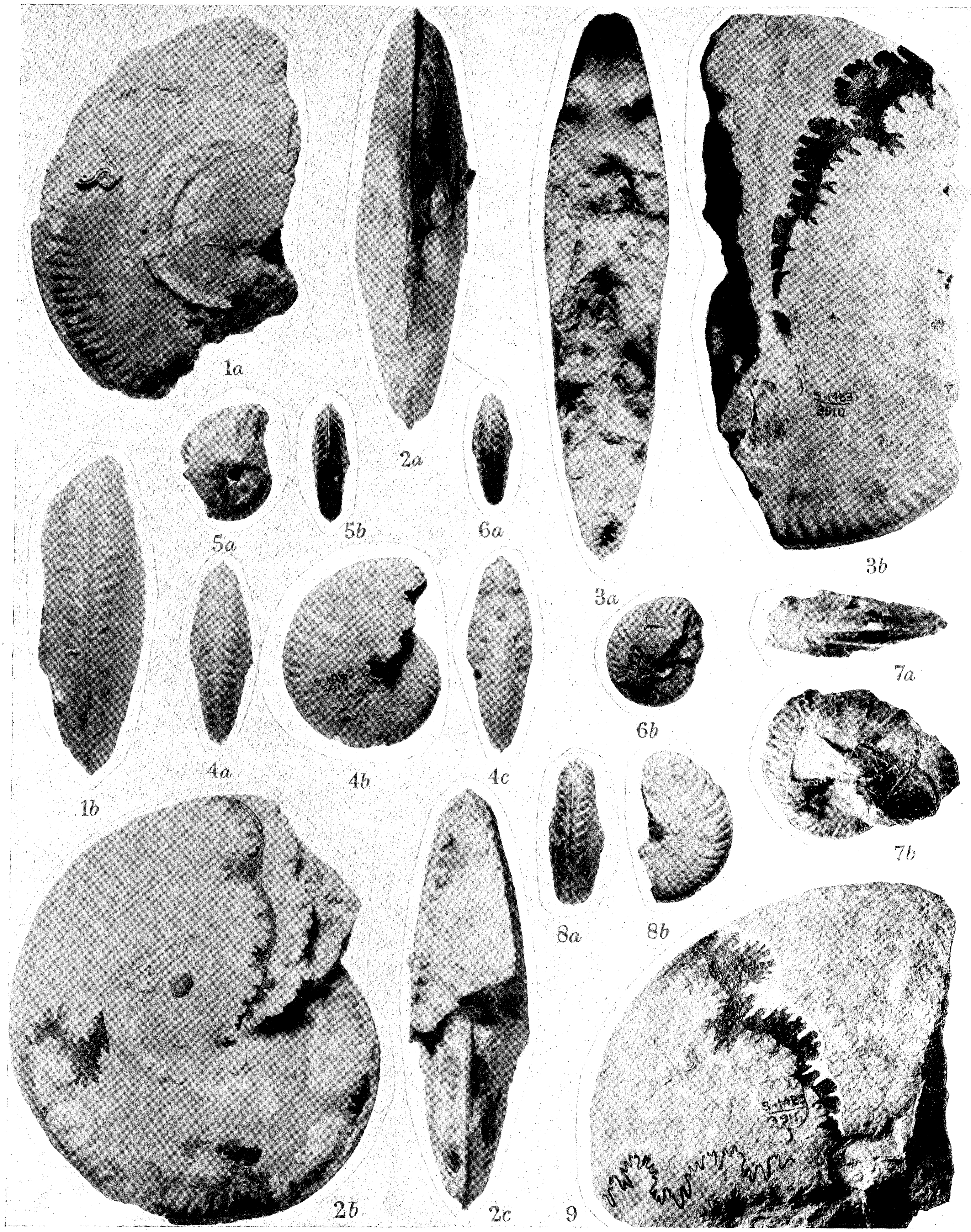
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Plate 26

Middle Bathonian ammonites from the Middle Dhruma formation.

Figures

1, 2, 3, 4. *Micromphalites clydocromphalus* n.sp., from the red clay near Juraifa, locality 16. Note scar of umbilical seam on figures 1*a*, 2*b*, proving final excentrumbilication. SM. F 10772–5. Figure 2 holotype, SM. F 10773 (p. 287).

5, 6, 7. *Micromphalites clydocromphalus* n.sp., from the chocolate cast bed, Juraifa area, locality 18 (figures 5, 6) and locality 17 (figure 7). SM. F 10776–8 (p. 287).

8*a*, *b*. *Micromphalites elegans* n.sp., Juraifa area, locality 17. SM. F 10779 (p. 286).

9. *Micromphalites clydocromphalus* n.sp., from the red clay, Juraifa area, locality 16. Compare the suture, especially the second lateral lobe, with figures 2*b* and 3*b*. SM. F 10780 (p. 287).

All figures natural size.

Plate 27

Middle Bathonian ammonites from the Middle Dhruma formation.

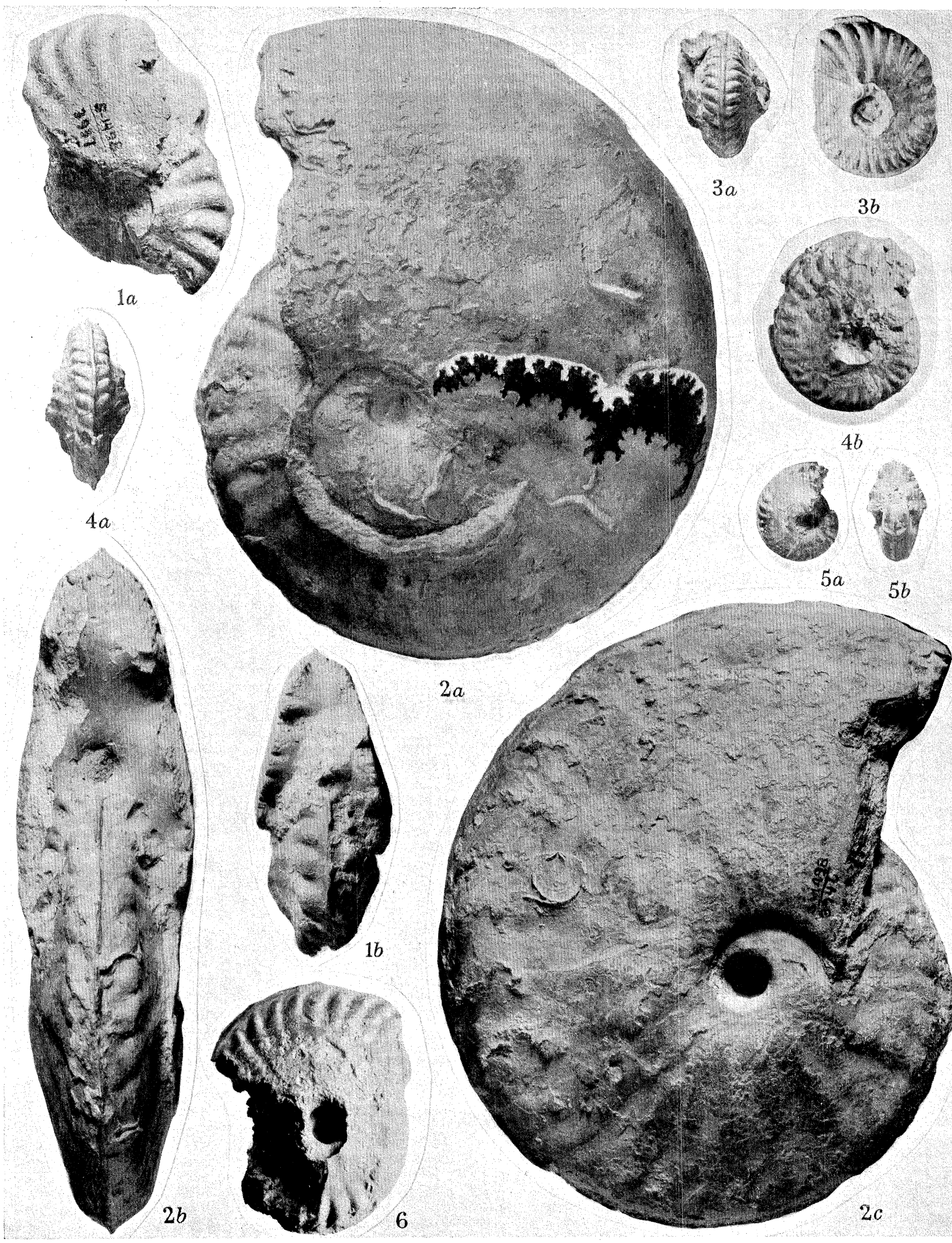
Figures

1, 2. *Micromphalites* cf. *busqueti* (de Grossouvre), Juraifa area, locality 20. SM. F 10781–2 (p. 284).

3, 4. *Micromphalites* cf. *busqueti* (de Grossouvre), from the red clay, Juraifa area, locality 17. SM. F 10783–4 (p. 284).

5, 6. *Micromphalites* cf. *busqueti* (de Grossouvre), from the chocolate cast bed, Juraifa area, locality 18. SM. F 10785–6 (p. 284).

All figures natural size.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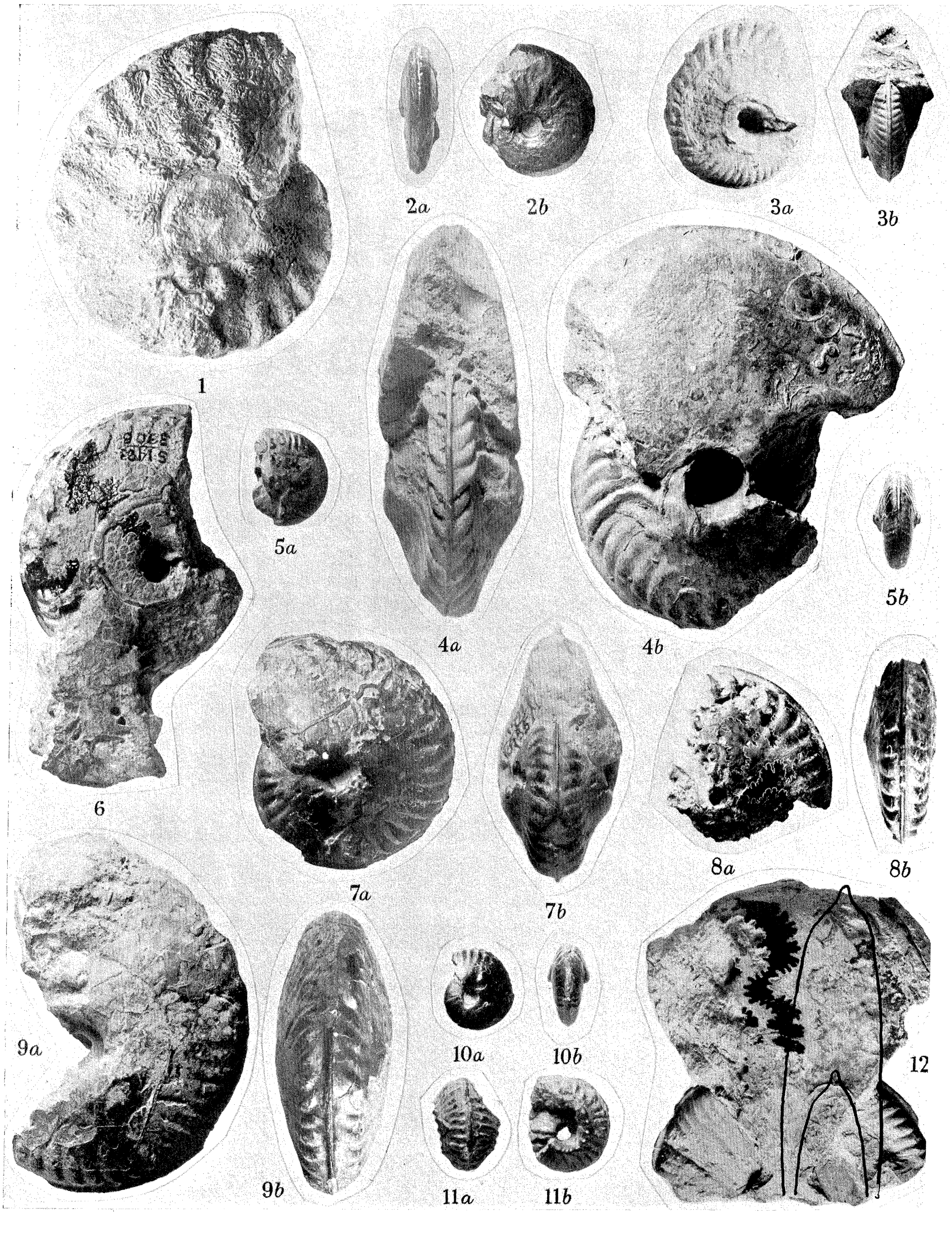
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Plate 28

Middle Bathonian ammonites from the Middle Dhruma formation.

Figures

1. *Micromphalites pustuliferus* (Douvillé), Wadi Birk, locality 65. (The back and much of the front is eaten away by sand-blast.) SM. F 10787 (p. 285).

2 *a*, *b*. *Strungia arabica* n.sp. Holotype, from the chocolate cast bed, near Juraifa, locality 18. SM. F 10788 (p. 287).

3 *a*, *b*. *Micromphalites elegans* n.sp. Holotype, Juraifa area, locality 17. SM. F 10789 (p. 286).

4 *a*, *b*. *Micromphalites elegans* n.sp., from the red clay Juraifa area, locality 16. SM. F 10790 (p. 286).

5, 8. *Micromphalites elegans* n.sp., from the chocolate cast bed, Juraifa area, locality 18. SM. F 10791–2 (p. 286).

6. *Micromphalites intermedius* n.sp., Juraifa area, locality 16. SM. F 10793 (p. 286).

7, 9. *Micromphalites intermedius* n.sp., from the chocolate cast bed, Juraifa area, locality 18. Figure 9 holotype, SM. F 10794; figure 7 aff. *intermedius*, SM. F. 10795 (p. 286).

10 *a*, *b*. *Micromphalites* sp. indet., chocolate cast bed, Juraifa area, locality 18. SM. F 10796.

11 *a*, *b*. *Micromphalites vertebralis* n.sp. Holotype, chocolate cast bed, Juraifa area, locality 18. SM. F 10797 (p. 286).

12. *Micromphalites clydocromphalus* n.sp. Specimen showing ribbed inner and smooth outer whorls, wholly septate. Juraifa area, locality 17. SM. F 10798 (p. 287).

All figures natural size.

Plate 29

Middle Callovian ammonites from the Tuwaiq Mountain Limestone; and a Lower Kimeridgian perisphinctid (figure 5) from the Jubaila formation.

Figures

1 *a*, *b*, *c*. *Erymnoceras philbyi* n.sp., holotype. Figure 1 *a*, outer whorls reduced × 0·70. 1 *b*, 1 *c*, detached inner whorls natural size. Barra area, locality 31. SM. F 10799 (p. 290).

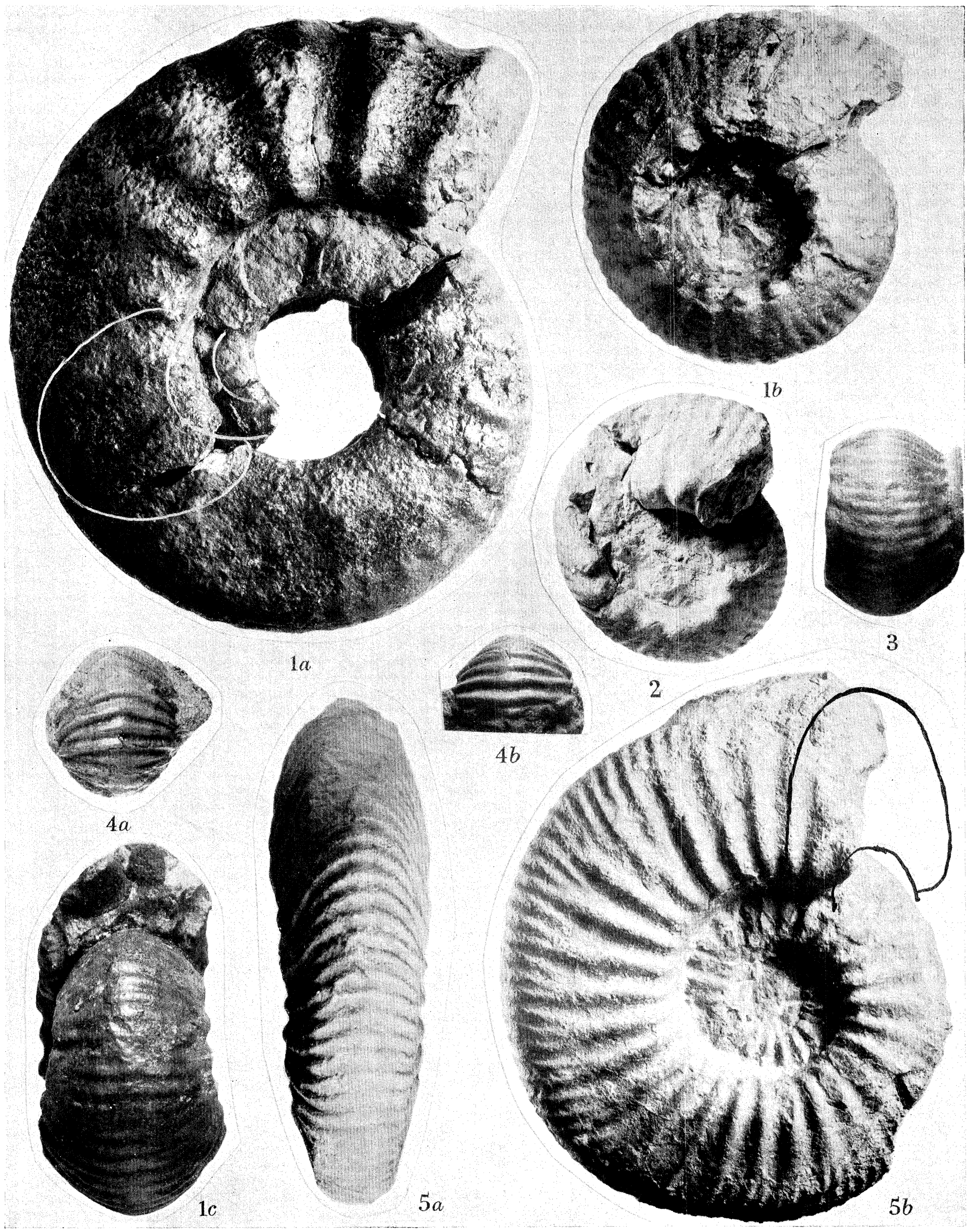
2. *Erymnoceras philbyi* n.sp. The specimen collected by H. St J. B. Philby in 1932 at Sha'ib Hassi, near Haisiya Pass. Brit. Mus. (Nat. Hist.) C. 35960 (p. 290).

3. *Erymnoceras* cf. *philbyi* n.sp., Barra area, locality 32. SM. F 10800 (p. 290).

4 *a*, *b*. *Erymnoceras* cf. *jarryi* (R. Douvillé), Barra area, locality 33. SM. F 10801 (p. 290).

5 *a*, *b*. *Perisphinctes jubailensis* n.sp. Holotype, Jubaila formation, Wadi Birk, locality 67. SM. F 10802 (p. 292).

All figures natural size, except figure 1 *a*.


1*a*
1*b*
2
3
4*a*
4*b*
1*c*
5*a*
5*b*

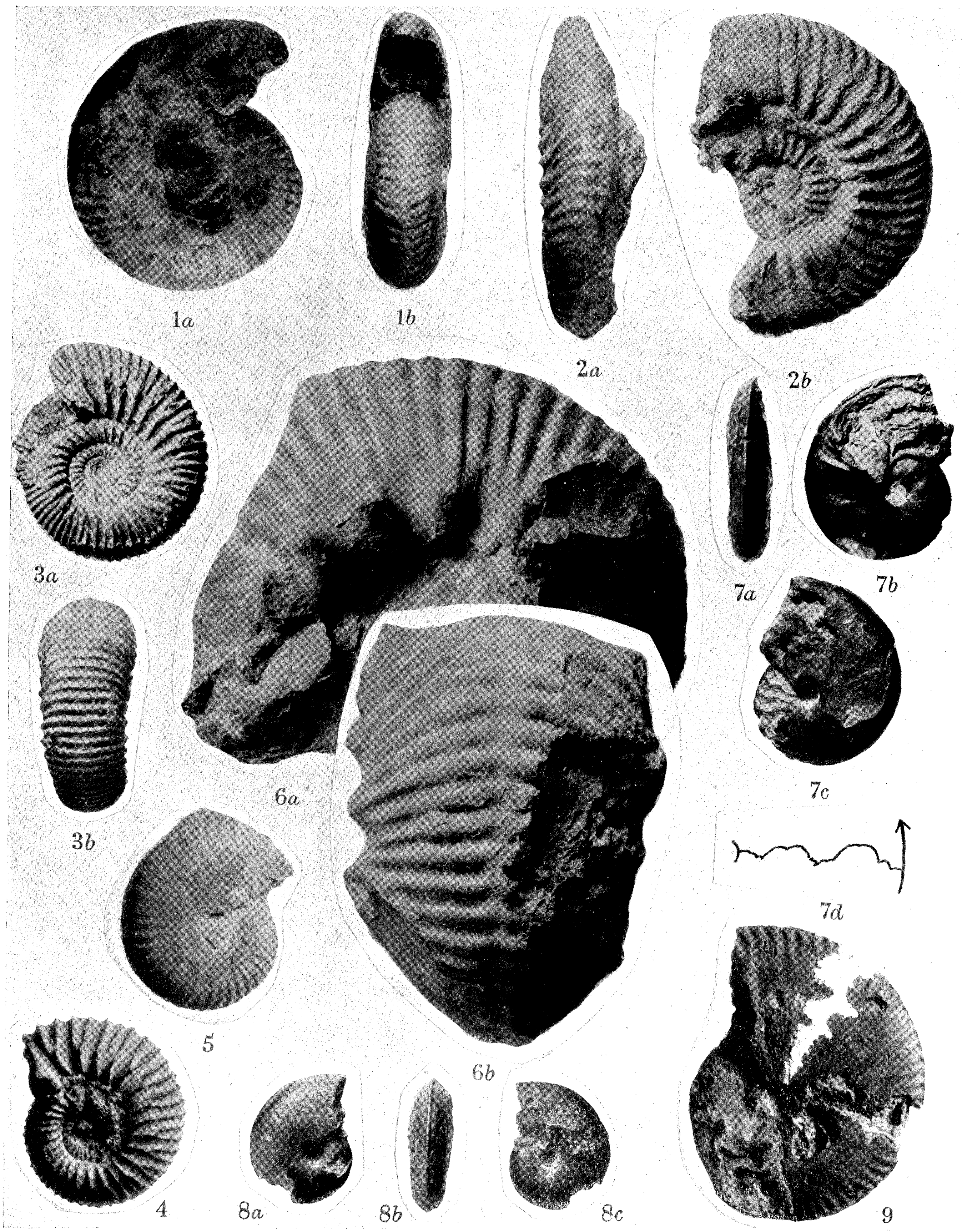

1a
1b
2a
2b
3a
3b
4
5
6a
6b
7a
7b
7c
7d
8a
8b
8c
9

Plate 30

Middle Callovian ammonite from the Tuwaiq Mountain Limestone (figure 1) and Lower Kimeridgian ammonite from the Jubaila formation (figure 2).

Figures

1 *a*, *b*. *Pachyceras* cf. *schloenbachi* (Roman), Barra area, locality 32. SM. F 10803 (p. 291).

2 *a*, *b*. *Perisphinctes* aff. *jubailensis* n.sp., locality 69; the most southerly ammonite yet found in the Jebel Tuwaiq. SM. F 10804 (p. 292).

Bajocian ammonites from Gebel Maghara, Sinai.

3 *a*, *b*. *Normannites* cf. *braikenridgii* (J. Sowerby). × 2. Sample 21074. Smithsonian Inst., Washington, D.C. (p. 309).

4. *Normannites egyptiacus* n.sp., holotype × 2. Geological Survey of Egypt, Cairo, no 16685 (p. 309).

5. *Ermoceras* sp., inner whorls × 2. Geological Survey of Egypt, Cairo, no. 16674 (p. 272).

6 *a*, *b*. *Ermoceras splendens* n.sp. × 1. Sample 21077 *a*. Smithsonian Inst., Washington, D.C. (p. 308).

7, 8. *Magharina magharensis* n.sp. × 2. Figures 7 *a–d* holotype. Sample 21082, *Ermoceras* beds. Smithsonian Inst., Washington, D.C. Figure 7 *d* suture-line (p. 307).

9. *Thamboceras mirabile* n.sp. × 2. Holotype, Geological Survey of Egypt, Cairo, no. 16687 (p. 278).

Figures 1, 2, 6 natural size, the rest × 2.

Plate 31

Typical Jurassic escarpments of Jebel Tuwaiq.

Above

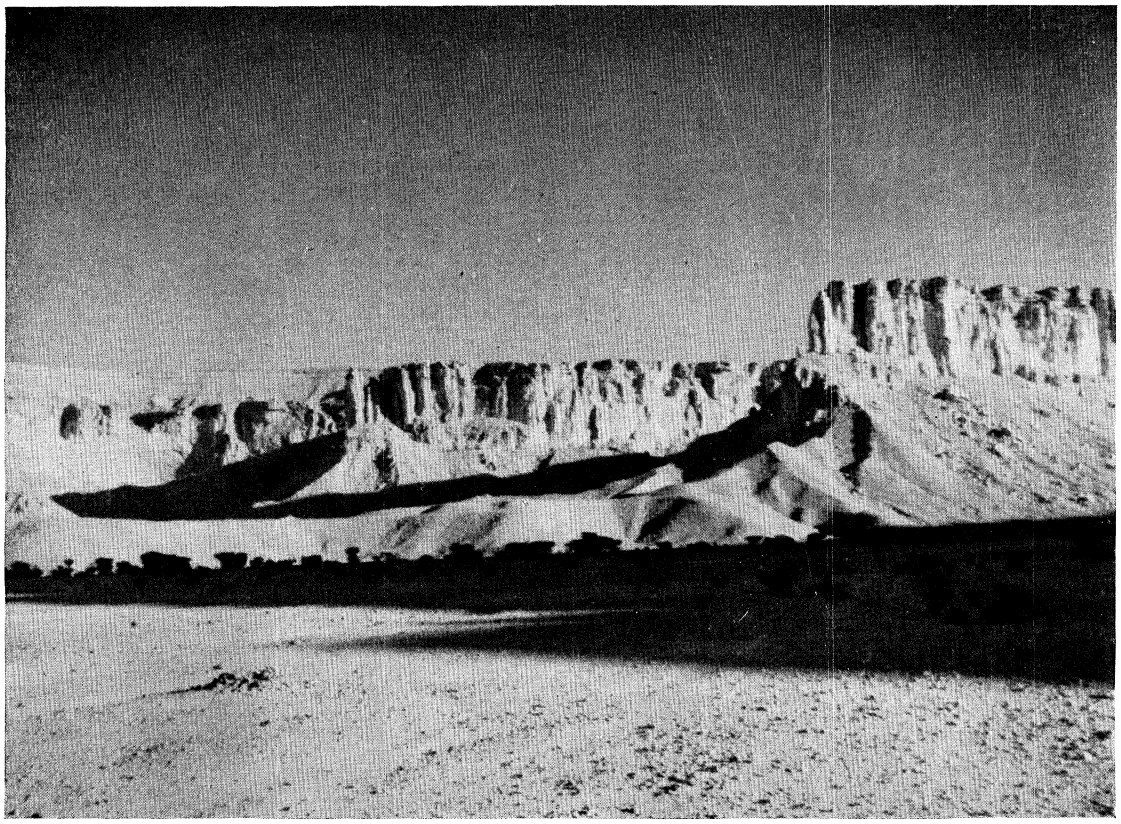
Tuwaiq Mountain Limestone and Upper Dhruma formation, south side of Wadi Birk. The cliff is about 600 ft. high. The vertical part is formed by coral limestones, the middle part by chalky and marly limestones with the Middle Callovian *Erymnoceras* fauna. The terrace feature near the base is the Upper Dhruma formation with abundant *Gryphaea costellata*. (Locality 64 is a short distance to left of picture.)

Below

Marrat formation, Jafair Trail, close to localities 55, 56, 57. The top of the mesa in the middle distance is just below the *Bouleiceras* horizon, with Lower Marrat and Minjur Sandstone forming the cliff below. The photograph is taken from unfossiliferous Middle Marrat beds, with the *Nejdia* bed above and behind the photographer.

The higher cliff in distance on left is formed by the Lower Dhruma formation and capped by the Dhibi Limestone (*Ermoceras* beds).

Photographs by W. J. Arkell, January 1951.



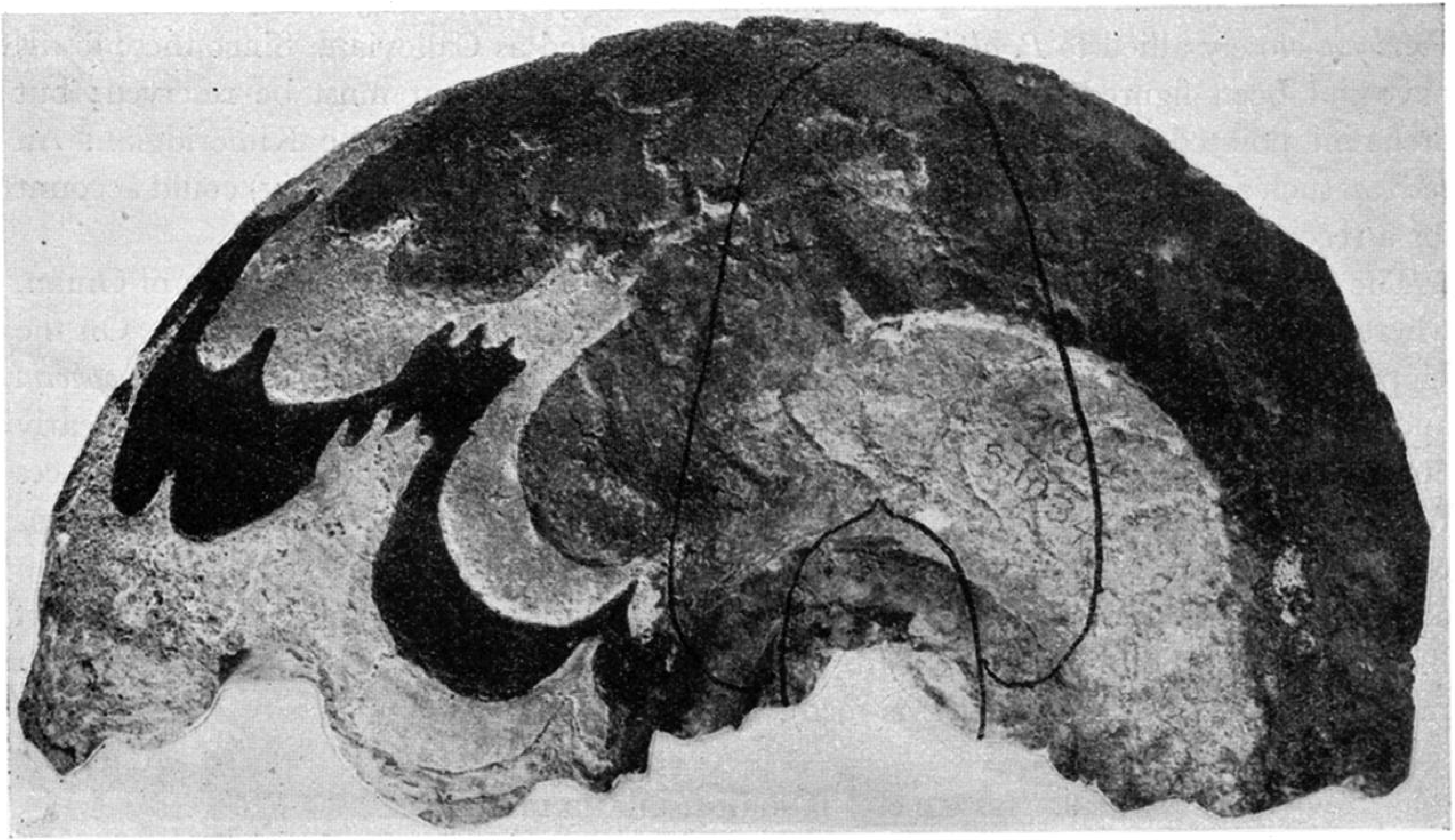


FIGURE 4. *Bouleiceras nitescens* Thevenin. Locality 55. Natural size. SM. F10805.

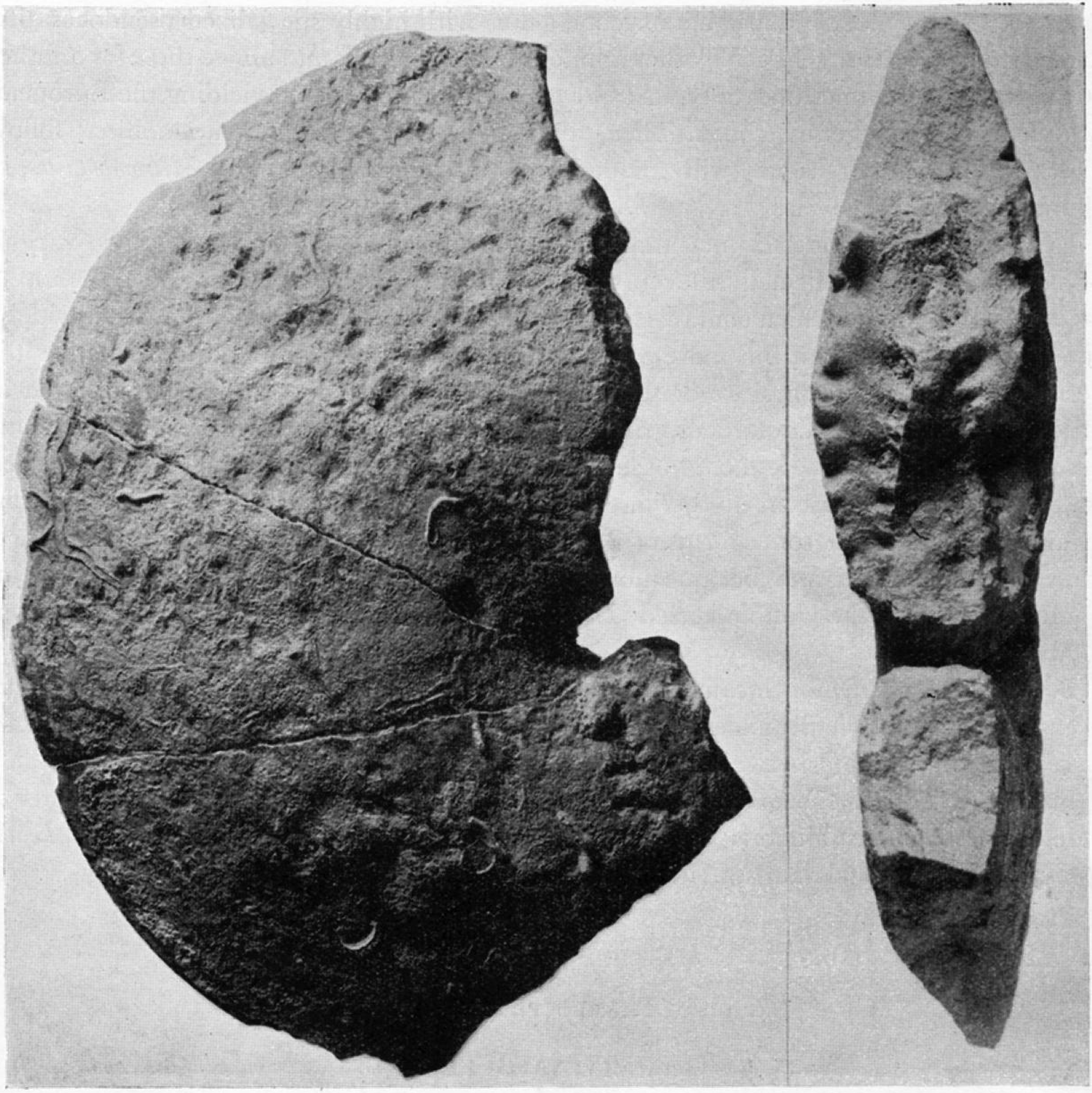


FIGURE 8. *Thambites planus* n.sp. Large specimen ×0·75. Locality 8. (Suture not decipherable in detail.) SM. F 10806.

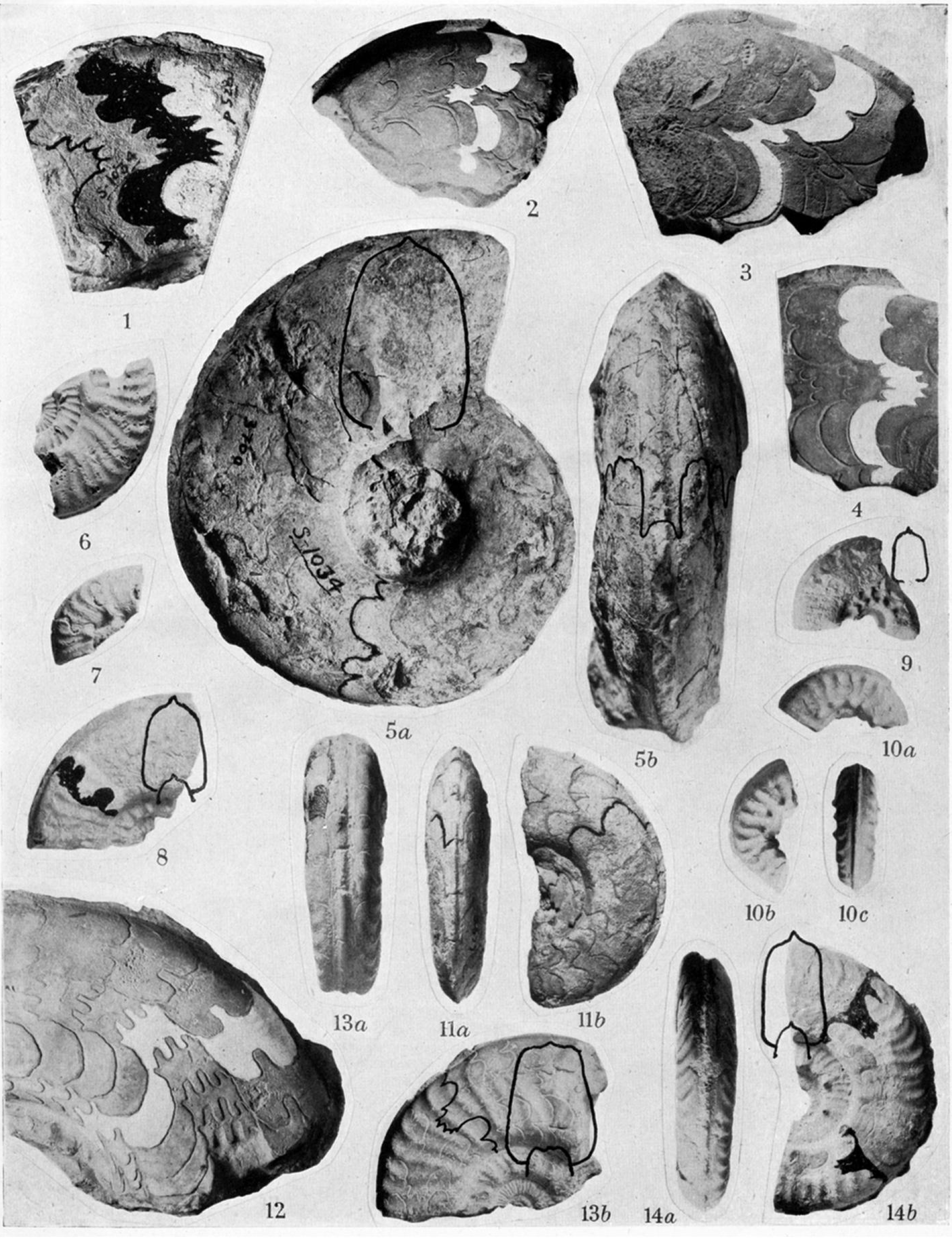


PLATE 15

Toarcian ammonites from the Bouleiceras bed, Lower Marrat formation.

FIGURES

1, 2, 3, 4.	*Bouleiceras* sp. or spp., fragments, locality 55. SM. F 10660–3 (p. 261).
5*a*, *b*.	*Bouleiceras nitescens* Thevenin, wholly septate; locality 55. SM. F 10664 (p. 261).
6.	*Bouleiceras arabicum* n.sp., locality 55. SM. F 10665 (p. 262).
7.	*Bouleiceras* n.sp. indet., locality 43. SM. F 10666.
8.	*Bouleiceras arabicum* n.sp., locality 55. SM. F 10667 (p. 262).
9.	*Bouleiceras elegans* n.sp., nucleus; locality 55. SM. F 10668 (p. 264).
10*a*, *b*, *c*.	*Bouleiceras marraticum* n.sp. Holotype, locality 55. SM. F 10669 (p. 263).
11*a*, *b*.	*Bouleiceras elegans* n.sp., locality 55. SM. F 10670 (p. 264).
12.	*Bouleiceras* sp., fragment, locality 55. SM. F 10671 (p. 262).
13*a*, *b*, 14*a*, *b*.	*Bouleiceras arabicum* n.sp., locality 55. Figure 13 SM. F 10672; figure 14 holotype, SM. F 10673 (p. 262).

All figures natural size.

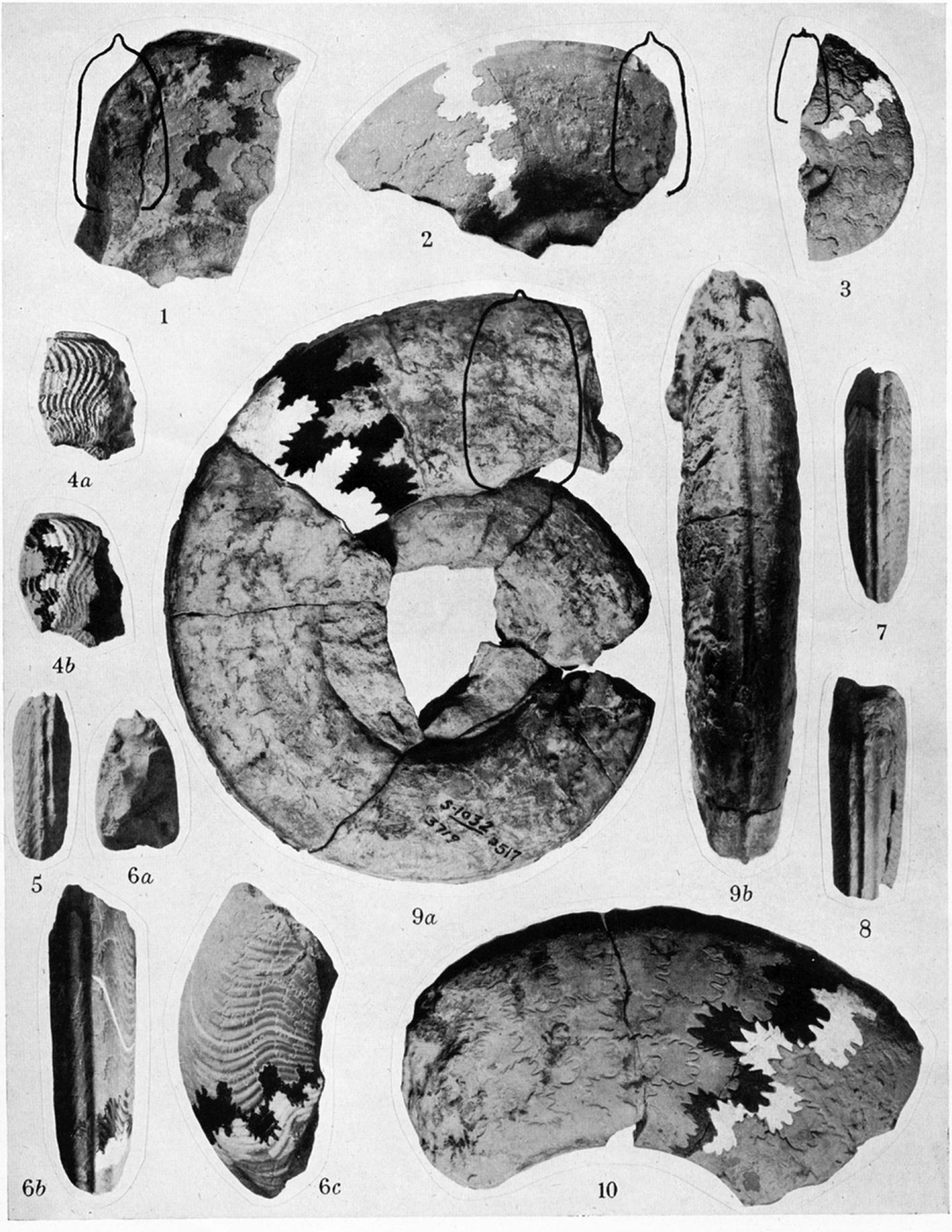


PLATE 16

Toarcian ammonites from the Marrat formation. (Figures 4 to 8 Lower Marrat, the rest Upper Marrat.)

FIGURES

1, 2. *Hildaites* sp?, fragments, locality 56. SM. F 10674–5 (p. 265).

3. Presumed inner whorls of *Hildaites sanderi*; loose, near locality 56. SM. F 10676 (p. 265).

4 to 8. *Protogrammoceras madagascariense* (Thevenin), fragments from the *Bouleiceras* bed, locality 55. SM. F 10677–10681 (p. 264).

9*a*, *b*. *Hildaites sanderi* n.sp. Holotype, locality 59. SM. F 10682 (p. 265).

10. *Hildaites sanderi* n.sp., locality 56. SM. F 10683 (p. 265).

All figures natural size.

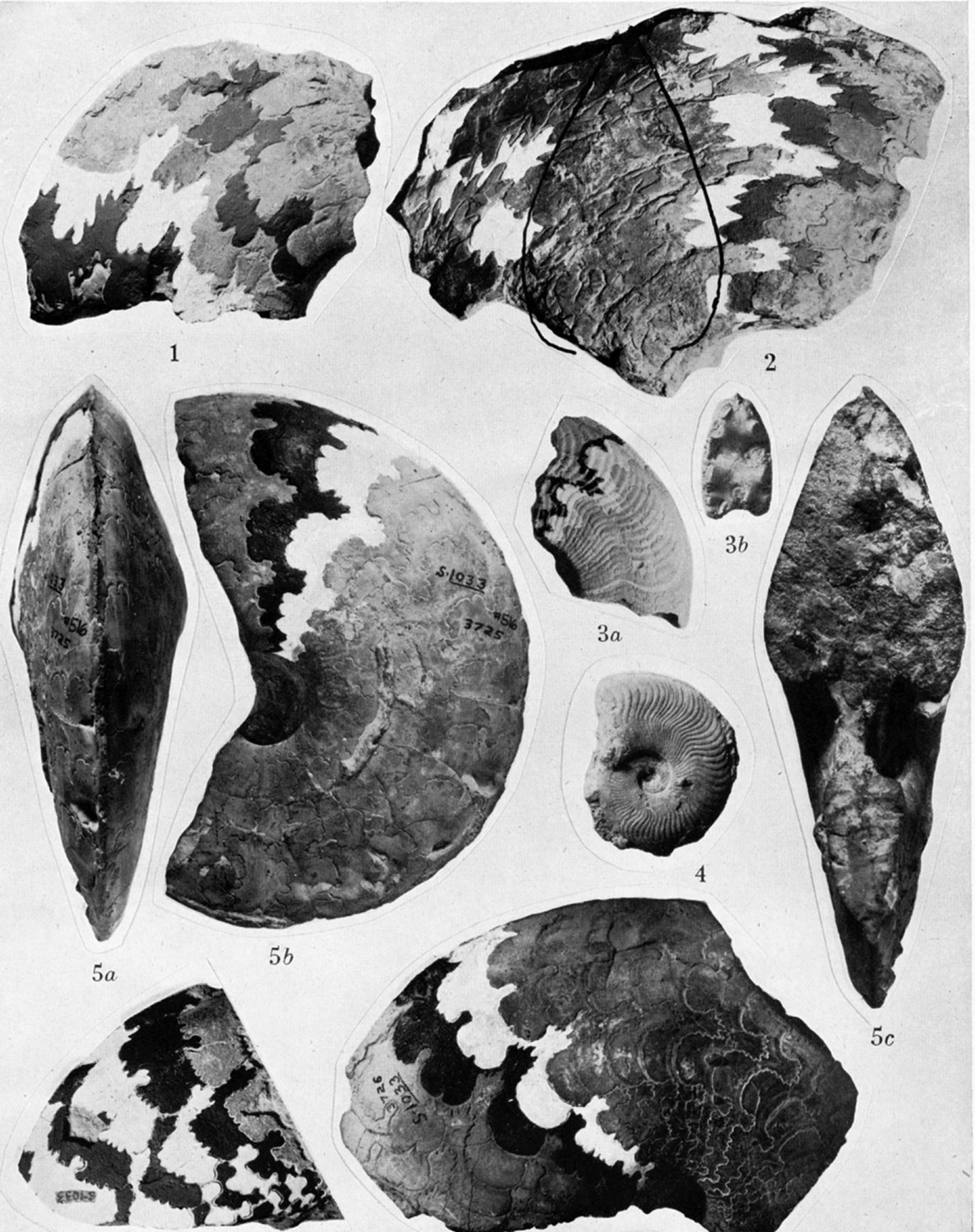


PLATE 17

Toarcian ammonites from the Marrat formation. (Figures 3, 4, Lower Marrat, the rest Upper Marrat.)

FIGURES

1, 2. *Nejdia furnishi* n.sp., *Nejdia* bed, locality 57. Figure 1, SM. F 10684; figure 2, holotype, SM. F 10685 (p. 268).

3*a*, *b*, 4. *Protogrammoceras madagascariense* (Thevenin). Bouleiceras bed, locality 55. SM. F 10686–7 (p. 264).

5*a*, *b*, *c*. *Nejdia bramkampi* n.sp. Holotype, Nejdia bed, locality 57. SM. F 10688 (p. 267).

6. *Nejdia bramkampi* n.sp., locality 57. SM. F 10689 (p. 267).

7. *Nejdia bramkampi* n.sp., locality 57; variety with minutely crenulate but straight-ended first and second lateral saddles. Note irregular and aberrant auxiliary lobes. SM. F 10690 (p. 267).

All figures natural size.

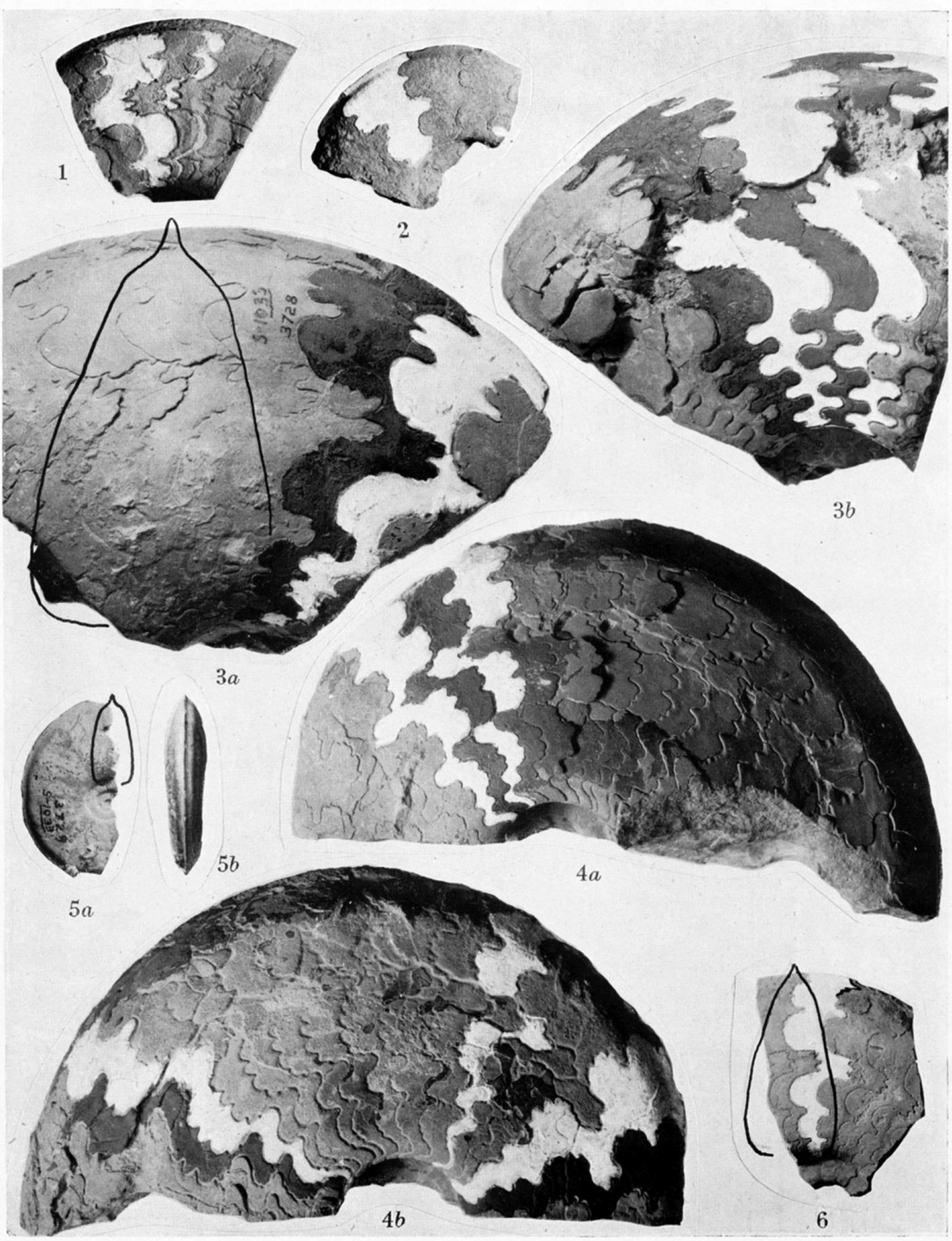


PLATE 18

Toarcian ammonites from the Marrat formation. (Figure 1 Lower Marrat, the rest Upper Marrat.)

FIGURES

1. *Bouleiceras* sp., locality 55. Fragment showing irregular spacing of suture-lines. SM. F10691 (p. 262).

2. Fragment, n.gen.?, *Hildaites* bed, locality 56. SM. F10692 (cf. plate 16, figure 2) (p. 265).

3 *a*, *b*. *Nejdia bramkampi* n.sp. Opposite sides of the same fragment, showing asymmetry and elongation of second lateral saddle (as in *Bouleiceras*) on both sides, and ceratitic suspensive lobe on one side only. Locality 57. SM. F10693. (Cf. plate 17, figure 7) (p. 267).

4 *a*, *b*. *Nejdia bramkampi* n.sp. Opposite sides of the same specimen, showing different suture-lines on the two sides, especially in the suspensive lobe. Locality 57. SM. F10694 (p. 267).

5 *a*, *b*. *Nejdia bramkampi* n.sp. Inner whorls from the Nejdia bed, locality 57. SM. F10695 (p. 267).

6. *Nejdia bramkampi* n.sp. Intermediate growth stage. Nejdia bed, locality 57. SM. F10696 (p. 267).

All figures natural size.

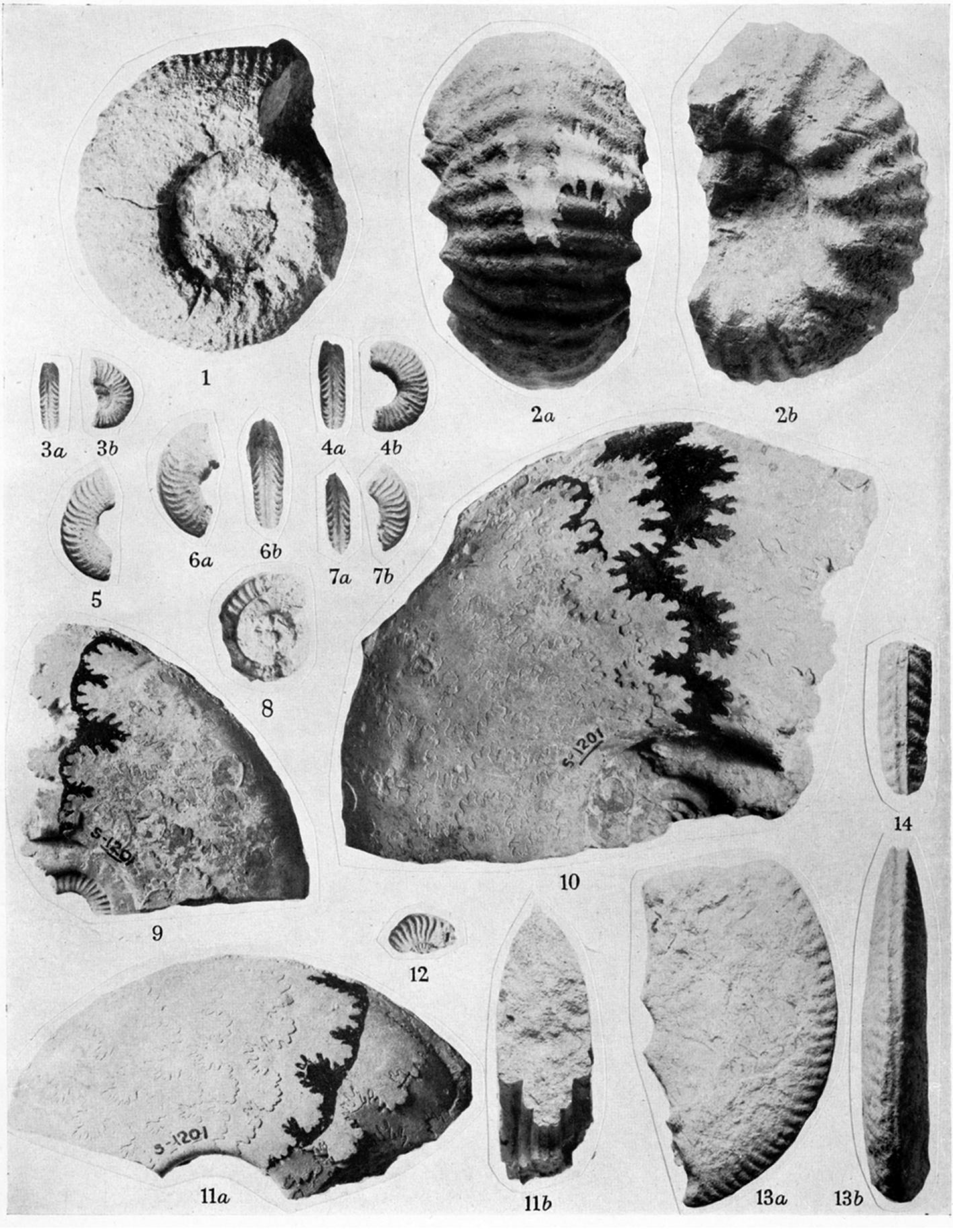


PLATE 19

Bajocian ammonites from the Lower Dhruma formation.

FIGURES

1.	*Stephanoceras* cf. *psilacanthus* Wermbter, Dhibi Limestone, Wadi Birk, locality 62. SM. F10697 (p. 270).
2*a*, *b*.	*Ermoceras coronatiforme* n.sp., holotype, brown limestone. Khashm Mawan, locality 68. SM. F10698 (p. 274).
3, 4, 5, 6, 7, 8.	*Dorsetensia arabica* n.sp., nuclei, Khasm Dhibi area, locality 46. SM. F10699–10704 (p. 269).
9, 10, 11.	*Dorsetensia arabica* n.sp., fragments. Figure 10 holotype. Khashm Dhibi area, locality 46. Note ribbed nucleus in figure 9, resembling figures 7 and 12. SM. F10705–7 (p. 269).
12.	*Dorsetensia arabica* n.sp., locality 46. SM. F10708 (p. 269).
13*a*, *b*.	*Thamboceras mirabile* n.sp., Dhibi Limestone, Dhruma area, locality 36. SM .F10709 (p. 278).
14.	*Thamboceras mirabile* n.sp., fragment from the purple-red band near Juraifa, locality 2. SM. F10710 (p. 278).

All figures natural size.

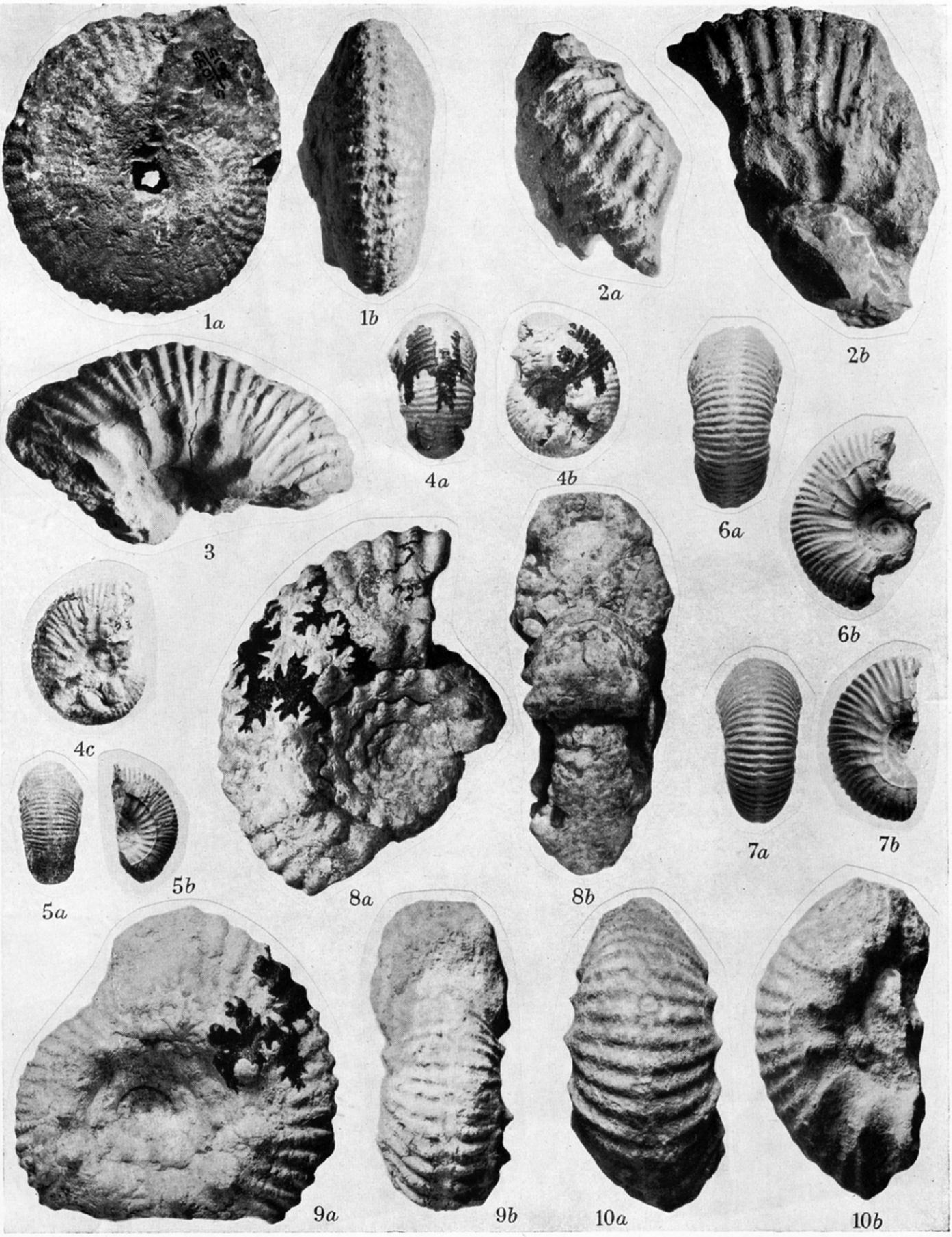


PLATE 20

Bajocian ammonites from the Ermoceras beds of the Lower Dhruma formation.

FIGURES

1, 2. *Ermoceras* cf. *runcinatum* n.sp., Dhibi Limestone, Wadi Birk, locality 62. (Tubercles worn off figure 1?). SM. F10711–2 (p. 276).

3. *Ermoceras* aff. *mogharense* Douvillé, limonitic specimen with test, locality 4, near Juraifa. SM. F10713 (p. 275).

4*a*, *b*, *c*. *Stephanoceras arabicum* n.sp., Dhibi Limestone, locality 37, near Dhruma. SM. F10714 (p. 270).

5, 6, 7. *Stephanoceras arabicum* n.sp., limonitic specimens, locality 4, near Juraifa. Figure 5, SM. F10715; figure 6 holotype, SM. F10716; figure 7, SM. F10717 (p. 270).

8, 9. *Ermoceras reineckeoides* n.sp. Dhibi Limestone, Dhruma area. Figure 8 holotype, locality 37, SM. F10718; figure 9, locality 38, SM. F10719 (p. 274).

10*a*, *b*. *Ermoceras* aff. *mogharense* Douvillé, cast, Dhibi Limestone, near Dhruma, locality 39. SM. F10720 (p. 275).

All figures natural size.

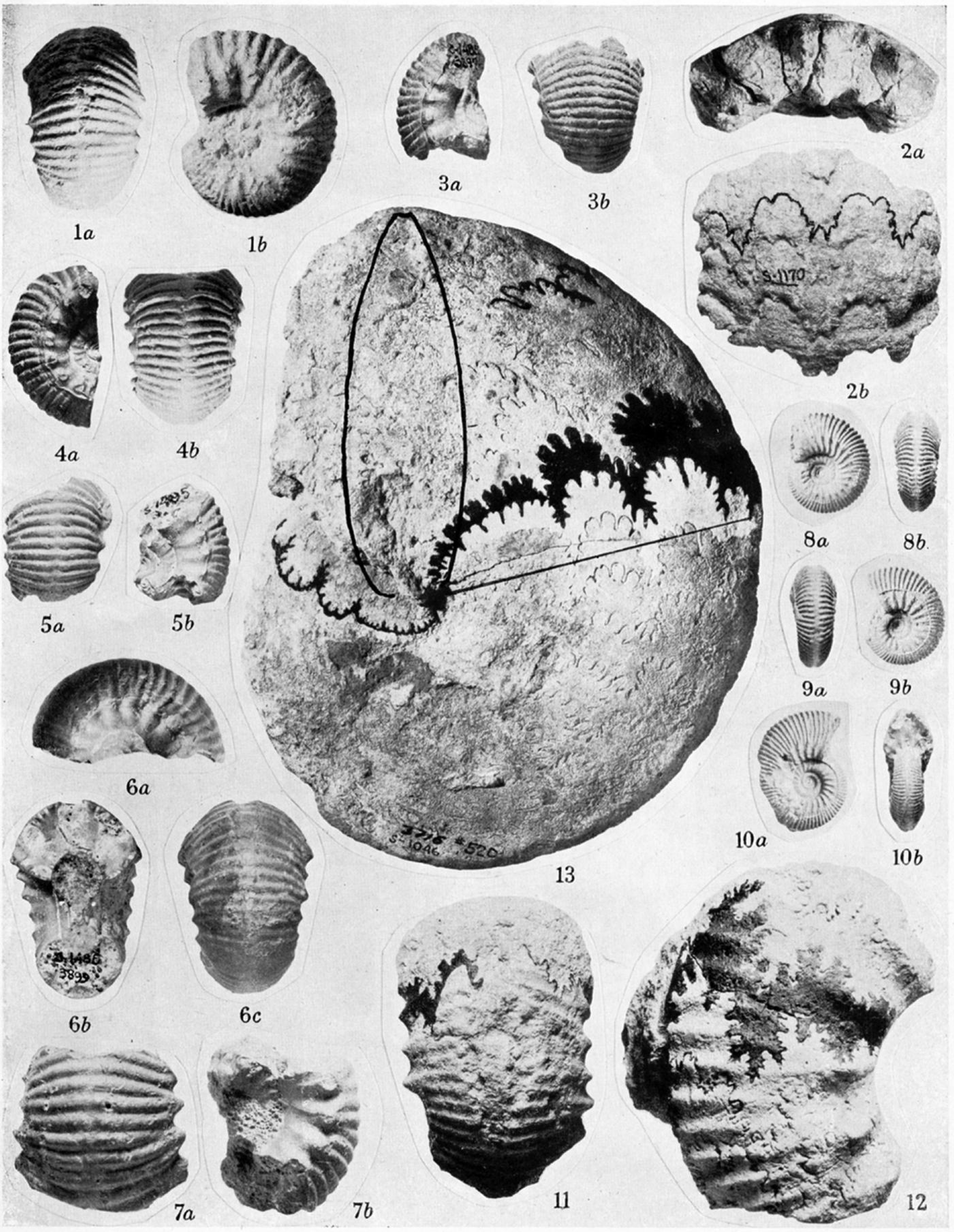


PLATE 21

Bajocian ammonites from the Lower Dhruma formation; and one (figure 13) Lower Bathonian? from the base of the Middle Dhruma.

FIGURES

1*a*, *b*. *Ermoceras coronatoides* (Douvillé), Dhibi Limestone, locality 38, near Dhruma. SM. F 10721 (p. 273).

2*a*, *b*. *Teloceras* cf. *labrum* Buckman, Dhibi Limestone, locality 39, near Dhruma. SM. F 10722 (p. 271).

3, 4, 5, 6, 7. *Ermoceras coronatoides* (Douvillé), limonitic specimens from the Juraifa area, locality 4. SM. F 10723–7 (p. 273).

8, 9, 10. *Ermoceras runcinatum* n.sp., limonitic nuclei from the Juraifa area locality 4. SM. F 10728–30 (p. 276).

11. *Teloceras* cf. *labrum* Buckman, Dhibi Limestone, Wadi Birk, locality 62. SM. F 10731 (p. 271).

12. *Ermoceras coronatoides* (Douvillé), Dhibi Limestone, locality 38, near Dhruma. SM. F 10732 (p. 273).

13. *Thambites oxynotus* n.sp. Holotype, Khashm Dhibi, locality 49. SM. F 10733 (p. 281).

All figures natural size.

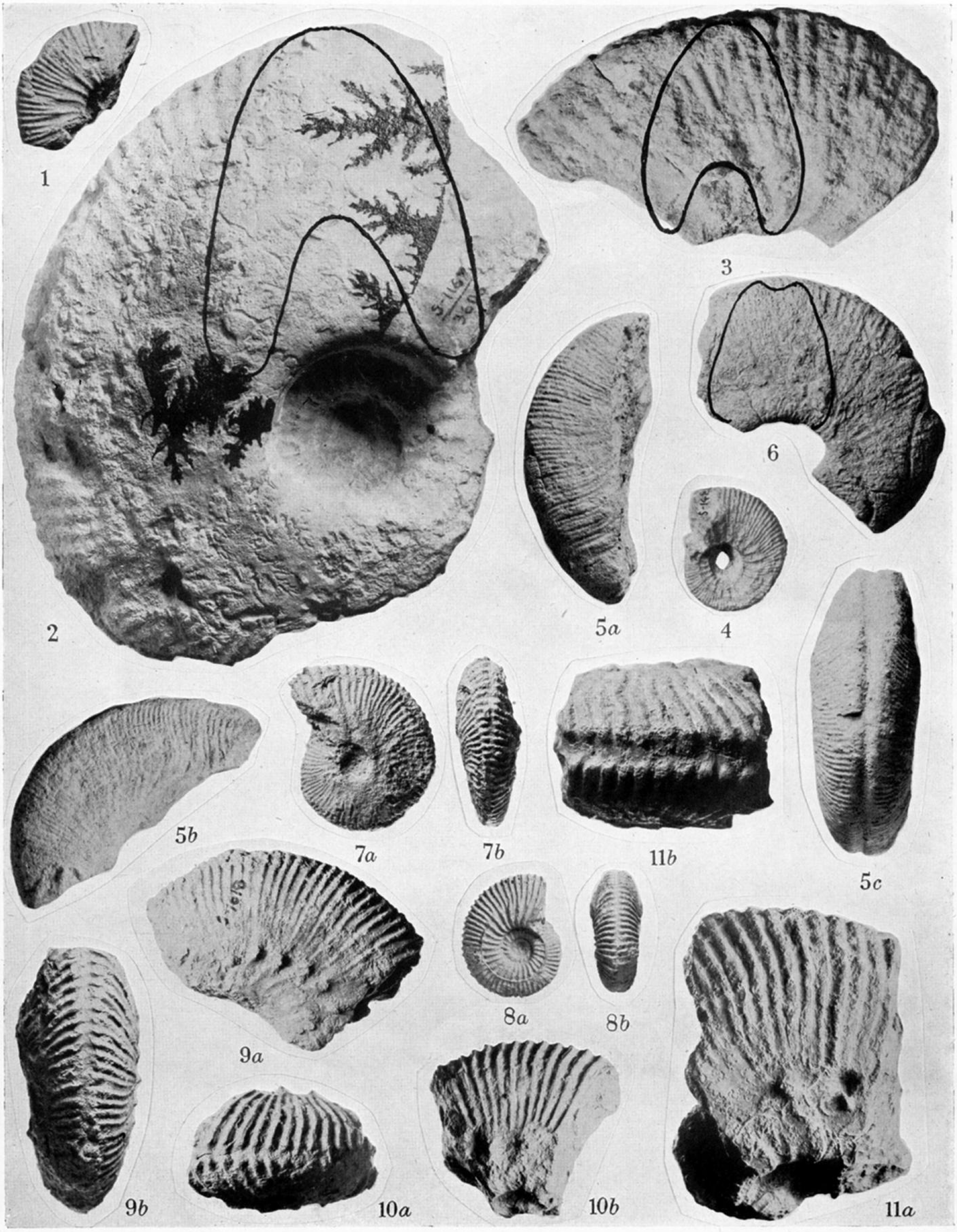


PLATE 22

Bajocian ammonites from the Lower Dhruma formation.

FIGURES

1, 2, 3. *Ermoceras magnificum* n.sp., Dhibi Limestone, near Dhruma, locality 38. SM. F 10734–6. Figure 2 holotype, SM. F 10735 (p. 275).

4. *Ermoceras magnificum* n.sp., limonitic specimen from the Juraifa area, locality 4. SM. F 10737 (p. 275).

5, 6. *Ermoceras elegans* (Douvillé), Dhibi Limestone, casts, locality 38. SM. F 10738–9 (p. 277).

7 *a*, *b*. *Ermoceras aulacostephanus* n.sp. Holotype, purple-red band, locality 2. SM. F 10740 (p. 276).

8 *a*, *b*. *Ermoceras runcinatum* n.sp. Holotype, limonitic inner whorls, locality 4. SM. F10741 (p. 276)

9, 10, 11. *Ermoceras runcinatum* n.sp. Fragments of middle and outer whorls, purple-red band, locality 2. SM. F 10742–4 (p. 276).

All figures natural size.

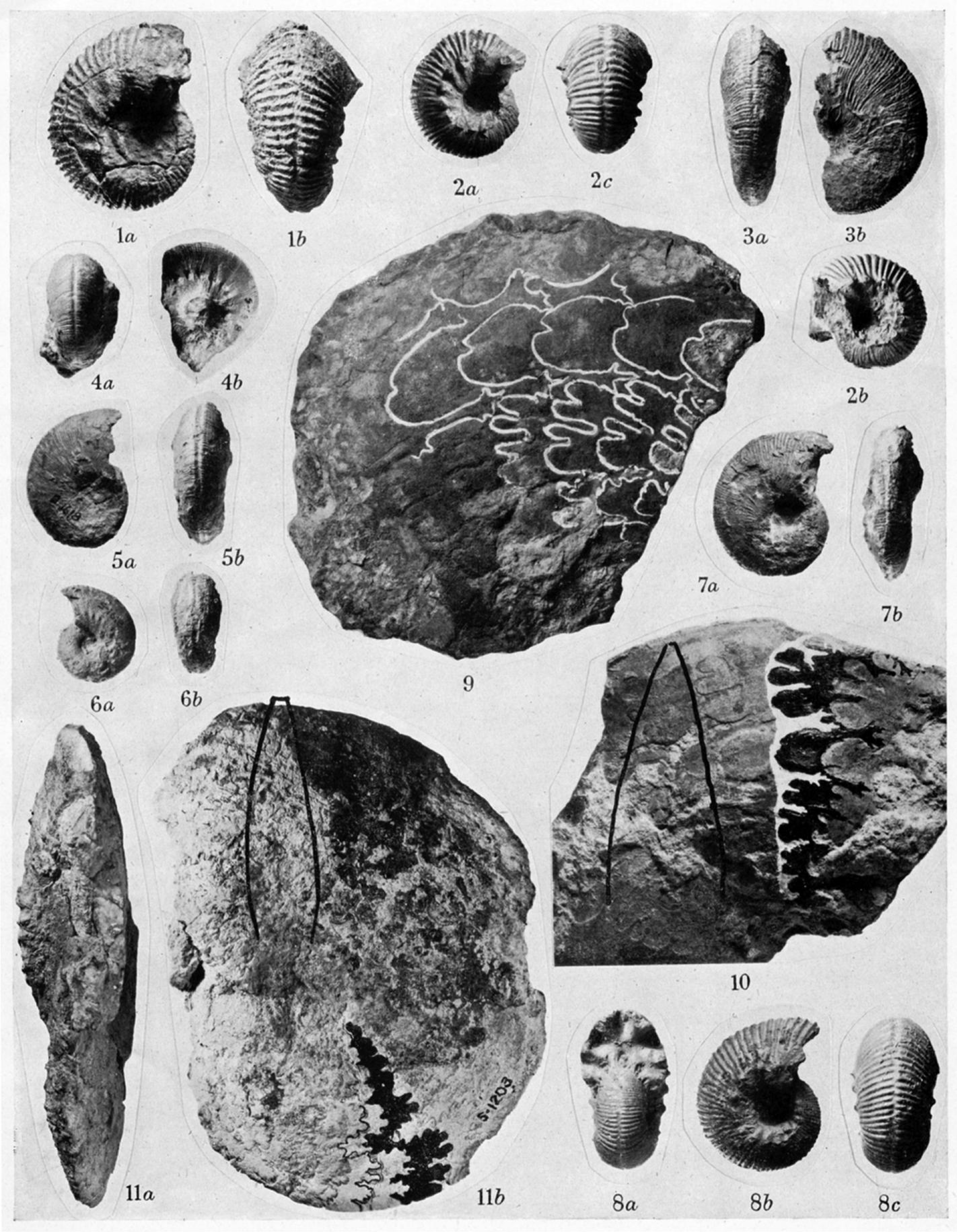


Plate 23

Bajocian ammonites from the Lower Dhruma formation, and three oxycones (figures 9, 10, 11) from the base of the Middle Dhruma.

Figures

1, 2. *Ermoceras splendens* n.sp., from the purple-red band near Juraifa, locality 2. SM. F 10745–6 (p. 274).

3, 5, 7. *Ermoceras elegans* Douvillé, from the purple-red band near Juraifa, locality 2. SM. F 10747–9 (p. 277).

4, 6. *Ermoceras strigatum* n.sp., from the purple-red band near Juraifa, locality 2. Figure 4 holotype, SM. F 10750; figure 6 SM. F 10751 (p. 277).

8*a*, *b*, *c*. *Ermoceras splendens* n.sp. Holotype, purple-red band near Juraifa, locality 2. SM. F 10752 (p. 274).

9, 10. *Bramkampia steinekei* n.sp. *Thambites* beds, base of the Middle Dhruma formation near Juraifa, locality 8. Figure 9, SM. F 10753; figure 10 holotype, SM. F 10754 (p. 282).

11 *a*, *b*. *Thambites planus* n.sp. Medium-sized specimen × 0·8, Khashm Dhibi, locality 51. SM. F 10755 (p. 280).

All figures except 11 *a*, *b*, natural size.

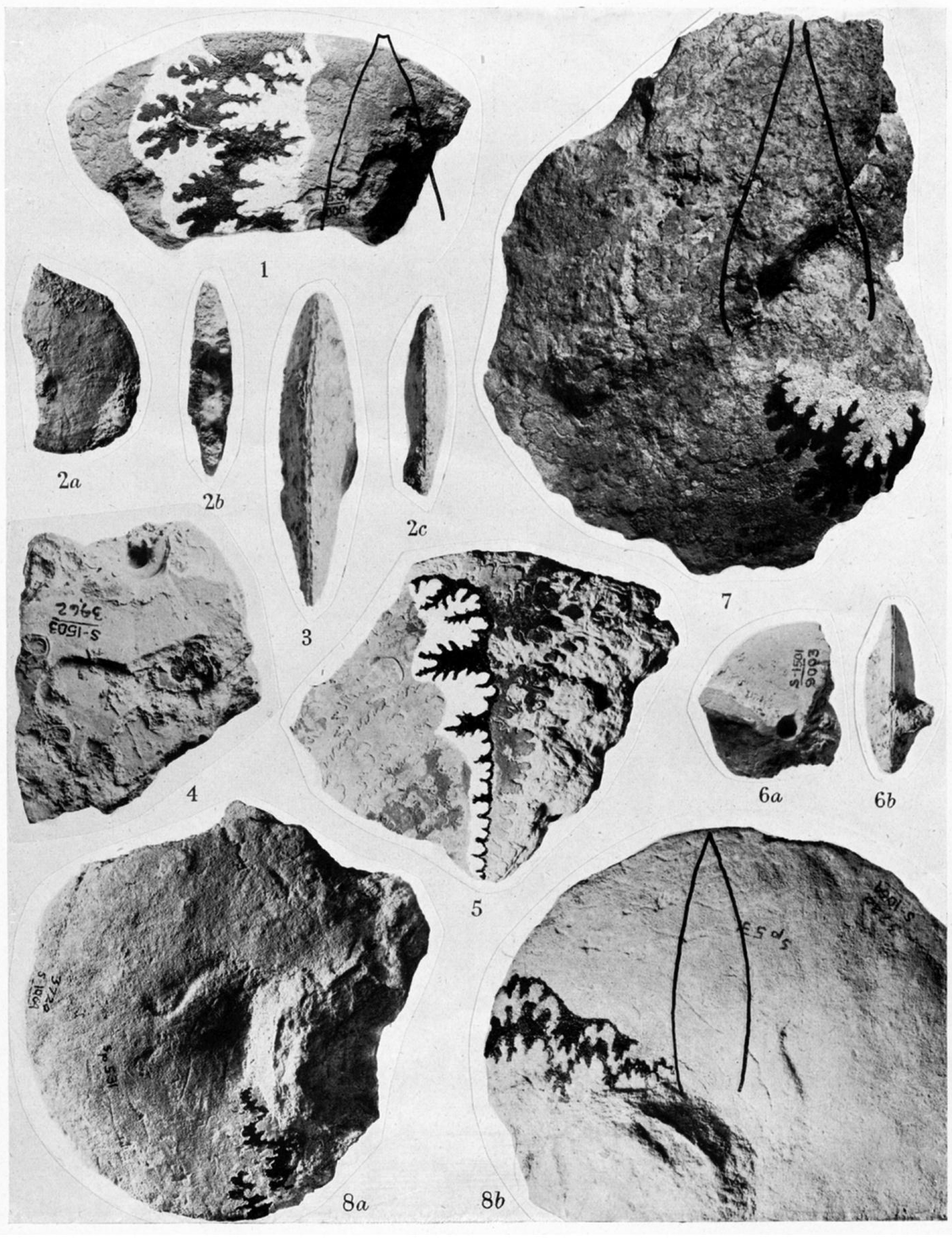


PLATE 24

Oxycones (Lower Bathonian?) from the base of the Middle Dhruma formation.

FIGURES

1. *Thambites planus* n.sp., detail of suture, showing adventitious branch of external lobe. Juraifa area, locality 6 (topotype). SM. F10756 (p. 280).

2, 3. *Thambites planus* n.sp., inner whorls showing concave venter. Juraifa area, locality 7. SM. F10757–8 (p. 280).

4. *Thambites planus* n.sp., fragment showing well-preserved umbilicus. Locality 7. SM. F10759 (p. 280).

5. *Thambites planus* n.sp., fragment with complete external suture. Locality 7. SM. F10760 (p. 280).

6*a*, *b*. *Thambites planus* n.sp. Holotype, Juraifa area, locality 6. SM. F10761 (p. 280).

7. *Thambites avus* n.sp. Holotype, Khashm Dhibi, locality 48. SM. F10762 (p. 281).

8*a*, *b*. *Clydoniceras pseudodiscus* n.sp. Holotype, Hauta Pass, locality 60. Figure 8*a*, reduced photo taken in Dhahran; figure 8*b*, part of same with more sutures inked, natural size. SM. F10763 (p. 282).

All figures natural size, except figure 8*a*.

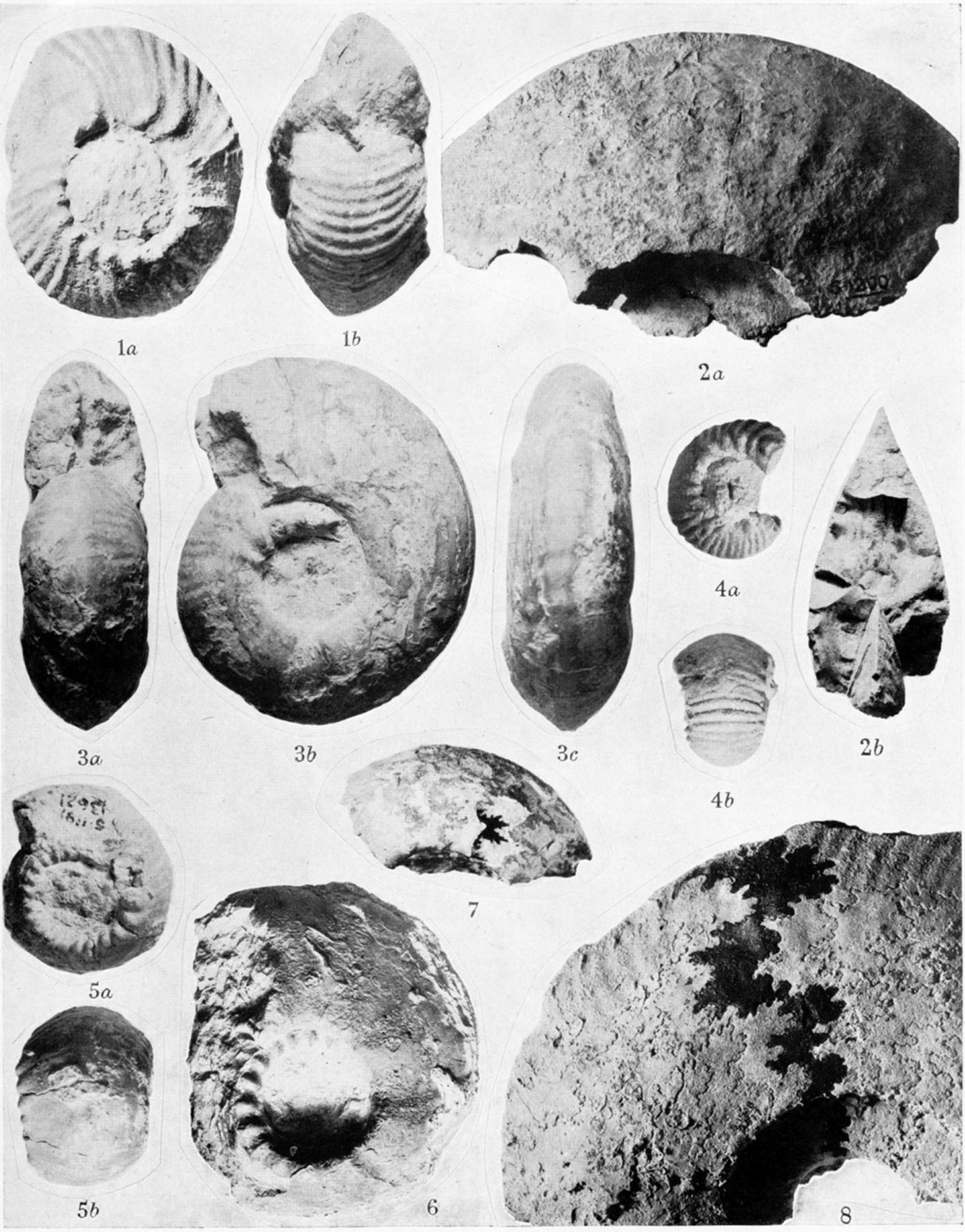


Plate 25

Middle Bathonian ammonites from the Middle Dhruma formation.

Figures

1 *a*, *b*. *Tulites erymnoides* n.sp. Holotype, Barra area, locality 25. SM. F10764 (p. 284).

2 *a*, *b*. *Dhrumaites cardioceratoides* n.sp. Interior of giant septate specimen from locality 30, of which the suture is shown in text-figure 10, p. 289. SM. F10765 (p. 288).

3 *a*, *b*, *c*. *Tulites tuwaiqensis* n.sp. Holotype, Juraifa area, locality 12. SM. F10766 (p. 284).

4 *a*, *b*. *Tulites erymnoides* n.sp. Barra area, locality 24. SM. F10767 (p. 284).

5 *a*, *b*. *Tulites arabicus* n.sp. Juraifa area, locality 12. SM. F10768 (p. 283).

6. *Tulites arabicus* n.sp. Holotype, Juraifa area, locality 12. SM. F10769 (p. 283).

7. *Tulites arabicus* n.sp. Fragment of topotype showing the cloven second lateral lobe, locality 12. SM. F10770 (p. 283).

8. *Dhrumaites cardioceratoides* n.sp. Holotype, reduced ×0·55. Collapse along a longitudinal line of weakness formed by part of the second lateral lobe produces a false umbilicus. SM. F10771 (p. 288).

All figures natural size, except figure 8.

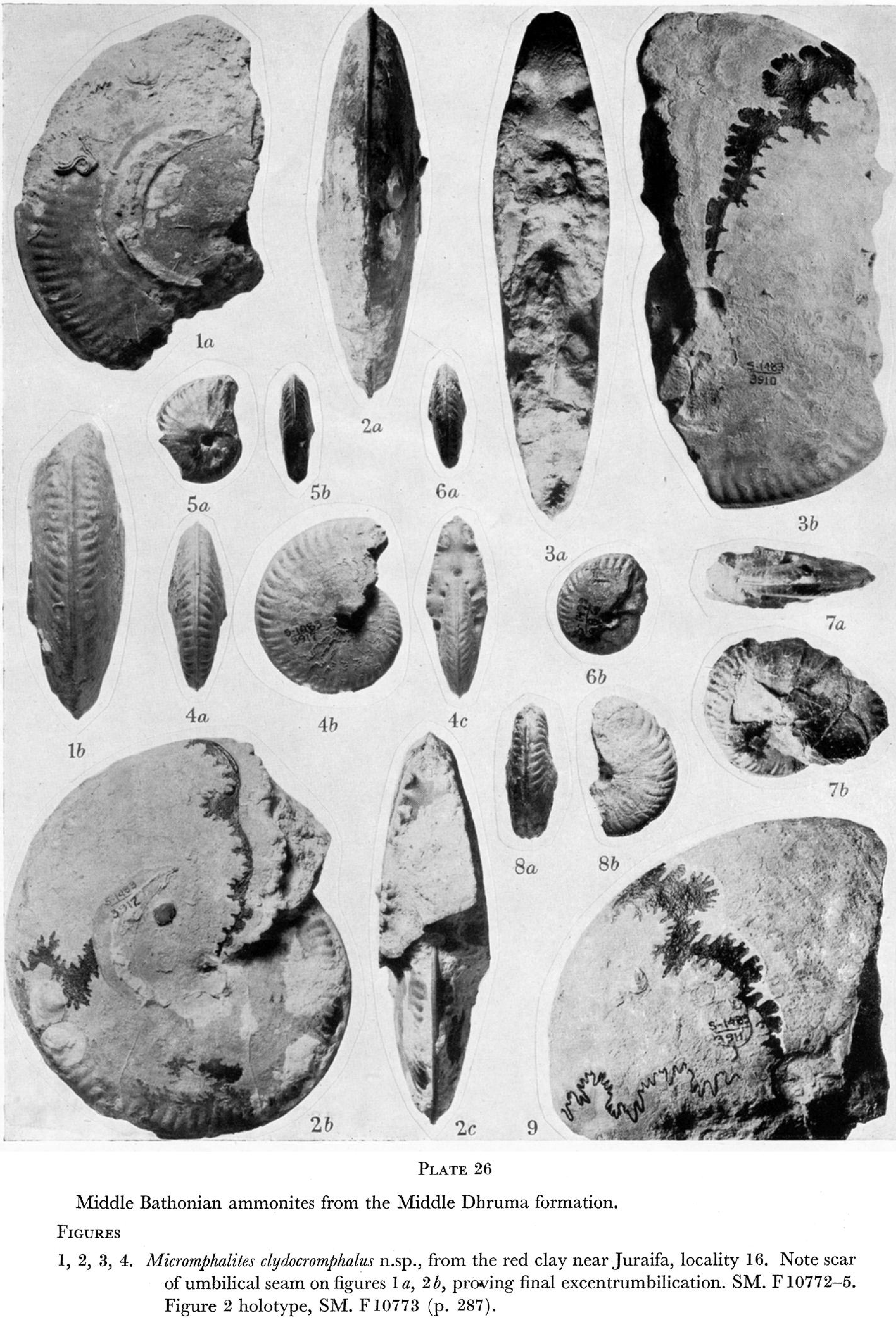


PLATE 26

Middle Bathonian ammonites from the Middle Dhruma formation.

FIGURES

1, 2, 3, 4. *Micromphalites clydocromphalus* n.sp., from the red clay near Juraifa, locality 16. Note scar of umbilical seam on figures 1*a*, 2*b*, proving final excentrumbilication. SM. F 10772–5. Figure 2 holotype, SM. F 10773 (p. 287).

5, 6, 7. *Micromphalites clydocromphalus* n.sp., from the chocolate cast bed, Juraifa area, locality 18 (figures 5, 6) and locality 17 (figure 7). SM. F 10776–8 (p. 287).

8*a*, *b*. *Micromphalites elegans* n.sp., Juraifa area, locality 17. SM. F 10779 (p. 286).

9. *Micromphalites clydocromphalus* n.sp., from the red clay, Juraifa area, locality 16. Compare the suture, especially the second lateral lobe, with figures 2*b* and 3*b*. SM. F 10780 (p. 287).

All figures natural size.

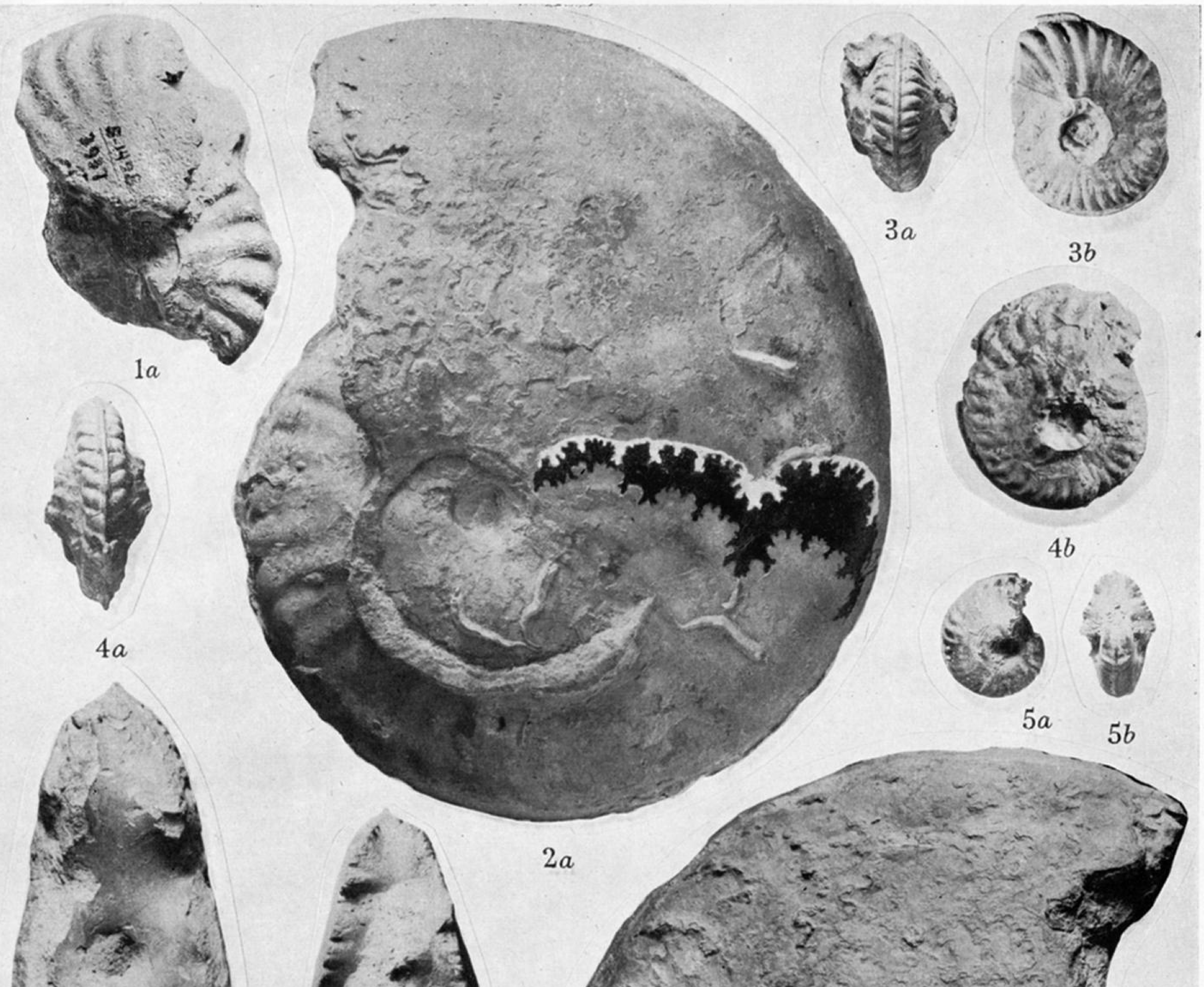


PLATE 27

Middle Bathonian ammonites from the Middle Dhruma formation.

FIGURES

1, 2. *Micromphalites* cf. *busqueti* (de Grossouvre), Juraifa area, locality 20. SM. F 10781–2 (p. 284).

3, 4. *Micromphalites* cf. *busqueti* (de Grossouvre), from the red clay, Juraifa area, locality 17. SM. F 10783–4 (p. 284).

5, 6. *Micromphalites* cf. *busqueti* (de Grossouvre), from the chocolate cast bed, Juraifa area, locality 18. SM. F 10785–6 (p. 284).

All figures natural size.

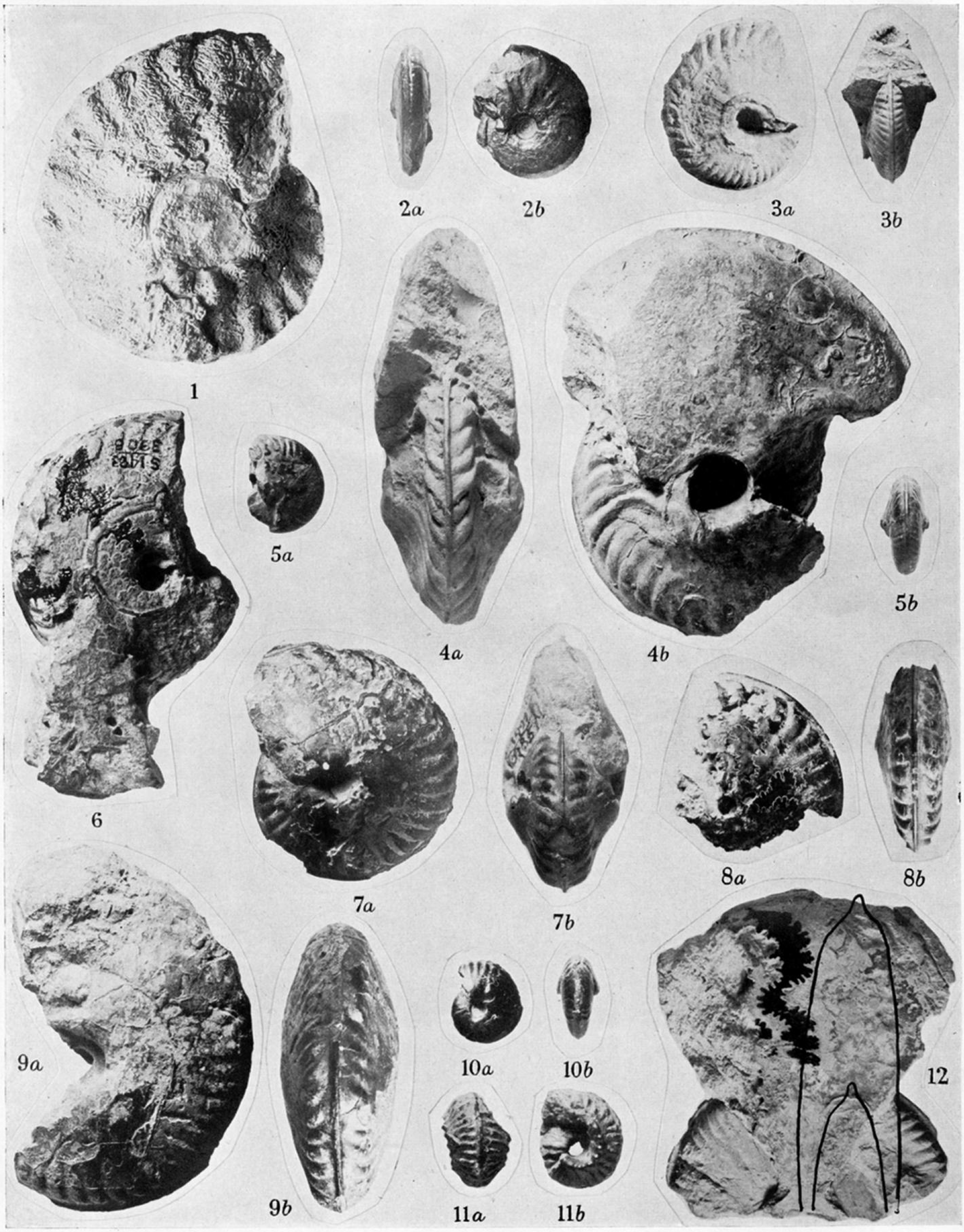


PLATE 28

Middle Bathonian ammonites from the Middle Dhruma formation.

FIGURES

1. *Micromphalites pustuliferus* (Douvillé), Wadi Birk, locality 65. (The back and much of the front is eaten away by sand-blast.) SM. F 10787 (p. 285).

2*a*, *b*. *Strungia arabica* n.sp. Holotype, from the chocolate cast bed, near Juraifa, locality 18. SM. F 10788 (p. 287).

3*a*, *b*. *Micromphalites elegans* n.sp. Holotype, Juraifa area, locality 17. SM. F 10789 (p. 286).

4*a*, *b*. *Micromphalites elegans* n.sp., from the red clay Juraifa area, locality 16. SM. F 10790 (p. 286).

5, 8. *Micromphalites elegans* n.sp., from the chocolate cast bed, Juraifa area, locality 18. SM. F 10791–2 (p. 286).

6. *Micromphalites intermedius* n.sp., Juraifa area, locality 16. SM. F 10793 (p. 286).

7, 9. *Micromphalites intermedius* n.sp., from the chocolate cast bed, Juraifa area, locality 18. Figure 9 holotype, SM. F 10794; figure 7 aff. *intermedius*, SM. F. 10795 (p. 286).

10*a*, *b*. *Micromphalites* sp. indet., chocolate cast bed, Juraifa area, locality 18. SM. F 10796.

11*a*, *b*. *Micromphalites vertebralis* n.sp. Holotype, chocolate cast bed, Juraifa area, locality 18. SM. F 10797 (p. 286).

12. *Micromphalites clydocromphalus* n.sp. Specimen showing ribbed inner and smooth outer whorls, wholly septate. Juraifa area, locality 17. SM. F 10798 (p. 287).

All figures natural size.

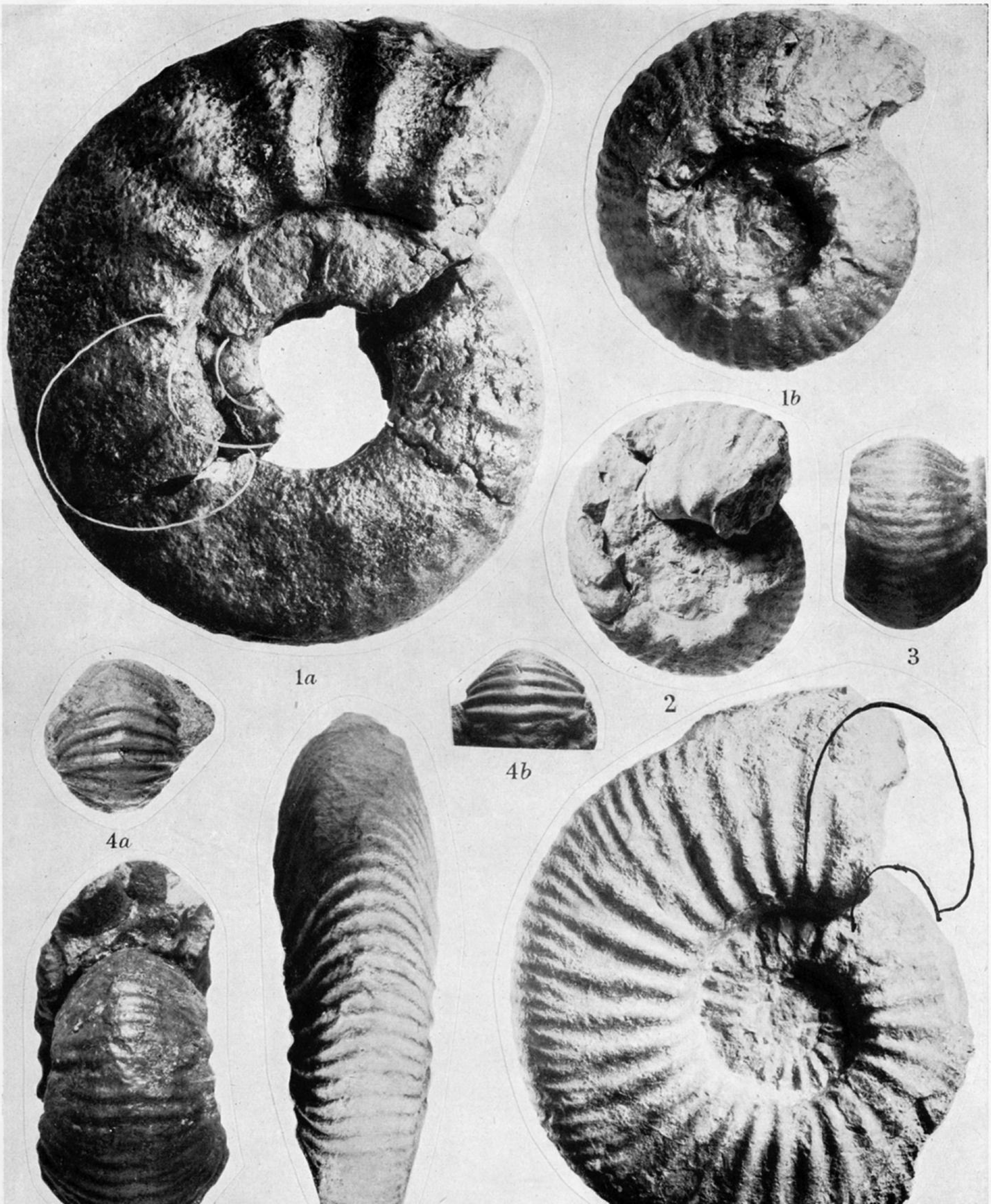


PLATE 29

Middle Callovian ammonites from the Tuwaiq Mountain Limestone; and a Lower Kimeridgian perisphinctid (figure 5) from the Jubaila formation.

FIGURES

1 *a*, *b*, *c*. *Erymnoceras philbyi* n.sp., holotype. Figure 1 *a*, outer whorls reduced × 0·70. 1 *b*, 1 *c*, detached inner whorls natural size. Barra area, locality 31. SM. F 10799 (p. 290).

2. *Erymnoceras philbyi* n.sp. The specimen collected by H. St J. B. Philby in 1932 at Sha'ib Hassi, near Haisiya Pass. Brit. Mus. (Nat. Hist.) C. 35960 (p. 290).

3. *Erymnoceras* cf. *philbyi* n.sp., Barra area, locality 32. SM. F 10800 (p. 290).

4 *a*, *b*. *Erymnoceras* cf. *jarryi* (R. Douvillé), Barra area, locality 33. SM. F 10801 (p. 290).

5 *a*, *b*. *Perisphinctes jubailensis* n.sp. Holotype, Jubaila formation, Wadi Birk, locality 67. SM. F 10802 (p. 292).

All figures natural size, except figure 1 *a*.

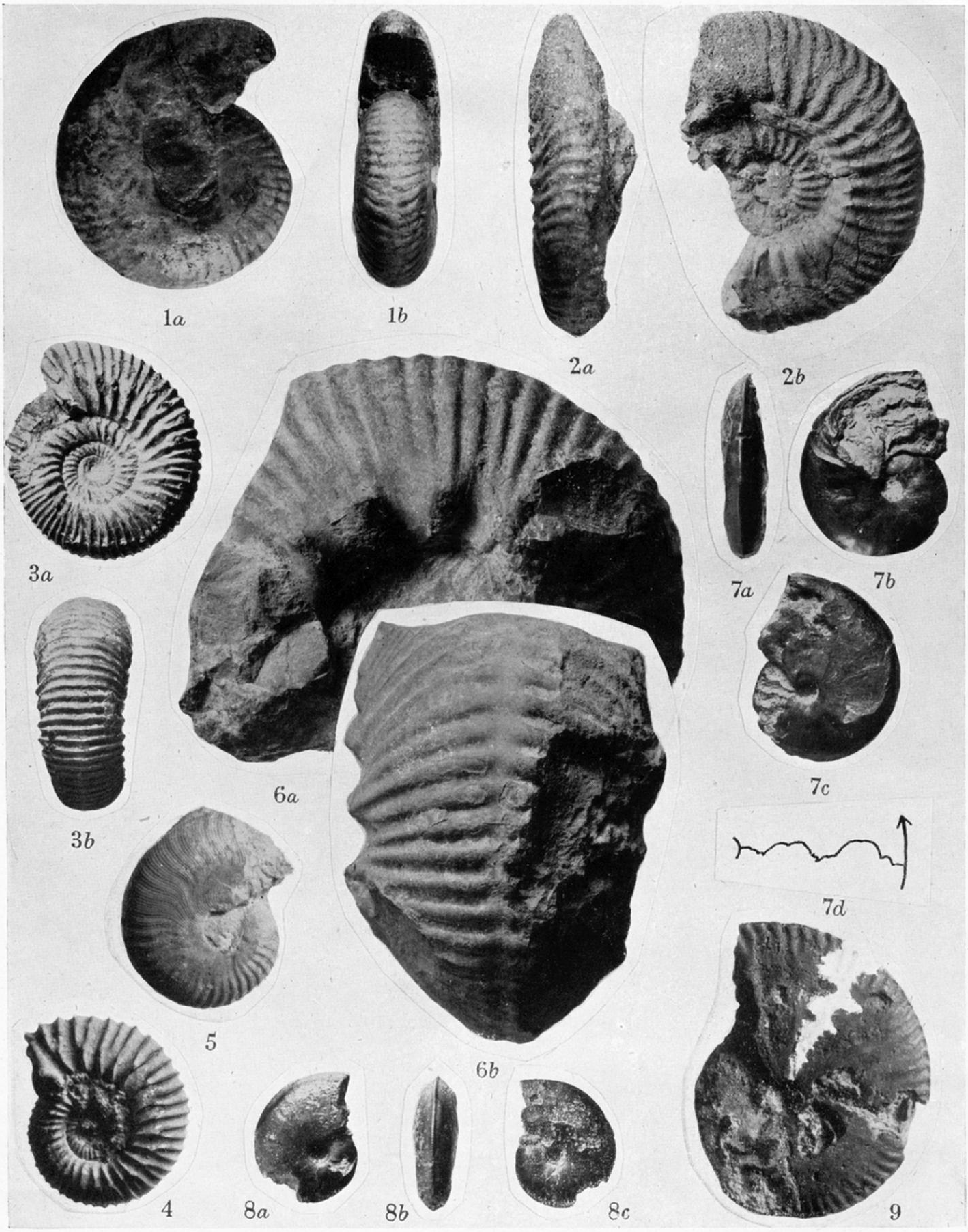


PLATE 30

Middle Callovian ammonite from the Tuwaiq Mountain Limestone (figure 1) and Lower Kimeridgian ammonite from the Jubaila formation (figure 2).

FIGURES

1 *a*, *b*. *Pachyceras* cf. *schloenbachi* (Roman), Barra area, locality 32. SM. F 10803 (p. 291).

2 *a*, *b*. *Perisphinctes* aff. *jubailensis* n.sp., locality 69; the most southerly ammonite yet found in the Jebel Tuwaiq. SM. F 10804 (p. 292).

Bajocian ammonites from Gebel Maghara, Sinai.

3 *a*, *b*. *Normannites* cf. *braikenridgii* (J. Sowerby). ×2. Sample 21074. Smithsonian Inst., Washington, D.C. (p. 309).

4. *Normannites egyptiacus* n.sp., holotype ×2. Geological Survey of Egypt, Cairo, no 16685 (p. 309).

5. *Ermoceras* sp., inner whorls ×2. Geological Survey of Egypt, Cairo, no. 16674 (p. 272).

6 *a*, *b*. *Ermoceras splendens* n.sp. ×1. Sample 21077 *a*. Smithsonian Inst., Washington, D.C. (p. 308).

7, 8. *Magharina magharensis* n.sp. ×2. Figures 7 *a–d* holotype. Sample 21082, *Ermoceras* beds. Smithsonian Inst., Washington, D.C. Figure 7 *d* suture-line (p. 307).

9. *Thamboceras mirabile* n.sp. ×2. Holotype, Geological Survey of Egypt, Cairo, no. 16687 (p. 278).

Figures 1, 2, 6 natural size, the rest ×2.

PLATE 31

Typical Jurassic escarpments of Jebel Tuwaiq.

Above

Tuwaiq Mountain Limestone and Upper Dhruma formation, south side of Wadi Birk. The cliff is about 600 ft. high. The vertical part is formed by coral limestones, the middle part by chalky and marly limestones with the Middle Callovian *Erymnoceras* fauna. The terrace feature near the base is the Upper Dhruma formation with abundant *Gryphaea costellata.* (Locality 64 is a short distance to left of picture.)

Below

Marrat formation, Jafair Trail, close to localities 55, 56, 57. The top of the mesa in the middle distance is just below the *Bouleiceras* horizon, with Lower Marrat and Minjur Sandstone forming the cliff below. The photograph is taken from unfossiliferous Middle Marrat beds, with the *Nejdia* bed above and behind the photographer.

The higher cliff in distance on left is formed by the Lower Dhruma formation and capped by the Dhibi Limestone (*Ermoceras* beds).

Photographs by W. J. Arkell, January 1951.