THE BAJOCIAN AMMONITES OF WESTERN AUSTRALIA

By W. J. ARKELL, F.R.S. and P. E. PLAYFORD

(*Received* 13 *January* 1954)

[Plates 27 to 40]

CONTENTS

PART I. STRATIGRAPHICAL INTRODUCTION

By P. E. Playford

The Bajocian (Middle Jurassic) ammonites of Western Australia are described on the basis of an extensive collection made in 1952–3 by Phillip E. Playford, who contributes a stratigraphical introduction and a geological map. In this introduction he subdivides the Jurassic sediments (total thickness at outcrop up to 550 ft.), names and defines most of the groups and formations for the first time, and elucidates complications due to lateritic alteration. All the ammonites come from the Newmarracarra Limestone (up to 38 ft. thick). The ranges of the species are determined so far as practicable.

The ammonite fauna comprises at least twenty-three species (at least eleven new), now assigned to seven genera. The new collection enables Crick's type specimens, named in 1894 on the basis of defective and inadequate material, to be reinterpreted, and necessitates complete generic revision. The age of the fauna is Middle Bajocian. Most of it belongs to the Sowerbyi Zone, but in places there is believed to be also a thin representative of the Humphriesianum Zone.

A comparison (now possible for the first time) is made with the Bajocian ammonite faunas of circum-Pacific countries and central Asia: New Guinea, the Moluccas, Tibet, eastern Siberia, Alaska, western Canada, western United States, Mexico and the Andes. Photographs are given of comparable ammonites from Tibet, Canada and Argentina, not previously published photographically.

Apart from the Moluccas, the peculiar Australian stephanoceratid ammonites, *Pseudotoites* and their allies, are not known from any of the extensive Bajocian outcrops in the Old World. Hitherto they have been thought to be confined to Western Australia. It is now shown that *Pseudotoites* occurs in the Moluccas, British Columbia, Alaska and Argentina, and that some rarer allied forms of Western Australia belong to the genus *Zemistephanus*, hitherto known only in Canada, Alaska and the United States. This distribution is held to indicate free migration across the Pacific Ocean.

The regional basis of evolutionary radiation in several groups of Middle Bajocian ammonites is pointed out, and the significance of the facts for evolutionary and systematic theory is briefly stated.

The Middle Bajocian stratigraphy of north-west Europe is historically summarized in order to provide a framework and scale of comparison for the Australian and circum-Pacific deposits.

PART I. STRATIGRAPHICAL INTRODUCTION

By P. E. PLAYFORD

1. Introduction

Geraldton is situated on the coast of Western Australia, about 230 miles north of Perth, the capital city. It is a port on Champion Bay, serving the surrounding agricultural and mining areas.

The marine Jurassic sediments of Geraldton have been known since the middle of the last century, and until comparatively recently were the only known exposures of marine Jurassic in Australia. Nevertheless, a detailed stratigraphic investigation has not been undertaken previously, owing largely to the lack of any economically important deposits associated with the sediments. During this investigation an area of approximately 400 square miles around Geraldton was examined in reconnaissance, and a detailed survey was carried out on approximately 14 square miles in the vicinity of Bringo, a small railway station 19 miles east of Geraldton on the Geraldton-Mullewa line. The mapping was done, working alone, using vertical air photographs and base maps compiled from the army one-mile-to-the-inch sheets. The investigation was undertaken as a research project at the Geology Department, University of Western Australia, while I was attached to the staff of the Bureau of Mineral Resources, Canberra. I wish to thank my supervisor Dr R. W. Fairbridge, also Professor R. T. Prider and Mr A. F. Wilson, for their willing co-operation throughout. Dr R. O. Brunnschweiler of the Bureau of Mineral Resources accompanied me on my last trip to Geraldton, and I am very grateful for his assistance.

Localities mentioned in the text will be referred to the same grid as that used on the army one-mile-to-the-inch sheets. This grid is shown in figure 1. Six numerals are given as the grid reference for each point, the first three being the east-west reading, estimated to the nearest tenth and the second three being the north-south reading. Taking Bringo as an example, the grid reference is given as (759365).

2. Historical review

The Geraldton district was one of the first parts of Western Australia to be settled, and in the early 1850's several sheep stations were established in the present area. The richly fossiliferous rocks attracted the attention of these early settlers, and as a result several fossil collections found their way to England.

The first to record the Jurassic age of these fossils was Moore (1862), who referred them to the Upper and Middle Lias of the English succession. Earlier, A. C. Gregory (1849),

GEOLOGICAL MAP OF THE GERALDTON DISTRICT

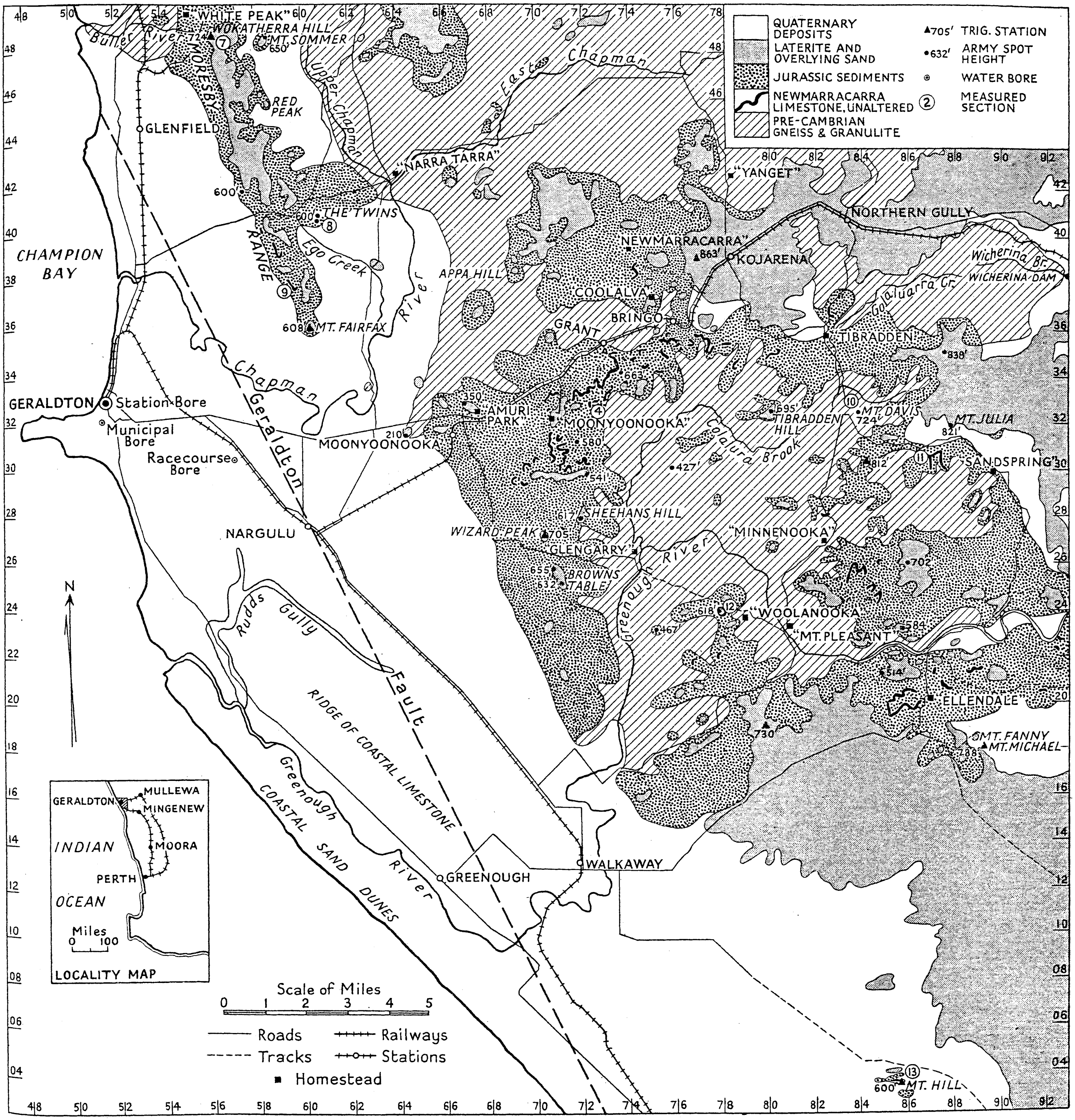


FIGURE 1. Geological map of the Geraldton district, by P. E. Playford.

J. W. Gregory (1849), F. von Sommer (1849), and F. T. Gregory (1861) had written brief accounts of the geology of the district, but none had recognized the Jurassic age of the sediments.

In 1867, the Reverend W. B. Clarke published a paper on fossils he had been sent from the Moresby Range, near Geraldton. His conclusion was that 'Taking the general aspect and association of these fossils, and the occurrence of such forms as *Avicula munsteri*, *Ostrea marshi* and *Ammonites moorei*, it is almost certain that the nearest representative of the formation is the Inferior Oolite'. This conclusion of Clarke's is held to the present day, the Newmarracarra Limestone being considered to be of Bajocian (Inferior Oolite) age, though it has been further narrowed down to the Middle Bajocian.

Moore (1870) correlated the fossils he described from Western Australia with the Lower Oolite, Upper and Middle Lias of England. These fossils were said to have come from either Shark Bay or Champion Bay, but they must have come from the latter locality, as no Jurassic sediments are known near Shark Bay.

In 1885, Neumayr described some Jurassic fossils in the collection of the Geological Institute of Vienna, and on the basis of ammonites correlated them with the Humphriesianum Zone (Middle Bajocian) of Europe. According to their labels, these specimens were collected from the Glenelg River in Western Australia, but they must have been wrongly localized. The Glenelg River is in the Kimberleys, 1100 miles north-east of Geraldton, and flows through rocks of Proterozoic age. Neumayr himself was doubtful about the locality and suggested that the fossils had come from the Glenelg Land Division (now non-existent), between latitudes 30 and 31° S. The upper reaches of the Moore River are in this district, and Neumayr thought that this might be the river from which the specimens came. This suggestion was supported by Maitland (1919). Nevertheless, no marine Jurassic has been recorded from the Moore River, and it is almost certain that Neumayr's specimens came from the Geraldton district. The Greenough River flows through this district and it is possible that Glenelg was misread for Greenough.

Crick (1894) published a paper on some cephalopods from the Geraldton district. He named seven new species, which succeeding authors have had difficulty in identifying as they were based on very poor specimens figured half natural size. One of the ammonites was supposed to have come from Cape Riche, east of Albany on the south coast. However, Tertiary sediments, not Jurassic, are found at Cape Riche, and this specimen must have been wrongly labelled. Crick reached the conclusion that all the fossils were of Lower Oolite (Middle Jurassic) age, and that no Liassic species were present in the collection.

Further palaeontological papers were published by Etheridge (1901), describing *Ctenostreon pectiniformis* (Schlotheim), Chapman (1904*a*) on the Foraminifera and Ostracoda, Chapman (1904*b*) on Mollusca, including ammonites, but describing no new species, and Etheridge (1910) establishing several new species of Pelecypoda.

W. D. Campbell (1907) published a geological map of the Greenough River district, with accompanying notes. This map shows the broad distribution of the Jurassic sediments and pre-Cambrian rocks, but the notes give little information on the stratigraphy of the area. Further work by Campbell was published in 1910 as part of his outstanding contribution to the geology of Western Australia: 'The Irwin River Coalfield and the adjacent districts from Arrino to Northampton.' This report embraced an area of about 2000 square miles and included the area covered by my survey. However, Campbell was mainly concerned with the Permian sediments of the Irwin River, and his report contains no detailed information on the stratigraphy of the Jurassic.

The next palaeontological study was by F. W. Whitehouse (1924), who examined fossils collected by W. G. Woolnough from near Bringo. He named several new species and, on evidence supplied by ammonites, suggested a Middle Bajocian age for the fauna.

Spath (1939) described a small collection of ammonites from the Geraldton district and considered that they were referable to the Sauzei or Sowerbyi Zones (Middle Bajocian) of the European succession.

3. General geology

The country to the east of Geraldton consists of remnants of a plateau dissected by the Greenough and Chapman rivers. Flat-topped hills (buttes and mesas) of Jurassic sediments capped by laterite and underlain by pre-Cambrian metasediments are very conspicuous in the district. The Jurassic sediments are practically horizontal, showing only minor differences in elevation, with dips of a few feet per mile.

The western margin of the dissected plateau is marked by the Geraldton Fault Scarp (Jutson 1914). This scarp is deeply eroded and has retreated several miles. In front of it is a coastal plain 3 to 10 miles wide.

The Geraldton Fault is the major structural feature of the area. This fault is thought to be post-Jurassic but pre-laterite and is a normal fault, with a throw to the west of about 750 ft. Minor normal faults, cutting both the pre-Cambrian and Jurassic rocks, have been observed in the area.

3·1. *Pre-Cambrian*

Pre-Cambrian metasediments crop out over a large proportion of the area, but exposures are generally poor. These rocks have undergone high-grade regional metamorphism, and consist of granitic gneisses and granulites, which are characteristically garnetiferous. At a few places in the area the metamorphic rocks are intruded by dolerite dykes.

The contact between the pre-Cambrian rocks and Jurassic sediments is very irregular. East of the Geraldton Fault the elevation of the unconformity above sea-level varies from about 250 ft. near 'Narra Tarra' (642428) to 717 ft. at Mount Davis (840325).

Although the pre-Cambrian basement rises gradually from west to east, this rise is not continuous, and there are irregularities in the surface of the unconformity which existed as hills and valleys before the Jurassic sediments were deposited. The basal formations of the Jurassic are found to pinch out against these buried hills, so that the lower the elevation of the unconformity, the greater is the thickness of the sediments.

3·2. *Jurassic*

In the Geraldton district flat-lying Jurassic sediments are known to extend from the northern end of the Moresby Range (562487) as far south as Mount Hill (858035). Both marine and continental deposits are found in this area. The marine transgression extended at least 25 miles east of Geraldton.

Although a Jurassic age is proved for the marine sediments, the Newmarracarra Limestone being accurately dated to the Middle Bajocian, there is no direct proof of the age of the associated continental deposits. However, the disconformity at the base of the marine sediments is believed to represent only a short time interval and the underlying continental sediments are taken to be also Jurassic.

The following classification of the Jurassic sediments of the Geraldton district is now proposed; the rock units, here named, with two exceptions, for the first time, will be more fully described in a forthcoming paper.

TABULATION OF FORMATIONS

(TOP)

2. CHAMPION BAY GROUP (first referred to by Maitland, 1907, as the 'Champion Bay beds'): Marine sandstones, shales and limestone, of Middle Jurassic age. The group is at least 150 ft. thick and is made up of the following formations:

2*d*. *Kojarena Sandstone:* Brown ferruginous sandstone with some claystones and shales near the top. The sandstone contains rare marine fossils of which the following have been identified: *Trigonia moorei* Lycett, *Isognomon* sp., *Belemnopsis* sp. Thickness: over 83 ft.

2*c*. *Newmarracarra Limestone* (first referred to by Glauert (1926) as the 'Newmarracarra Beds'): yellow to grey, massive, richly fossiliferous limestone. The limestone is subject to irregular alteration (lateritization), and may be replaced by hematite, or leached of calcium carbonate leaving a residue of its clastic impurities. All the fossils previously described from the Geraldton district were obtained from this formation. For details see §4 below, p. 555. Thickness: 16 to 38 ft.

2*b*. *Bringo Shale:* black shale, with thin yellow phosphatic bands. Phosphatic nodules are often found at the contact with the overlying Newmarracarra Limestone. Dwarf pelecypods, including species of *Meleagrinella*, are abundant at several horizons. Thickness: 0 to 8 ft.

2*a*. *Colalura Sandstone:* predominantly brown to black ferruginous sandstone, in places grading into yellow sandy claystone. Fossil wood is abundant and small oval nodules are frequent. Both nodules and fossil wood are sometimes phosphatic, but are usually replaced by limonite. Marine fossils are occasionally found and include *Astarte cliftoni* Moore, *Astarte* sp., *Lopha* cf. *marshi* (J. Sowerby), *Ctenostreon pectiniformis* (Schlotheim), *Trigonia moorei* Lycett, *Ostrea* sp., *Oxytoma* sp., *Belemnopsis* sp. Thickness: 0 to 28 ft.

1. CHAPMAN GROUP: Continental fluviatile sandstones with subordinate lenses of shale, claystone, siltstone and conglomerate. The group rests unconformably on the irregularly eroded surface of the pre-Cambrian basement and is overlain disconformably by the Champion Bay Group of marine sediments. The group varies from 0 to 400 ft. in thickness and is made up of the following formations:

1*b*. *Moonyoonooka Sandstone:* predominantly yellow, fine-grained felspathic sandstone and arkose, with subordinate lenses of shale and conglomerate. Well bedded, with cross-bedding and current ripple-mark common. Ferruginous concretions are characteristic, fossil wood is abundant; fossil leaves very rare. Thickness: 0 to 120 ft.

1*a*. *Greenough Sandstone:* mottled red, white, yellow and purple argillaceous sandstone, poorly sorted, with subordinate lenses of shale, claystone, siltstone and conglomerate. Poorly bedded and containing rare fossil wood. Thickness: 0 to 280 ft.

The total maximum thickness of the Chapman and Champion Bay Groups probably does not exceed 550 ft. in the area examined; no single section exposes so great a thickness.

Around Geraldton, on the downthrown side of the Geraldton Fault, several bores have been put down for water. The Racecourse Bore (569305) penetrated 1530 ft. of sediments without striking basement, while the Municipal Bore (514322) struck granitic rocks at 1408 ft. The uppermost 200 ft. or so of these sediments is probably Kainozoic, and though there is no evidence as to the age of the rest of the sequence, it may well be Jurassic.

Marine Jurassic sediments apparently equivalent in age to those from the Geraldton district have been found in two other localities in Western Australia. Teichert (1940) discovered a calcareous sandstone containing *Meleagrinella sinuata* (Teichert), *Ostrea tholiformis* Etheridge fil. and *Parachaetetes megalocytus* Pia in a small fault block on the Minilya River, 350 miles north of Geraldton. He believes this may be correlated with the marine Bajocian of the Geraldton district. Bajocian limestone was also found by Conrad & Maynard (ms. 1948) near the Hill River, 100 miles south of Geraldton. R. W. Fairbridge identified fossils from this locality, finding such forms as *Meleagrinella sinuata* (Teichert), *Oxytome decemcosta* Whitehouse, and *Belemnopsis*, all of which are characteristic of the Newmarracarra Limestone of the Geraldton district. Since then ammonites have been found (see p. 556).

Thus the Bajocian transgression is known to have extended for at least 450 miles along the Western Australian coast.

3·3. *Laterite and sand-plain*

A considerable part of the area is covered by laterite which is frequently overlain by sand. These deposits, which have a widespread development throughout Western Australia, are generally considered to be fossil soil horizons formed during a pluvial period in the late Tertiary (probably Pliocene according to Whitehouse (1940). The laterite is up to 20 ft. thick and crops out as large massive blocks around the edges of hills, giving rise to 'breakaways'. It consists of hydrous and anhydrous oxides of iron and aluminium, with minor amounts of quartz and other insoluble minerals.

Deposits of quartz sand up to about 20 ft. thick are found overlying the laterite wherever erosion has not been too severe. The sand is thought to be essentially *in situ* and genetically related to the underlying laterite.

The laterite in the district formed on a dissected surface of fairly well-marked relief, not on a low-lying peneplain as supposed by previous authors. This is shown by the fact that the laterite dips towards present-day river valleys at up to 10° and also shows a continuous variation in elevation from 210 to 863 ft. above sea-level.

A deep zone of alteration exists below the laterite itself. The pre-Cambrian rocks are completely kaolinized to depths of 100 ft. or more. Among the sediments the Newmarracarra Limestone shows most clearly the effects of lateritization. To a depth of 80 ft. or so beneath the laterite, the limestone is completely altered, calcium carbonate being entirely removed.

In the field the relationship between limestone outcrop and elevation of laterite is very evident. Wherever the undulating upper surface of the laterite sinks to within a certain vertical distance above the base of the Newmarracarra Limestone, the outcrop of unaltered limestone ceases and only the altered limestone continues. Thus owing to the undulations in the surface of the laterite the thickness of the unaltered limestone shows considerable variation even over short distances.

Close to the laterite the limestone has been altered to a grey sandy clay with red (haematitic) patches. Calcium carbonate has been entirely leached from the rock, leaving the clay and sand which were present as impurities in the limestone. Also a certain amount of clay has apparently been introduced into the rock during lateritization, as the ratio of clay to sand seems higher than in the unaltered limestone. Fossils are almost completely destroyed, though obscure moulds are sometimes found on breaking open the ferruginous patches. As this rock grades upwards into normal laterite, and shows so few features to connect it with the Newmarracarra Limestone, it has been mapped simply as laterite.

At depths greater than about 20 ft. below the laterite, the limestone alters in a different manner. Directly above the unaltered limestone is a zone from which all calcium carbonate has been leached, leaving the clastic impurities (clay and sand). Above this the limestone has been replaced by ferric oxide (mainly haematite).

The haematite rock varies in colour from deep red to almost black and has a high content of iron. Moore (1870) gave analyses of two blocks of the haematite and they contained 49 and 56% respectively of metallic iron. Fossils are usually preserved as internal or external moulds. Several of the ammonite specimens described in this paper were obtained from this rock.

Owing to the abundance of marine fossils in the haematite rock it may appear at first sight to be a normal marine sediment. However, both the unaltered limestone and the haematite vary in thickness, and when the solid limestone is thick the haematite is thin and vice versa. Moreover, most of the fossils which have been found in the solid limestone have also been identified from the haematite. This shows that the haematite rock is not a primary sediment, but is secondary and has formed by the irregular replacement of limestone.

The leached zone between the unaltered limestone and the haematite also varies considerably in thickness. In places it is only an inch or so thick, while in others there may be as much as 8 ft. The leached zone was formed by removal of calcium carbonate followed by compaction of the insoluble clastic impurities remaining. Very few fossils survive, those which are found being internal moulds of ammonites and closed pelecypod valves.

Both the haematite rock and the underlying leached zone are readily recognized as altered limestone and have been mapped as such. They are included in the Newmarracarra Limestone.

The origin of laterite has been debated for many years. It is now accepted by most authors that it was deposited as a pseudo-illuvial soil horizon in the zone of fluctuation of the water table. The sand overlying laterite is considered to be the fossil A horizon (Prescott & Pendleton 1952). From evidence in the Geraldton district, however, it is clear that the laterite did not form on a peneplain.

In addition to laterite and sand-plain, other superficial deposits are widely distributed. These are of Quaternary age and include surface travertine (or caliche), Coastal Limestone, sand dunes and alluvium.

4. The Newmarracarra Limestone

All the ammonites described in this paper having been obtained from the Newmarracarra Limestone, it merits description in more detail than the other formations.

Definition. The name Newmarracarra Limestone is here introduced for the limestone, including altered limestone, which overlies either the Bringo Shale, Colalura Sandstone, Moonyoonooka Sandstone or the pre-Cambrian rocks and underlies the Kojarena Sandstone. The name is taken from Newmarracarra Station, a well-known pastoral property in the Geraldton district, the homestead being located at (741398).

The name 'Newmarracarra' had previously been used in a stratigraphic sense by Glauert (1926), who defined the 'Newmarracarra Beds' as the fossiliferous beds exposed in the 'Nineteen Mile' (Bringo) railway cutting, near which the fossils described by Whitehouse (1924) were obtained. Actually Whitehouse's fossils probably came from a railway well near Bringo and not from the cutting, but in either case they certainly came from the limestone and Glauert's name must be used in reclassification.

Teichert (1947) apparently independently proposed the name 'Newmarracarra Series' for the marine sediments of the Geraldton district. Fairbridge (ms. 1951) reclassified Glauert's and Teichert's terms as the 'Newmarracarra Formation' to include all the marine sediments. However, in the present detailed classification, taking Glauert's original definition into account, the name 'Newmarracarra' seems best restricted to the limestone.

The type section is on Round Hill, on Newmarracarra Station, near Grant (729351, 28° 45′ 31″S., 114° 48′ 23″E.).

Lithology. The Newmarracarra Limestone, where it has not suffered secondary alteration, usually consists of yellow to greyish white limestone, composed largely of entire or little-broken shells. It is generally massive, hard and smooth-weathering, cropping out as large slabs which frequently break off and tend to migrate down the hill-slopes, making it difficult to say when the slabs are *in situ*. There is little variation in lithology, except for a variable content of clay and sand. The percentage of these clastic impurities rises around residual hills of pre-Cambrian basement rocks, and near these hills the limestone occasionally grades into calcareous sandstone.

The limestone has been extensively altered by lateritization, as described in the preceding section. In addition, it is often stained red by haematite without complete removal of calcium carbonate. This is most noticeable where the limestone overlies Bringo Shale, with springs issuing at the contact. At these places the limestone is bright red near the base and unreplaced fossils are abundant. The haematite is thought to have been secondarily introduced by circulating ground water close to the contact with the impervious Bringo Shale.

Distribution and thickness. Unaltered Newmarracarra Limestone has a very limited distribution in the Geraldton district, by far the most extensive outcrops being found in the area mapped in detail (figure 1). Elsewhere, outcrops are very sporadic, owing to the fact that over a large part of the area the limestone is completely altered by lateritization. Owing to this irregular alteration, the thickness of limestone cropping out is very variable, the thickest exposures being near Round Hill (the type section), where up to 33 ft. of unaltered limestone is exposed. Elsewhere the formation is invariably altered to some extent, so that at least the upper part is replaced by haematite or simply leached of calcium carbonate. Because of the irregular leached zone, which causes compaction of the formation, it is impossible to give accurate primary thicknesses of the formation at those localities where it has been altered. The thickest section that has been measured is at (690297), where there is about 28 ft. of limestone and 10 ft. of altered limestone.

The Newmarracarra Limestone has been traced from Wokatherra Hill (562488), where there are poor exposures of altered limestone, as far south as Mount Hill (859035), where there are some good outcrops of unaltered limestone. The formation has been identified as far east as (964202), where it was struck in a well put down by Mr J. Prendergast, who

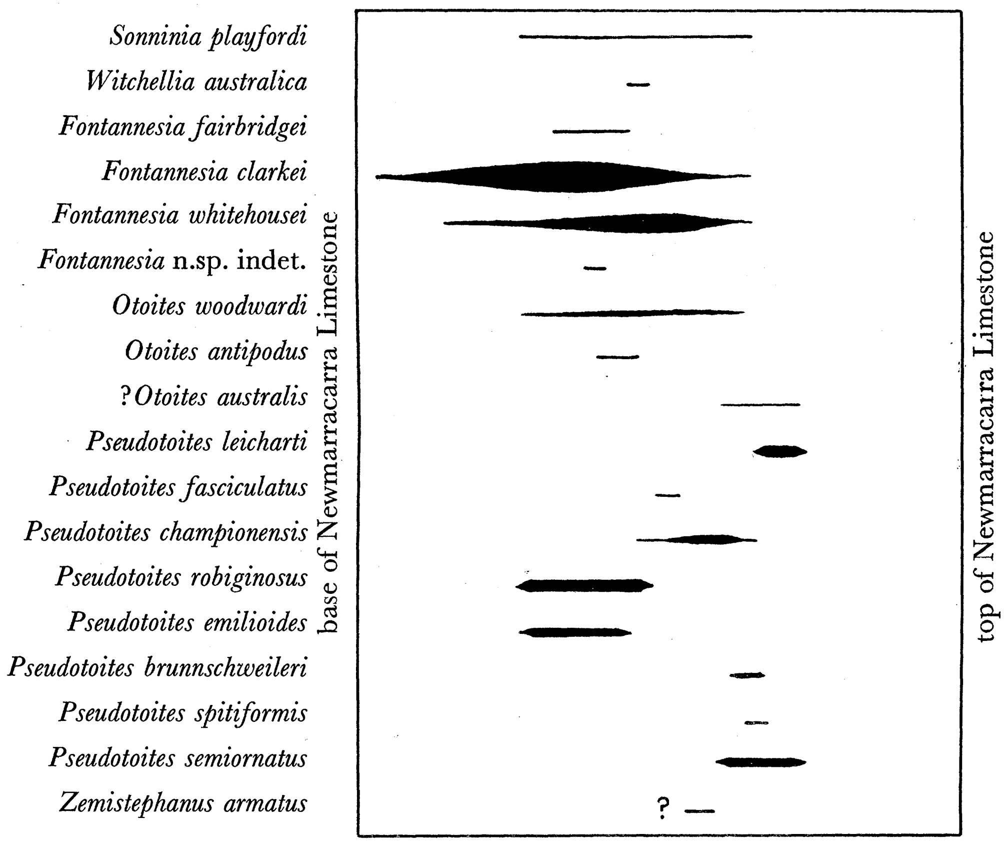


FIGURE 2. Range diagram of ammonites in the Newmarracarra Limestone, by P. E. Playford. The thickness of the spindles gives an idea of the relative abundance of the species.

kindly gave me some ammonites he had collected there. Marine beds of the same age, with some of the same ammonites, were found by Mr M. H. Johnstone and myself in 1953 on Doust Station, Hill River district, 110 miles south of Geraldton, in an area reported on by Conrad & Maynard (1948). The formation is at least 90 ft. thick and includes oyster lumachelles.

Palaeontology. The Newmarracarra Limestone contains abundant well-preserved marine fossils, but they are usually difficult to extract, owing to the toughness of the matrix. Fragments of wood up to 2 ft. long are not uncommon.

The marine fossils are all shallow-water forms. The commonest are palecypods, and *Trigonia moorei* Lycett is by far the most frequent fossil. It is found all through the limestone and sometimes is a rock-former.

Ammonites are seldom abundant. Most of those described in this paper came from an area of about 14 square miles around Bringo, Grant and 'Moonyoonooka', where the limestone is well exposed. The commonest species is *Fontannesia clarkei* (Crick). At one locality (about 1 mile south-east of Bringo) large numbers of this species, in perfect preservation, with test and free of matrix, have been excavated by rabbits from a marly band in the limestone. Some are shown on plates 27 to 30. Most of the species are much rarer, and consequently it is difficult to determine their ranges. A few are represented only by one or two specimens, and of these some were found years ago and are not sufficiently localized. There are no quarries or cuttings exposing continuous sections of the unaltered limestone. With the object of determining the stratigraphical ranges of the ammonites (figure 2) a special expedition was made to Geraldton after Dr Arkell had identified most of the species and supplied photographs of the types. On this trip I was accompanied by Dr R. O. Brunnschweiler of the Bureau of Mineral Resources, and I gratefully acknowledge his help.

The abundant pelecypods and less numerous gastropods require revision. There is also a peculiar *Nautilus*, *N. perornatus* Crick, belemnites, some rhynchonellids and numerous ostracods and Foraminifera (Clarke 1867; Moore 1870; Crick 1894; Chapman 1904*a*; Whitehouse 1924).

PART II. THE AMMONITES AND THEIR PLACE IN THE BAJOCIAN FAUNAS OF THE WORLD

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

5. Introduction

The ammonites here described are of exceptional interest because of their isolated position and peculiar characters. They comprise the only Middle or Lower Jurassic ammonite fauna known on the continent of Australia. The rock in which they lie was formed during a temporary transgression over the western margin of the continent by a sea that must have occupied the eastern part of the Indian Ocean and been connected with the Timor-East Celebes geosyncline (Teichert 1939), and thence with the Pacific Ocean.

This ammonite fauna is therefore of unusual importance for an eventual understanding of the problems of sea connexions, migration routes, and the distribution of oceans and continents in the Mesozoic era. It also poses problems in systematics and world-wide correlations. For solution of all these problems a prerequisite is the description of the material and as accurate dating in the world scale as can be achieved.

Material from Western Australia has hitherto been inadequate to admit of detailed comparison with other occurrences in eastern Asia and the Pacific seaboard of North and South America. This comparison is now attempted on the basis of much better material. Owing, however, to the crushing of many of the specimens by rock pressure, little reliance can be placed on measurements, and tabling of dimensions would be misleading. Characterization of the species is necessarily by photographs supplemented by verbal description.

Mr P. E. Playford is to be congratulated on his thorough stratigraphical investigation and remarkable collection, and I am deeply indebted to him for allowing me to work out his material. The lack of good sections and the baffling effects of lateritic alteration presented him with a task of uncommon difficulty. I am also indebted to Dr R. O. Brunnschweiler for his energetic participation at a later stage of the investigation and for some collecting.

The main Playford collection is the property of the Geology Department of the University of Western Australia. Unless otherwise stated, all material referred to in the following systematic account came from the area mapped in detail by Playford, around Bringo, Grant and 'Moonyoonooka', where the limestone is well exposed. A few duplicates (none of the types or figured material) have been retained in the Sedgwick Museum by kind permission of Professor R. T. Prider. Material collected by Mr Playford and Dr Brunnschweiler on their later expedition in 1953 is in the Bureau of Mineral Resources, Canberra, and is here quoted by registration numbers prefixed by the letter F. Some of this material was damaged by fire which destroyed a large part of the Bureau's collections and library in 1953, just after the ammonites had arrived from the field. Some additional specimens were sent me by Dr R. W. Fairbridge in 1948, and I am grateful to him for putting me in touch with Mr Playford..

The palaeontological work has been done at the Sedgwick Museum, Cambridge, where I am indebted for facilities to Professor W. B. R. King, F.R.S., and the Curator, Mr A. G. Brighton. It has been made possible solely by my Research Fellowship at Trinity College. The photographs were taken at the Sedgwick Museum by Mr Albert Barlow.

6. Previous work on the ammonites

Six previous authors have figured isolated specimens or fragments of ammonites from the Geraldton district.

Moore (1870) published drawings of four specimens and assigned them to Toarcian, Bajocian and Callovian species of Europe. Neumayr (1885) figured a new species, *Stephanoceras leicharti*, and some fragments, from which he dated the limestone to the Middle Bajocian, Humphriesianum Zone. Crick (1894) overlooked Neumayr's publication and named six new species, arriving independently at a Bajocian date, chiefly through supposed recognition of the genera *Normannites* (though not so named by him) and *Dorsetensia* (so named on the advice of S. S. Buckman). Both these genera are mainly of Humphriesianum Zone age. Crick's figures are from drawings, reduced to half natural size, and being also based on very poorly preserved and fragmentary material, give little idea of the true characters of the species named. All his generic attributions have had to be abandoned, but comparison of the type specimens in the British Museum (Natural History), through the kindness of Mr W. N. Edwards, Keeper of Geology, with the new collections has enabled all Crick's species to be interpreted and his specific names to be used.

Etheridge (1910) refigured one of Crick's species (*Dorsetensia clarkei* Crick) from new material. Whitehouse (1924) renamed Etheridge's figured specimen *D. etheridgei* and considered it to be generically distinct from Crick's, which he assigned to *Sonninia*. At the same time he figured a new species, *Otoites depressus* Whitehouse, which suggested the Sauzei

Zone. Spath (1939) reproduced Neumayr's figures of *Stephanoceras leicharti* and founded on it a new genus, *Pseudotoites*, and refigured the holotype fragment of *Dorsetensia clarkei* Crick, which he reaffirmed to be a *Dorsetensia* in opposition to Whitehouse's opinion, and placed *D. etheridgei* Whitehouse in synonymy. Spath also figured an ?*Emileia* sp., which is now considered to be the inner whorls of a *Pseudotoites*, and a '*Normannites*' which he identified as '*N.*' *woodwardi* (Crick), but which is now believed to be another species and not a *Normannites*. He also discussed the affinities and age of the fauna, which he considered to be of the Sowerbyi and Sauzei Zones.

A reference by me (Arkell 1949, p. 402) in support of Neumayr's dating to the Humphriesianum Zone was based upon the assumption that the fauna was all of one date, and upon the following three considerations: (1) The authority of Buckman, Crick and Spath for the identification of the abundant *D. clarkei* as *Dorsetensia*, a genus which in Europe is characteristic of the Humphriesianum Zone; but the new collection has shown that the Australian forms are closer to *Fontannesia*, a genus of the Sowerbyi Zone. (2) The reported occurrence (Neumayr 1885, p. 140; Whitehouse 1924, p. 9) of forms which appeared to belong to *Teloceras*, a genus characteristic of the upper part of the Humphriesianum Zone; but the new collection contains *Teloceras*-like forms, probably the ones alluded to by Whitehouse, which are cadicone relatives of *Pseudotoites*, homoeomorphs of *Teloceras* but probably much earlier; and the fragment identified by Neumayr with *T. blagdeni* (Sow.) turns out to be a *Pseudotoites*. (3) The authority of Spath (1939) that the auriculate stephanoceratids figured by Crick (*woodwardi*) and Whitehouse (*depressus*) are *Normannites*, a genus which in Europe belongs overwhelmingly to the Humphriesianum Zone; but these are now believed to be more closely related to *Otoites* as supposed by Whitehouse, and in fact to be ancestral to true *Otoites* of the Sauzei Zone, and (at least *depressus*) close to the dwarf subgenus *Trilobiticeras* of the early Sowerbyi Zone (Discites Subzone).

All three lines of evidence were, therefore, deceptive. As indicated by the Sonninidae, the main Newmarracarra Limestone fauna is of the age of the Sowerbyi Zone, possibly but doubtfully including the Sauzei Zone. This question is more fully discussed in §9, in which an attempt is made to clarify the confused stratigraphy and terminology. In addition, there are a few species, always in different preservation, from the haematitic uppermost layer of the limestone in a few places, which suggest the presence of patches of the Humphriesianum Zone.

7. Systematic descriptions

Superfamily Hildocerataceae Hyatt, 1867

Family Sonninidae Buckman, 1892

(including Poecilomorphidae pars and Zurcherinae pars Hyatt, 1900)

Genus **SONNINIA** Bayle, 1879

Type species by original designation *Waagenia propinquans* Bayle, 1878 (Sauzei Zone). Objective synonym: *Waagenia* Bayle, 1878, non Kriechbaumer, 1874. Subjective synonyms: *Stiphromorphites*, *Sherbornites* Buckman, 1923, *Sonnites* (*sic*) Buckman, 1925.

Large single-keeled planulates of the Sowerbyi and Sauzei Zones, with strong irregular ribbing bearing a median row of lateral tubercles; last whorl of body chamber becoming more or less smooth.

In the subgenus *Papilliceras* Buckman, 1920 (*Prepapillites* Buckman, 1927) a median row of small close lateral tubercles persists over all the septate whorls and sometimes also on the body chamber, often after ribbing has faded, and the surface is sometimes strigate. There are transitions to *Sonninia*. *Euhoploceras* Buckman, 1913, is similar to *Sonninia*, but tubercles die out earlier and strong rursiradiate ribbing and a keel persist to the end.

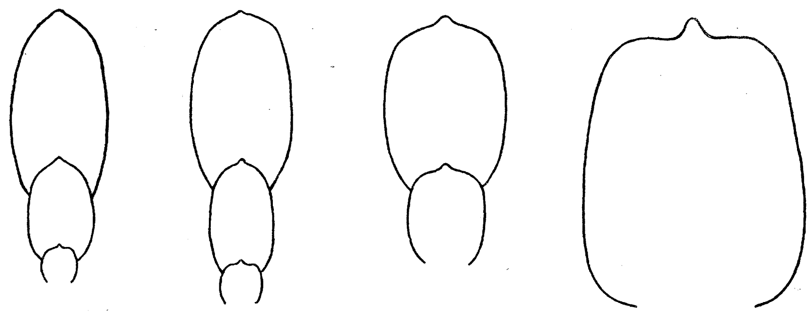


FIGURE 3. Whorl sections of, left to right: *Fontannesia whitehousei* n.sp.; *F. whitehousei* with persisting flatter venter; *F. clarkei* (Crick); *Sonninia playfordi* n.sp. (holotype). All magn. × 1·5.

Sonninia playfordi n.sp., plate 27, figure 1; figure 3

Material. Holotype (33869) from well at (964202, Mungarra 1-mile military sheet), off the map; fragment (714309); large crushed half-specimen F21088.

Description. The holotype is 90 mm in diameter and sharply and evenly ribbed to the end, with tall sharp keel. In the umbilicus there are about ten flared tuberculate ribs per whorl up to a diameter of about 40 mm, separated by two, later sometimes three, normal ribs. The last septum is at 63 mm, after which follows half a whorl of body chamber. Sutures not seen. The large crushed half-specimen is 180 mm in diameter and shows ribbing still distinct at about 140 mm and is septate to at least 130 mm.

Comparisons. S. playfordi belongs to the group of *S. dominica* Buckman (1894, p. 410, pl. lxix) and *S. submarginata* Buckman (ibid. pl. lxxi, figs. 1–3), these two species providing the closest comparison among all the drawers full of named species in the Buckman collection (in the Sedgwick Museum). In the Australian species, however, the ribbing on the body chamber is sharper and more flexuous, especially on the shoulders, where it is more projected. A new name therefore seems advisable, although there can be no doubt that the number of specific names for the English *Sonniniae* needs to be much reduced. Buckman distinguished his species by trivial details in the first lateral lobe of the sutures, which cannot be regarded as even worthy of varietal names. This is not the place to undertake a revision of Buckman's monograph, but when this is done it is possible that the Australian specimens will be found to fall into whatever species eventually includes the type specimen of *S. submarginata* Buckman.

Date. S. playfordi is perhaps the most important ammonite of all for correlation. Its characters are those of the oldest group of *Sonniniae*, which abound in the Discites Subzone of the Sowerbyi Zone (see table, p. 596).

Genus **WITCHELLIA** Buckman, 1889

Type species by original designation *Ammonites laeviusculus* J. de C. Sowerby, 1824 (holotype refigured Buckman & Secretary, 1908, pl. vi, figs. 1, 2). Subjective synonyms: *Zugophorites* Buckman, 1922; *Sonninites* Buckman, 1923; *Gelasinites* Buckman, 1925; *Dundryites*, *Anolkoleiites*, *Rubrileiites* Buckman, 1926; *Zugella* Buckman, 1927.

Nucleus as in *Sonninia*, but whorls soon becoming more compressed and involute, enlarging more rapidly, heightening and smoothing early, long before septation ceases. Venter narrow, tabulate and carinate, often bisulcate, sometimes becoming fastigate. Sowerbyi and Sauzei Zones.

There is a passage by way of the progressively more evolute '*Dundryites*' *pavimentarius* and '*Gelasinites*' *gelasinus* Buckman (1925, vol. vi, pl. dxciii) to the evolute *Sonninia*. It is also difficult to draw any definite line between some *Witchelliae* and the smooth genus *Shirbuirnia* Buckman, 1910 (type species *S. trigonalis* Buckman, now designated), with simplified sutures, from which *Fissilobiceras* Buckman, 1919, differs only in its highly complex sutures. On the other hand, there are passage forms to *Dorsetensia* Buckman, 1892, and *Hyalinites* Buckman, 1924 (the latter perhaps a synonym, being hardly distinguishable from *Dorsetensia romani* Oppel sp.). The Canadian genus *Guhsania* McLearn, 1926, is also similar, but is ribbed to the end of its oxycone outer whorl. There are forms in South America, included in *Sonninia* in the most recent literature, which are much more worthy of separation than Buckman's English forms, but which are best retained at present in *Witchellia*.

Witchellia australica n.sp., figures 4 and 9 (p. 585).

Dorsetensia? sp.ind., Spath 1939, p. 130, fig. 1*c*.
Witchellia aff. *platymorpha* Buckman, Arkell 1953, p. 333, pl. xiv, fig. 6.

Material. Three specimens and one larger fragment, one from Fossil Hill (706333).

Description. Holotype 144 mm in diameter, wholly septate. The large fragment is wholly septate at a stage representing about 150 mm. Faint ribbing on the nucleus soon fades and thereafter the whorls are smooth or carry only faint, indefinite, falcoid folds after the manner of those in *W. laeviuscula* (Sow.), the type species. Coiling is involute, the whorls moderately high, almost parallel-sided, with gradual umbilical slope (no angles) and broad tabulate venter bearing a large but blunt median keel flanked by grooves (tricarinate). The median keel is only a little higher than the others, and where seen it is merely a wrinkle of test directly over and in contact with the siphuncle (hollow, unfloored keel). Sutures with distant well-formed lobes, the inner part slightly retracted; first lateral (external) saddle wide. A large specimen, about 230 mm in diameter, was referred to by Spath (see synonymy).

Comparisons. In whorl shape, coiling and the character of the venter, this species falls into *Witchellia*, but it differs from the type species in being less involute, less compressed, with less convergent whorl sides and less angular umbilical edge. It is, however, much more involute than '*Gelasinites*' *gelasinus* Buckman (1925, pl. dxciii) and '*Zugophorites*' *zugophorus* Buckman (1922, pl. cccxli), both of which Spath (1936, p. 5) included in *Witchellia*. The style of the venter in *W. gelasina* as shown in Buckman's plate A (upper photograph) closely resembles that of *W. australica*; but this is misleading because it is a comparison between cast and test. Where the test is preserved (Buckman's plate B) the median keel is much taller and sharper than at any stage in *W. australica*.

There is closer correspondence in whorl shape and coiling with *W. pavimentaria* Buckman sp. (1927, pl. dccli), which Spath (1936, p. 6) has compared to a specimen from Persia, but inspection of Buckman's holotype from the Cotswolds shows that in that, too, the keel is taller and sharper, and the umbilical edge is more angular; also ribbing is stronger and more persistent and sutures are more complex. *Sonninia parvicostata* Buckman (1892, pl. lxxv, figs. 3, 4) is similar in whorl section, thickness and venter, but is considerably more evolute and has a sharp umbilical angle.

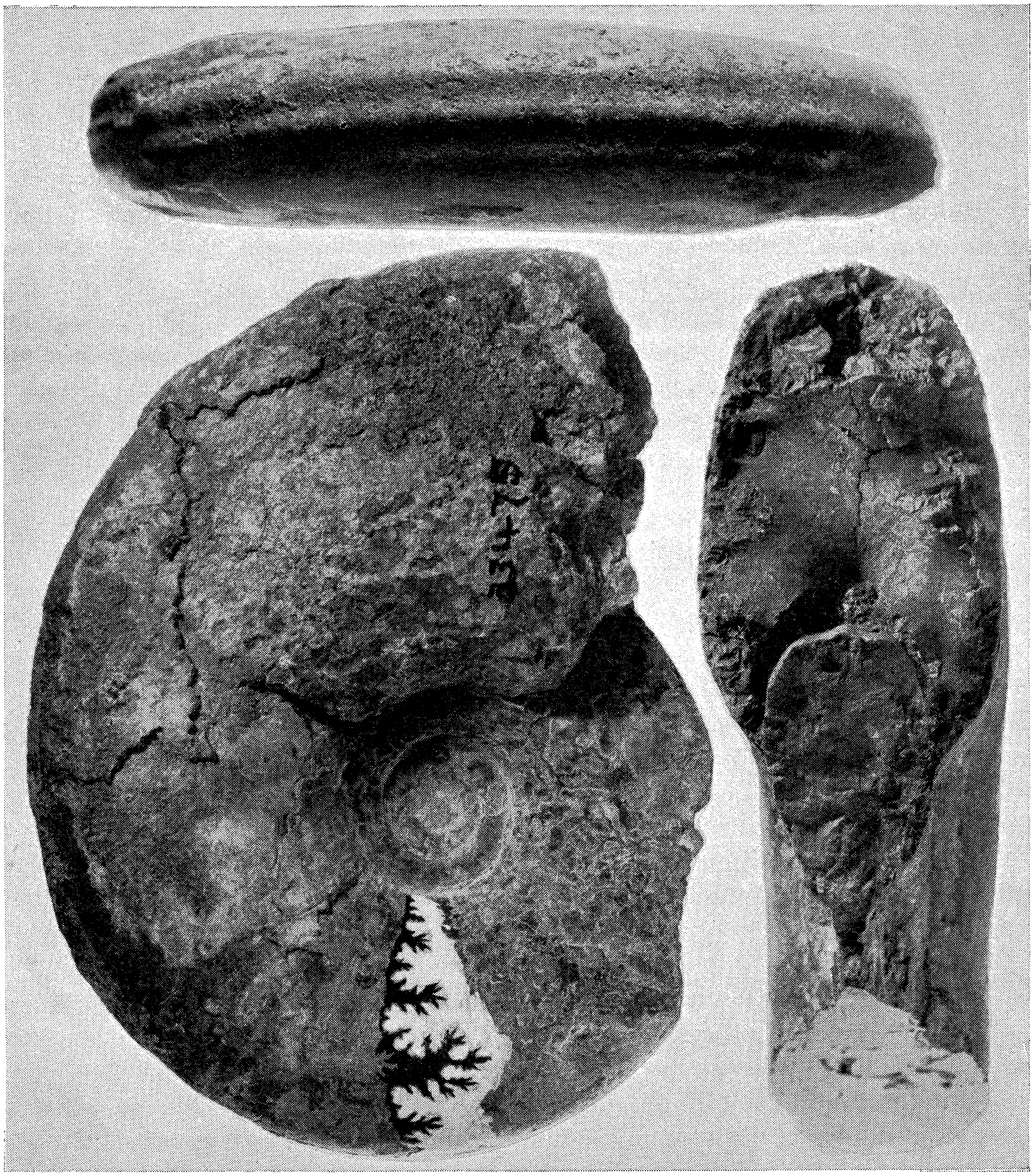


FIGURE 4. *Witchellia australica* n.sp. Left, holotype. Right, whorl section of a large septate fragment. Above, venter of a third specimen, with test. Newmarracarra Limestone. Natural size.

The blunt keel and blunt umbilical edge or slope of *W. australica* are points of resemblance to the genus *Shirbuirnia* Buckman (1910*a*, p. 91; holotype refigured 1924, pl. dxvii), but the narrow and fastigate to acute venter and convergent whorl sides (subtriangular whorl section) rule this genus out. (See also Buckman 1921, pl. cdlx.) The sutures of *W. australica*, moreover, are more like those of *Sonninia* and *Witchellia* and do not show the curious bunching or degeneration of the auxiliary elements seen in *Shirbuirnia*. In the side view, however, and when the sutures are ignored, there is close resemblance to *S. stephani* (Buckman) as figured from north-west Germany (Hiltermann 1939, pl. xii, fig. 10; pl. xiii, fig. 4).

The blunt, not floored, keel, if eventually established for all stages of growth, would separate *W. australica* from perhaps all the European *Witchellia* and *Sonninia* and point to closer connexion with *Fontannesia*; but the material so far available does not suffice to generalize for the whole course of development. As Haug (1893, p. 321) pointed out, the hollow floored keel ('septicarina') may be present in the young and absent in the adult, or vice versa.

A good specimen of this species (figure 9, p. 585) was collected by Sir Henry Hayden near Kampadzong, Tibet, and on comparison with the holotype from Western Australia appeared to be identical (see Arkell 1953, p. 333).

Fragments of *Witchellia* with test preserved, sent me from central Arabia since my paper was published (Arkell 1952), show the tall hollow floored keel and whorl section just as in *W. gelasina* (Buckman), but ribbing is much feebler, especially on inner whorls.

Genus **FONTANNESIA** Buckman, 1902

Type species by original designation *Dumortieria grammoceroides* Haug, 1887, which was based on an English Inferior Oolite specimen said by Buckman (1892, p. 265) to be 'almost exactly like the specimen depicted in figs. 4, 5, of plate xlvi (of his monograph), but with slightly coarser ribs'. Later (Supplt., 1905, p. clxxxviii) on receipt of a plaster cast of Haug's type he restricted *grammoceroides* to the coarser-ribbed forms shown in figs. 1–3 of his pl. xlvi and renamed figs. 4, 5 *Fontannesia luculenta* (see figure 5). Subjective synonym, *Nannina* Buckman, 1927.

Small to medium-sized planulates with falcoid ribbing, no tubercles, venter with wide, strong, blunt, hollow, unfloored keel, and more or less gradual and smooth umbilical slope. Sutures as in *Witchellia* and some *Sonninia*, inclined to be simple. No floor to the keel seems to have been proved at any stage.

Probably closely allied are dwarf forms with similar coiling and generally more rursiradiate ribbing, which possess large lappets. Some authors (e.g. Hiltermann 1939) consider these the young, but there seems no evidence for this assumption. Buckman provided several generic names, of which the earliest is *Pelekodites* (1923); subjective synonyms: *Nannoceras* (1923), *Maceratites*, *Spatulites* (1928).

Fontannesia fairbridgei n.sp., plate 27, figures 4 to 7.

Material. Holotype, 102 mm in diameter, and at least five smaller specimens, not, however, definitely distinguishable from *F. clarkei* when immature (784357).

Description. Of the known Australian material, this species is the stoutest whorled and the most coarsely ribbed, and its ribbing is more often visibly biplicate. The keel is strong and wide but blunt and never floored; it is as strong as ever at the end of the largest specimen (diameter 102 mm.). The fact that this specimen is still wholly septate shows that *F. fairbridgei* is a large species. Sutures where visible are as in *F. clarkei* (in which they are much better displayed). The test is completely preserved over almost the whole of all the material.

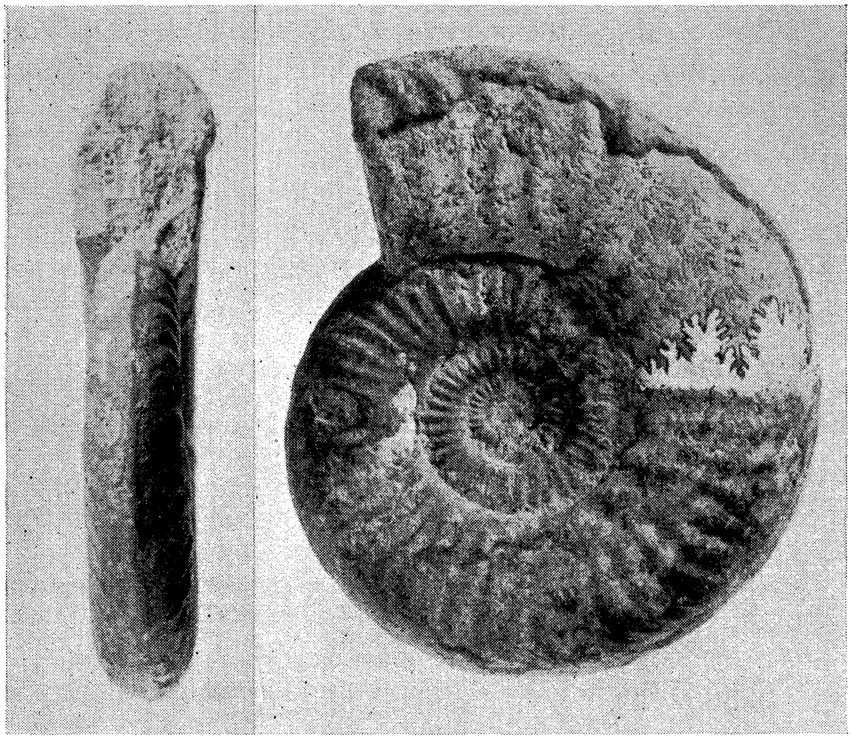


FIGURE 5. *Fontannesia luculenta* Buckman, basal Sowerbyi Zone (Discites Subzone), Bradford Abbas, Dorset. Buckman Coll., Sedgwick Museum, Cambridge, J 6283. Natural size.

Comparisons. The peculiar backward biplication of blunt ribs exemplified in this species can be best matched among European Bajocian material in *F. grammoceroides* (Haug), the type species. The holotype of *F. fairbridgei* is similar in essentials to the largest specimen in the Buckman collection (Sedgwick Museum), well figured by Buckman, 1892, pl. xlvi, figs. 1–3. The ventral view is almost identical. The differences are that *F. fairbridgei* has wider and more distant ribs, of which a higher proportion are biplicate, a stronger and more persistent keel, which shows no signs of degeneration at the end (102 mm diam.), and a gentler and smoother umbilical slope. The same differences distinguish it from *F. explanata* Buckman (pl. xlvi, figs. 6, 7). *F. luculenta* Buckman (pl. xlvi, figs. 4, 5) bridges the gap in some respects, for it has just the smooth and gentle umbilical slope of all the Australian species, and also a rather stronger keel. This species is further discussed below.

In almost all characters there is also a strong resemblance between *F. fairbridgei* and *Grammoceras doerntense* Denckmann sp. (1887, p. 50, pl. viii, fig. 5), from the much earlier Lower Doernten Shales in north-west Germany, Striatulum Subzone, basal Upper Toarcian. Denckmann's figure, however, shows smooth inner whorls. But other forms which he included in the same species (e.g. figs. 1, 3, 4), and his figures of *G. struckmanni* and *G. saemanni* (pl. iii, figs. 1, 2) bear an equally striking resemblance to the Australian

F. clarkei (Crick). Moore (1870) and subsequent authors have been struck by this resemblance which Spath (1939, p. 128) ascribed to heterochronous homoeomorphy. This must be one of the most remarkable instances on record, for it extends over a whole range of intimately related forms at both horizons (cf. also Buckman, 1890, pls. xxxiii–vii).

Fontannesia clarkei (Crick), plate 28, figures 1 to 6; plate 29, figures 1, 2; plate 30, figures 1 to 4; figure 3.

Ammonites radians Moore (non Schlotheim), 1870, pp. 230, 231, 232, pl. xv, fig. 2.
A. (*Dorsetensia*) *clarkei* Crick, 1894, p. 388, pl. xii, figs. 2*a–c*.
Dorsetensia clarkei Etheridge, 1910, p. 38, pl. vi, fig. 4 and pl. ix, fig. 7.
D. etheridgei Whitehouse, 1924, p. 9.
D. clarkei Spath, 1939, p. 129, pl. i, fig. 2 and pl. ii, figs. 1, 2 (type refigured, fig. 1).

Material. At least 100 specimens, the majority from rabbit warrens (784356–7 and near by) with the test intact and wholly septate. Also two from Mount Hill (858035) and a few in limestone, including possibly two large, poorly preserved, with body chambers (722303). Also F21077–8. Holotype fragment Brit. Mus. (N.H.) C30376.

Description. Most of the specimens are about 60 to 75 mm in diameter or less; a few reach 80 mm. All these are wholly or almost wholly septate. It appears that this size represents the septate part of the adult, for the only two specimens that exceed it (preserved in a hard limestone) are septate to about 80 mm, after which they have respectively half a whorl and just over half a whorl of body chamber (smooth and keeled to the end).

The coiling is evolute, the whorl-shape distinctly slimmer than in *F. fairbridgei*. The ribbing is strong, mainly simple but often vaguely twinned, always fading on the umbilical slope, which is gradual and smooth. Ribbing dies out gradually at diameters most often between 50 and 60 mm, but sometimes more (up to 70 mm), sometimes less (down to 45 mm). The keel is large, hollow and blunt, not seen at any stage to be floored. It sometimes is accompanied by two shallow grooves, more or less well defined. All this applies to the test, which is thick. In the rarer internal casts the ribbing is a good deal feebler and dies out earlier, and the whorl section appears to be correspondingly more compressed. Sutures simple and open, the lobes small, narrow and distant.

Variation. Comparison of about 100 well-preserved specimens from the same bed at the same locality shows that there is continuous and more or less independent variation of the following characters:

Width and spacing of ribs on nucleus.
Width and spacing of ribs on last ribbed whorls.
Stage at which ribbing fades.
Frequency of twinned ribs at various stages.
Style of ribbing on nucleus up to 4 or 5 mm diameter: in some specimens it is parabolic, and rarely there are alternate flared ribs with tendency to develop a minute spine.
Degree of compression of whorl.
Prominence or bluntness of keel.
Presence and degree of accentuation of grooves each side of keel.
Degree of emphasis of shoulders with corresponding flatness of venter each side of keel.
Diameter at which these ventral features appear or change.

With all these variables, it is impossible to provide strict and infallible definitions, by which to separate all specimens of *F. fairbridgei* and *F. whitehousei*. It is believed, however, that three recognizable species are present, but that their variants overlap.

The holotype of *Dorsetensia etheridgei* Whitehouse (1924, p. 9) is slightly more compressed than the norm for the species, but Dr Spath (1939, p. 129) was correct in contending that *etheridgei* (as based on the holotype) must be regarded as a synonym of *clarkei*, for with abundant material no distinction other than varietal can be made between them.

Generic position and affinities. Five previous authors have dealt with this species on the basis of two or three incomplete specimens, lacking most of the test, and the type is a scrappy fragment of a natural internal cast. The Playford collection necessitates a fresh assessment.

Crick (1894, p. 389) stated that he sent the holotype fragment of *clarkei* to Buckman, who reported that 'it would be advisable to ascribe it to *Dorsetensia*'. This verdict was accepted by Spath (1939, p. 129), although it had been questioned by Whitehouse (1924, p. 9). But while Buckman had founded his genus *Dorsetensia* in 1892 (i.e. one or two years before he saw *clarkei*), he did not found *Fontannesia* until eight years afterwards (1902). Until then the species of *Fontannesia* had stood in his monograph under the genus *Dumortieria* (Buckman 1892, pls. xlvi, xlvii).

Now that for the first time adequate material of *clarkei* is available, it becomes impossible to retain it in *Dorsetensia*. The type species, *D. edouardiana* (d'Orb.), and its allies, all differ by their sharp umbilical angle and more acute periphery, and most of them also by their squat, thick first lateral lobe. On the other hand, the characteristic gradual smooth umbilical slope of *clarkei* and the same style of sutures and ribbing, keel and coiling are all matched in *Fontannesia* Buckman. The nearest European form seems to be *F. luculenta* Buckman (1905, supplt., p. clxxxix; 1892, pl. xlvi, figs. 4, 5, 8). The specimen figured only as a suture line in Buckman's fig. 8 (in the Sedgwick Museum) is almost identical in every feature with *clarkei* up to a diameter of about 70 mm, but after that its ribbing continues while on all the Australian material it fades (figure 5).

Conclusive evidence for attributing *clarkei* to *Fontannesia* is its association with *F. fairbridgei* described above, and the difficulty of separating all but mature specimens (plate 27, figures 2, 3). No one could doubt that the two species are closely allied, and no one would place *fairbridgei* in *Dorsetensia*.

While *Dorsetensia* belongs mainly to the Humphriesianum Zone but begins in the Sauzei Zone, the home of *Fontannesia* is the early Sowerbyi Zone. This agrees with the dating of *clarkei* from the other associated ammonites.

The extraordinary resemblance to Upper Toarcian *Grammoceras* spp. is discussed above, under *F. fairbridgei*, and below, under *F. whitehousei*.

Fontannesia whitehousei n.sp., plate 29, figures 3 to 8; plate 30, figures 5, 6; figure 3 (p. 560).

Ammonites aalensis var. *moorei* Lycett, Moore 1870, pp. 231, 232, pl. xv, fig. 1 (non *Ammonites moorei* Lycett, 1857, a *Dumortieria*).

Material. At least sixteen specimens, all in or from hard limestone matrix, mostly from (714309, 710305); also Mount Hill (858035); R. W. Fairbridge Coll., 1948; and Charles Moore Coll., Brit. Mus. (N.H.) C47366; F21079–21082.

Descriptive remarks and comparisons. A small minority of the '*clarkei* group' in the Playford collection belong to a decidedly more compressed and smoother species, and to it also belongs the specimen ('Sharks Bay, W. Australia') figured by Moore in 1870 as *Ammonites aalensis* var. *moorei*, which was presented to the British Museum (Nat. Hist.) in 1940 by the Bath Literary and Scientific Institute from the Charles Moore collection. It was probably this compressed species that Whitehouse (1924, p. 9) intended to name *Dorsetensia etheridgei*, but unfortunately he designated as holotype the original of *Dorsetensia clarkei* Etheridge (1910, pl. ix, fig. 7). Etheridge's drawing (side view only, without whorl section) looks indistinguishable from the compressed species, but as stated above, inspection of the specimen shows that, as Spath found (1939, p. 129), it has a well-shouldered venter and the typical whorl section of *F. clarkei* (Crick), with which *D. etheridgei* Whitehouse is therefore synonymous.

Nearly all the specimens of *F. whitehousei*, from the Playford, Fairbridge and Moore collections, come out of a hard limestone and are in the form of smooth casts with most of the shell missing. Only six specimens in this matrix and preservation are *F. clarkei*. This suggests that the two species have distinct if overlapping epiboles, an inference confirmed by Messrs Playford and Brunnschweiler in the field (see figure 2, p. 556).

The distinction between the two species is by no means clear-cut. Some specimens of *F. whitehousei* develop the compressed whorl shape and sloping shoulders at an earlier stage than others, and some lose their ribbing earlier than others. These points of variation are parallel to those in *F. clarkei*, with the result that there is overlap, and some fragments are indeterminable. Nevertheless, it is probable that two distinct species are present, the specific differentiation of *F. whitehousei* from *F. clarkei* being definable as 'more compressed, with narrower and less shouldered venter except in the nucleus, and feebler ribbing which dies out earlier'. The septal sutures are identical. There is strong resemblance to *Dumortieria moorei* (Lycett) (refigured Buckman 1905, p. clxxxii, fig. 179).

The problem presented by *F. clarkei* and *F. whitehousei* recalls the difficulty encountered by Buckman (1890, pp. 178, 232) in separating *Grammoceras mactra* from *Dumortieria moorei*. Buckman believed that the resemblance was due to convergence between two different lineages, descended from different genera in the Lower Lias (Jamesoni Zone). More wholesale convergence has been invoked much more recently to account for the polymorphism or intergradation between a wide range of forms of Amaltheidae in the Upper Pliensbachian (Monestier 1928). The theory is now rejected in favour of repeated divergence on similar trends (heterochronous homoeomorphy).

The homoeomorphy between these ammonites from the Middle Bajocian of Western Australia and *Grammoceras* of the Upper Toarcian (discussed by Crick) is again strikingly shown by a plate of presumably Toarcian forms from the Sula Islands figured by Kruizinga (1926, pl. i). His *G. baumbergeri* is indistinguishable (in the absence of a peripheral view or whorl section) from *F. whitehousei*. Even the coarse-ribbed nucleus and frequent bifid ribs on the early whorls are matched on specimens of *F. whitehousei*, though the nuclei of otherwise identical specimens vary greatly, as in many ammonites. *G. kiliani* Kruizinga is remarkably like *F. clarkei* (Crick), but more involute. *Harpoceras arietitiforme* Kruizinga closely resembles *F. luculenta* Buckman (cf. figure 5), but is probably a *Fuciniceras* or a parallel development from *Phymatoceres* or some other contemporary genus. From the figures alone one cannot exclude the possibility that this Sula Islands fauna is not Toarcian but Middle Bajocian; especially since Kruizinga's pl. vi, figs. 1, 2, pl. xii, fig. 3, represent a *Pseudotoites* (see below, p. 576). Only stratigraphical collecting could solve the problem, but so far these Sula Islands ammonites have been found only as loose pebbles in stream-beds or on the surface.

Fontannesia spp. indet.

Sonninia spp., Whitehouse 1924, p. 8, figures 6–9.

Material. A large but much damaged specimen 136 mm in diameter, F21086 (734349); five small fragments as casts in chocolate-coloured irony mudstone, some showing sutures perfectly, from Bringo cutting.

Comparisons. Among the fragments, both whorl sections figured by Whitehouse are represented. The sutures most resemble those in his figure 7.

Whitehouse was correct in assigning these fragments to the same genus as '*Dorsetensia*' *clarkei* Crick, but his drawings of both whorl sections and sutures exclude the genus *Sonninia* and point to *Fontannesia*. No *Sonninia* completely lacks an umbilical area as do these specimens, nor do any *Sonniniae* have such a stocky, thick-based first lateral lobe. These characters show that the resemblance to smooth *Sonniniae* like *S. contusa* Buck., *S. simplex* Buck., *S. papilionacea* Buck. (especially as figured by Hiltermann 1939, pl. xi, fig. 1) is superficial, and the conclusion drawn by Whitehouse that the material 'favours a late horizon in the Sonninian range' must be reversed. The Discites Subzone is the most likely (see below, p. 596).

In ventral view the large specimen much resembles *Witchellia australica*, and in the gentle umbilical slope these two species resemble one another more than the European *Witchelliae*, to which *W. australica* belongs by most of its characters.

Superfamily Stephanocerataceae Neumayr, 1875

Family Otoitidae Mascke, 1907

Genus **OTOITES** Mascke, 1907

Type species by original designation *Ammonites sauzei* d'Orbigny, 1846. Involute, cadicone or sphaerocone forms, in which the umbilicus opens out in the last whorl as the body chamber contracts; aperture with long lappets; primary ribs short, secondaries long with a tubercle at the points of furcation; well-developed second lateral lobe. Sauzei and Sowerbyi Zones, Middle Bajocian.

Normannites Munier-Chalmas and its allies differ by having more evolute, coronate, inner whorls and longer primary ribs, shorter secondaries, and small second lateral lobe. (For *Normannites* see *Bull. Zool. Nomenclature*, 1951, vol. ii, parts 6/8, p. 222.) In the Australian material the two genera run together and the distinction between them becomes arbitrary. Some species could be ancestral to *Normannites*, others to the (probably later) *Otoites* of the European and American Sauzei Zone. Since the characters are on the whole more *Otoites*-like than *Normannites*-like, all are here assigned to *Otoites*. In particular, there is a well-developed second lateral lobe. The inner whorls are extremely depressed-coronate, barrel-shaped, as in *Trilobiticeras* Buckman (1919, vol. iii, pl. cxl; 1922, vol. iv, pls. cclxxvii A, B) of the English Discites Subzone (lowest Sowerbyi Zone), but the Australian forms become much larger and more *Otoites*-like on the one hand, *Normannites*-like on the other.

The Australian species were referred by Crick (1894) to *Sphaeroceras* (which at that date included *Otoites*, although *Normannites* had been separated in 1892), by Whitehouse (1924) to *Otoites*, and by Spath (1939) to *Normannites*.

Otoites woodwardi (Crick), plate 30, figures 9 to 12.

Ammonites (*Sphaeroceras*) *woodwardi* Crick, 1894, p. 433, pl. xii, figs. 6*a*, *b*.
Non *Normannites woodwardi* Spath, 1939, p. 126, pl. ii, figs. 3*a*, *b*.

Material. At least a dozen specimens, of which two from Fossil Hill (706333) and three from Mount Hill, F21091–2, F21089 (plaster cast). Crushed holotype Brit. Mus. (N.H.) C30378.

Descriptive remarks and comparisons. The holotype shows part of the peristome and the bases of lappets (diameter 59 mm) but is severely crushed. Only a few specimens in the Playford collection are crushed to anything like so great an extent, and at first I was inclined to regard them as belonging to a much less inflated species than Spath's figure, perhaps conspecific with the well-preserved half-whorl here figured in plate 30, figure 13. The ribbing, however, is different and agrees exactly with that of the holotype of *O. woodwardi* and with the much more inflated, uncrushed specimens such as plate 30, figure 12*a*, *b*. It is a matter of opinion whether crushing can produce so great a difference in whorl section, but in the light of sectioned specimens of *Pseudotoites leicharti* in the same matrix and preservation (see plate 33, figure 3) it is inadvisable to create a new species for such inflated specimens as plate 30, figures 10 to 12.

O. woodwardi, however, has finer and closer ribs and feebler tubercles than the specimen figured by Spath (see *O. antipodus*, below).

The specimen in plate 30, figure 12, and some others, show in the internal cast on part of the venter only (not all of any whorl) a minute, slit-like siphuncular groove, as figured for *O. depressus* by Whitehouse (1924, pl. 1, fig. 5*b* [recte 6*a*]).

Spath (1939, pp. 126–8, pl. ii, fig. 3) interpreted *O. woodwardi* (Crick) as a *Normannites*, and in some respects it is intermediate between the two genera. As compared with the type species of *Normannites*, however, *N. orbignyi* Buckman (1927, vol. vii, pl. dccxxxiv; and Fallot & Blanchet, 1923, pl. x, figs. 1–7; pl. xii, fig. 2), *O. woodwardi* is more involute, more tumid, and has shorter primary ribs. Moreover, in the Playford collection it is sometimes hard to separate *O. woodwardi* specifically from the form here figured (plate 31, figures 6*a* to *d*), which is much more like an *Otoites* than any *Normannites*, although Spath himself figured a specimen as *N. woodwardi* (Crick). The barrel-shaped inner whorls, short primaries, large tubercles, coarse and backward-swung secondary ribs all point to *Otoites* rather than *Normannites*. No suture well enough exposed for figuring can be found in any Australian specimens yet seen, but parts of sutures seen here and there also agree better with those of *Otoites*, for they show a well-developed second lateral lobe.

Otoites antipodus n.sp., plate 30, figure 8; plate 31, figures 5, 6; plate 32, figure 1.

Aff. *Otoites* sp., Whitehouse 1924, p. 7, pl. ii, figs. 7*a–c* (more depressed).
Normannites woodwardi Spath, 1939, p. 126, pl. ii, figs. 3*a*, *b* (non Crick sp., 1894).

Material. Holotype, Mount Hill (858035), F21093; topotype, figured by Spath; another from (710305); others, including F21098.

Descriptive remarks and comparisons. Differs from *O. woodwardi* (Crick) by its coarser and more distant ribs and sharper, more distant tubercles. Examination of the specimen figured by Spath (a topotype of *O. antipodus*, from Mount Hill) shows that the tubercles are sharper and more distinct than might be inferred from the photograph. In this respect *O. antipodus* more nearly resembles *O. reesidei* Crickmay (1933, p. 912, pl. 27, figs. 9–11) from Mount Jura in California, but it is much more inflated. '*Epalxites*' *formosus* Buckman (1920, vol. iii, pl. cli), from the English Blagdeni Zone, has comparable inflation and strength of ribbing, and even sharper and more discrete tubercles; but *formosus* shows unmistakably the evolute coiling and long primary ribs of the true *Normannites* and its allied subgenera. For all their *Otoites* characters, however, all the Australian species have sharper primary ribs than in any English *Otoites* of the Sauzei Zone (many forms at all sizes in the Sedgwick Museum); it would be reasonable to consider these last as exaggerated or specialized descendants of the Australian stock.

? *Normannites etheridgei* Gerth sp. (1927, p. 226, pl. 36, fig. 1, holotype), from New Guinea, is similar, but the holotype differs from the Australian specimens by having more distant primary ribs on the inner whorls and more numerous intercalatories on at least the whole outer whorl. The first half of the outer whorl of the holotype of *N. etheridgei*, however, with its indistinct tubercles and regular intercalatories, is reminiscent of the Australian specimen here figured on plate 30, figure 13. According to Gerth's description, the whorls are twice as thick as high.

'*Stephanoceras* cf. *blagdeni*' Etheridge (1890, p. 175, pl. xxix, fig. 2), also from New Guinea, which Gerth compared with *Normannites etheridgei*, becomes tuberculate at an earlier stage, as do *N. orbignyi* and *N. formosus*.

Part of the venter of the specimen shown in plate 30, figure 8, when lit from the side, shows the minute siphuncular groove also observed in *O. woodwardi* and *O. depressus*.

The half-whorl of body chamber shown in plate 30, figure 13, though well preserved as an ironstone cast, is insufficient for naming. It does not agree with anything else in the collection and bears a distinct resemblance to *Stephanoceras arabicum* Arkell (1952, pl. 20, figs. 4–7). It is believed, however, to be deceptively crushed, judging by the unnatural narrowness of the impressed area and parallel sides of the whorl (no enlargement in either direction longitudinally).

Otoites (?Trilobiticeras) depressus Whitehouse, plate 30, figure 7

Otoites depressus Whitehouse, 1924, p. 6, pl. i, figs. 4, 5, 6.
Normannites depressus Spath, 1939, p. 129.

Descriptive remarks and comparisons. A gutta-percha squeeze of the holotype is in the Sedgwick Museum and is figured here. It is characterized by small size (presumably full-grown since lappets are present), very depressed whorl section with wide, low venter, and coarse biplicate ribbing with distinct tubercle at the point of furcation. Though it does not show on the holotype, the venter has a minute slit-like siphuncular groove (Whitehouse 1924, pl. i, fig. 5*b* [recte 6*a*]). A similar minute groove occurs on parts of whorls in *O. woodwardi* and *O. antipodus*.

The type material came from a well near Bringo railway-cutting. Although the holotype is a natural external mould, Mr Playford informs me that the matrix is iron-stained and calcareous, and therefore did not come from the haematite rock, which is never calcareous. The unnamed fragment figured in Whitehouse's pl. ii, fig. 7, which has been sent me on loan, is also calcareous. Mr Playford thinks, however, that the level is probably near the local top of the limestone.

O. depressus is unrepresented in the Playford collection. No specimen is so small or so coarsely ribbed at so early a stage. The small specimens, though poorly preserved, all seem to be inner whorls of the larger *O. woodwardi* or *O. antipodus*.

Dr G. Westermann, who has made a detailed study of *Normannites* and its allies (not yet published), informs me that from Whitehouse's figures he would place *O. depressus* in the genus *Trilobiticeras* Buckman (1919, vol. iii, pl. cxl; and 1922, vol. iv, pls. cclxxvii A, B), of the Discites Subzone, lowest Sowerbyi Zone, of Dorset. This date would agree well with the evidence of all the other Australian ammonites of the main Newmarracarra fauna. Mr R. V. Melville has kindly sent me the types of Buckman's two species, and although this suggestion is possibly correct, all the known material is so small (Buckman's figures are enlarged by 1·25 and 1·5) that a positive assertion would be unwarranted. It is quite possible that *Trilobiticeras* may prove to be the nearest European subgenus to all the Australian *Otoites* here described. (Until *Trilobiticeras* is better known, it is advisable to subordinate it to *Otoites* as a subgenus.)

?**Otoites australis** (Crick), plate 31, figures 1 to 4.

Ammonites (*Stephanoceras*) *australe* Crick, 1894, p. 391, pl. xii, figs. 4*a*, *b*.
Normannites australe Chapman, 1904*b*, p. 330.

Material. Two specimens and a fragment from (691296); also F 21099. Distorted holotype Brit. Mus. (N.H.) C 30379.

Descriptive remarks and comparisons. The holotype is the most unsatisfactory of all Crick's types. Chapman (1904*b*, p. 330) considered it a *Normannites*, and Spath (1939, pp. 124, 128) was uncertain whether to regard it as a *Normannites* or as inner whorls of a *Pseudotoites*. Crick (1894) thought it 'evidently closely allied to *Ammonites braikenridgii* J. Sowerby'. Three specimens which, from their style of ribbing and other characters, are unquestionably the same species as *A. australe* Crick, are represented in the Playford collection and measure respectively 65, 70 and 83 mm in diameter. From the point of view of size, this brings the species well within the normal range of *Pseudotoites*, and the style of ribbing shows marked resemblance to that of *Ps. semiornatus* (Crick). But in all the new specimens most of the last whorl consists of body chamber, and one has part of the base of a lappet. This feature excludes *Am. australis* from *Pseudotoites* and places it with the group that Chapman and Spath referred to *Normannites*. On the other hand, in view of the resemblance of its ribbing to that of some *Pseudotoites*, and especially the shortness of the primaries, it is unlikely to be closely related to true *Normannites*, or to *Am. braikenridgii* Sow., which Buckman (1914, vol. ii, pl. lxxxi) when refiguring the holotype referred to *Otoites*, but which from the length of its primary ribs and evolute coiling is now generally placed in *Normannites*. The large size of *Am. australis* and ignorance of its true whorl shape preclude reference to the barrel-shaped and dwarf *Trilobiticeras*. Despite the lappets, close relationship to *Pseudotoites* may be inferred from the style of the ribbing. Probably it represents a new genus, but a new generic name cannot be given in ignorance of the inner whorls, the whorl shape at all stages, and the sutures.

Genus **PSEUDOTOITES** Spath, 1939 (p. 124)

Type species by original designation *Stephanoceras leicharti* Neumayr, 1885 (from Western Australia).

Large Otoitidae with stout planulate inner whorls, cadicone middle whorls, gradually becoming more compressed and ending with a contracted body chamber. The nuclei are smooth or striate, the striae gradually giving place to ribs, which on the inner and middle whorls may closely resemble those of *Emileia*, but differ in that the primaries are shorter than in *Emileia*, with more definite lateral tuberculation. In this respect the later middle whorls more nearly resemble *Otoites*: in some species they have heavy tubercles placed near or on the rim of a crater-like umbilicus with vertical and almost smooth walls. *Otoites*, however, ends with lappets, while *Pseudotoites* continues to grow, forming a large, contracted, slightly uncoiling body chamber with degenerated ribbing and feeble bullae, more as in *Emileia*, and no lappets. (Compare *Emileia polyschides* (non Waagen) as figured by Greppin, 1898, pl. i.) The suture lines of *Emileia* vary so widely (cf. Buckman, 1927, vols. vi, vii, pls. dccx (A–D), dccxxiii (A, B), dccxxxii (C), and 1920, vol. iii, pl. clxiv) with thick-stemmed to extremely slender lobes, that those of *Pseudotoites*, now known for the first time, would fall readily into *Emileia* in a classification dependent on sutures. The chief feature of the suture of *Pseudotoites* is a long, slanting, accessory lobe, which branches off obliquely outwards from near the outer side of the base of the first lateral lobe. But even this feature occurs in some specimens of *Emileia*, for instance in *E. brocchii* (Sow.) (figure 13, p. 592), and it is noticeable in many *Teloceras* (see Weisert, 1932, figs. on pp. 170, 171, 174, 181) and *Docidoceras* (Buckman, 1921, vol. iii, pl. cxxxiii B).

The genus *Docidoceras* Buckman can with equal logic be classified in the Otoitidae and Stephanoceratidae and may be an ancestor of both. The type species, *D. cylindroides* Buckman (1919, vol. iii, pl. cxxxiii, A, and 1921, vol. iii, pl. cxxxiii B), from the Discites Subzone, is in some respects closer to *Pseudoites* than is *Emileia*, notably in its 'bullatiform' coiling. To this extent a Discites date is probable for *Pseudotoites*. But *Docidoceras* is more strongly ribbed on the inner whorls and has a strongly collared and lipped aperture, as in *Stephanoceras*. Buckman seems to have used *Docidoceras* as a receptacle for all forms of stephanoceratids found in the Discites Zone, but this concept of the genus is open to serious question. None of the other divergent species assigned by Buckman to *Docidoceras*, however, is so like *Pseudotoites* as is the type species, and that could not safely be asserted to be congeneric with the Australian stock. The nominal genus *Pseudotoites* is therefore justified and is retained here.

Pseudotoites leicharti (Neumayr), plate 32, figures 2, 3; plate 33, figures 2 to 4

Stephanoceras leicharti Neumayr, 1885, p. 140, pl. i, fig. 4.
S. leicharti Redlich, 1896, p. 162.
Pseudotoites leicharti Spath, 1939, p. 124, pl. i, fig. 1; pl. ii, fig. 4 (Neumayr's figures reproduced).

Material. Six complete or nearly complete specimens comparable with Neumayr's figures, all from (691296). At least six more, but too damaged or incomplete for specific determination (including F21125). Believed inner whorls F21107–8.

Descriptive remarks and comparisons. In making Neumayr's species, on the evidence only of the drawings, type of the genus *Pseudotoites,* Spath did not mention that Redlich (1896) had stated that the type specimen was in such a bad condition that its relationships could only be conjectured. Neumayr's figure of the ventral view, reproduced by Spath, shows regular, slow enlargement of the whorl and implies that *P. leicharti* is a planulate. This is deceptive. Among the new material some specimens, otherwise indistinguishable, have inflated middle whorls, and all those of planulate form have been more or less crushed. All the specimens are at least to some extent crushed or irregularly 'stove in', and none shows the inner whorls, which have proved impossible to free from the tough and clinging, mottled red and yellow-brown limestone. Nor do they show in Neumayr's original figure. Sectioning of two of the planulate specimens, however, has proved that in these the inner and middle whorls are severely crushed and the middle whorls have been distorted to adapt themselves to the flattened interior, with deceptive results (plate 33, figure 3).

Comparison of all available material has led to the belief that the inner whorls are represented by the two specimens in plate 32, figure 3, and plate 33, figure 2.

Specimens not so crushed (plate 33, figure 4) show that at least the penultimate three-quarter whorl is inflated and possessed of a nearly vertical umbilical wall with bullae on the edge, as in *P. robiginosus* (p. 574). The beginning of the last whorl of Neumayr's holotype, shown in his drawing as smooth and featureless, if undamaged would have had a crater edge with bullae. The coiling and whorl development is, in fact, more like that of *Docidoceras cylindroides* and some *Bullatimorphites* and *Rugiferites* of the Middle Bathonian (cf. Arkell 1951–3, text-fig. 24).

The diameter of the holotype, 110 mm, is about normal. The two largest specimens in the Playford Collection are 132 and 139 mm in diameter.

P. carlottensis Whiteaves sp. (1876, p. 38, p. vi) from British Columbia, has all the essential characters of *P. leicharti* and is strikingly similar, but is larger and stouter. (See below, p. 587.)

Pseudotoites fasciculatus n.sp., plate 36, figures 1, 2; plate 37, figure 2

Material. Holotype from Fossil Hill (706333); another, F21124, and fragment F21118; ?inner whorls (690296).

Descriptive remarks and comparisons. Differs from *P. leicharti* by having more numerous and sharper secondary ribs on the middle (and probably also on the inner) whorls, conspicuously bundled in quadruplicate sheaves where those of *P. leicharti* are triplicate; and in having coarser and more distant primary bullae on the outer whorl.

Pseudotoites championensis (Crick), plate 32, figure 4; plate 33, figure 1

Ammonites (*Perisphinctes*) *Championensis* Crick, 1894, p. 436, pl. xiii, figs. 2*a*, *b*, *c*.
A. (*Stephanoceras*) sp. Crick, 1894, p. 392, pl. xii, figs. 5*a*, *b* (fragment).
Stephanoceras championensis Redlich, 1896, p. 162.
Perisphinctes championensis Chapman, 1904*b*, p. 331.
Pseudotoites championensis Spath, 1939, p. 124.

Material. Four specimens, including F21122, F21119. Also ?(714314) in haematite. Holotype Brit. Mus. (N.H.) C30385.

Descriptive remarks and comparisons. It was pointed out by Redlich (1896) and accepted by Uhlig (1911, p. 409) that *P. championensis* is 'certainly very closely related to, perhaps even identical with' *P. leicharti* (Neumayr), which Crick had overlooked. Spath (1939, p. 124) referred to the holotype as 'merely a more delicately ribbed edition of *Pseudotoites leicharti*'.

The holotype (plate 32, figure 4) is in difficult matrix like the *leicharti* bed and shows nothing of the middle or inner whorls. For the first half of the last whorl the umbilical wall is vertical and smooth, and in the last half-whorl it gradually becomes inclined and smooth; all as in *P. leicharti.* But the secondary ribbing throughout is decidedly feebler than in *P. leicharti*, on both cast and test. This is not due to polishing by water action, which parts of the holotype may have suffered. Four totally unpolished specimens were readily picked out of the Playford collection for the same feature of smoothness. On the last part of the body chamber the secondary ribs almost fade away just where in *P. leicharti* they are strongest, but the bullae remain unimpaired. According to Mr Playford the stratigraphical position is not the same (see range diagram, p. 556).

Chapman (1904*b*, p. 331) described a topotype in Melbourne Museum with aptychus in place, and according to him it belongs to the group called by Zittel the Granulosi (= Granulaptychus of Trauth), characteristic of *Stephanoceras* and *Perisphinctes.*

Pseudotoites robiginosus (Crick), plate 34, figures 1 to 4; plate 35, figures 1, 2; plate 37, figure 5; figure 6

Stephanoceras blagdeni Neumayr, 1885, p. 140, pl. i, fig. 3 (fragment).
Ammonites (*Perisphinctes*) *robiginosus* Crick, 1894, p. 438, p. xiii, figs. 3*a*, *b*.
Pseudotoites robiginosus Spath, 1939, p. 124.
Emileia (?) sp. juv. Spath, 1939, pl. i, figs. 3*a*, *b*.

Material. At least twenty specimens, including one each from Mount Hill (858035) and Fossil Hill (706333), and including F21110, F21112, F21114, F21120–1 and F21127. Holotype fragment Brit. Mus. (N.H.) C30381.

Descriptive remarks and comparisons. The fragment of large body chamber which Crick described as holotype gave him no clue to the real character of the species, which he stated was 'very nearly related' to the Bathonian perisphinctid, *Wagnericeras wagneri* (Oppel), and which he then compared to the Kimeridgian genera *Dorsoplanites* and *Rasenia.* The first words of his description are particularly unfortunate: 'Shell (cast) discoidal...', which is the opposite of the truth.

Fortunately, the Playford collection contains one large, complete, undistorted specimen with almost a whole whorl of body chamber (plate 35, figure 1). The last half-whorl, allowing for weathering (it carries growths of lichen), is identical with Crick's holotype.

By breaking away a deeply weathered fifth of the outer whorl and developing the umbilicus I have succeeded in revealing all but the nucleus; and the ammonite that emerged is a cadicone with contracted and reduced body chamber, resembling in form an *Emileia* of the typical *brocchii* group. (Cf. *E. bulligera* and *E. contrahens* Buckman, 1927, vol. vii, pls. dccxxxii, dccxliv).

In the Newmarracarra Limestone most of these inflated forms must come from a different bed from most of the *P. leicharti*, for they are not crushed or distorted and have a harder or brittler matrix, which parts much more satisfactorily from the shells and casts. (This conclusion was confirmed in the field by Mr Playford; see his range diagram, p. 556.) Consequently it is possible to prepare specimens displaying all stages of growth down to a nucleus of 20 mm diameter.

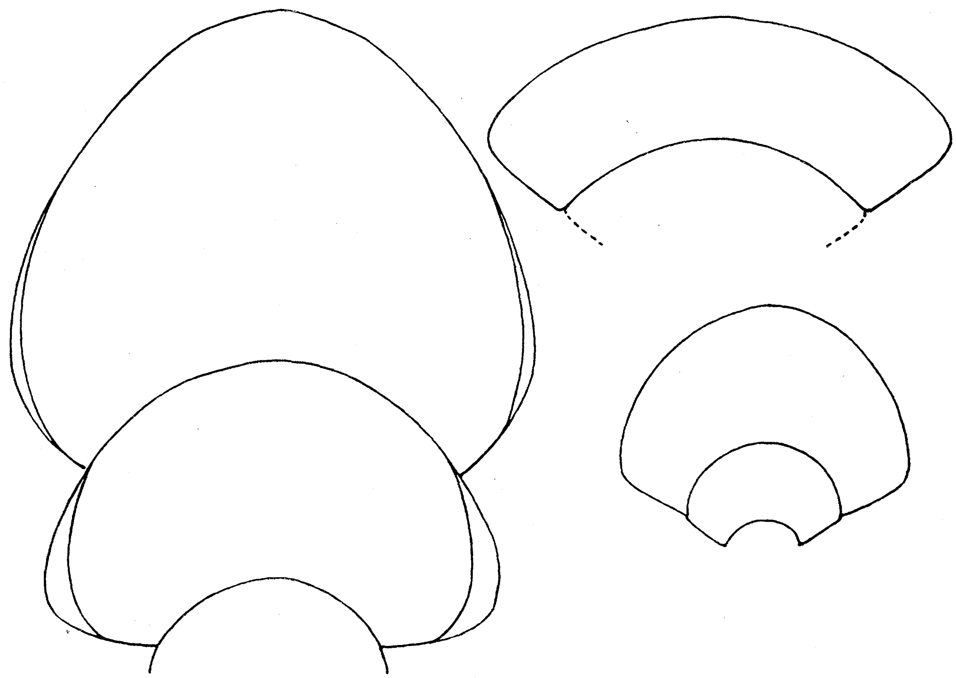


FIGURE 6. Whorl sections of *Pseudotoites robiginosus* (Crick), left and lower right; and of *Zemistephanus corona* n.sp., upper right. Natural size.

At 20 mm diameter the whorl section is subcircular, the umbilicus of medium width, the regular, fine, gently prorsiradiate ribbing confined to the venter and outer half of the whorl sides. By 30 mm the whorl section has begun to grow depressed, and feeble primary ribs have appeared, but no tubercles. Thereafter an umbilical slope gradually transforms itself into a steep and finally almost vertical umbilical wall, the inner part of which is smooth, the outer undulated by large primary ribs which thicken to bullae on the crater edge of the umbilicus, and there branch into three secondaries and an intercalatory, which pass evenly across the sides and venter with a gentle forward swing and no interruption. From about 80 to 100 mm is the stage of maximum whorl thickness, when the form is that of a *Teloceras*, *Tulites* or *Cadoceras*. Thereafter, as in *P. leicharti*, the whorl gradually contracts and the umbilical wall becomes more gently inclined, with the result that in normal side-view the bullae appear to migrate up the whorl sides. (This effect is illusory, however, for the bullae in fact sink gradually nearer to the umbilical seam, but in a different plane.) The maximum diameter of the nearly complete specimen is 165 mm.

The chief reasons for assigning this species to *Pseudotoites* rather than *Emileia* are: (1) the restriction of primary ribbing to the outer half of the umbilical wall or slope, leaving a smooth inner band, which is also characteristic of *P. leicharti*; (2) the nature of the inner whorls, which are much less depressed than in *Emileia* and devoid of primary ribs; (3) the continuance and coarsening of the characteristic ribbing on the modified adult body chamber, as in *P. leicharti*, whereas at the corresponding stage in *Emileia* ribbing becomes feeble or disappears. In fact, it is only at the middle stages of growth that *Pseudotoites* and *Emileia* are comparable. On the nucleus and on the adult body chamber the styles of ribbing are strikingly dissimilar (cf., for example, Buckman 1927, vol. vii, pl. dccxliv, and Greppin 1898, pl. i).

Pseudotoites emilioides n.sp, plate 34, figure 5; plate 37, figures 3, 4

Stepheoceras cf. *humphriesianum* forma *indica* Kruizinga, 1926, p. 49, pl. vi, figs. 1, 2, and pl. xii, fig. 3. (Non *Cadomites indicus* Kruizinga sp.)

Material. Twelve specimens, ranging from 35 to 102 mm in diameter, including one from Mount Hill (858035) and F21102–6, and one from Doust Station, Hill River district (34889).

Descriptive remarks and comparisons. Differs from *P. robiginosus* by its sharper, finer and denser ribbing. In particular, the primary ribs of the coronate middle stage are sharper, less bullate, more linear like those of *Emileia*, and inclined to have sharp terminal tubercles.

There appears to be close agreement in side and ventral view, whorl section, and suture-line, with the Sula Islands specimen erroneously compared by Kruizinga (1926, p. 49) to his '*Stepheoceras*' [*Cadomites* ?] *indicus* (p. 48, pl. xiii, fig. 1; pl. vii, fig. 3). For that species see below, p. 584.

Pseudotoites brunnschweileri n.sp., plate 36, figures 3, 4

Material. Holotype F21128; also F21129–30, F21132.

Description and comparisons. The holotype, 112 mm in diameter, though crushed at the extremity, seems to retain part of the mouth border, which appears to have been lipped and gently constricted behind the lip, as in *Docidoceras* but much less so. It also shows marked contraction of the last quarter whorl, with opening out of the umbilicus, from which it is inferred that the specimen is full grown although no sutures are visible. The species is therefore much smaller than *P. robiginosus* or *P. emilioides*. The inner whorls resemble those of *P. emilioides* but are not nearly so inflated; they are untuberculated to a late stage (about 40 mm diameter) and bear dense, fine, prorsiradiate ribbing on subcircular whorls. Except for the denser ribbing they are hardly distinguishable from small specimens interpreted as inner whorls of *P. leicharti*. Tubercles appear very gradually, are discrete, and placed a third of the way up the whorl sides on the last half-whorl. The style of tuberculation and ribbing on the last whorl recall those of *P. spitiformis*, but the ribbing is feebler, the inner whorls are much more compressed, and the total size is substantially larger. Nevertheless, *P. brunnschweileri* is in some ways transitional between the large *P. robiginosus* and *P. emilioides* on the one hand and the small *P. spitiformis* and *P. semiornatus* on the other.

Pseudotoites spitiformis n.sp., plate 38, figure 8

Material. Holotype from (691296) and probably F21123.

Description and comparisons. At its maximum diameter of 81 mm the holotype embodies all the successive stages represented in specimens of *P. robiginosus* of more than double the size. In the umbilicus can be clearly seen the coronate stage with wide, vertical umbilical wall, but the ribs are sharp and linear as in *P. emilioides*. The outer whorl, of which three-quarters are body chamber, is depressed and *Rasenia*-like at first, but gradually becomes planulate, retaining very strong secondary ribbing and lateral tubercles to the end, as in *P. leicharti*. The primary ribs of the outer whorl are both bullate and tuberculate, thus combining features of *P. robiginosus* and *P. emilioides*. This character and the general style of the ribbing on the outer whorl gives a strong resemblance to some species of Tithonian and Lower Neocomian *Spiticeras* (cf., for instance, Djanélidzé, 1922, pl. iii, fig. 2*a*; pl. viii, fig. 3*a*; pl. xix). The resemblance even extends to the inner whorls, which in *Spiticeras* also are coronate with lateral tubercles on the umbilical edge (cf. Djanélidzé, 1922, pl. iii, figs. 1*a*, 4).

In size *P. spitiformis* is nearest to *P. semiornatus*, but *P. spitiformis* is stouter up to the beginning of the last whorl, is more strongly tuberculate and has rursiradiate instead of prorsiradiate secondaries.

Pseudotoites semiornatus (Crick), plate 38, figures 1 to 6

Ammonites (*Sphaeroceras*) *semiornatus* Crick, 1894, p. 434, pl. xiii, figs. 1*a*, *b*.

Material. At least eighteen specimens, including one from Fossil Hill (706333) and one from the well that yielded the holotype of *Sonninia playfordi*, also including F21100–1, F21090, F21095–7, ?F21131, and one from Doust Station, Hill River district (34888). Holotype Brit. Mus. (N.H.) C30377.

Descriptive remarks and comparisons. While assigning this species to *Sphaeroceras*, Crick compared it to various species now assigned to *Stephanoceras*, *Emileia*, *Chondroceras*, *Otoites* and *Morphoceras*. Spath (1939, pp. 124, 125) did not place it generically. The largest known specimen (plate 38, figure 5) shows that it is indubitably a *Pseudotoites*. This specimen is 69 mm in diameter (as compared with the holotype's 64 mm) and is uncrushed and nearly complete, with three-quarters of a whorl of body chamber. It is a typical *Pseudotoites* in all but its small size, but even in this respect it is linked to the other species by *P. spitiformis*, which is little bigger. The coronate middle whorls show clearly, and the reduced outer whorl becomes subcircular in section, with triplicate sheaves of prorsiradiate secondaries, gradually becoming biplicate near the aperture. There is no sign of lappets in any of the material. *P. semiornatus* may be described as a miniature and less strongly tuberculate *P. leicharti*. The uniformly small size of all the specimens and their adult features prove that it is not the young of *P. leicharti*.

Pseudotoites n.spp. indet.

There are several specimens which cannot be accounted for under any of the seven species recognized above, but which are too poorly preserved or too fragmentary for description and naming. One is a large and stout species, as large as *P. robiginosus* but considerably more inflated at larger diameters. Another resembles *P. robiginosus* in the coronate stage but has slenderer inner whorls (plate 37, figure 1).

Genus **ZEMISTEPHANUS** McLearn, 1927

Type species by original designation *Ammonites richardsoni* Whiteaves (1876, p. 32, pl. v, figs. 1, 2), from the Lower Yakoun formation, Skidegate Channel, Skidegate Inlet (probably Mackenzie Bay), Queen Charlotte Islands, British Columbia.

Dr McLearn has rediscovered the type species in the Lower Yakoun at Mackenzie Bay, Maude Island, and figured a plesiotype and two associated species (1929, p. 19, pls. ix–xi). His detailed generic diagnosis agrees with the Australian species in every particular, except for the presence in two of the Canadian species (but not the third, *Z. vancouveri* McLearn) of numerous 'small costulae' on the test all over the ventral area. An excellent plaster cast of the holotype of *Z. richardsoni* which Dr McLearn has kindly sent me (figure 10) shows that these 'costulae' are superimposed on feeble but much wider and more distant normal secondary ribs which show faintly on the internal cast where the test is broken away. They are therefore regarded as accentuated growth lines and not of generic importance. Similar striation has been observed on some species of Bajocian *Emileia*, *Otoites* and *Ermoceras*, but is absent from others (Arkell, 1952*a*, p. 272, pl. 30, fig. 5; Buckman, 1920, vol. iii, pl. clxiv).

One of the Australian specimens enables the generic diagnosis to be completed by addition of the aperture, which is broken away from all the known Canadian material of all three species. The aperture is constricted and collared, with a wide lip, no lappets. The body chamber occupies at least a whole whorl.

Zemistephanus corona n.sp., plate 39, figures 2, 3; figures 6, 7

Material. Two good specimens (732343); perhaps some others incomplete, but only one seems likely to be conspecific (722303).

Description. The holotype is 115 mm in diameter and has almost the whole test preserved. The aperture is perfect (as described under the genus, above). The umbilicus is a perfect crater or hollow cone and is visible almost to the centre. It is uniformly ribbed with strong, distant primary ribs on the outer half of the umbilical wall of each whorl, the inner half smooth. Only in the last half whorl does the umbilical wall begin to assume a more gentle slope, accompanied by slight uncoiling, so that the tuberculate ends of the primary ribs protrude clear of the umbilical seam. Fifteen of these large, blunt tubercles encircle the crater edge of the umbilicus on the outer whorl, the last one coinciding with the apertural collar. Secondary ribs are very faint on the first half of the last whorl and fade on the second half.

Sutures (partly visible on one specimen only; figure 7) are more intricate than in *Z. richardsoni*, with more deeply incised saddles, due chiefly to greater development of accessory lobes; but they have the principal lobes thick-based as in *Z. richardsoni*, not thin as in most *Emileia* (e.g. Buckman, 1927, vol. vi, pls. dccx B, vol. vii, pls. dccxxiii A, dccxxxii C and our figure 13, p. 592). The degree of indentation of the sutures is no more different than between the various English species all assigned to *Emileia* even by Buckman.

The second specimen, showing the sutures (same locality), is an internal cast of the last $1\frac{1}{4}$ whorls. It is larger, 150 mm in diameter, and believed to be a larger and older individual, for after the stage represented by the holotype there is an additional half-whorl bearing seven primary ribs (counting the final one at the collar), and at this stage the whorl contracts slightly more, and coarse feeble secondary ribs appear, of the style of those of *Pseudotoites robiginosus* (Crick).

Comparisons. The 'large ammonite...with a diameter of 1150 mm and umbilical width of 650 mm', compared by Whitehouse (1924, p. 9) to *Teloceras*, is not 46 in. in diameter as calculated by Spath (1939, p. 126), for the dimensions became multiplied by ten through an error of transcription, as Whitehouse had indicated on the Sedgwick Museum copy of his paper many years earlier. Although the diameter of 115 mm is the same as that of the holotype of the present species, however, the umbilical width of 65 mm does not agree; for the width of the umbilicus of the holotype at 115 mm is 45 mm if measured correctly from the umbilical seam, and 73 or 74 mm if measured from the centre of the tubercles. Possibly Whitehouse's form belongs to *Z. armatus*.

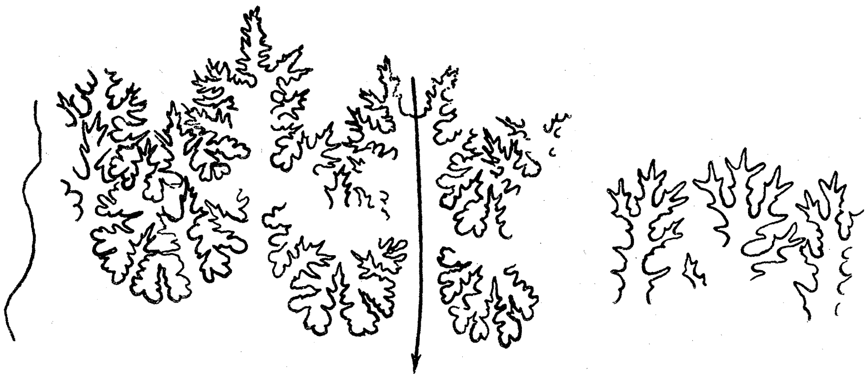


FIGURE 7. Left: *Zemistephanus corona* n.sp., oblique view of final sutures of topotype. Right: part of internal suture of a *Pseudotoites*. Natural size.

In essential characters of form, coiling, ribbing and sutures, *Zemistephanus corona* is a *Teloceras*. In typical *Teloceras* of the *blagdeni* group (holotype of *T. blagdeni* Sowerby sp. refigured Buckman & Secretary, 1908, pls. ii, iii) the tubercles and secondary ribbing are sharper. But in *T. banksi* (Sowerby) and its allies this distinction does not hold; the nodes and secondary ribs become just as blunt as in the Australian form and die out on the giant last half-whorl. The sutures in true *Teloceras* are usually complex (see many figures in Weisert 1932), but in some they are unusually open (e.g. Buckman 1922, vol. iv, pl. cccl).

The only tangible distinction is in the aperture. By definition (Mascke 1907, p. 30) the aperture of *Teloceras* and *Stemmatoceras* is 'a simple ending to the tube, without special peristome and without lappets'. Mascke's statement is borne out by many specimens from the Sherborne district. In *Z. corona* there is a distinct collar and lip. Despite the need for caution in view of the blunt nodes and ribbing of *Teloceras banksi*, it is believed that these Australian ammonites, with their blunt ribbing, are not true *Teloceras* but merely expressions of the same trend from *Pseudotoites* or *Docidoceras* or *Emileia*. *E. crater* Buckman (1920, vol. iii, pl. clxiv) is analogous but differs in its aperture, and from the linear character of its primary ribs it is clearly linked to *Emileia* of the typical *brocchii* group (Buckman & Secretary 1908, pl. iv).

Accordingly, although through lack of perfect specimens the apertural features of *Pseudotoites* are still uncertain, *Z. corona* is regarded as a contemporary expression of the

Teloceras trend from *Pseudotoites*. It is at least as worthy of generic separation as *Teloceras*, which Weisert (1932, p. 133) found 'easy to distinguish' in Württemberg, but which Spath (1936, p. 12) stated was connected [in England] by passage forms with *Stemmatoceras* and *Stephanoceras*. This does not imply that Weisert's observations were necessarily faulty,

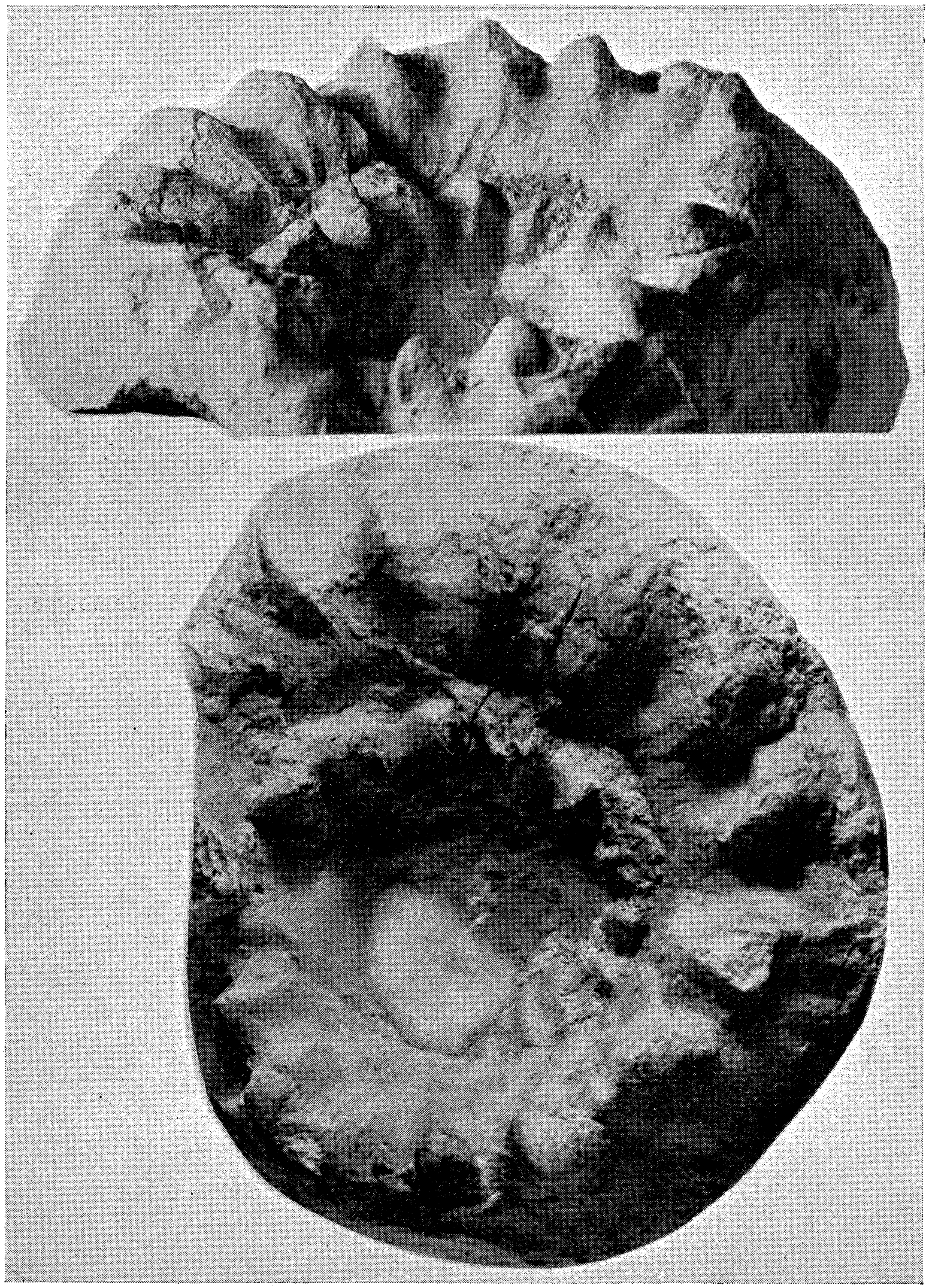


FIGURE 8. *Zemistephanus armatus* n.sp. Plaster cast of holotype, natural size.

for allied species and subgenera which are sharply divided in one part of Europe are connected by transitional forms in another, as has been shown for the Upper Oxfordian perisphinctids; also it may be presumed that the apertural features of the 'passage forms' were unknown.

Among the Canadian species of *Zemistephanus* the nearest is the type species, *Z. richardsoni* (Whiteaves), which differs by its more distant ribbing, especially on the early umbilical whorls (thirteen tubercles on the last whorl as compared with fifteen, showing that, as Dr McLearn pointed out (1929, p. 19), the number of tubercles per whorl increases with growth); by the conspicuous growth lines ('small costulae'); by slightly more arched venter, which in side view gives the impression that the tubercles are nearer the umbilicus; and by less deeply incised saddles and smaller accessory lobes.

Zemistephanus armatus n.sp., figure 8

Material. Plaster cast of an external mould, 90 chains south of Moonyoonooka Homestead (707304), F 21133 (holotype).

Descriptive remarks and comparisons. The plaster cast gives a tantalizingly incomplete impression of one side only of a large, extremely coronate ammonite, for which the genus *Teloceras* at once springs to mind, but in the size and length of its spines it outdoes any figured *Teloceras*, and it also differs by virtual absence of ribs on the last whorl. At a diameter of 115 mm the width of the umbilicus is 60 mm measured at the umbilical seam and 90 mm measured from the centre of the tubercles. This species, therefore, may be the *Teloceras* of Whitehouse (1924, p. 9) (see above, p. 579). It is, however, closer to *Z. corona* than to any known species of *Teloceras*. It differs from *Z. corona* by its much more prominent and spinous tubercles and more depressed whorl shape.

?**Zemistephanus** n.spp.

A latex mould of parts of one side of two whorls shows the presence of a much larger species with enormous tubercles still at a diameter of about 140 mm. Not enough is preserved, however, to exclude the possibility that this is a large *Stephanoceras* or *Stemmatoceras*. Another specimen (F 21111 A, B), much damaged in the fire, is believed to be a squashed *Zemistephanus*, of which it shows the characteristic aperture; but not enough is known yet about the apertural features of *Pseudotoites* to exclude it on those grounds.

Family STEPHANOCERATIDAE Zittel, 1884 and H. Douvillé, 1884

(ex Neumayr, 1875, in vernacular as Stephanoceratinen)

The remaining ammonites are the least satisfactory, because the most imperfectly known, of all the fauna of the Newmarracarra Limestone. They are each represented by only one or two very incomplete natural ironstone or artificial casts. Both singly and collectively they give the impression that some horizon is scantily represented here and there, later in date than the main Newmarracarra fauna and perhaps destroyed elsewhere by erosion or lateritization, or not deposited. All show characters closer to normal stephanoceratid genera of the Humphriesianum Zone than to *Pseudotoites* and *Zemistephanus*, but not a single one is complete enough for definite identification. These problematic forms raise questions which only future field researches can answer.

Genus **STEPHANOCERAS** Waagen, 1869

Subgenus **STEMMATOCERAS** Mascke, 1907

Type species by original designation *Ammonites humphriesianus coronatus* Quenstedt (1886, pl. 66, fig. 11), which is type of *Stephanoceras frechi* Renz (1913, p. 684) (objective synonym *Stephanoceras quenstedti* Roché, 1939, p. 205). Type specimen from Eningen, Württemberg, refigured Weisert, 1932, pl. xviii, fig. 4.

Stephanoceras (**Stemmatoceras**) cf. **subcoronatum** (Oppel), plate 38, figure 7

Ammonites coronatus oolithicus Quenstedt, 1849, *Atlas zu den Cephalopoden*, pl. xiv, fig. 4.
A. subcoronatus Oppel, 1856, *Juraformation*, p. 376 (for preceding).
Stemmatoceras subcoronatum Buckman, 1911 *a*, p. 206
S. subcoronatum Weisert, 1932, p. 161, pl. xviii, figs. 6, 7.

Material. An imperfect external mould, 38 to 39 mm in diameter, in haematite (765366), from the railway well near Bringo (Univ. W. Australia, old collection).

Comparisons. At the diameter of just under 40 mm it is still hardly possible to separate middle whorls of *Normannites orbignyi* Buckman and its allies from inner whorls of large *Stemmatoceras*. Squeezes from this mould, however, show a massive style of tuberculation, and primary ribs still lengthening and strengthening, so that identification with a *Stemmatoceras* close to the type species, if not identical with it, is virtually certain. In particular, the squeeze is indistinguishable from a *S.* aff. *subcoronatum*, 57 mm in diameter, so determined by Dr Spath, from the Scarborough Limestone, in the Sedgwick Museum (J 1459) and probably the species so determined from Scarborough by Buckman (1911 *a*, p. 206). In this the ventro-lateral angle is much sharper than in Quenstedt's figure, and if the same type of whorl section continued, it seems that the adult would be a *Teloceras* rather than a *Stemmatoceras*. Weisert's statement (1932, p. 162) that *S. subcoronatum* is 'kleinwuchsig' is not consistent with Quenstedt's figure of the holotype, which is wholly septate at 50 mm diameter.

The sharp ventro-lateral angle is better matched in *S. frechi* (Renz sp., 1913, p. 684) (= *Am. humphriesianus coronatus* Quenstedt, 1886, pl. 66, fig. 11), the type species of *Stemmatoceras*, but in that the whorls enlarge more slowly and the primary and secondary ribs are not so coarse.

Two fragmentary and problematic Australian specimens mentioned below, though similar, have smaller and sharper tubercles and less regularly triplicate ribbing.

Stephanoceras (**Stemmatoceras**) aff. **triptolemus** (Morris & Lycett), plate 39, figure 1

Ammonites triptolemus Morris & Lycett (ex Bean MS), 1851, p. 111, pl. xiv, fig. 1.
Skirroceras? triptolemus Buckman, 1911 *a*, p. 205.

Material. A fragmentary cast and mould in red friable ironstone (707304).

Comparisons. A single specimen is represented by short lengths of four successive whorls up to a diameter of about 95 mm. The whorl section is very depressed, thickness about double the height, and the narrow sides are separated from the broad flat venter by a right-angle. Ribbing strong and sharp at all stages, bifurcating and trifurcating at the ventro-lateral angle from a tubercle.

The outer whorl is an exact match with some evolute and flat-ventered *Stemmatoceras* found in the Scarborough Limestone (e.g. Geol. Survey Mus. no. 25254), which there grow to at least 250 mm in diameter, retaining unchanged ribbing to the end (Sedgwick Mus. no. 34949). The correct name for these is probably *S.* (*S.*) *triptolemus* (Morris & Lycett) (despite their curious use of the word 'discoidal'), but the holotype has not come to light. The inner whorls of the Australian form, however, are more finely ribbed and by themselves could not be separated from Upper Bajocian *Cadomites*. (Cf. *C. homalogaster* Buckman, 1925, vol. v, pl. dxliii.)

It is possible that '*Stepheoceras humphriesianum*' var. *indicum* Kruizinga (1926, p. 48, pl. xiii, fig. 1 and pl. vii, fig. 3), from the Sula Islands, is the same as or closely allied to the Australian form, notwithstanding its apparent affinity with *Cadomites* such as the more finely ribbed *Cadomites* sp. figured from the same islands by Boehm (1912, pl. xxxiv, fig. 5). Kruizinga's type is at a stage before that at which *Stemmatoceras*-like features would have begun to form in the Australian ammonite.

8. Comparisons with circum-Pacific Bajocian faunas

8·1. *New Guinea*

From various parts of New Guinea typical *Stephanoceras*, *Chondroceras* and *Normannites* have been figured. They seem to represent the Humphriesianum Zone in European development, though one was likened to an Andean species, and others seem to be best matched in Canada.

Stephanoceras aff. *humphriesi crassicosta* (Quenst.) Boehm, 1913, pl. iii, fig. 2. This was compared by Buckman (1922, vol. iv, pl. cccxlv A) to his '*Kumatostephanus*' *kumaterus*, from the Sowerbyi Zone of Dorset, but some Humphriesianum Zone forms since figured from Canada provide a closer comparison (e.g. McLearn 1932, pl. ii, and Warren 1947, pl. iii).

Stephanoceras of the *humphriesianum* group; inner whorls of a large specimen said by Boehm to be indistinguishable from Bayeux specimens: Boehm 1913, pl. v, fig. 4.

Chondroceras sp. or spp., Boehm 1913, pl. ii, figs. 3, 4, compared by Boehm to the Andean *C. submicrostoma* (Gottsche), but very close to Dorset species.

? *Normannites etheridgei* (Gerth): Gerth 1927, p. 226, pl. xxxvi, fig. 1 (holotype).

? *Normannites* sp. indet., aff. *etheridgei* (Gerth): Etheridge 1890, p. 175, pl. xxix, fig. 2.

In addition a fragment of *Cadomites*, with aperture, suggests that Upper Bajocian is present, as in the Moluccas: Boehm 1913, pl. iii, fig. 1.

8·2. *Sula Islands* (*Moluccas*)

At least two zones of the Bajocian are represented by ammonites so far known: Humphriesianum Zone and Upper Bajocian, as in New Guinea.

'*Coeloceras*' *indicum* Kruizinga, 1926, pl. xiv, fig. 1, seems to be comparable with *Teloceras stelki* Warren (1947, pl. vi, fig. 1) from the Canadian Humphriesianum Zone, though larger.

Chondroceras godohense (Kruizinga) non Boehm, Kruizinga 1926, pl. xiv, figs. 2, 3, also suggests the Humphriesianum Zone.

The Upper Bajocian is represented by two well-preserved *Cadomites*:

Cadomites daubenyi (Gemmellaro) Boehm, 1912, pl. xxxiv, fig. 5, which Boehm declared identical with types borrowed from Sicily. Specific identity, however, may be doubted in view of the extremely wide interpretation of ammonite species by Boehm in other families, for example, *Macrocephalites*, under which he united several subgenera in the single species *Macrocephalites keeuwensis* Boehm.

Cadomites indicus Kruizinga sp., 1926, pl. xiii, fig. 1; pl. vii, fig. 3. This may be a synonym of *C. homalogaster* Buckman (1925, vol. v, pl. dxliii), from the Subfurcatum Zone of Dorset.

In addition, as mentioned above (p. 576), a Sula Islands specimen figured by Kruizinga (1926, pl. vi, figs. 1, 2; pl. xii, fig. 3) may be specifically identical with the Australian *Pseudotoites emilioides*. Unfortunately, the relative stratigraphical positions of these ammonites are unknown.

Stephanoceras pseudohumphriesi Cloos and *S. pseudoblagdeni* Cloos were named and described but not figured by the late H. Cloos in his doctor's thesis (1916). To save others trouble it is worth recording that in the hope of tracing either type material or unpublished illustrations of these species I have written to: (1) Frau Cloos, (2) Marburg University, where Cloos submitted the thesis for his degree, (3) Freiburg im Breisgau University, where he wrote it and where Boehm lived, (4) Bonn University, where Cloos later held the Chair of Geology, (5) Leiden University Museum, where Cloos stated the Nouhuys Collection was housed, from which some of the material was sent, (6) Utrecht University, where the Nouhuys Collection turned out in fact to be. Negative replies were received to all these enquiries. The conclusion is that the types were in the private Boehm Collection and were destroyed during the 1939–45 war, and that the illustrations either were not made (owing to the 1914–18 war) or were destroyed or mislaid. It is impossible to recognize the species from the descriptions alone, and so the names have had to be ignored. Cloos's third species, *Hammatoceras moluccanum* Cloos (1916), has been recognized among Moluccan material and figured by Kruizinga (1926, p. 36, pl. ii.).

The disappearance of these ammonites named by Cloos is particularly regrettable because from his descriptions it seems probable that they were *Pseudotoites* and *Zemistephanus*, which would further strengthen the single link between Australia and the Moluccas already provided by Kruizinga's figures of a *Pseudotoites* mentioned above.

8·3. *Tibet*

Since no Bajocian ammonites are known from the marine Jurassics of New Zealand, New Caledonia, or Japan, although the successions range from Hettangian to Tithonian, the next nearest locality for comparison is Kampadzong in Tibet (Hayden 1907). Here the Lungma Limestone, 50 ft. thick, has yielded the following Middle Bajocian assemblage in a shelly, hard ironshot matrix (Arkell 1953): *Sonninia* aff. *dominans* Buckman, *Witchellia tibetica* Arkell, *W. australica* Arkell (= aff. *platymorpha* Buckman) (figure 9), *Dorsetensia* cf. *romanoides* (Douvillé), *Dorsetensia* cf. *regrediens* (Haug), *D. haydeni* Arkell, and *Emileia* (*Frogdenites*) sp. juv. The limestone appears to be a condensed representative of the Sowerbyi and Sauzei Zones, for the first four species suggest correlation with the Sowerbyi Zone and the last with the Sauzei Zone, while the remaining two may possibly indicate a representation of the Humphriesianum Zone also.

Only one species, *Witchellia australica*, is common to the Newmarracarra Limestone, but *Dorsetensia haydeni* has some features which suggest relationship to the Australian *Fontannesia clarkei* group. The affinities of the rest of the fauna are all with the west. *Dorsetensia* cf. *regrediens* has also been recorded from the Pamirs.

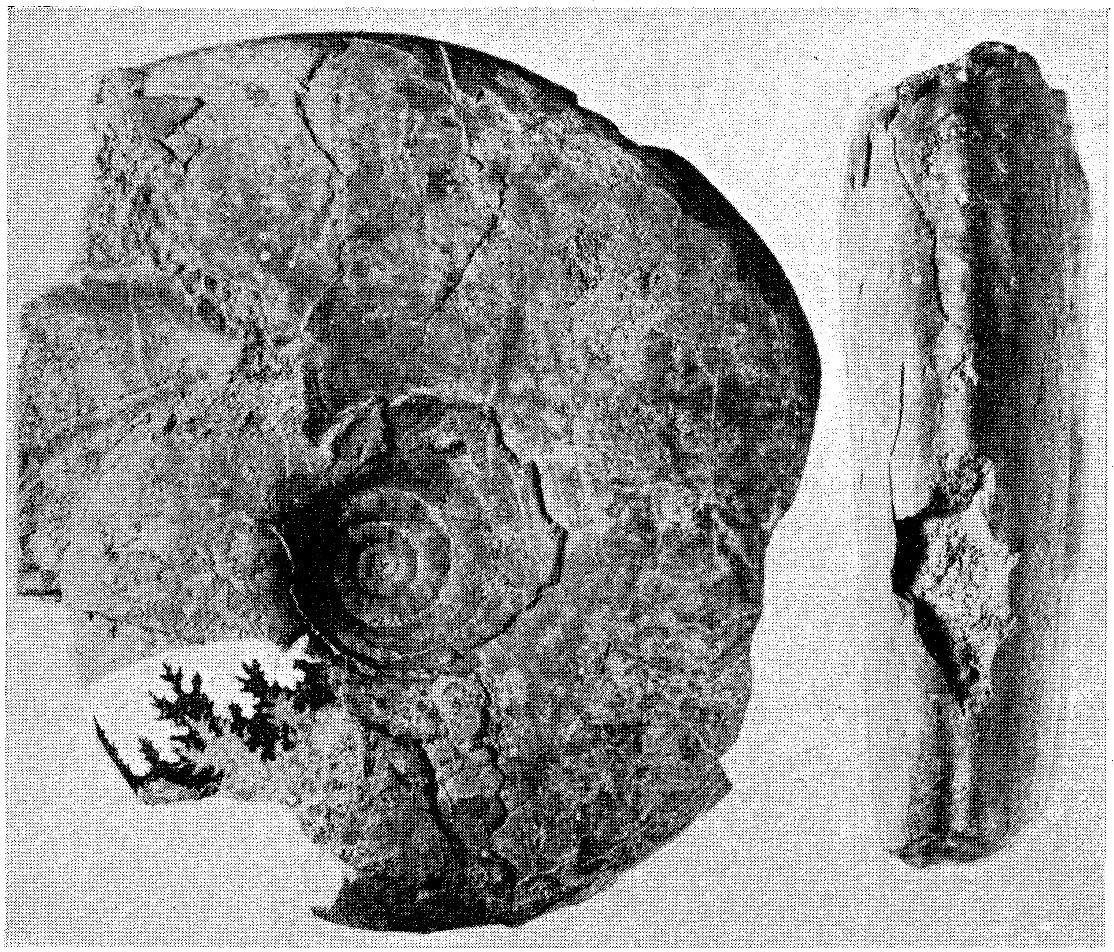


FIGURE 9. *Witchellia australica* n.sp., Lungma Limestone, Tibet. Hayden Coll., Geol. Surv. India no. K9/231. Natural size.

8·4. *Eastern Siberia*

Lower and Upper Bajocian ammonites are recorded from eastern Transbaikal; but so far no Middle Bajocian. Following on Pliensbachian and Toarcian ammonite faunas are beds with *Leioceras* cf. *opalinum* (120 m), then up to 300 m of Bajocian without ammonites but with lamellibranchs, followed by Upper Bajocian-Bathonian lamellibranch beds (1100 m), with *Garantiana* cf. *bifurcata* (Zieten), *Garantiana* sp. indet., and *Lytoceras* sp., in the lower part. They are overlain by over 1000 m of conglomerate (Khudiaev 1931).

'*Sphaeroceras*' *era* Krimholz (1939, pl. ii, figs. 1–3), from the Bureya basin in eastern Siberia, appears from the photographs to be a Lower Callovian *Cranocephalites*. The next lower ammonite horizon is Lower Bajocian with *Ludwigia brasili* (Buckman) and *Hammatoceras* (Murchisonae Zone). The Murchisonae Zone is also known in the basin of the Vilui River, but no Middle Bajocian has been recorded.

8·5. *Alaska*

Numerous Bajocian ammonites are recorded from southern Alaska (Imlay 1952, pp. 978–81), but very few have been figured. From the genera and few species recorded, the following zones seem to be present.

Upper Bajocian: assemblage of *Sphaeroceras*, *Polyplectites*, *Leptosphinctes*, *Lissoceras* (p. 980).

Middle Bajocian.

Humphriesianum Zone: abundant *Normannites*, *Teloceras* and *Chondroceras* (p. 980).

Sauzei and Sowerbyi Zones: abundant *Stemmatoceras*, *Stephanoceras* and *Sonninia*, with a few *Emileia*, *Chondroceras* and *Lissoceras* (p. 981). Elsewhere is recorded an assemblage of *Stemmatoceras*, *Emileia*, *Lissoceras*, *Leptosphinctes* and an oppeliid (p. 979). Elsewhere again, abundant *Emileia*, associated with *Sonninia*, *Erycites*, *Pseudolioceras* and an oppeliid (p. 978).

Some of these associations seem impossible and one is forced to doubt the accuracy of the collecting or recording.

Lower Bajocian and Upper Toarcian: assemblage with *Erycites* (?), *Pseudolioceras* and *Tmetoceras* (with at top a few *Sonninia*, which presumably belong in the overlying zone) (p. 978). The *Pseudolioceras* points to Upper Toarcian and to condensed deposition.

The Alaskan Jurassic promises to be of great interest for world correlation, but until it has been monographed with illustrations of the ammonites little further can be inferred. According to the records both *Zemistephanus richardsoni* (Whiteaves) and *Pseudotoites* cf. *carlottensis* (Whiteaves) occur on Cook Inlet (Martin 1926, p. 153).

8·6. *Canada*

From Canada the only ammonite figured that could be an Upper Bajocian form is *Stephanoceras pluto* Whiteaves (1909, p. 22), based on Whiteaves 1884, pl. 23, fig. 1, non 1876, which strongly suggests a *Cadomites* like *C. homalogaster* Buckman (1925, vol. v, pl. dxliii) of the Subfurcatum Zone. Unless the type can be found, however, the specimen must be suspected of being a Callovian *Seymourites*.

The Middle Bajocian is represented by at least two well-marked assemblages. The best known is that of the Humphriesianum and Sauzei Zones, which is widespread in the Lower Yakoun formation of the coast and the Middle Fernie group inland, in eastern British Columbia and Alberta. It comprises many species of *Stephanoceras*, *Stemmatoceras*, *Teloceras*, *Zemistephanus*, *Normannites* (including *Kanastephanus* and *Itinsaites*) and *Chondroceras* (including *Defonticeras* and *Saxitoniceras*), which have been well figured by Whiteaves (1909), McLearn (1927, 1929, 1930, 1932, 1932*a*) and Warren (1947). A supposed *Frogdenites* from the Lower Yakoun (McLearn 1929, p. 18, pl. xii, fig. 6) supports the inference that that formation includes the Sauzei Zone.

The Sowerbyi Zone is represented as a distinct horizon near the base of the Hazelton group of British Columbia by an assemblage of *Sonninia* and *Witchellia* (including *Sonninites*), with a local sonninid genus *Guhsania* McLearn. *Fontannesia* is also recorded from the Ashcroft area (Crickmay 1930, p. 27), and a *Sonninia* from the Middle Fernie.

The separation of sonninids at a different locality is interesting and may be assumed to have time significance, as in Europe and also Argentina (Gröber 1918, p. 36).

Lower Bajocian is represented by beds in the Lower Hazelton group with *Tmetoceras regleyi* (Dumortier) (Frebold 1951) which correlates with the Scissum Zone of Europe.

The stephanoceratid assemblage of the Lower Yakoun is the most important yet known in the world for comparison with Australia. Struck by the resemblance of the old but excellent drawings of *Ammonites richardsoni* and *A. carlottensis* Whiteaves (1876, pls. v, vi) to Australian species, I asked Dr F. H. McLearn, of the Geological Survey of Canada, to send me casts of the types, and this he most kindly did. *A. richardsoni* had already been made type species of the genus *Zemistephanus* McLearn (see above, p. 578), but the type had

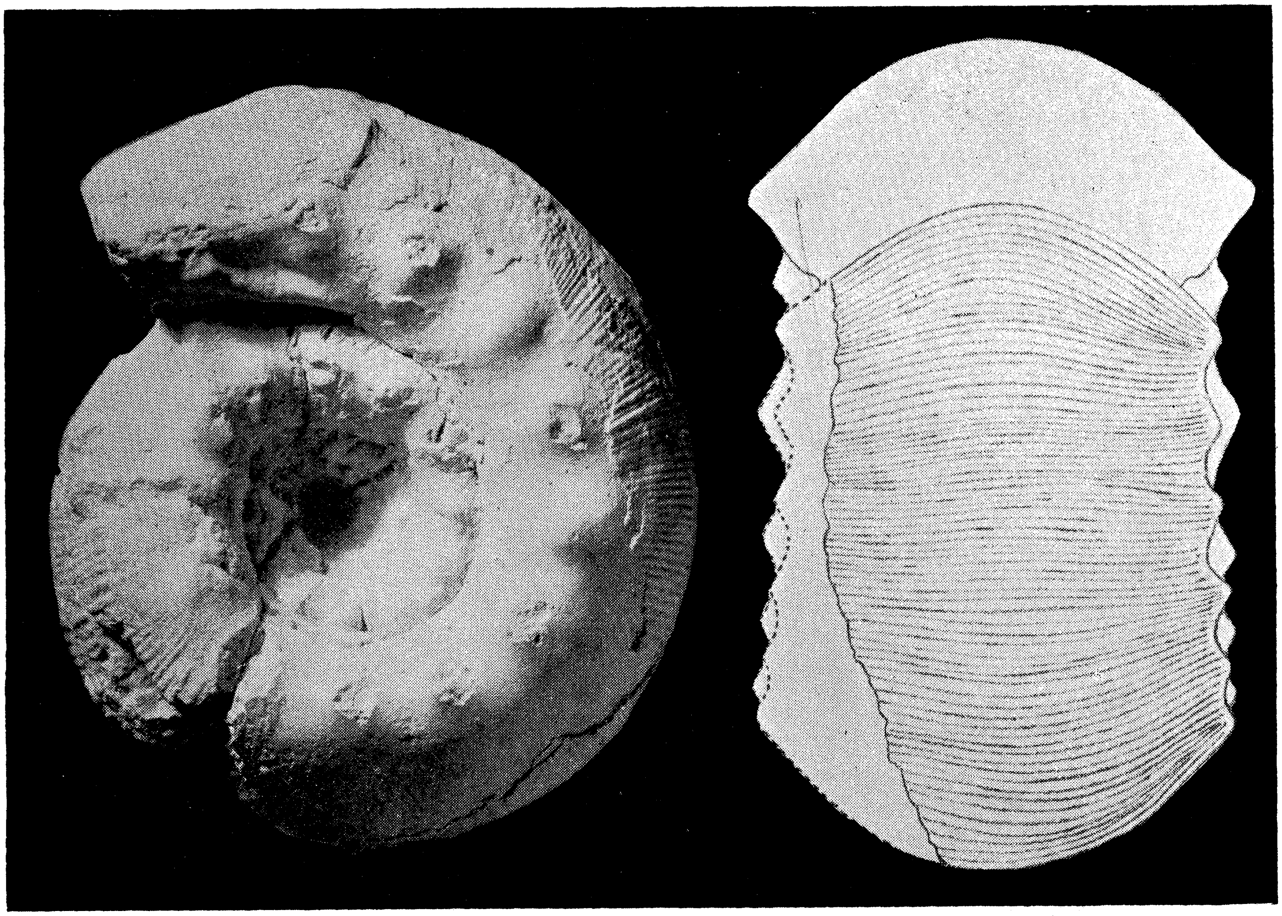


FIGURE 10. *Zemistephanus richardsoni* (Whiteaves), holotype, Skidegate Inlet, British Columbia. Geol. Surv. Canada. Plaster cast, Sedgwick Museum, natural size. The ventral view on right after Whiteaves, restored.

not been refigured (figure 10). The type of *A. carlottensis*, being unique and not showing the umbilical whorls, had not been considered fit for redescription and generic placing. In the light of the Australian material now available, however, there can be no doubt that it is a *Pseudotoites*, very close to *P. leicharti* (Neumayr) but larger and stouter (figures 11, 12). So far as it goes, it has all the essential characters of *P. leicharti* and its allies; but the inner whorls and suture-line are unknown.

At the probable type-locality, on the north-west shore of Maude Island, *Zemistephanus richardsoni* has been found associated with *Z. funteri* McLearn, *Z. vancouveri* McLearn, *Normannites* (*Kanastephanus*) *canadensis*, *mackenzii*, *altus* and *crickmayi* McLearn (McLearn 1949, p. 13). On the south-east shore of Maude Island (ibid. p. 10) is a different assemblage, comprising *Stephanoceras skidegatense* (Whiteaves) and several species of *Chondroceras* (*Defonticeras*). On palaeontological grounds it seems likely that these two beds are not of exactly the same age, and that the former is the older (Sauzei or Sowerbyi Zone), the latter the younger (Humphriesianum Zone).

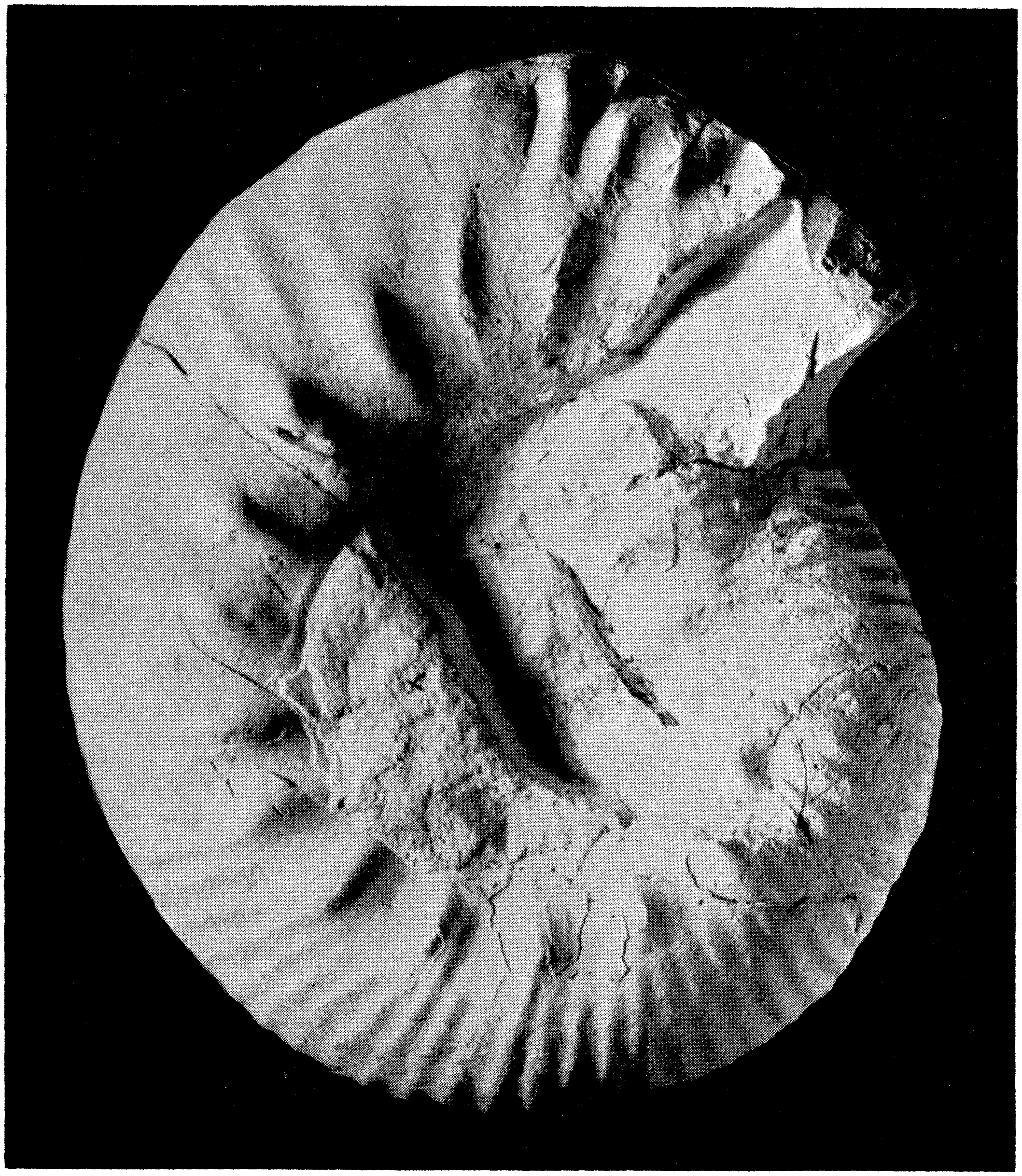


FIGURE 11. *Pseudotoites carlottensis* (Whiteaves), holotype, Skidegate Inlet, British Columbia. Geol. Surv. Canada. Plaster cast in Sedgwick Museum, natural size. (For ventral views see figure 12.)

8·7. *United States*

In central Oregon Middle Bajocian ammonites have been recorded from an enormous thickness of deposits, totalling 1320 m (more than the whole British Jurassic). Careful stratigraphical collecting will no doubt one day yield important results. So far only two assemblages have been distinguished, as follows (Lupher 1941):

(2) Izee Group. Snoeshoe formation (840 m). *Skirroceras* spp., including *Skirroceras* cf. *leptogyrale* Buckman, *Witchellia* aff. *simulans* (Buck.), *Witchellia* aff. *felix* (Buck.), *Sonninia* (*Papilliceras*) *stantoni* Crickmay, *Sonninia* aff. *blackwelderi* Crick., *Hebetoxyites* cf. *hebes* Buck., *Hebetoxyites* cf. *clypeus* Buck. The age of the last two in England, according to Buckman, is the upper part of the Sowerbyi Zone (Laeviuscula Subzone), but all the others are of the Sauzei Zone. *Stemmatoceras* and *Normannites* also occur in a conglomerate derived from this formation.

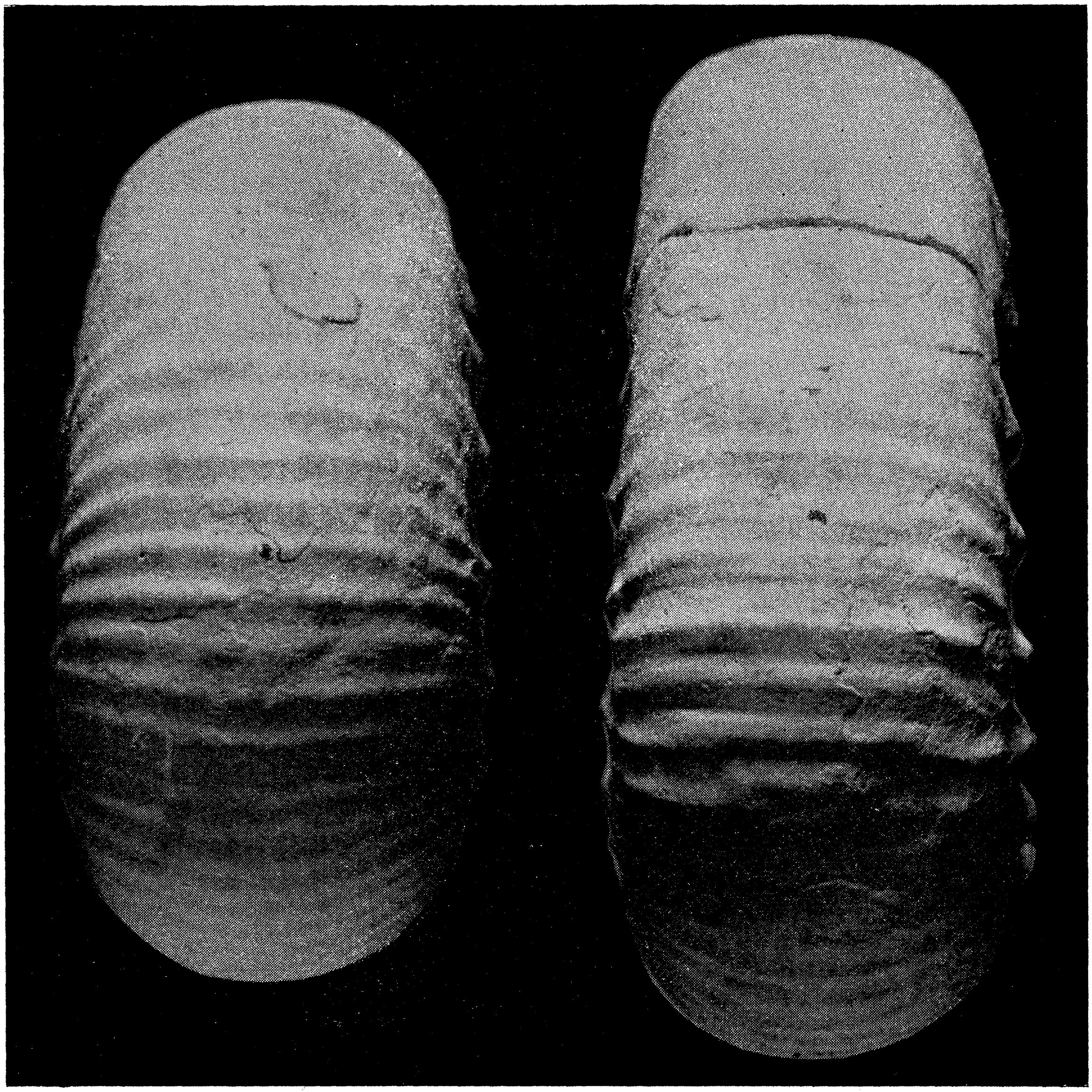


Figure 12. *Pseudotoites carlottensis* (Whiteaves), ventral views of plaster cast of holotype, natural size. (See figure 11.)

The Hyde formation (324 m), next below, contains *Skirroceras* and sonninids similar to those above.

(1) Colpitts Group. Warm Springs and Weberg formations (60 to 157 m). The ammonites from these formations, not differentiated, include many *Sonniniae* like those from

the lower part of the Sowerbyi Zone figured in Buckman's monograph, including *Euhoploceras*, also *Witchelliae* ('*Zugophorites*', '*Zugella*') and *Docidoceras* spp., all of the Sowerbyi Zone. In addition are recorded *Tmetoceras* cf. *scissum* (Benecke) and *Praestrigites* ('*Deltostrigites*') cf. *deltatus* (Buckman), which both denote the Lower Bajocian.

The most suggestive records from our point of view are 'species of Sphaeroceratidae belonging to a new genus having the external appearance of *Emileia*' (Lupher 1941, p. 253). Unfortunately, despite the helpful attitude of Dr Lupher and of the authorities at the California Academy of Sciences, San Francisco, where the collections are, it has not been possible to examine these ammonites to ascertain whether they are *Pseudotoites* or *Zemistephanus*, for the collections are still unsorted and uncatalogued.

In California, the Mormon formation (283 m) at Mount Jura also yields an assemblage that seems to cover the Sowerbyi and Sauzei Zones, including *Sonninia schucherti*, *S. stantoni*, *S. blackwelderi*, *S. juromontanum*, *Otoites reesidei*, *Chondroceras russelli* and *Holocophylloceras falciferum*, all of Crickmay (1933, pp. 909–913, pls. xxvii–xxxi).

The Canadian *Chondroceras*, *Stemmatoceras*, *Zemistephanus* and *Teloceras* are also recorded in Wyoming, Montana and Idaho (Imlay 1948, 1952), but records so far published throw no new light on possibilities of subdivision. The Middle Bajocian of these Western Interior states represents a transgression from the west.

8·8. *Mexico*

In the province of Oaxaca there is an ammonite fauna interpreted by Burckhardt (1927, 1930, pp. 25–6) as Middle Bajocian, but the only named species that seems to be correctly dated is *Stephanoceras undulatum* Burck. (1927, pl. xii, figs. 1–4), which appears to be a *Normannites* comparable to *N. etheridgei* (Gerth); its ribbing is similar to the Australian species here described as *Otoites antipodus*, but its coiling is much more evolute and its whorl section approximately circular. The other forms can scarcely be contemporaneous with *undulatum*. *Stephanoceras brodiaei* (non Sow.) Burck. and *S. floresi* Burck. (pl. xii, figs. 10–16, 18–20) proclaim themselves by their narrow, curved primary ribs, peculiar tubercles like parabolic nodes, and arcuately projected secondaries, to be *Zigzagiceras* (*Procerozigzag*) aff. *crassizigzag* Buckman (1922, vol. iv, pl. cccxxxv), of the Lower Bathonian. This explains the presence in the same beds of many small perisphinctids (figured as *Dactylioceras* spp. ind., Burckhardt, 1927, pl. xi, figs. 5–9), some of which resemble *Siemiradzkia* (fig. 8), others *Planisphinctes*.

If the fragment figured as *Strenoceras* aff. *bifurcatum* (non Quenst.) (Burckhardt, 1927, pl. xvi, figs. 10, 11, 16) really comes from later beds as supposed (but it is from a different locality), it presumably belongs to some Bathonian form, like *Garantiana bathonica* Lissajous.

8·9. *Andes of Argentina, Chile and Peru*

Upper Bajocian and Bathonian ammonites are not known from the Andes.

The Humphriesianum Zone seems to be represented in Chile and Peru but not in Argentina, to judge by records and some figures by Steinmann (1881, pl. xii, fig. 7) and Möricke (1894, p. 20); but the ammonites need reinvestigating.

Sauzei and Sowerbyi Zones. These zones are represented by the so-called Sauzei Limestones, or Sonninia Beds (up to 150 m thick), in places crowded with ammonites and other fossils. Abundant figures have been published by Gottsche (1878), Tornquist (1898), Jaworski (1914, 1926, 1926*a*) and others, and the stratigraphy has been discussed by Jaworski (1914–15, 1926) and Gröber (1918). The dominant genera are *Witchellia*, *Sonninia* and *Emileia* (including *Frogdenites* in Peru; see Lisson 1937, pl. i), with which occur *Otoites*, *Chondroceras*, *Fontannesia*, *Eudmetoceras*, *Bradfordia* and what appears to be an early *Leptosphinctes* (Jaworski 1926, pl. xiii, fig. 8). The last (which may be compared to the record of *Leptosphinctes* from the Middle Bajocian of Alaska; Imlay 1952, p. 978) seems nearest, among European species, to *L. davidsoni* Buckman (1921, vol. iii, pl. cci), of the Subfurcatum Zone, in which *Teloceras* persists in Europe.

Underlying the main Sauzei and Sonninia Beds in Mendoza Province, Argentina, are beds correlated by Jaworski (1926) with the Lower Bajocian, Concava and Murchisonae Zones. They contain this early *Leptosphinctes* and also *Hammatoceras gerthi* Jaworski (1926, pl. xii, fig. 5), which is a *Eudmetoceras* (= *Euaptetoceras*) (cf. Buckman 1920, vol. iii, pl. clxxix, and 1922, vol. iv, pl. ccxcix), presumably of the lower Sowerbyi Zone; also *Oppelia mörickei* Jaworski (1926, pl. xi, fig. 9), a typical *Bradfordia* (= *Iokastelia* Rentz, 1925), which all over Europe is characteristic of the Sauzei and Sowerbyi Zones. Hence this assemblage is Middle, not Lower, Bajocian.

True Lower Bajocian with *Tmetoceras regleyi* occurs immediately below the Sonninia Beds at Espinazito Pass (Gottsche 1878, pl. ii, fig. 3; Tornquist 1898, p. 6), thus providing a firm correlation with Canada and Europe. The faunule with *Sphaerocoeloceras brocchiiforme* Jaworski and *Dumortieria pusilla* Jaw. at Arroyo Negro in Mendoza, which Jaworski (1926) regarded as Lower Bajocian, is Upper Toarcian; *Sphaerocoeloceras* has been recorded farther south, in Chubut, with various Toarcian ammonites (Feruglio 1949, pp. 106–108).

From the many published figures there is no reason to doubt that the Sauzei Limestones belong to the Sauzei and Sowerbyi Zones. Anyone who has seen the baffling variety of *Sonniniae* and *Witchelliae* that occur in the Sowerbyi and Sauzei Zones of Dorset would hesitate to attempt closer zonal definition by means of the published figures (all drawings) of South American forms. Jaworski (1915, p. 395) attempted a revision, but he was not using the same palaeontological language as Buckman working on the English material. Of Buckman's genera now recognized, *Shirbuirnia* appears to be represented by *Harpoceras zitteli* Gottsche; but *Sonninia argentinica* Tornquist, with its flanged and vertical umbilical wall is not a *Shirbuirnia* but is close to *Witchellia* ('*Sonninites*') *felix* Buckman (1923, vol. v, pl. cdxxviii), of the Sauzei Zone. On the other hand, *Sonninia altecostata* Tornquist, which Jaworski included in the same group, is not a *Witchellia* but a *Sonninia*. *S. espinazetensis* Tornquist is a *Sonninia* with outer whorl resembling the subgenus *Papilliceras* Buckman, but with much smoother inner whorls, so that it is closely comparable with *Sonninia arenata* (Quenstedt), of the German Sowerbyi Zone (type refigured by Dorn 1935, pl. vii, fig. 1), though differing by its gentle umbilical slope. These two Argentine species (*altecostata* and *espinazetensis*) are no doubt closely allied, as Dorn (1935, p. 37) perceived. *S. mirabilis* Tornquist is a typical *Sonninia* of the *sowerbyi* group.

Of greatest interest in connexion with the Australian ammonites are the stephanoceratids, which according to Gröber (1918, p. 36) occur at a higher level. None of these having yet been figured photographically, a selection is now shown in plate 40, from the Bodenbender Collection at Göttingen Geological Institute, kindly lent by Professor

Hermann Schmidt. They come from Espinazito Pass, Argentina, and include the types of *Stephanoceras sphaeroceroides* Tornquist and *S. transatlanticus* Tornquist (figure 13) and one of the two body-chamber examples of *S. singulare* Gottsche mentioned by Tornquist (1898, p. 25), which is not the true *singulare* of Gottsche but the aff. *singularis* of Jaworski (1926, p. 255, pl. ii, fig. 3; pl. iv, fig. 21). The last is much more evolute and larger than Gottsche's original and is here renamed ***argentinus*** (holotype the specimen now figured, plate **40**, figure 1).

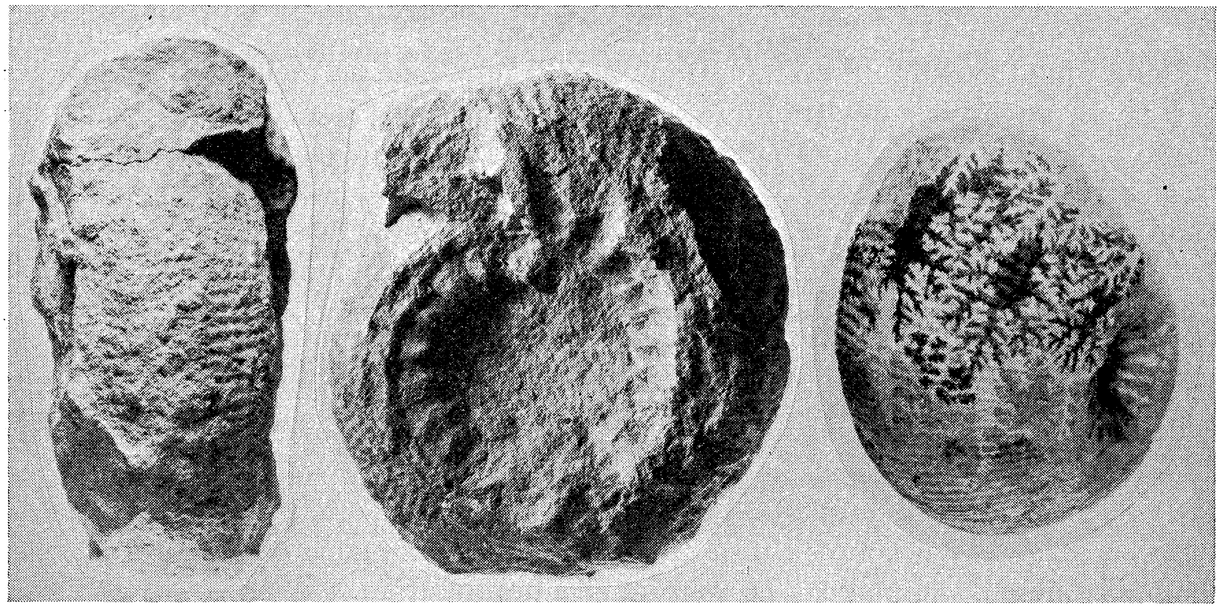


FIGURE 13. Left and centre: '*Stephanoceras*' *transatlanticus* Tornquist, holotype, Espinazito Pass, Argentina, Bodenbender Coll., Geol. Inst. Göttingen, natural size. Right: *Emileia brocchii* (Sowerby), to show sutures, for comparison with those of *Pseudotoites* and *Zemistephanus*: Sowerbyi Zone, Milborne Wick, Somerset, Geol. Surv. Mus. no. 24743; natural size.

Jaworski transferred all these species to the genus *Emileia* (type species by original designation *Ammonite brocchii* Sowerby, refigured Buckman & Secretary 1908, pl. iv, and a good series of this and allied forms figured by Buckman in *Type Ammonites*), but when the specimens from the Bodenbender Collection are compared with the English *Emiliae* and the Australian and Canadian *Pseudotoites* there can be no doubt that they belong to *Pseudotoites*. They show the characteristic style of ribbing and tuberculation of the Australian forms and the same coiling sequence, and the sutures are identical (see Jaworski 1926, pl. iv, fig. 21). The resemblance between *P. argentinus* and *P. brunnschweileri* is particularly striking, despite the specific differences. From Torniquist's pl. v, fig. 1, it might be supposed that *P. sphaeroceroides* is a *Zemistephanus*, but the original specimen (the lower half since badly damaged before being sent on loan) is not nearly so inflated as that genus, the outer whorl (allowing for some crushing) being reversionary planulate as in *Pseudotoites leicharti* and its allies. The holotype of *Stephanoceras transatlanticus* Tornquist (figure 13) is too poorly preserved for certainty, but there is no reason to suppose it is not also a *Pseudotoites*.

Unfortunately, these Argentine members of the genus do not at present admit of any closer dating than the Australian, though this may be remedied in future by more careful field work, considering the much greater thickness of the Middle Bajocian (up to 150 m). At Cerro China, *Pseudotoites argentinus* is said to occur with *Emileia polyschides* (Waagen), which would indicate late Sowerbyi or Sauzei Zone, and *Eudmetoceras gerthi* (Jaworski), which would indicate early Sowerbyi Zone, as well as with three species of *Sonninia* of uncertain date but most likely Sowerbyi Zone (Jaworski 1926, p. 273).

4·10. *Conclusions*

The outstanding result of the foregoing inquiry is the discovery that the characteristic genus *Pseudotoites*, hitherto thought not to occur outside Western Australia, is present not only in the Moluccas, but also in southern Alaska, British Columbia and Argentina; and that the allied genus *Zemistephanus*, hitherto known only from North America (Alaska, Canada, and United States), is present in Australia. Since neither genus is known from anywhere in the Old World, it is to be inferred that in Middle Bajocian times there was free marine communication across the Pacific Ocean.

It appears that the whole western side of North and South America was lapped by the Pacific Ocean, in which lived at least some characteristically Pacific ammonite genera, and that periodically it overspread the continental margins. In the neighbourhood of Indonesia this ocean was in free communication with the Tethys. In both early and late Jurassic times (Hettangian, Sinemurian and Tithonian) there was certainly free migration along and out of the Tethys, from the Himalayas through Indonesia, New Guinea and New Caledonia to New Zealand (Papuan geosyncline), as shown by ammonite faunas now known from all these places. Since, however, typical European Lower Lias genera such as *Psiloceras*, *Schlotheimia*, *Arietites* and *Arnioceras*, with their relatives, occur not only throughout the Tethyan-Papuan geosyncline but also all down the west side of both the Americas, it is to be inferred that these genera were as indigenous in the Pacific Ocean as in Europe, and were world-wide.

The fact that all these known occurrences are on the sites of geosynclines led Haug (1900, 1910) to identify the geosynclines with waterways and to infer land almost everywhere else; but the coincidence of known occurrences with geosynclines is due to the compression and upheaval of the geosynclines above sea-level in relatively recent geological times, and it is illogical to suppose that regions outside them which are under oceanic water to-day could not have been also under water in the Jurassic.

An equally fantastic notion, that the Liassic ammonites of western North America and Japan lived in a landlocked inland sea covering a small part of the north Pacific only, as shown on J. W. Gregory's map in his Presidential Address to the Geological Society (1930, p. xci), is negatived by the identity at specific level between the Lower Lias ammonites of western Canada, Europe and Peru, and at least at generic level between those of the Americas, Indonesia, New Caledonia and New Zealand.

The evidence of the Bajocian ammonites from Western Australia, here adduced, provides the first concrete evidence of migration right across the Pacific continent of Haug and across the lines of the waterways and separating lands shown in Gregory's map. The new evidence tends to support the more modern concept of a Jurassic Pacific Ocean in which mobile volcanic island festoons off the coast of the Americas provided the volcanic and terrigenous clastic materials which were spread out eastwards in the cordilleran geosynclines. (For North America see Crickmay (1931, p. 19) and Eardley (1951, maps), and for South America see Gerth (1935) and Oppenheim (1947, 1948).)

9. Correlation with the European Bajocian

Attempts by European workers, notably Buckman, Haug and Mascke, to refine the time scale of the Bajocian have produced results of interest locally and for the general theory of correlation by means of ammonites, but they have also led to much confusion in terminology. As the foregoing review of circum-Pacific occurrences shows, these refinements are not applicable to distant regions, so that a more general zonal scheme is required for universal use.

Oppel, in his classic works (1856, pp. 305, 335, 369; 1862, p. 128), divided the Middle Bajocian into three zones, as follows (substituting the modern genera):

(Top)
Zone of *Stephanoceras humphriesianum* (Sow.)
Zone of *Otoites sauzei* (d'Orb.)
Zone of *Sonninia sowerbyi* (Sow.)

In 1856 (p. 369) he considered that *Sonninia sowerbyi* occurred in the Sauzei Zone, but in 1862 (p. 128) he added the separate Sowerbyi Zone, below Sauzei, and this arrangement was confirmed by Waagen (1867), who monographed the fauna of the Sowerbyi Zone all over extra-Alpine Europe. (The type specimens of the two index species named by Sowerby have been refigured by the Palaeontolographical Society: Buckman & Secretary 1908, pls. iii, vii.)

As is already clear from the systematic discussion in §7, the main ammonite assemblage of the Newmarracarra Limestone falls into the Sowerbyi Zone, and there is no longer any definite evidence for the Sauzei Zone. In addition, however, there may be, in a few places, a still incompletely known representation of the Humphriesianum Zone, which is well developed in some other circum-Pacific countries. Owing to inconsistency in the terminology used in the European literature, this bald statement requires amplification. The following brief historical résumé is designed to make clear what is meant in terms of the detailed successions worked out in Europe.

Buckman's *Monograph on the Ammonites of the Inferior Oolite Series* gives a magnificent series of figures of *Sonniniae* of the Sowerbyi Zone (pls. lvii–ciii), but the description of every plate is headed 'Concavum Zone', which is a subdivision of the Murchisonae Zone and always regarded as Lower Bajocian. The explanation is to be found opposite pl. xlvi (published 1892), where Buckman stated: 'It has been thought advisable to call this horizon definitely "Concavum Zone". It is the same horizon which was described as "Sowerbyi Zone" or "Sowerbyi Zone (concavum beds)" until plate xiv, and afterwards "Concavum beds".' This change has confused some authors, e.g. Jaworski (1926*a*, p. 219), in his monograph on the South American Bajocian, and Dorn (1935, p. 23), dealing with the German. It was unfortunate, for Buckman soon afterwards (1893*a*, p. 483) subdivided the 'Concavum Zone', recognizing a Concavum Zone proper below, and a Discites Zone above. Most if not all of the *Sonniniae* called 'Concavum Zone' in his monograph, pls. lvii–ciii, are from the horizon ascribed to 'Discites hemera' on p. 447 (1894) and pl. xxiv of the supplement (published 1905) and so called in his later papers and Richardson's.* The 'Discites Zone' is in fact part of the Sowerbyi Zone of Oppel, of which it is at best a subzone. Buckman (1891 *a*, 1910, p. 78) considered that 'true *Sonniniae*', i.e. the involute, high-whorled, high-keeled group to which the genotype, *S. propinquans* (Bayle), belongs, were to be found only in the Sauzei Zone, whereas the classic *Sonninia* fauna of Gingen, Württemberg, described by Waagen, occupied an intermediate position, for which he coined the 'hemera *Shirbuirniae*'. Instead of Oppel's Sowerbyi Zone, Buckman therefore introduced four horizons (subzones):

(Top)

Witchellia spp. (1893 *a*, following Munier-Chalmas, 1892)
Shirbuirnia trigonalis (1910) (formerly *Sonninia* spp.)
Hyperlioceras discites (1893 *a*) and 'post-*discites*' (1910)

These divisions were adopted in all Richardson's papers on the Inferior Oolite and in my *Jurassic System in Great Britain* (1933), as best expressing the detailed stratigraphy in Dorset and Somerset. According to Dorn (1935, p. 24), however, the two groups of *Sonninia* distinguished by Buckman overlap in their ranges: for instance, the involute, smooth *Sonninia gingensis* occurs in the Sowerbyi Zone and the evolute *S. alsatica* Haug in the Sauzei Zone. Buckman had himself long ago realized this, for he figured *S. alsatica* Haug in 1924 (vol. v, pl. dxxviii) from a horizon which (1930, p. 34) he placed at the very top of the Sauzei Zone.

Buckman never seems to have established the exact horizon of *S. sowerbyi*, for it is not mentioned in his later papers nor placed in his (largely imaginary) table of hemerae (1930, pp. 34–36). According to Dorn (1935, p. 120) in Germany it occurs in the lower half of the Sowerbyi Zone, separated from the Sauzei Zone by a '*Witchellia pinguis* Zone' (= Buckman's *Witchellia* subzone?); but there are records of it also in the Sauzei Zone (Frank 1942, p. 19).

Haug (1910, p. 998), in his widely used *Traité*, called the Sowerbyi Zone the zone of *Witchellia laeviuscula*, but as he recorded *Sonninia sowerbyi* as one of the supporting fossils for this zone, there seems no justification for the change of index.

Haug (1891, 1910) also abandoned Oppel's index for the Humphriesianum Zone, using instead *Witchellia* [*Dorsetensia*] *romani* (Oppel), in the belief that *Stephanoceras humphriesianum* was a fossil of the Sauzei Zone. This, however, is contrary to observation, and was probably due to misidentification; for according to Buckman in England (1893 *a*, p. 483; 1930, p. 34) and Mascke (1907) and Frank (1942) and others in Germany *S. humphriesianum* occupies a position above and distinct from the Sauzei Zone, as Oppel and Waagen showed. It was only in Buckman's later papers, published after the appearance of Haug's views, that Buckman too changed the zonal index to *Teloceras blagdeni* (Sow.) (Buckman 1910 *a*, p. 55). In 1933 (p. 189) I followed Buckman, but I have since advocated reverting to Oppel's zonal indices on grounds of priority and simplicity (Arkell 1946, p. 13). In the latest publications only '*humphriesianum*-like forms' are recorded in the Swabian Sauzei Zone (Frank 1942, p. 19).

* I am indebted to Mr L. Richardson for confirming this (January 1953).

Teloceras blagdeni is in any case at least as objectionable as *Stephanoceras humphriesianum*, for (as Mascke and later Buckman himself showed) it occurs only in the upper part of the zone. Waagen (1867, p. 539) had already put it above the Humphriesianum Zone. Either it or closely allied species range up into the Subfurcatum Zone of the Upper Bajocian in Germany, Lorraine, Poland and Arabia.

Some of the inconsistency and duplication in zonal nomenclature in the Bajocian is attributable to the small coincidence that the two principal authorities, Buckman and Haug, working independently, three times published important works simultaneously, in 1891, 1893 and 1910 (see list of references).

TABLE 1. SHOWING THE ZONES AND SUBZONES OF THE MIDDLE BAJOCIAN AS PROPOSED BY DIFFERENT AUTHORS

Stage	zones of world scale (Oppel 1856–62)	Buckman (1893*a*)	Haug (1891 1893, 1910)	Buckman (1910) Richardson, Arkell (1933)	subzones for Europe cf. Spath (1936), Arkell (1951, p. 8)
Middle Bajocian	*Stephanoceras humphriesianum* (Oppel 1856)	*humphriesianum*	*Dorsetensia romani* (1891)	*Teloceras blagdeni* (subdivided by Mascke 1907)	*Teloceras blagdeni* *Stephanoceras humphriesianum*
	Otoites sauzei (Oppel 1856)	*sauzei*	*sauzei*	*sauzei*	*Otoites sauzei*
	Sonninia sowerbyi (Oppel 1862)	*Witchellia* spp. *Hyperlioceras discites*	*Witchellia laeviuscula* (1910)	*Witchelliae* *Shirbuirnia* (*trigonalis*) post-*discites* *discites*	*Witchelliae laeviuscula* *Shirbuirnia trigonalis* *Hyperlioceras discites*

Table 1 is intended for quick reference and as a historical summary. In the left-hand column are Oppel's three zones, which seem to provide all that is required for a world-wide time scale. In the right-hand column the indices proposed by Buckman and Haug in the period 1891–1910 are arranged in their stratigraphical order as subzones in a more detailed scale for Europe (cf. Spath 1936, p. 16; but it is inadvisable to use *Dorsetensia romani* as index for the lower subzone of the Humphriesianum Zone, since it may occur above *Stephanoceras humphriesianum*, in the Blagdeni Subzone).

10. SYSTEMATICS AND EVOLUTION OF THE AUSTRALIAN AMMONITES

Uhlig (1911, p. 409) remarked that closer examination of the stephanoceratids from Western Australia figured by Neumayr and Crick diminished their likeness to European forms and brought out a certain local stamp; and he referred to them as belonging to a 'narrow group'.

The Playford collection, which for the first time reveals the true characters of the various forms, fully bears out Uhlig's judgement. There is a gradation in style of ribbing from large forms with simple peristome (*Pseudotoites*) to small forms with lappets (*Otoites*, *Trilobiticeras*, *Normannites*?), and the impression is irresistible that they are all more closely related to one another than to their European counterparts.

Zemistephanus also is certainly a close relative of *Pseudotoites* and not of *Teloceras*, which is much later. Even *Pseudotoites* at the coronate stage may be confused with *Teloceras*; and, in fact, the fragment figured by Neumayr (1885, pl. i, fig. 3) as [*Teloceras*] *blagdeni* (Sow.) is a *Pseudotoites robiginosus* (Crick).

It appears that at any given time and place an ammonite stock may by evolutionary radiation, or deployment, give rise to various 'genera', more or less parallel to those produced by other stocks in other parts of the world at the same or a different time.

The Bajocian provides some other notable examples. One striking case recently described is that of the genus *Ermoceras* in Arabia and Sinai (Arkell 1952, pp. 272 ff.). Another is the European genus *Emileia*. Some of these become inflated and coronate like *Teloceras* (*Emileia crater* Buckman 1920, pl. clxiv), others evolute with reduced body-chamber (*E. catamorpha* Buckman, pl. cdxiv), while others develop spines (*Frogdenites* Buckman 1921, pl. ccxv). Again, among European *Stephanoceras* there is a wide range of forms, some converging towards *Perisphinctes* (*S. kumaterum* Buckman 1922, pl. cccxlv), some becoming involute and coronate (*S. brodiaei* Sowerby sp.), others evolute, 'serpenticone' (*Skirroceras* spp.); and there is even the *Otoites*-like trend towards short primary and long secondary ribs with umbilical tubercles, producing a form parallel to *Pseudotoites* (*S. skolex* Buckman sp., 1921, pl. ccxlix). In Canada again there is a similar but somewhat different range of species, and apportionment to *Skirroceras*, *Teloceras*, *Stemmatoceras* (all nominal genera based on European types) becomes difficult and artificial.

Similar regional evolutionary deployment also took place among the Sonniniidae. The basic genus *Sonninia* is represented in Australia by the typically European *S. playfordi*, but the *Witchellia* and *Fontannesia* are more local and peculiar in the Pacific area. The lucky chance of perfect preservation of scores of *Fontannesia* in a single thin marly bed in the Newmarracarra Limestone reveals the remarkable 'plasticity' or 'variability' of the genus at this one locality. There is every gradation between forms which, if found singly, would be referred without hesitation to distinct species. This whole range of forms is most closely paralleled, not by contemporary *Fontannesia* in other parts of the world, but by an equally variable community of *Grammoceras* of much earlier date in Europe. Between some of them there is almost perfect homoeomorphy. But for the associated ammonites, the Australian *Fontannesia* would pass for Upper Toarcian.

An analogous case of 'plasticity' is provided by the Domerian Amaltheidae, where these occur in sufficiently large numbers in various European localities. Both Monestier (1928) and Frentzen (1937) who monographed these ammonites were obliged to preserve an extremely conservative nomenclature. Monestier accounted for the polymorphism by postulating convergence from various unrelated stocks. The view here taken is the opposite of Monestier's, divergence being substituted in place of convergence.

References

Arkell, W. J. 1933 *The Jurassic system in Great Britain.* Oxford: Clarendon Press.

Arkell, W. J. 1946 Standard of the European Jurassic. *Bull. Geol. Soc. Amer.* **57**, 1.

Arkell, W. J. 1949 Jurassic ammonites in 1949. *Sci. Progr.* no. 147, p. 401.

Arkell, W. J. 1951–3 *Monograph of the English Bathonian ammonites*, parts 1–4. Palaeontogr. Soc.

Arkell, W. J. 1952 Jurassic ammonites from Jebel Tuwaiq, central Arabia. *Phil. Trans.* B, **236**, 241.

Arkell, W. J. 1953 Bajocian ammonites collected by Sir Henry Hayden near Kampadzong, Tibet. *Geol. Mag.* **90**, 331.

Boehm, G. 1912 Die Südküsten der Sula-Inseln Taliabu und Mangoli. 4. Unteres Callovien. *Palaeontographica*, Suppl. IV, Lief. 3, p. 123.

Boehm, G. 1913 Unteres Callovien und Coronatenschichten zwischen Maccluer Golf und Geelvink Bai. *Nova Guinea*, **6**, Geol. 1, Leiden.

Buckman, S. S. 1887–1907 *Monograph of the ammonites of the Inferior Oolite Series*. Palaeontogr. Soc.

Buckman, S. S. 1891*a* The ammonite zones of Dorset and Somerset. *Geol. Mag.* (3), **8**, 502.

Buckman, S. S. 1893*a* The Bajocian of the Sherborne district. *Quart. J. Geol. Soc. Lond.* **49**, 479.

Buckman, S. S. 1909–30 *Type ammonites*. London: Wheldon and Wesley.

Buckman, S. S. 1910*a* Certain Jurassic (Inferior Oolite) species of ammonites and brachiopoda. *Quart. J. Geol. Soc. Lond.* **66**, 90.

Buckman, S. S. 1911*a* Ammonites from the Scarborough Limestone. *Proc. Geol. Ass.* **17**, 205.

Buckman, S. S. & Secretary 1908 *Illustrations of type specimens of Inferior Oolite ammonites in the Sowerby collection*. Palaeontogr. Soc.

Burckhardt, C. 1927 Cefalopodos del Jurasico medio de Oaxaca y Guerrero. *Bol. Inst. Geol. Mexico*, **47**.

Burckhardt, C. 1930 Etude synthétique sur le Mésozoïque mexicain. *Mém. Soc. Pal. Suisse*, **49**.

Campbell, W. D. 1907 Notes upon the geological map of the Greenough River district. *Bull. Geol. Surv. W. Aust.* **26**, 34.

Campbell, W. D. 1910 The Irwin River coalfield and the adjacent districts from Arrino to Northampton. *Bull. Geol. Surv. W. Aust.* **38**.

Chapman, F. 1904*a* On some Foraminifera and Ostracoda from Jurassic (Lower Oolite) strata near Geraldton, Western Australia. *Proc. Roy. Soc. Vict.*, N.S., **16**, 185.

Chapman, F. 1904*b* On a collection of Upper Palaeozoic and Mesozoic fossils from Western Australia and Queensland in the National Museum, Melbourne. *Proc. Roy. Soc. Vict.*, N.S., **16**, part 2, 306.

Clarke, W. B. 1867 On marine fossiliferous secondary formations in Australia. *Quart. J. Geol. Soc. Lond.* **23**, 7.

Cloos, H. 1916 Doggerammoniten aus den Molukken. Habil.-Schrift Univ. Marburg. Stuttgart.

Conrad, S. D. & Maynard, R. G. (MS.) 1948 Geological report on reconnaissance field work along the coast of Western Australia. Unpublished report for Richfield Oil Corp.

Crick, G. C. 1894 On a collection of Jurassic Cephalopoda from Western Australia. *Geol. Mag.* (4) **1**, 385, 433.

Crickmay, C. H. 1930 The Jurassic rocks of Ashcroft, British Columbia. *Bull. Dep. Geol. Univ. Calif.* **19**, 23.

Crickmay, C. H. 1931 Jurassic history of North America. *Proc. Amer. Phil. Soc.* **70**, 15.

Crickmay, C. H. 1933 Mount Jura investigation. *Bull. Geol. Soc. Amer.* **44**, 895.

Denckmann, A. 1887 Ueber die geognostische Verhältnisse der Umgegend von Dörnten nördlich Goslar; Atlas. *Abh. geol. Specialk. Preussen*, **8**, Heft 2.

Djanélidzé, M. A. 1922 Les Spiticeras du sud-est de la France. *Mém. Carte géol. dét. France*, Paris.

Dorn, P. 1935 Die Hammatoceraten, Sonninien, Ludwigien, Dorsetensien und Witchellien des süddeutschen, insb. fränkischen Doggers. *Palaeontographica* (A), **82**.

Eardley, A. J. 1951 *Structural geology of North America*. New York: Harper Bros.

Etheridge, R. 1890 Our present knowledge of the palaeontology of New Guinea. *Rec. Geol. Surv. N.S.W.* **1**, 172.

Etheridge, R. 1901 *Ctenostreon pectiniformis* Schlotheim, an Australian fossil. *Rec. Aust. Mus.* **4**, 13.

Etheridge, R. 1910 Oolitic fossils of the Greenough River district, Western Australia. *Bull. Geol. Surv. W. Aust.* **36**, 29.

Fairbridge, R. W. (MS.) 1951 Stratigraphical nomenclature of Western Australia. *Bureau Min. Res., Geol. Geophys.* unpublished stencil.

Fallot, P. & Blanchet, F. 1923 Observations sur la faune des terrains jurassiques de la région de Cardo et de Tortosa (Province de Tarragone). *Treb. Inst. Catalana Hist. Nat.* vol. 1921–2, fasc. 11.

Feruglio, E. 1949 *Descripcion geologica de la Patagonia*, 3 vols. Buenos Aires.

Frank, M. 1942 Die Schichtenfolge des mittleren Braunen Jura (γ/δ Bajocien) in Württemberg. *Jb. Mitt. Oberrhein. geol. Ver.*, NF., **31**, 1.

Frebold, H. 1951 Contributions to the palaeontology and stratigraphy of the Jurassic system in Canada. *Bull. Geol. Surv. Can.* **18**.

Frentzen, K. 1937 Ontogenie, Phylogenie und Systematik der Amalthien des Lias Delta Südwestdeutschlands. *Abh. Heidelberger Akad. Wiss.* (M.N. Kl.) **23**.

Gerth, H. 1927 Ein neues Vorkommen der bathyalen Cephalopoden-Facies des mittleren Jura in Niederländisch Neu-Guinea. *Leidsche Geol. Meded.* **2** (3), 225.

Gerth, H. 1935 Geologie Südamerikas, Teil 2. *Geol. der Erde*, Berlin.

Glauert, L. 1926 A list of Western Australian fossils. Suppl. 1. *Bull. Geol. Surv. W. Aust.* **88**, 36.

Gottsche, C. 1878 Über jurassische Versteinerungen aus der argentinischen Cordillere, *Palaeontographica*, Suppl. 3, Lief. 2, Abt. 3.

Gregory, A. C. 1849 Report on an expedition to the northward of the colony of Western Australia. *West. Aust. Almanack* (for 1849), p. 69.

Gregory, F. T. 1861 On the geology of a part of Western Australia. *Quart. J. Geol. Soc. Lond.* **17**, 475.

Gregory, J. W. 1849. Notes on the geology of Western Australia. *West. Aust. Almanack* (for 1849), p. 107.

Gregory, J. W. 1930 The geological history of the Pacific Ocean. *Quart. J. Geol. Soc. Lond.* **86**, lxxii.

Greppin, E. 1898 Description des fossiles du Bajocien supérieur des environs de Bâle. *Mém. Soc. Pal. Suisse*, **25**, **1**.

Gröber, P. 1918 Estratigrafia del Dogger en la República Argentina. *Bol. Dir. Gener. Minas* (B), no. **18**.

Haug, E. 1891 Les chaines subalpines entre Gap et Digne. *Bull. Serv. Carte Géol. Fr.* **3**, no. 21.

Haug, E. 1893 Etude sur les ammonites des étages moyens du système jurassique. *Bull. Soc. géol. Fr.* (3), **20**, 277.

Haug, E. 1900 Les géosynclinaux et les aires continentales. *Bull. Soc. géol. Fr.* (3), **28**, 617.

Haug, E. 1910 *Traité de Géologie*, **2**, part 2 (1st ed.). Paris: Colin.

Hayden, H. H. 1907 The geology of the provinces of Tsang and Ü in central Tibet. *Mem. Geol. Surv. India*, **36**, 1.

Hiltermann, H. 1939 Stratigraphie und Palaeontologie der Sonninienschichten von Osnabrück und Bielefeld. *Palaeontographica* (A), **90**, 109.

Imlay, R. W. 1948 Characteristic marine Jurassic fossils from the western interior of the United States. *Prof. Pap. U.S. Geol. Surv.* no. **214**B.

Imlay, R. W. 1952 Correlation of the Jurassic formations of North America, exclusive of Canada. *Bull. Geol. Soc. Amer.* **63**, 953.

Jaworski, E. 1914–15 Beiträge zur Kenntniss des Jura in Süd-Amerika. *N. Jb. Min. Geol. Paläont.* B.-B. **37**, 285 and **40**, 365.

Jaworski, E. 1926 La fauna del Lias y Dogger de la Cordillera Argentina en la parte meridional de la Provincia de Mendoza. *Actas Acad. Nac. Ciencias Rep. Argentina*, **9**, nos. 3, 4. Cordoba.

Jaworski, E. 1926*a* Beiträge zur Paläeontologie und Stratigraphie des Lias, Doggers, Tithons und der Unterkreide in den Kordilleren im Süden der Provinz Mendoza (Argentinien). 1, Lias und Dogger. *Geol. Rundschau,* **17**A (Festschrift), 373.

Jutson, J. T. 1914 An outline of the physiographical geology (physiography) of Western Australia. *Bull. Geol. Surv. W. Aust.* **61**.

Khudiaev, J. 1931 The marine Jurassic deposits of eastern Transbaikalia. *Bull. Geol. Serv. U.S.S.R.* **50**, 621.

Krimholz, G. Y. 1939 Materials on the geology of the Bureya coal basin, 4. *Trans. United Central Geol. Prosp. Inst. Russia*, **117**, 1.

Kruizinga, P. 1926 Ammonieten en eenige andere Fossielen uit de Jurassische Afzettingen der Soela Eilanden. *Jb. Mijnewesen Ned. Oost.-Indie*, **54**, Verh. 1 Ged., p. 13.

Lisson, C. I. 1937 Genero *Sphaeroceras* Bayle: *S. broggianus* nov.sp. *Rev. Cienc.* no. **422.** Lima, Peru.
Lupher, R. L. 1941 Jurassic stratigraphy of central Oregon. *Bull. Geol. Soc. Amer.* **52**, 219.
McLearn, F. H. 1927 Some Canadian Jurassic faunas. *Trans. Roy. Soc. Can.* (3), **21**, sect. 4, p. 61.
McLearn, F. H. 1929 Contributions to the stratigraphy and palaeontology of Skidegate Inlet, Queen Charlotte Islands, British Columbia. *Bull. Dep. Mines Can.* **54.**
McLearn, F. H. 1930 Notes on some Canadian Mesozoic faunas. *Trans. Roy. Soc. Can.* (3), **24**, sect. 4, p. 1.
McLearn, F. H. 1932 Contributions to the stratigraphy and palaeontology of Skidegate Inlet.... Part 2. *Trans. Roy. Soc. Can.* (3), **26**, sect. 4, p. 51.
McLearn, F. H. 1932*a* Three Fernie Jurassic ammonoids. *Trans. Roy. Soc. Can.* (3), **26**, 111.
McLearn, F. H. 1949 Jurassic formations of Maude Island and Alliford Bay, Skidegate Inlet, Queen Charlotte Islands, British Columbia. *Bull. Geol. Surv. Can.* **12.**
Maitland, A. G. 1907 Recent advances in the knowledge of the geology of Western Australia. *Bull. Geol. Surv. W. Aust.* **26**, 37.
Maitland, A. G. 1919 A summary of the geology of Western Australia. *Mem. Geol. Surv. W. Aust.* **1**, 39.
Martin, G. C. 1926 The Mesozoic stratigraphy of Alaska. *Bull. U.S. Geol. Surv.* **776.**
Mascke, E. 1907 Die Stephanoceras-Verwandten in den Coronatenschichten von Norddeutschland. Dissert. Univ. Göttingen.
Monestier, J. 1928 Recherches sur le polymorphisme et la phylogénie des Amalthéidés domériens d'après les matériaux aveyronnais. *Mém. Soc. Lettres Sci. Arts l'Aveyron*, **22**, 61.
Moore, C. 1862 Contributions to Australian geology and palaeontology. *Brit. Ass. Adv. Sci.*, Rep. Trans. Sections of 32nd meeting, p. 83.
Moore, C. 1870 Australian Mesozoic geology and palaeontology. *Quart. J. Geol. Soc. Lond.* **26**, 226.
Möricke, W. 1894 Versteinerungen des Lias und Unteroolith von Chile. *N. Jb. Min. Geol. Paläont.* B-B, **9**, 1.
Morris, J. & Lycett, J. 1851 *A monograph of the Mollusca from the Great Oolite*, Part 1. Palaeontogr. Soc.
Neumayr, M. 1885 Die geographische Verbreitung der Juraformation. *Denkschr. Akad. Wiss. Wien*, **50**, 57.
Oppel, A. 1856–8 Die Juraformation Englands, Frankreichs und des Südwestlichen Deutschlands. *Württemb. naturw. Jahreshefte*, Jahrg. **12–14.**
Oppel, A. 1862–3 Ueber jurassische Cephalopoden. *Pal. Mittheil.* **3.**
Oppenheim, V. 1947 Structural evolution of the South American Andes. *Amer. J. Sci.* **245**, 158.
Oppenheim, V. 1948 Theory of Andean orogenesis. *Amer. J. Sci.* **246**, 578.
Prescott, J. A. & Pendleton, R. L. 1952 Laterite and lateritic soils. *Tech. Commun. Commonw. Bur. Soil Sci.* **47.**
Quenstedt, F. A. 1849 Atlas zu den Cephalopoden. *Petrefaktenkunde Deutschlands*, 1 Abt, 1 Band. Tübingen.
Quenstedt, F. A. 1883–8 *Die Ammoniten des Schwäbischen Jura.* 3 vols., Atlas. Stuttgart.
Redlich, K. 1896 [Review of Crick's paper of 1894.] *N. Jb. Min. Geol. Paläont.* **1**, 161.
Renz, C. 1913 Zur Geologie des östlichen Kaukasus. *N. Jb. Min. Geol. Paläont.* B-B, **36**, 651.
Roché, P. 1939 Aalénien et Bajocien du Maconnais. *Trav. Lab. Géol. Lyon*, fasc. 35, mém. 29.
Sommer, F. von 1849 A sketch of the geological formation and physical structure of Western Australia. *Quart. J. Geol. Soc. Lond.* **5**, 51.
Spath, L. F. 1936 On Bajocian ammonites and belemnites from eastern Persia. *Palaeont. Indica*, N.S., **22**, mem. 3.
Spath, L. F. 1939 On Jurassic ammonites from Western Australia. *J. Roy. Soc. W. Aust.* **25**, 123.
Steinmann, G. 1881 Zur Kenntniss der Jura-und Kreideformation von Caracoles (Bolivia). *N. Jb. Min. Geol. Paläont.* B-B, **1**, 239.
Teichert, C. 1939 The Mesozoic transgressions in Western Australia. *Aust. J. Sci.* **2**, no. 3, 84.
Teichert, C. 1940 Marine Jurassic in the North-West Basin, Western Australia. *J. Roy. Soc. W. Aust.* **26**, 17.

Teichert, C. 1947 Stratigraphy of Western Australia. *J. Proc. Roy. Soc. N.S.W.*, **80**, 81, and *Bull. Amer. Ass. Petrol. Geol.* **31**, 1.

Tornquist, A. 1898 Der Dogger am Espinazito-Pass.... *Pal. Abh. Jena*, **8**, Heft 2, 135.

Uhlig, V. 1911 Die marinen Reiche des Jura und der Unterkreide. *Mitt. Geol. Ges. Wien*, **4** Jahrg. Heft 3, 329.

Waagen, W. 1867 Über die Zone des *Ammonites sowerbyi*. *Benecke's Geognost.-Pal. Beitr.* **1**, 507.

Warren, P. S. 1947 Description of Jurassic ammonites from the Fernie formation. *Rep. Res. Counc. Alberta*, no. **49**, p. 62.

Weisert, K. 1932 *Stephanoceras* im schwäbischen Braunen Jura Delta. *Palaeontographica*, **76**, 121.

Whiteaves, J. F. 1876–84 On some invertebrates from the coal-bearing rocks of Queen Charlotte Islands. *Geol. Surv. Canad., Mesozoic Fossils*, **1**, part 1 (1876), part 3 (1884).

Whiteaves, J. F. 1909 Description of a new species [of *Stephanoceras*] from some rocks of presumably Jurassic age in the Nicola Valley, B.C. *Ottawa Nat.* **23**, 21.

Whitehouse, F. W. 1924 Some Jurassic fossils from Western Australia. *J. Roy. Soc. W. Aust.* **11**, 1.

Whitehouse, F. W. 1940 Studies in the late geological history of Queensland. The lateritic soils of western Queensland. *Univ. Queensl. Pap. Dep. Geol.* **2**, 2.

Description of Plates 27 to 40

Plate 27

Figures

1. *Sonninia playfordi* n.sp. Holotype, from well about 15 miles south-east of Bringo (964202) (p. 560).

2, 3. *Fontannesia clarkei* (Crick) or *F. fairbridgei* n.sp., at early stage when the two species are not distinct. Rabbit warrens at type locality of *F. fairbridgei* (p. 563).

4, (5?), 6, 7. *Fontannesia fairbridgei* n.sp. Rabbit warrens at and near type locality. Figure 7 holotype (784357). Figure 5 is as compressed as *F. clarkei* var. *etheridgei* (plate 29, figure 2*b*) (p. 563).

All figures natural size.

Plate 28

1 to 6. *Fontannesia clarkei* (Crick). Typical specimens, all wholly septate with test complete except in figure 1, showing some of the variations. In figures 1 and 4 the ribbing persists longer than usual, in figure 6 it fades earlier. Of the specimens taken to London to compare with the type fragment, figure 3 was the most exact match. All from rabbit warrens at and near the type locality of *F. fairbridgei* (784357, 775352, 768356) (p. 565).

All figures natural size.

Plate 29

1. *Fontannesia clarkei* (Crick) var. *etheridgei* (Whitehouse). F 21078 (p. 566).

2. *Fontannesia clarkei* (Crick) var. *etheridgei* (Whitehouse). Holotype of *Dorsetensia etheridgei* Whitehouse, figured by Etheridge, Tibraddon Station. The last quarter whorl (with test) may be body chamber (p. 566).

3 to 8. *Fontannesia whitehousei* n.sp. (p. 566).

3, involute, more shouldered variety, transitional to *F. clarkei*. Wholly septate. (718304.)

4, 5, fragments showing sutures. For enlarged view of the nucleus of 5, see plate 30, figure 6. (714309.)

6, original of Charles Moore's '*Ammonites aalensis* var. *moorei Lycett*'; Brit. Mus. (N.H.). C 47366. Wholly septate.

7, variety with shouldered inner whorls as in figure 3 (but not so involute), transitional to *F. clarkei*, but acquiring venter of *F. whitehousei* on the outer whorl. The whitened area covers the last two camerae. (714309.)

8, holotype. Septation ceases at the cross. F 21081, very hard limestone matrix.

All figures natural size.

PLATE 30

FIGURES

1 to 4. *Fontannesia clarkei* (Crick). Closely-ribbed varieties (figure 2 var. *etheridgei* Whitehouse), showing the ribbing fading at different stages. Rabbit burrows, same locality and preservation as plate 28.

5. *Fontannesia whitehousei* n.sp. Wholly septate inner whorls. (710305) (p. 566).

Fontannesia whitehousei n.sp. Nucleus of the specimen shown in plate 29, figure 5, magn. × 4 (p. 566).

7. *Otoites depressus* Whitehouse. Gutta percha squeeze (Sedgwick Museum F 1880) of holotype (natural external mould), showing adult aperture with lappet. Well near Bringo railway-cutting (765366) (p. 570).

8. *Otoites antipodus* n.sp. Ventral view of specimen shown in plate 31, figure 5 (p. 570).

9 to 12. *Otoites woodwardi* (Crick) (p. 569).

9, holotype, internal cast with parts of aperture and of lappet (too crushed to show ventral view), Champion Bay. Brit. Mus. (N.H.) C 30378.

10, slightly crushed specimen with some test. (714309.)

11, plaster cast of natural mould, Mt. Hill. F 21089.

12, full-sized specimen, internal cast, with parts of aperture and of a lappet. F 21091.

13. *Otoites* n.sp. Well-preserved half-whorl, internal cast, deceptively crushed (p. 570).

All figures natural size except figure 6.

PLATE 31

1 to 4. ? *Otoites australis* (Crick) (p. 571).

1, holotype, crushed and distorted, Champion Bay. Brit. Mus. (N.H.) C 30379.

2, largest specimen known. F 21099.

3, 4, two imperfect specimens (691296), figure 3 with base of a lappet.

5. *Otoites antipodus* n.sp. Internal cast lit from two directions; for ventral view see plate 30, figure 8. (710305) (p. 570).

6. *Otoites antipodus* n.sp. Holotype, four views. Most of the test is preserved. Three-quarters of the last whorl is body-chamber. F 21093, Mount Hill (p. 570).

All figures natural size.

PLATE 32

1. *Otoites* aff. *antipodus* n.sp. Depressed fragment agreeing with *Otoites* sp. indet. of Whitehouse, Bringo cutting (p. 570).

2. *Pseudotoites leicharti* (Neumayr). Typical specimen matching the type figures. (691296) (p. 573).

3. Believed inner whorls of *Pseudotoites leicharti* or *P. championensis*. F 21107.

4. *Pseudotoites championensis* (Crick). Holotype, Champion Bay. Brit. Mus. (N.H.) C 30385 (p. 574).

All figures natural size.

PLATE 33

1. *Pseudotoites championensis* (Crick), from (718335) (p. 574).

2. Believed inner whorls of *P. championensis* or *P. leicharti*. F 21108.

3. Cross-section of a *Pseudotoites leicharti* to show common style of crushing by rock pressure. Probably same locality as figure 4 (p. 573).

4. *Pseudotoites leicharti* (Neumayr). Largest specimen, with some uncrushed tumid outer whorl before stage of contraction; from (691296) (p. 573).

All figures natural size.

Plate 34

Figures

1. *Pseudotoites robiginosus* (Crick). Holotype fragment of body-chamber, from Champion Bay. Brit. Mus. (N.H.) C30381. Compare plate 35, figure 1 (p. 574).
2. *Pseudotoites robiginosus* (Crick). Venter of specimen shown in plate 35, figure 2, from Mount Hill. F21110 (p. 574).
3. *Pseudotoites robiginosus* (Crick). Wholly septate specimen showing sutures, from (774351) (p. 574).
4. *Pseudotoites robiginosus* (Crick). Middle whorls, cadicone stage, from (714309) (p. 574).
5. *Pseudotoites emilioides* n.sp. Sutures of specimen from (714309) (p. 576).

All figures natural size.

Plate 35

1, 2. *Pseudotoites robiginosus* (Crick) (p. 574).
1, Complete specimen from (725337) with weathered body-chamber, matching the holotype (see plate 34, figure 1).
2, Wholly septate specimen from Mount Hill. F21110. For back view see plate 34, figure 2.

All figures natural size.

Plate 36

1, 2. *Pseudotoites fasciculatus* n.sp. 1, Holotype, Fossil Hill (706333); 2, F21124 (p. 573).
3. *Pseudotoites brunnschweileri*? n.sp. (732343) (p. 576).
4. *Pseudotoites brunnschweileri* n.sp. Holotype, F21128 (p. 576).

All figures natural size.

Plate 37

1. *Pseudotoites* sp. indet., middle whorl-fragment as in *P. robiginosus*, inner whorls less inflated, appropriate to *P. leicharti* and *P. fasciculatus*. (714309) (p. 577).
2. *Pseudotoites fasciculatus* n.sp. (690296) (p. 573).
3, 4. *Pseudotoites emilioides* n.sp. 3, Holotype (714309), and 4, inner whorls, F21102 (p. 576).
5. *Pseudotoites robiginosus* (Crick), (691296) (p. 574).

All figures natural size.

Plate 38

1 to 6. *Pseudotoites semiornatus* (Crick) (p. 577).
1, Holotype, much worn natural cast, from Champion Bay, Brit. Mus. (N.H.) C30377.
2, 3, 4, sharply preserved specimens with test (691296).
5, complete natural cast with body-chamber, from well (964202).
6, from Doust Station, Hill River district (223528, Hill River one-mile military sheet).
7. *Stephanoceras* (*Stemmatoceras*) cf. *subcoronatum* (Oppel). Plasticene squeeze of natural mould from railway well (765366) (p. 582).
8. *Pseudotoites spitiformis* n.sp. Holotype (691296) (p. 577).

All figures natural size.

Plate 39

1*a* to *c*. *Stephanoceras* (*Stemmatoceras*) aff. *triptolemus* (Morris & Lycett). Three fragments of a single specimen, each in ventral and lateral views; red ironstone (707304) (p. 582).
2, 3. *Zemistephanus corona* n.sp. 2, holotype, with test and peristome; 3, natural cast showing suture; both from (732343) (p. 578).

All figures natural size.

PLATE 40

FIGURES

1. *Pseudotoites argentinus* n.sp. Holotype (p. 592).

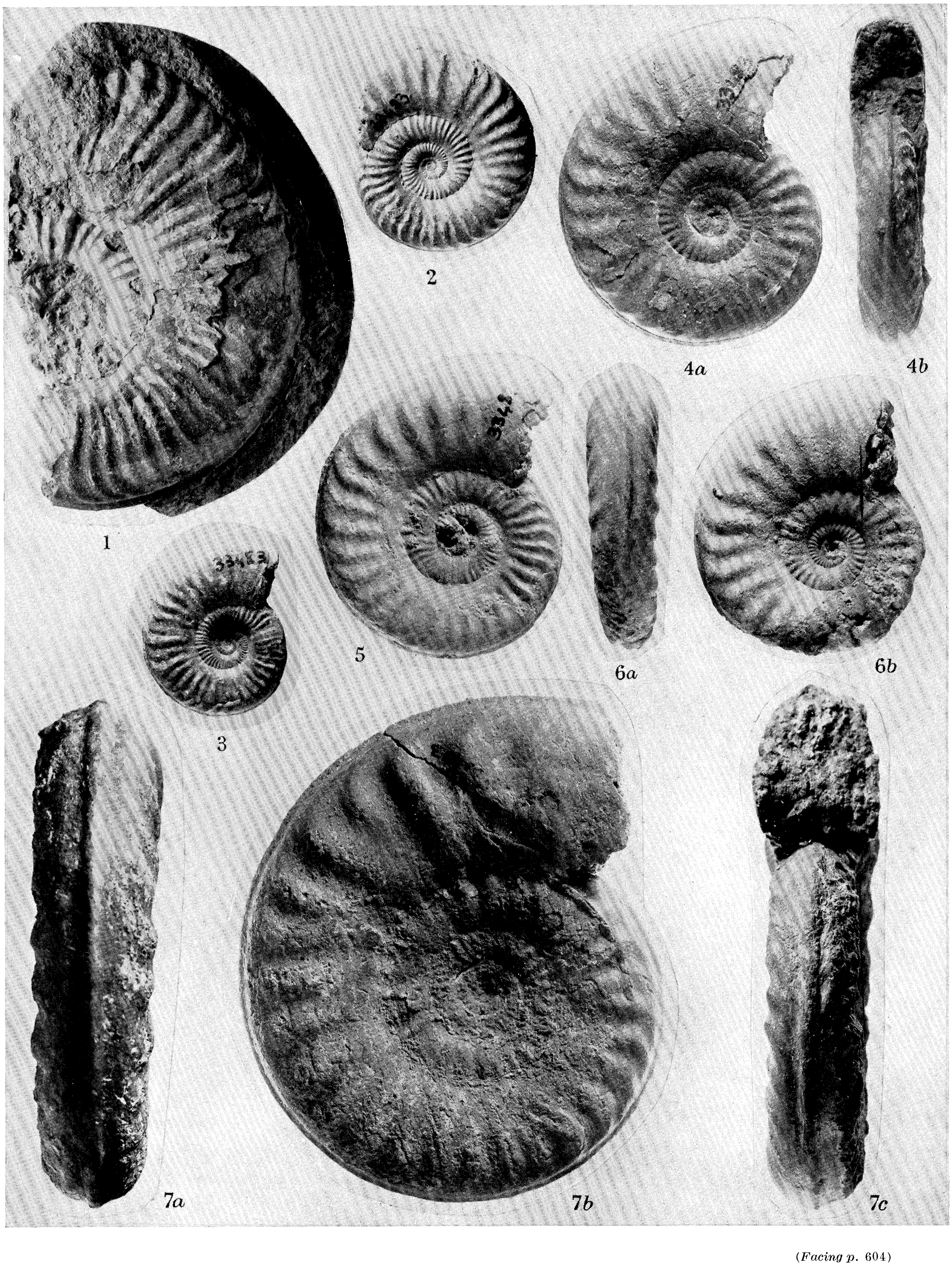
2, 3. *Pseudotoites sphaeroceroides* (Tornquist) (p. 592).

2, holotype (Tornquist, pl. vi, fig. 2).

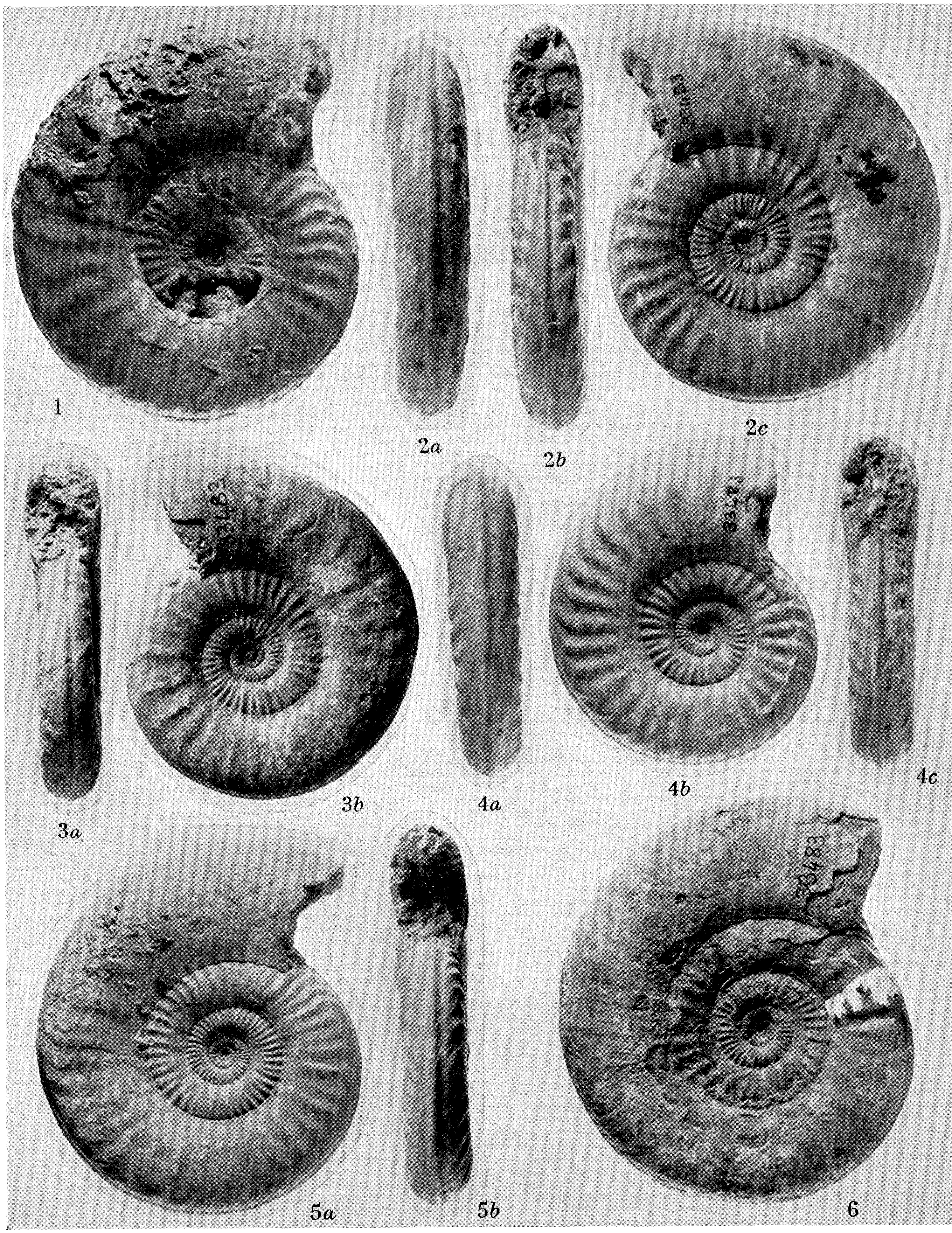
3, original of Tornquist, pl. v, fig. 1 (different species?-much more compressed).

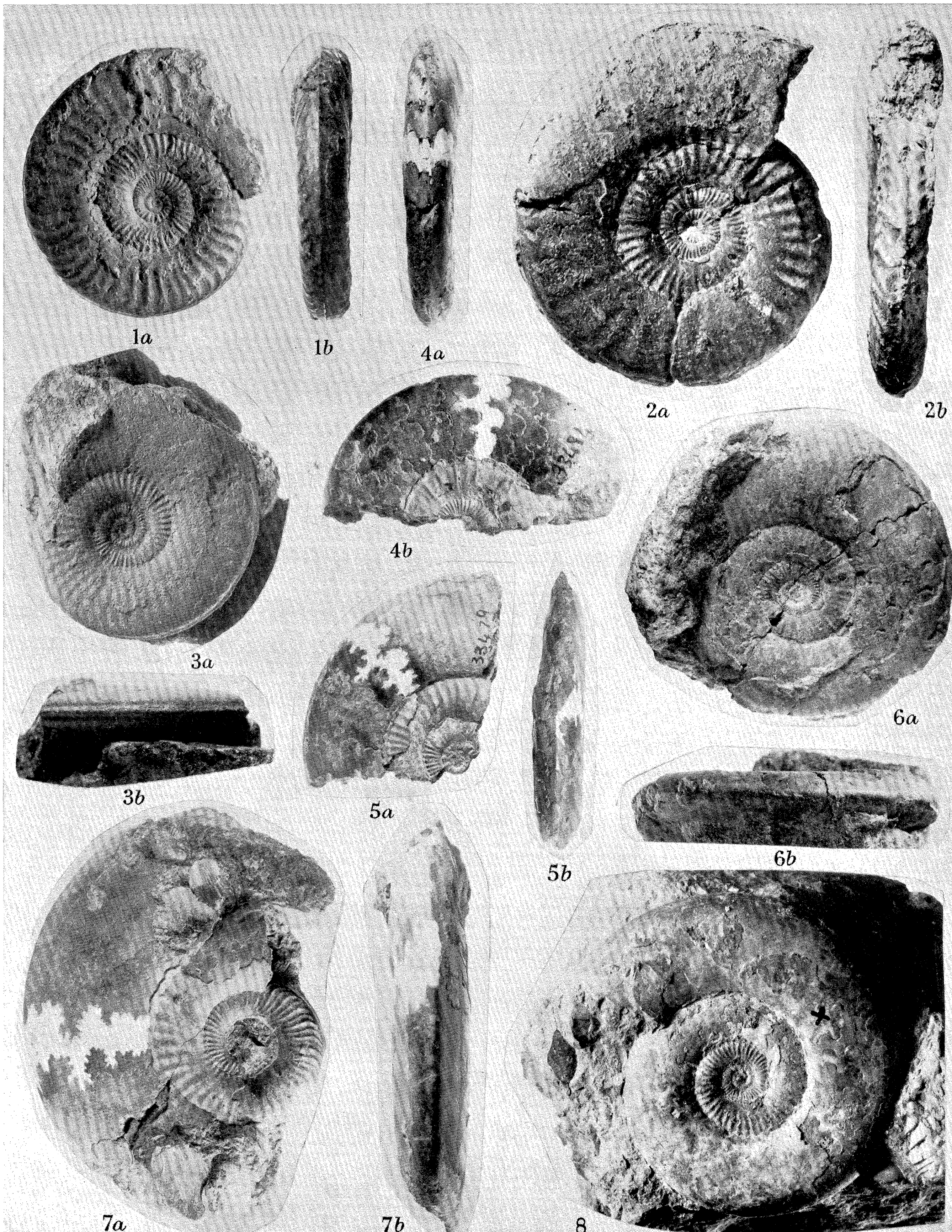
All from Espinazito Pass, Argentina, Bodenbender Coll., Geologisches Institut, Göttingen, kindly lent by Professor Hermann Schmidt.

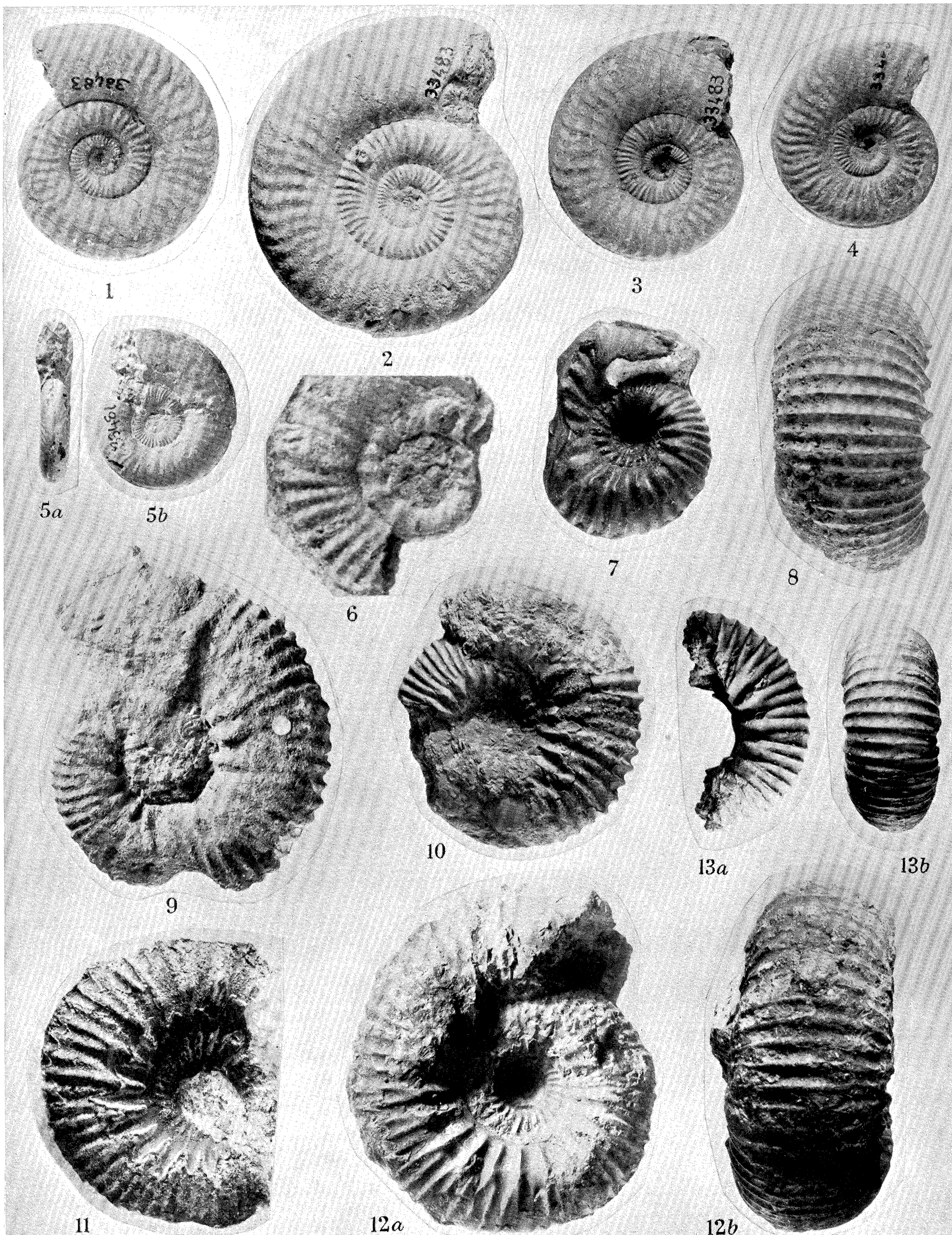
All figures natural size.

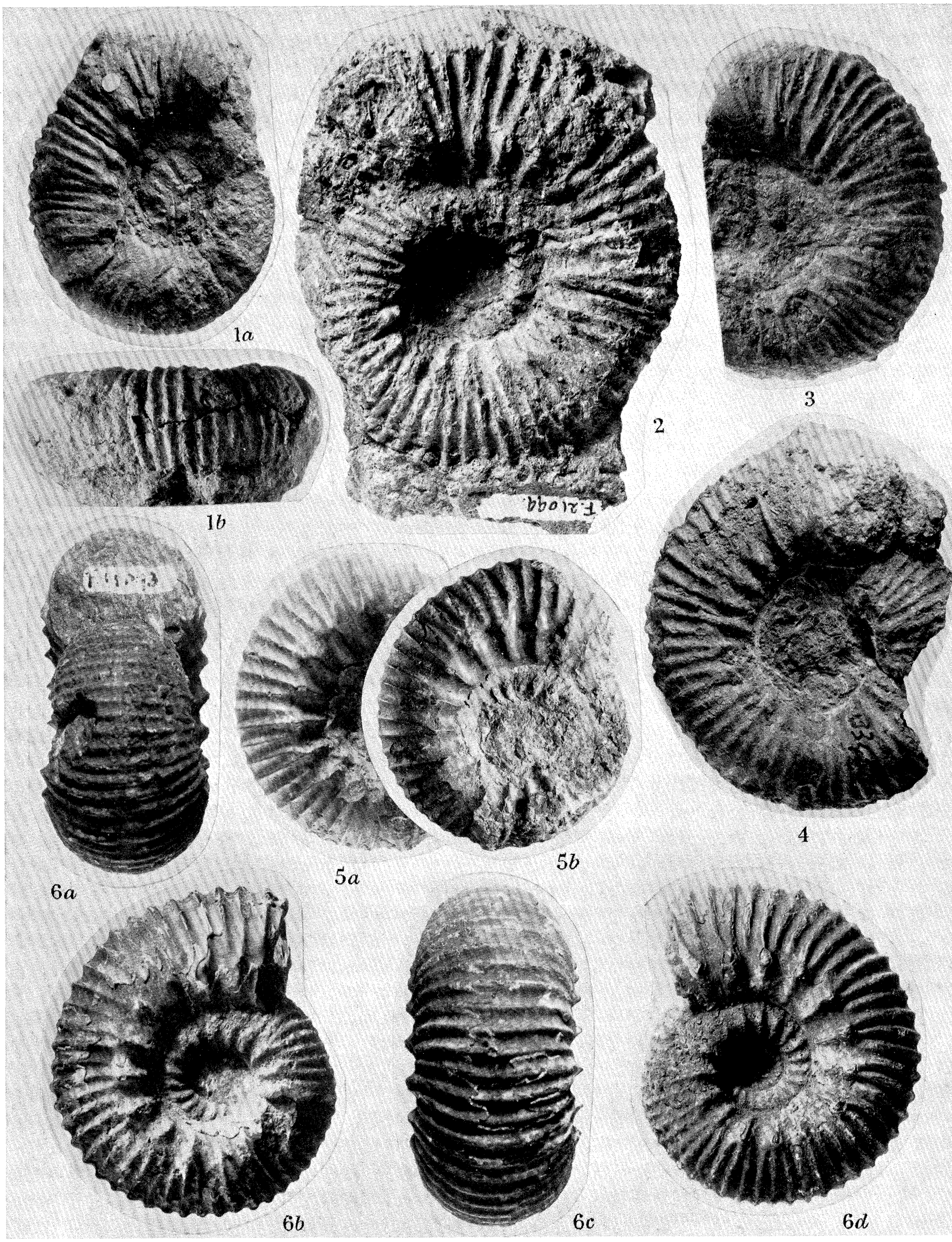


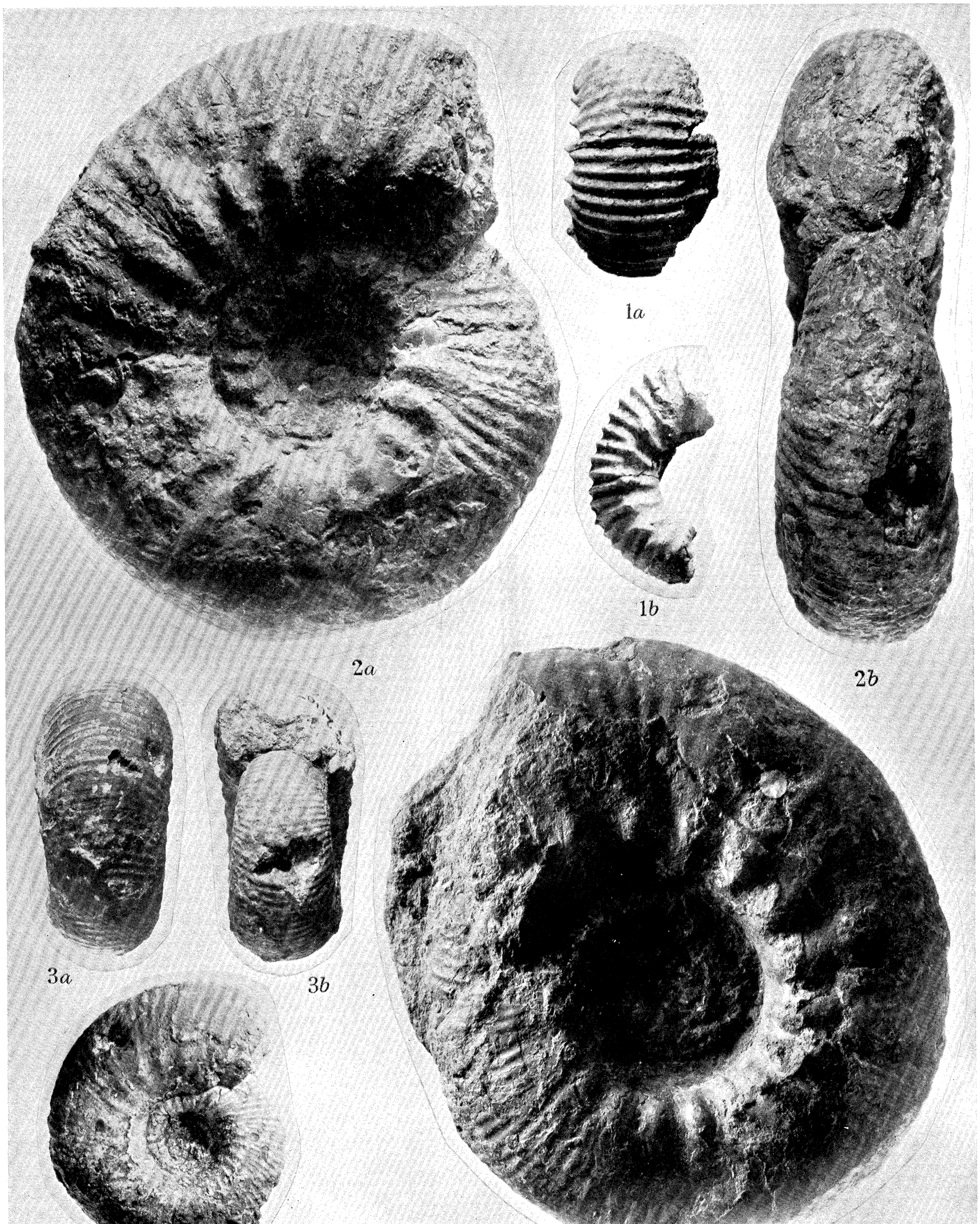
(*Facing p.* 604)

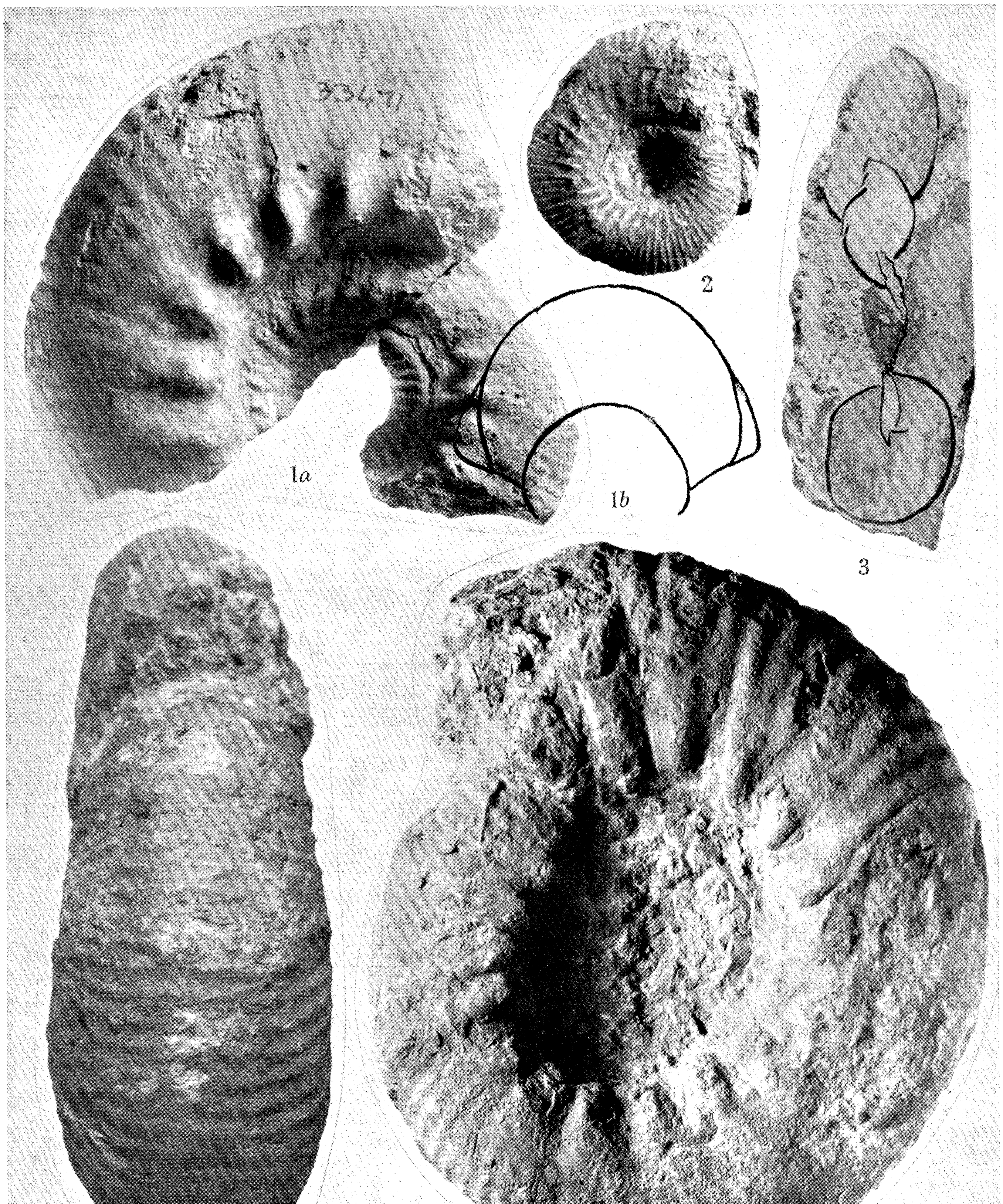

1
2*a*
2*b*
2*c*
3*a*
3*b*
4*a*
4*b*
4*c*
5*a*
5*b*
6

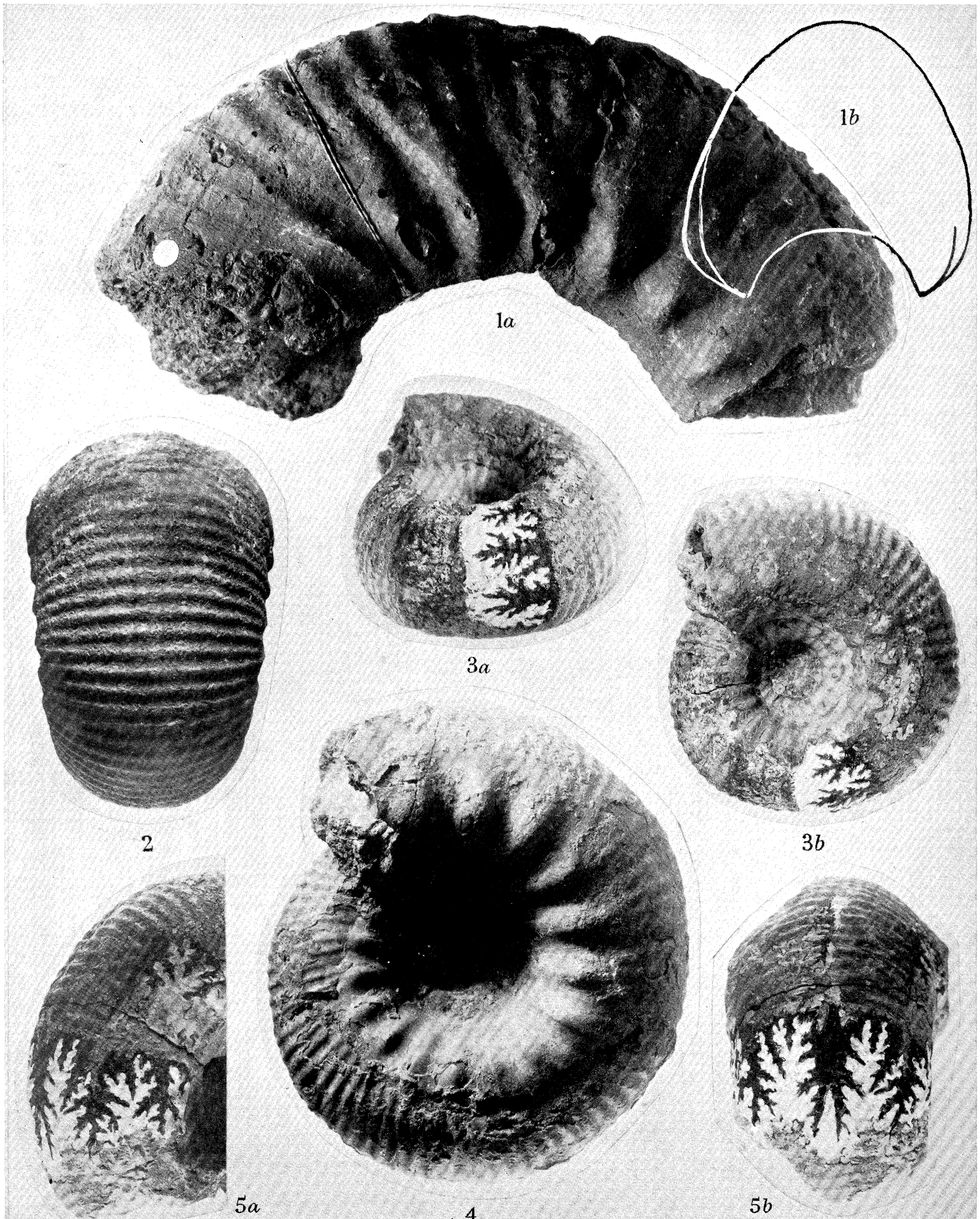

1a
1b
4a
2a
2b
4b
3a
6a
3b
5a
5b
6b
7a
7b
8


1
2
3
4
5a
5b
6
7
8
9
10
13a
13b
11
12a
12b


1a
1b
2
3
4
5a
5b
6a
6b
6c
6d

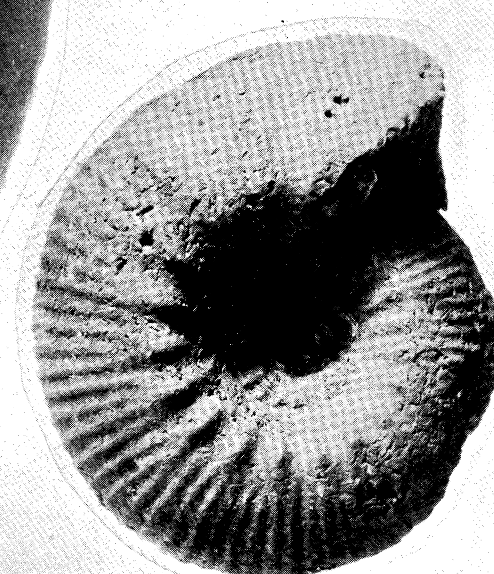

1*a*
1*b*
2*a*
2*b*
3*a*
3*b*
3*c*
4


33471
1*a*
1*b*
2
3
4*a*
4*b*

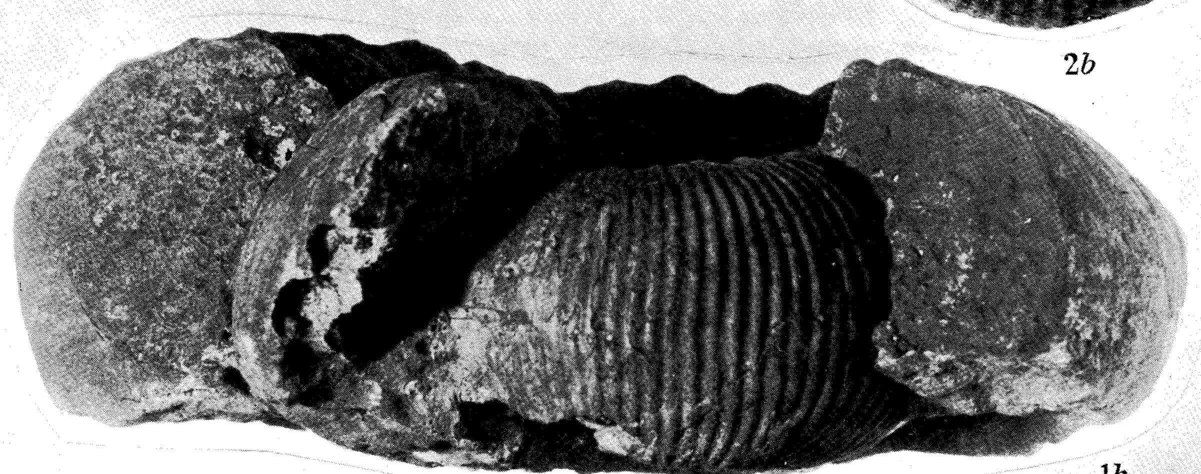

1*b*
1*a*
2
3*a*
3*b*
5*a*
4
5*b*

1*a*

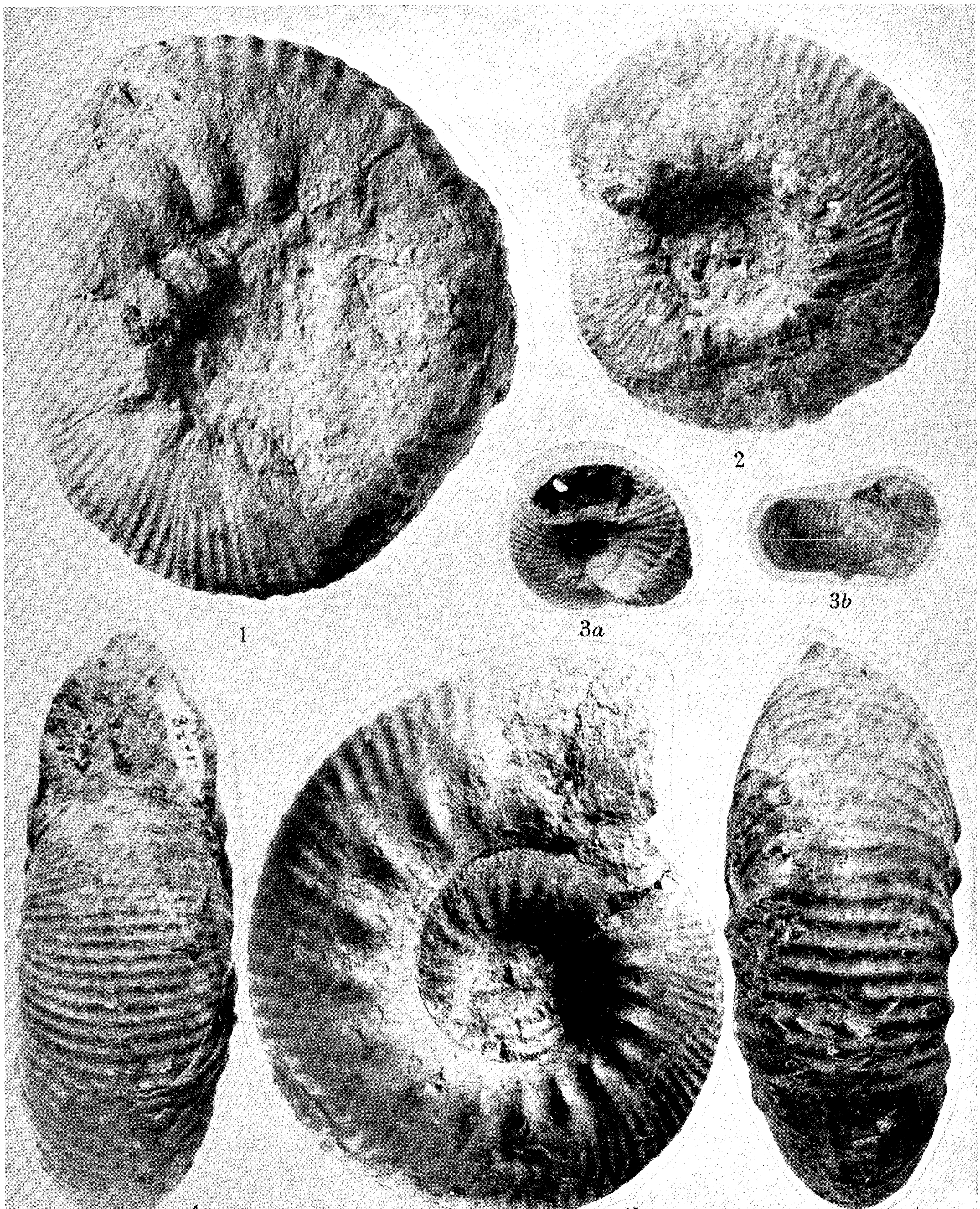
2*a*

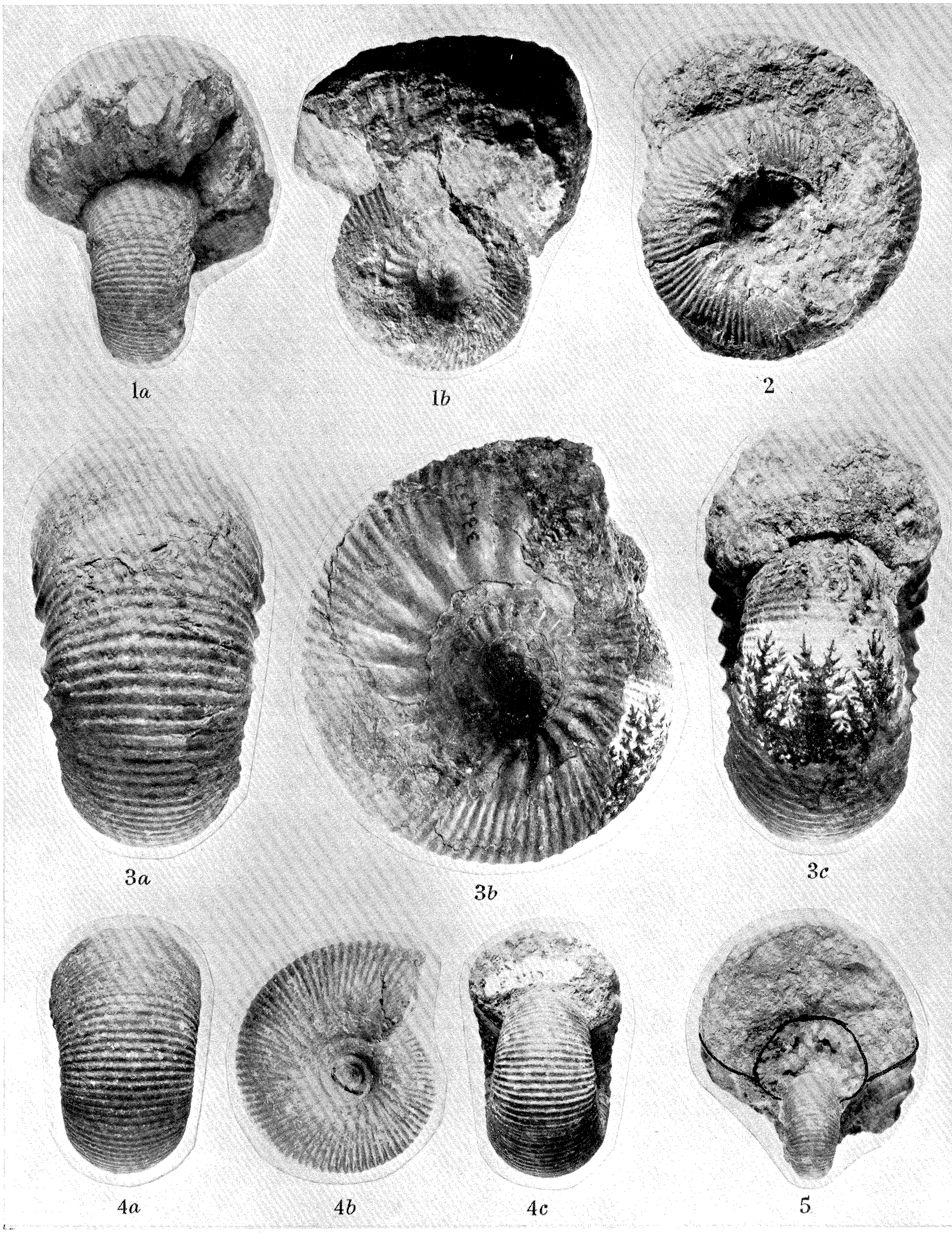


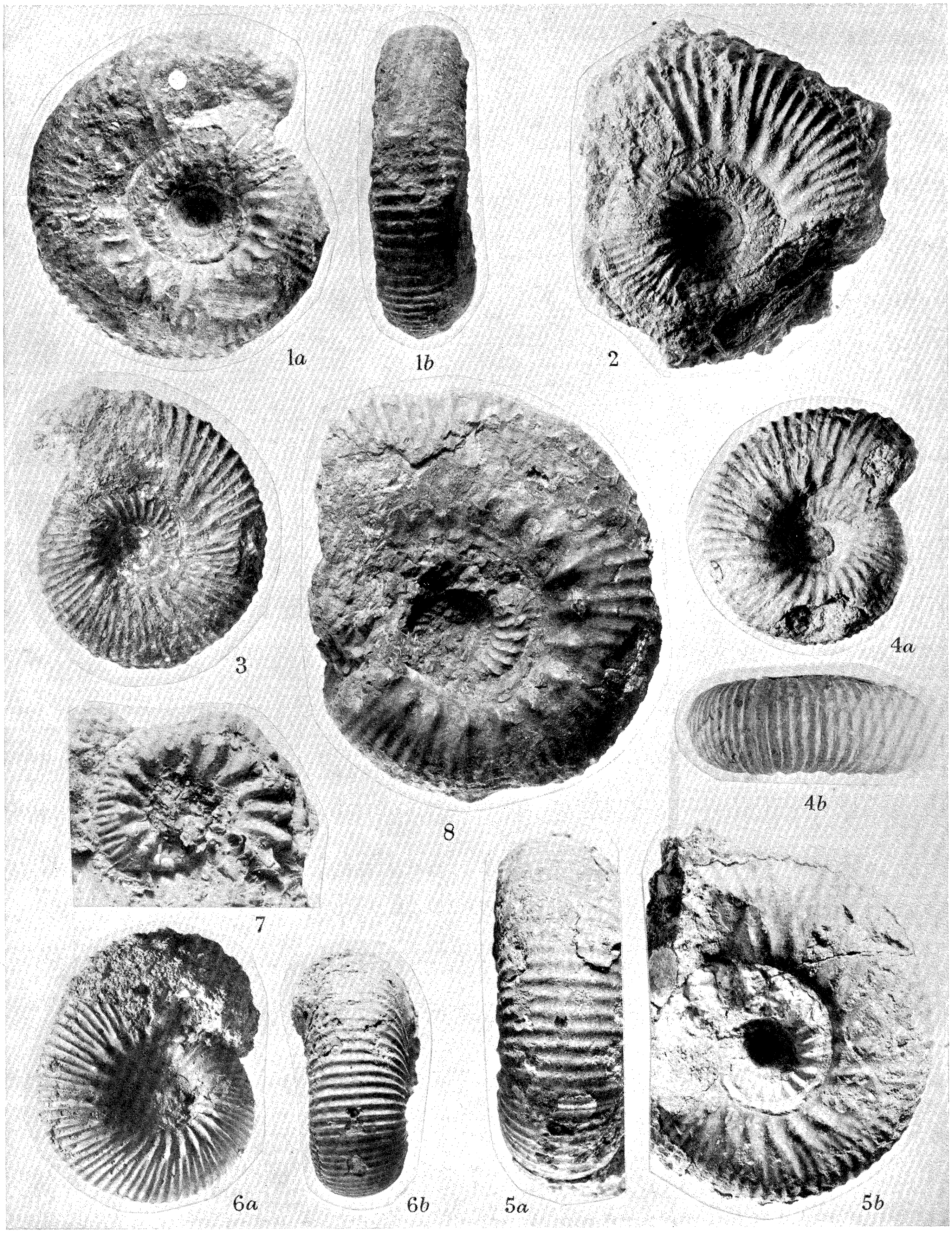
2*b*

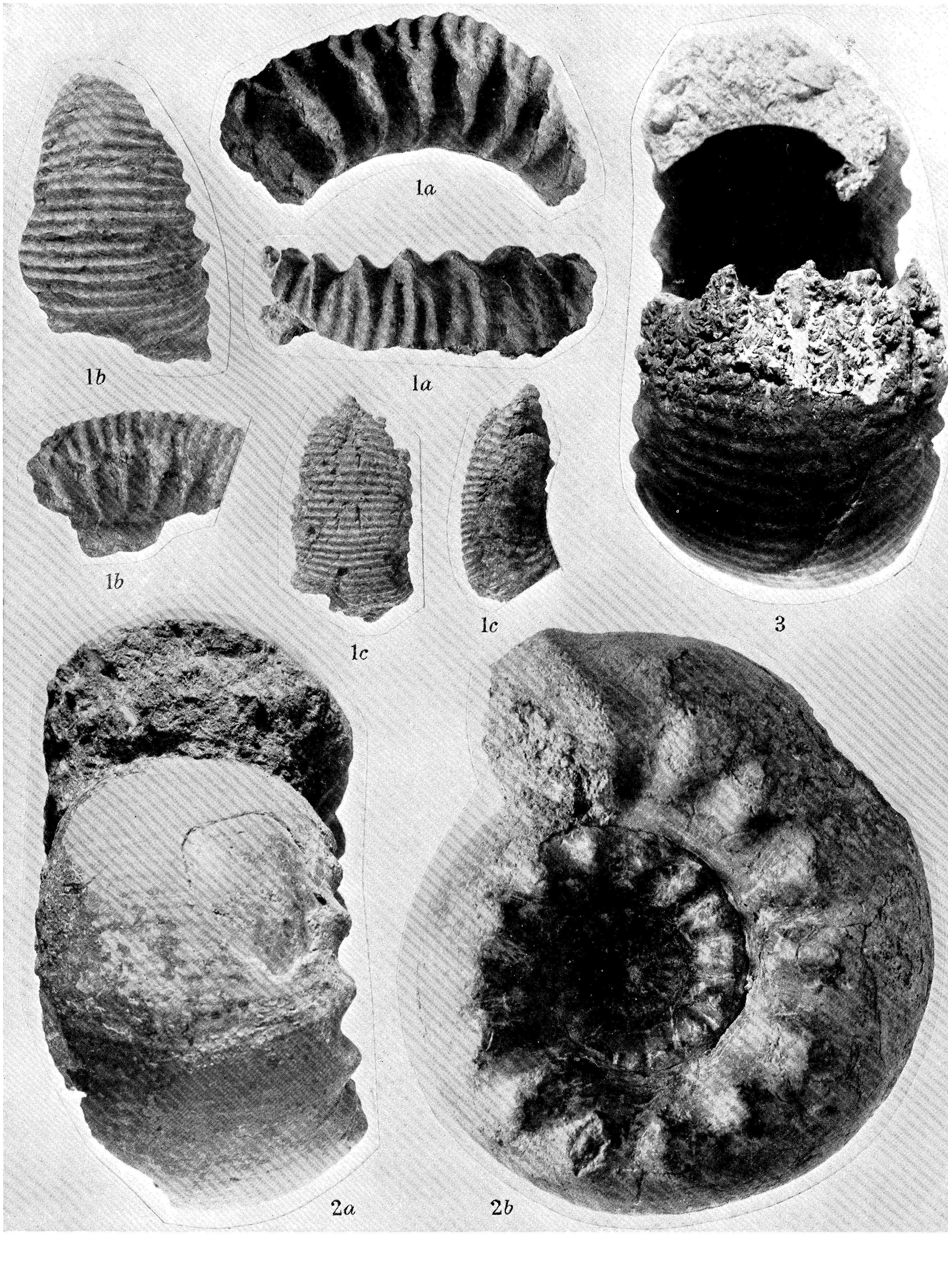


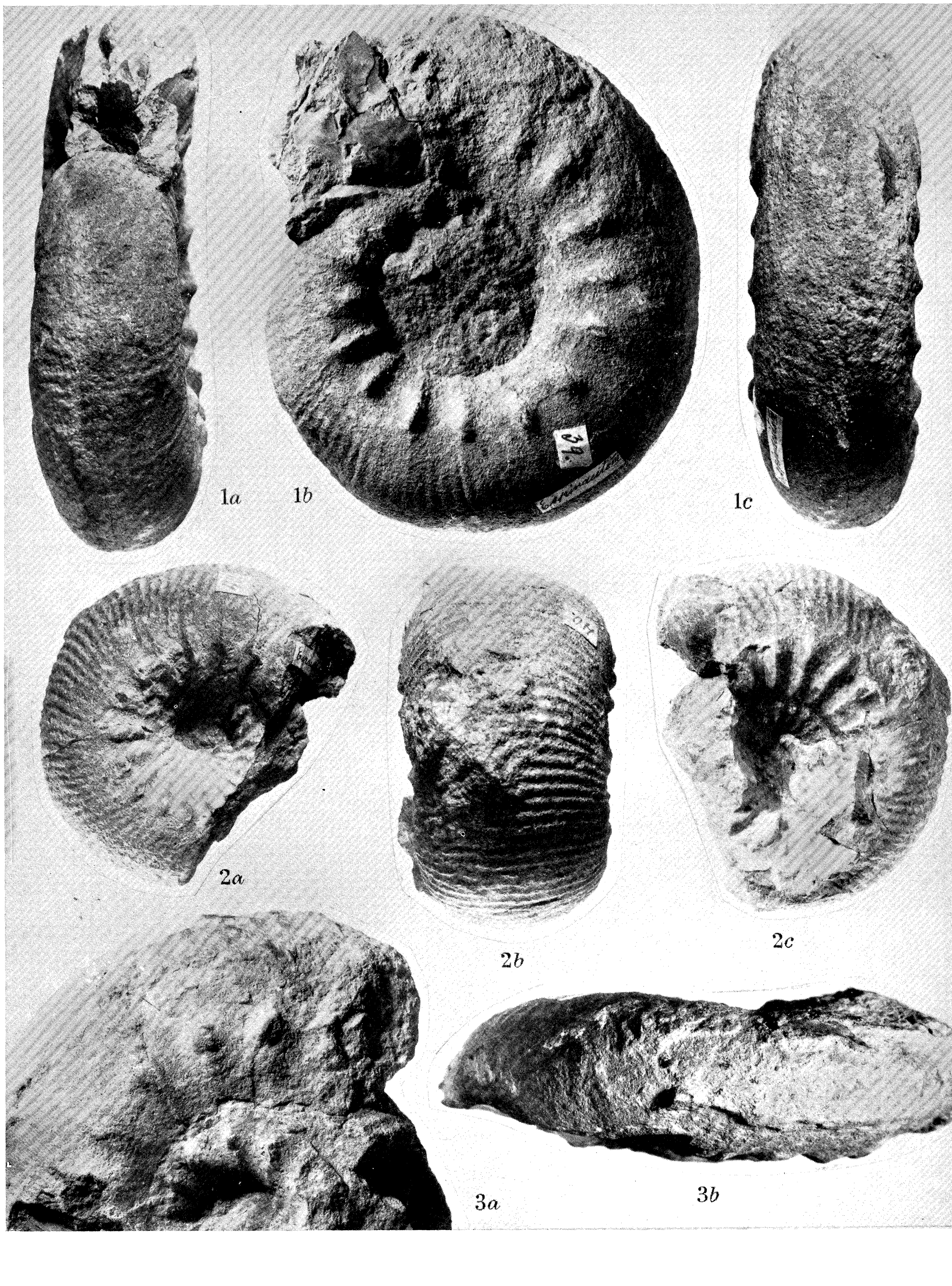
1*b*


1
2
3a
3b
4a
4b
4c


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


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


1a
1a
1b
1b
1c
1c
3
2a
2b


1*a*
1*b*
1*c*
2*a*
2*b*
2*c*
3*a*
3*b*

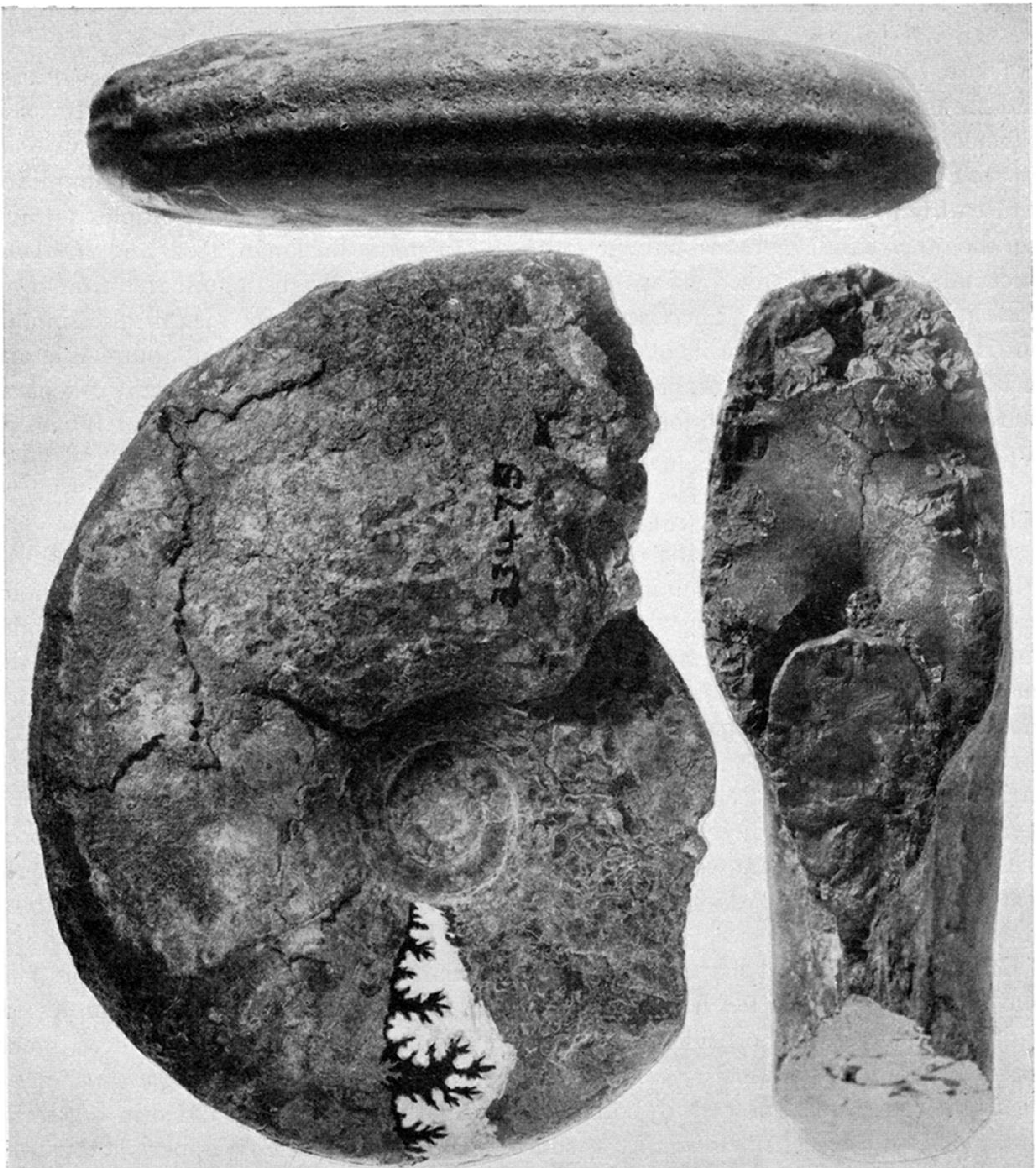


FIGURE 4. *Witchellia australica* n.sp. Left, holotype. Right, whorl section of a large septate fragment. Above, venter of a third specimen, with test. Newmarracarra Limestone. Natural size.

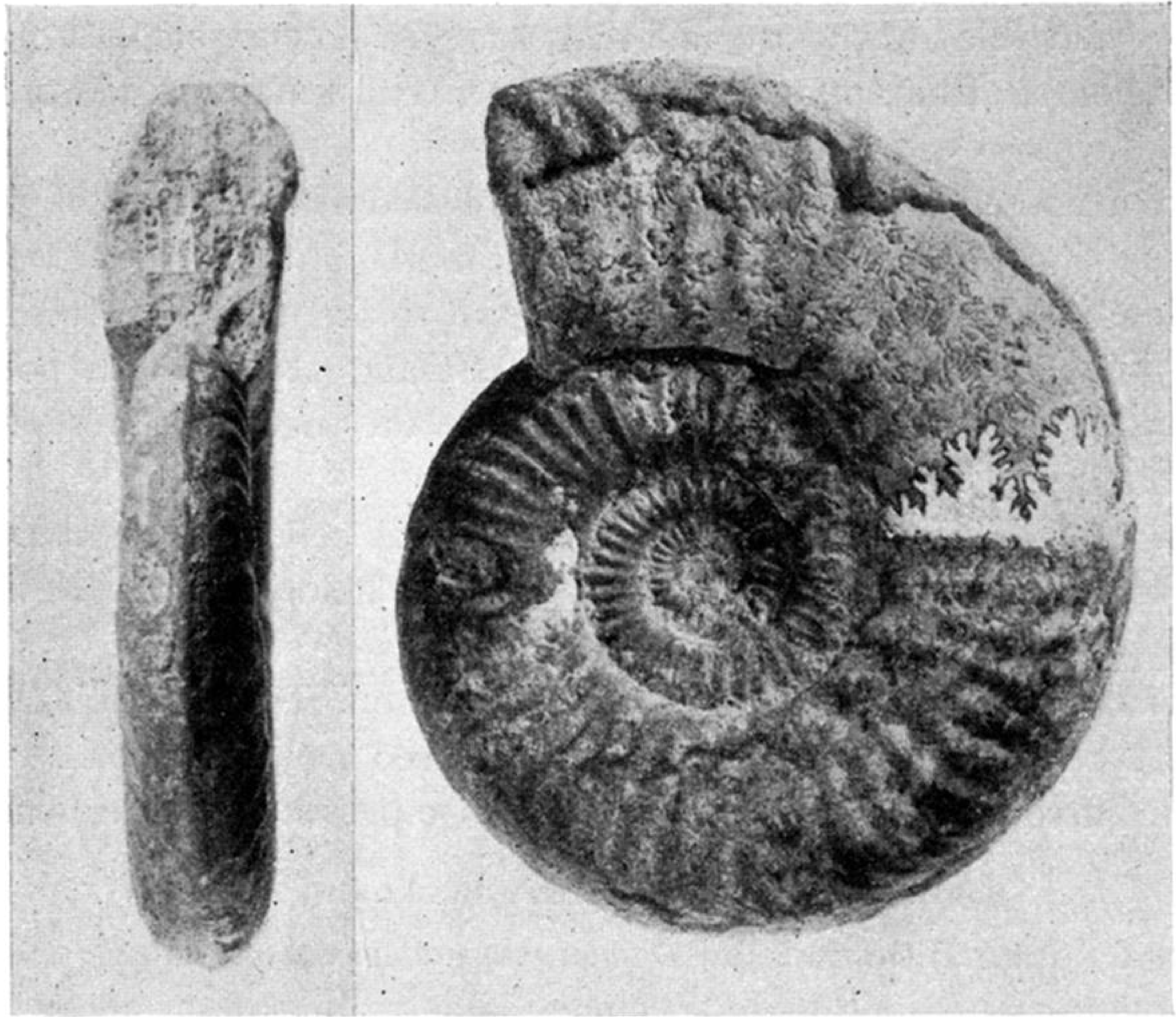


FIGURE 5. *Fontannesia luculenta* Buckman, basal Sowerbyi Zone (Discites Subzone), Bradford Abbas, Dorset. Buckman Coll., Sedgwick Museum, Cambridge, J 6283. Natural size.

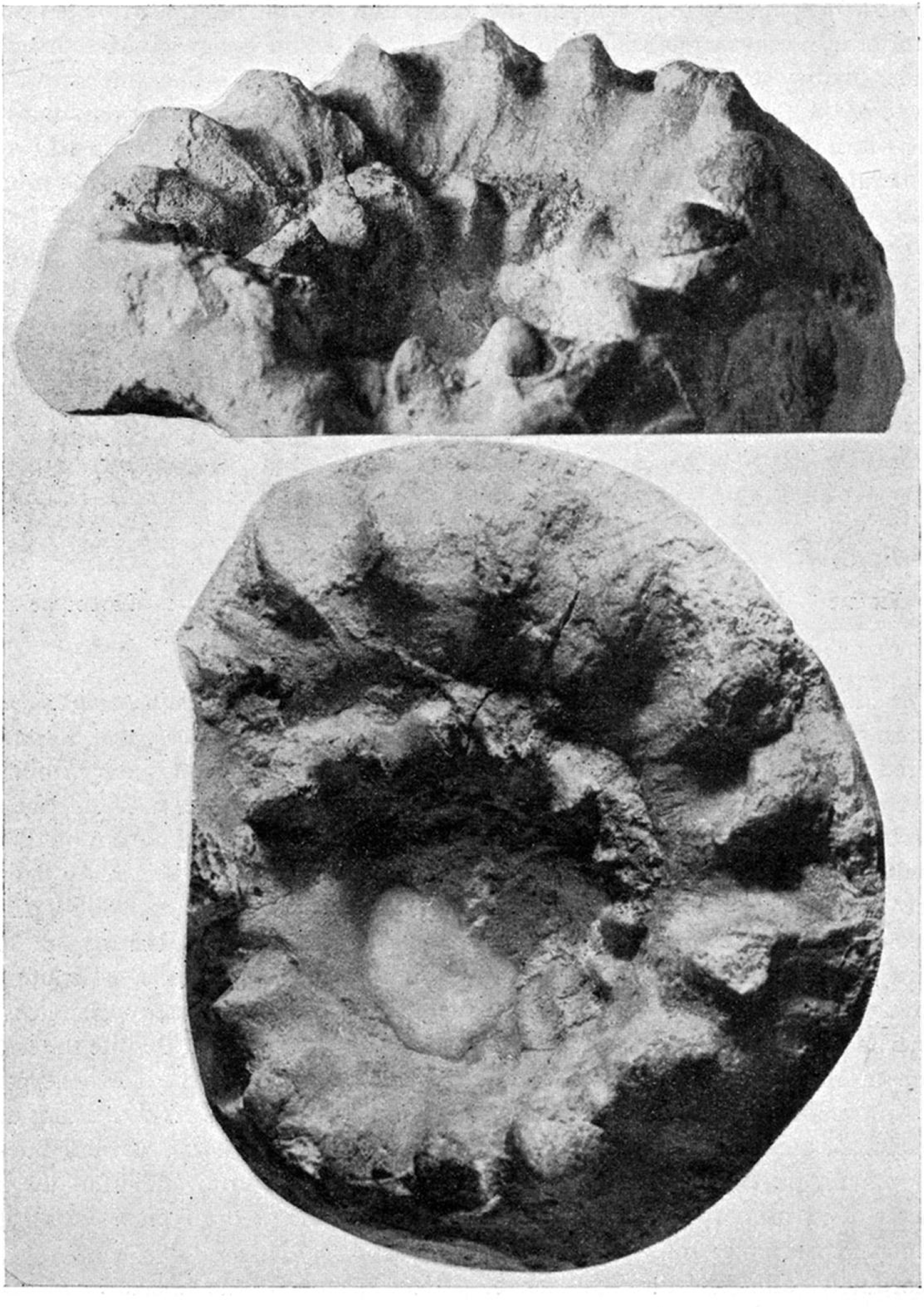


FIGURE 8. *Zemistephanus armatus* n.sp. Plaster cast of holotype, natural size.

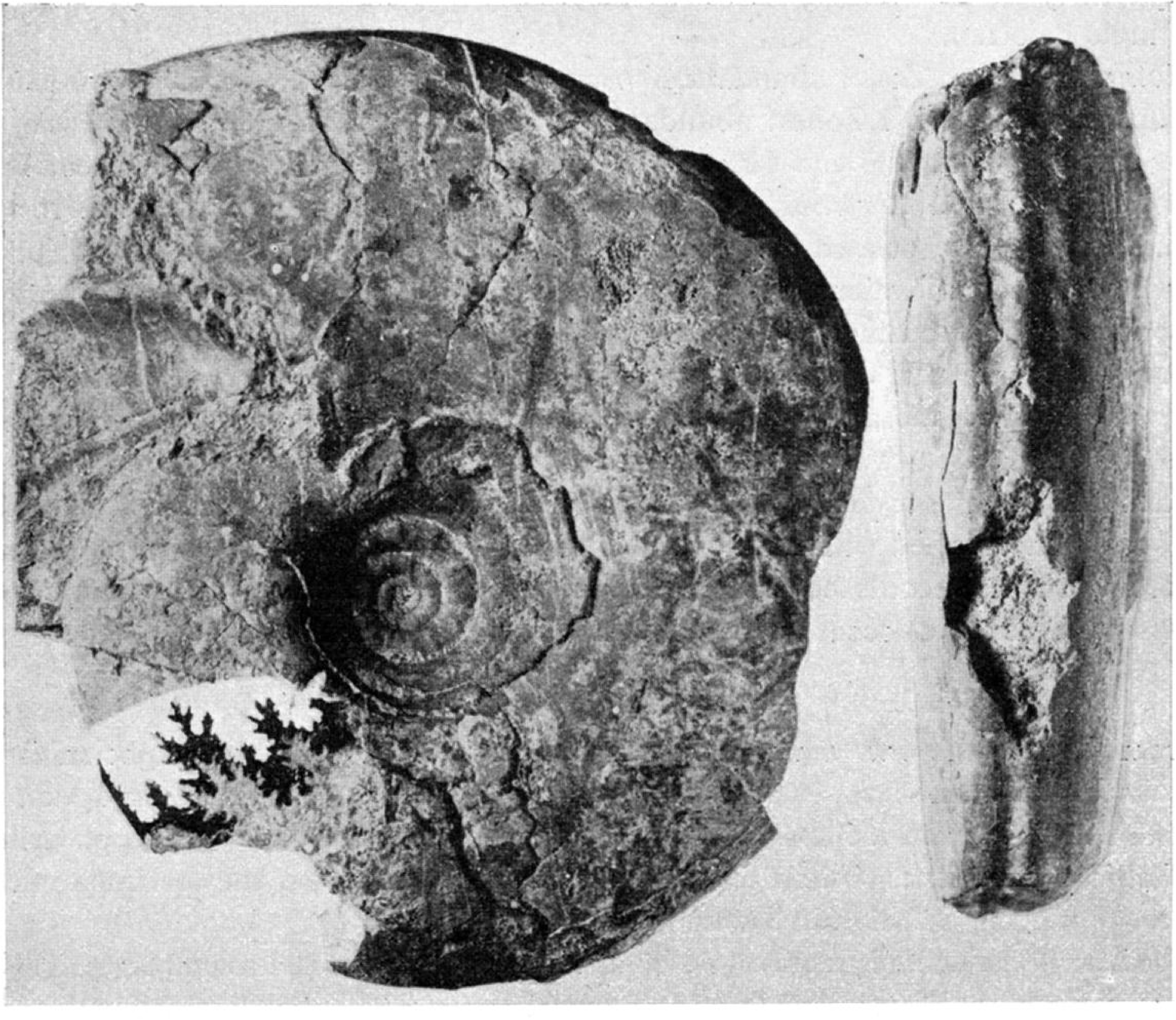


FIGURE 9. *Witchellia australica* n.sp., Lungma Limestone, Tibet. Hayden Coll., Geol. Surv. India no. K 9/231. Natural size.

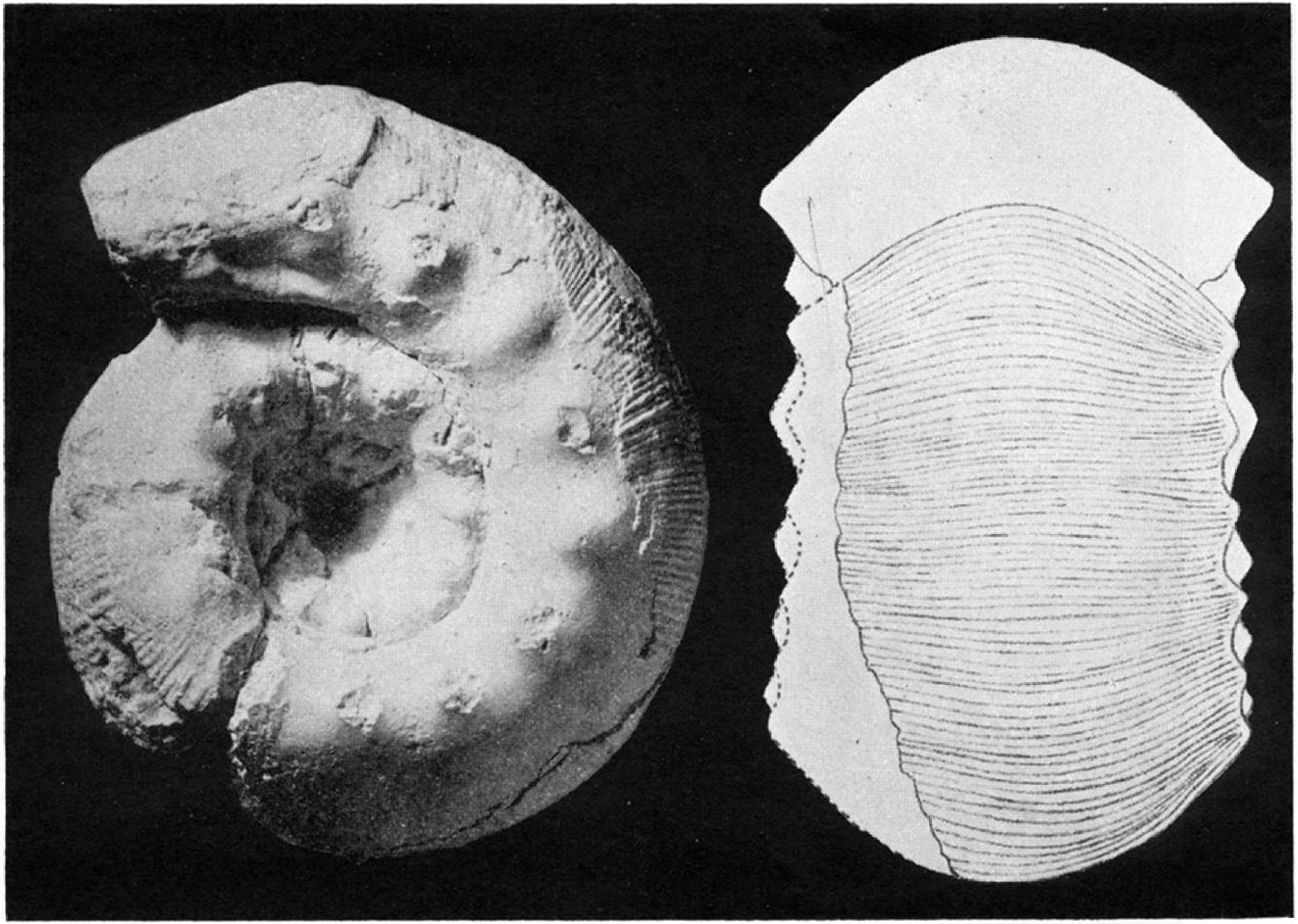


FIGURE 10. *Zemistephanus richardsoni* (Whiteaves), holotype, Skidegate Inlet, British Columbia. Geol. Surv. Canada. Plaster cast, Sedgwick Museum, natural size. The ventral view on right after Whiteaves, restored.

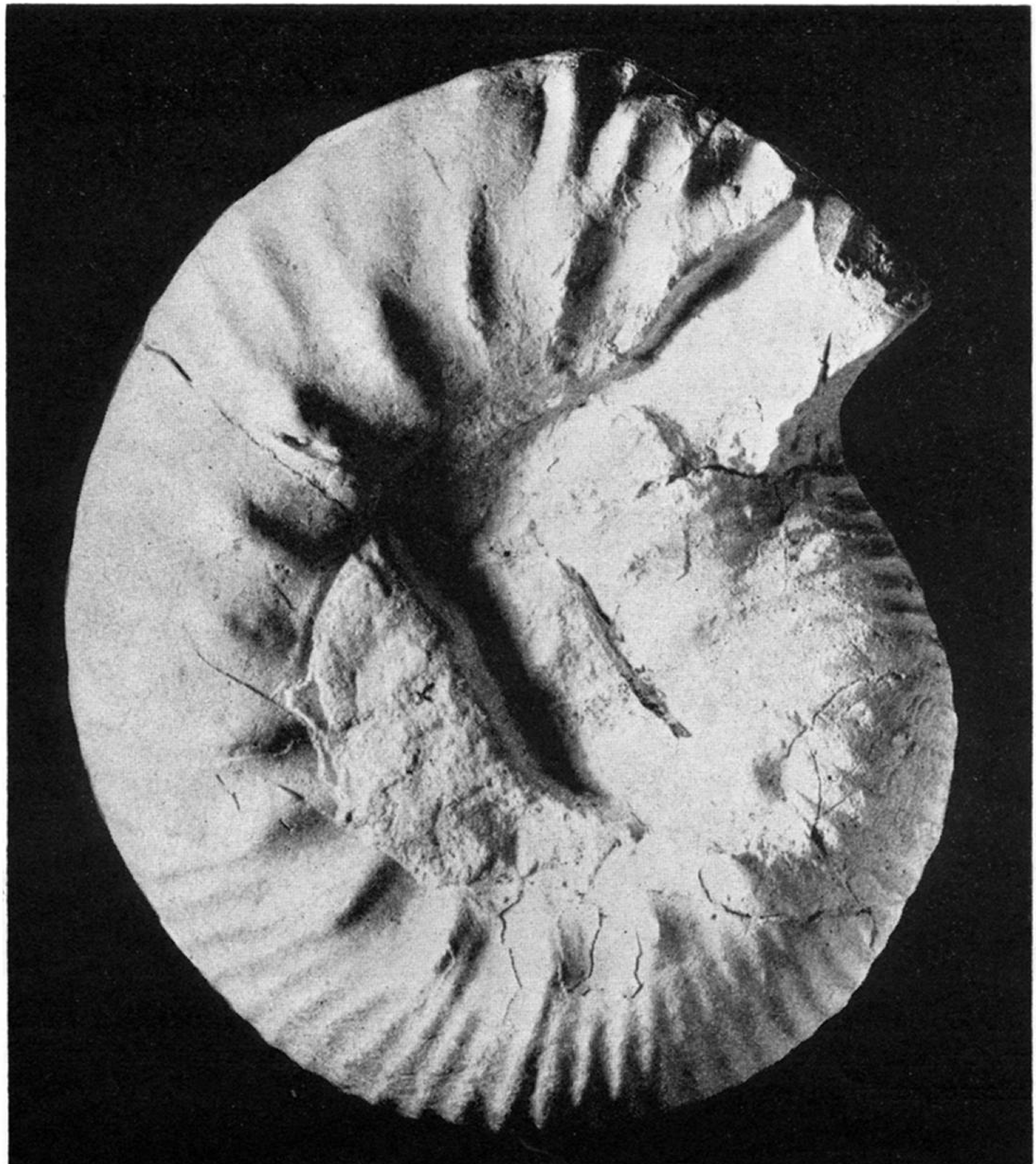


FIGURE 11. *Pseudotoites carlottensis* (Whiteaves), holotype, Skidegate Inlet, British Columbia. Geol. Surv. Canada. Plaster cast in Sedgwick Museum, natural size. (For ventral views see figure 12.)

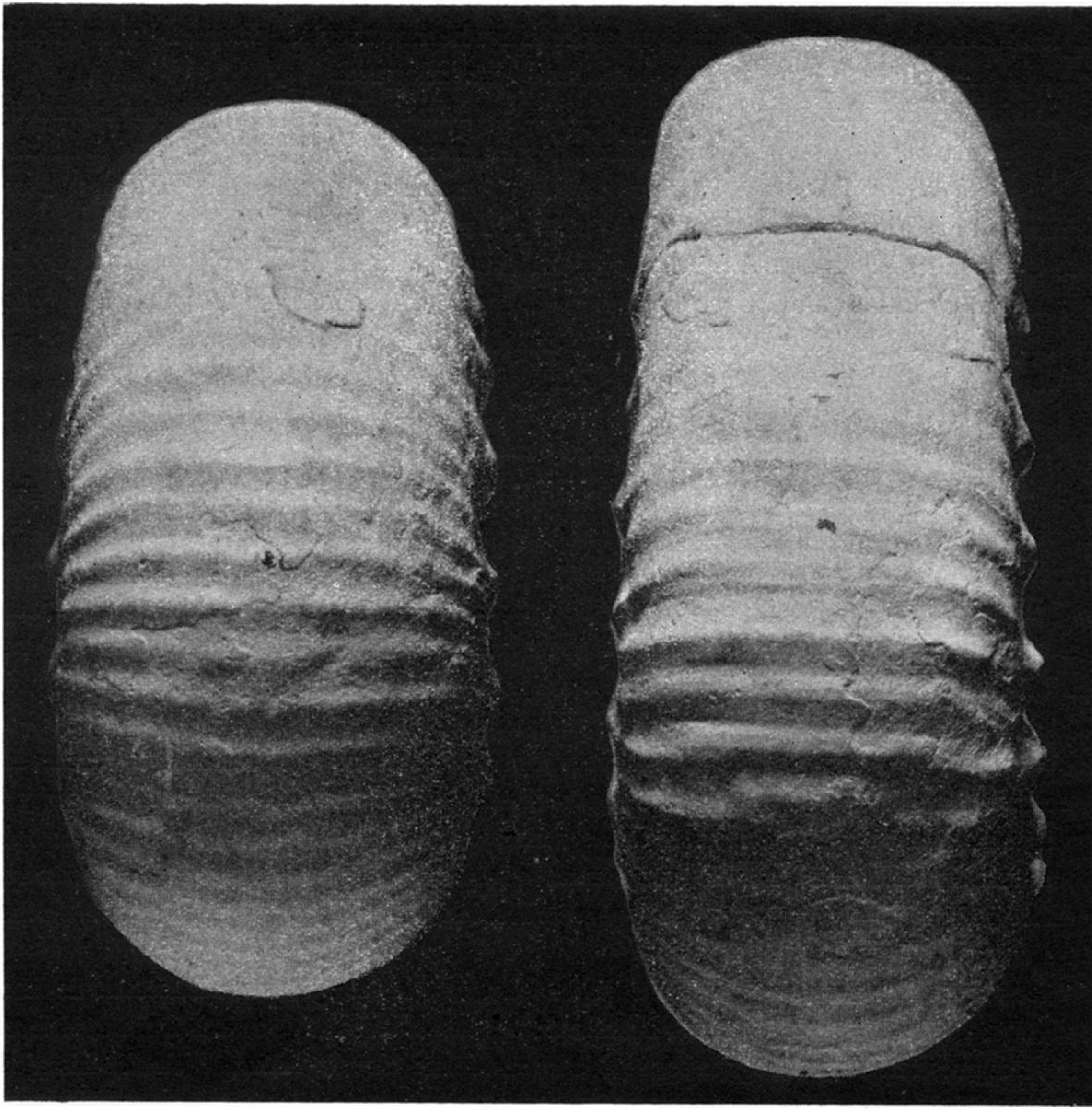


FIGURE 12. *Pseudotoites carlottensis* (Whiteaves), ventral views of plaster cast of holotype, natural size. (See figure 11.)

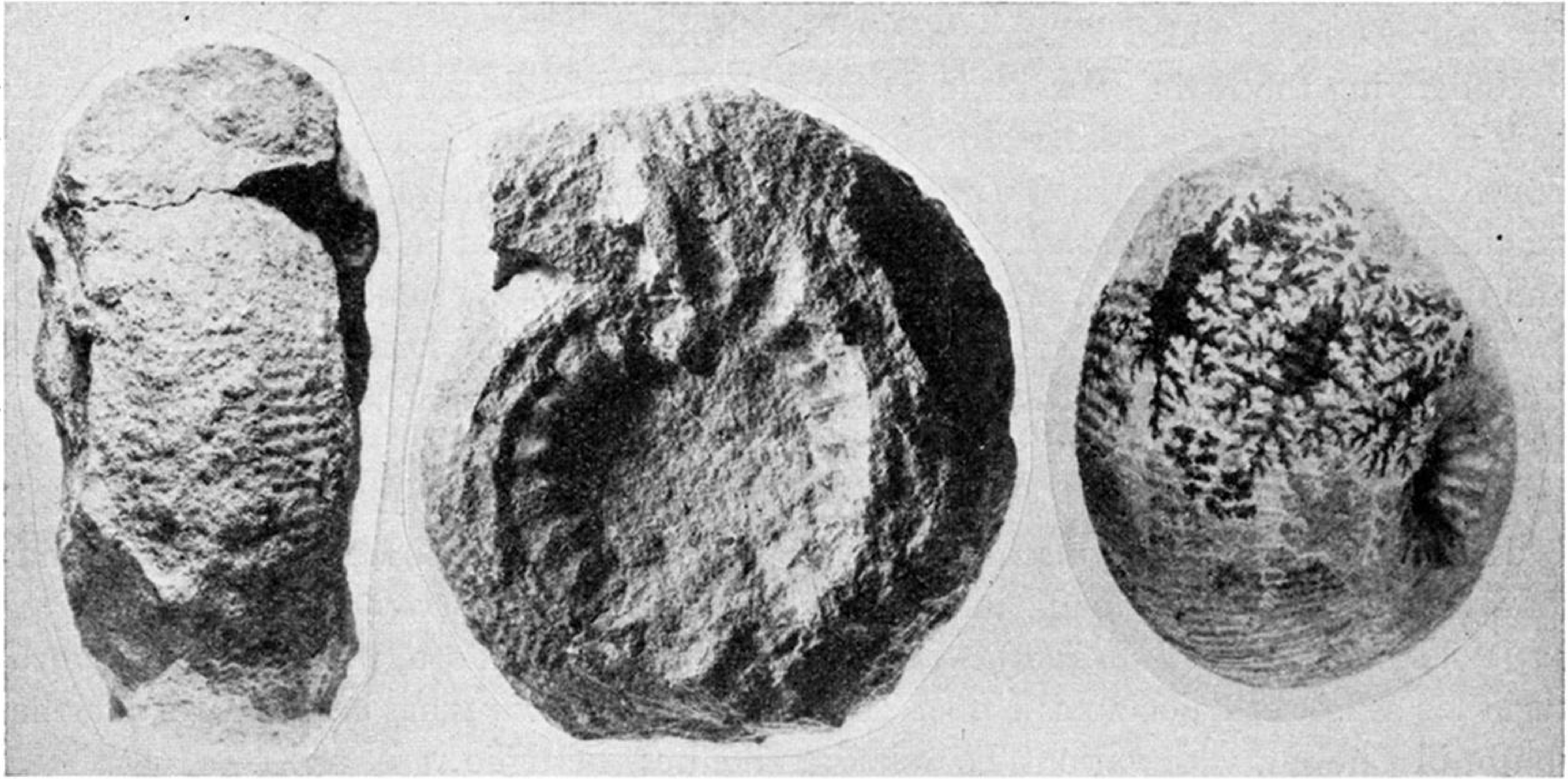


FIGURE 13. Left and centre: '*Stephanoceras*' *transatlanticus* Tornquist, holotype, Espinazito Pass, Argentina, Bodenbender Coll., Geol. Inst. Göttingen, natural size. Right: *Emileia brocchii* (Sowerby), to show sutures, for comparison with those of *Pseudotoites* and *Zemistephanus*: Sowerbyi Zone, Milborne Wick, Somerset, Geol. Surv. Mus. no. 24743; natural size.

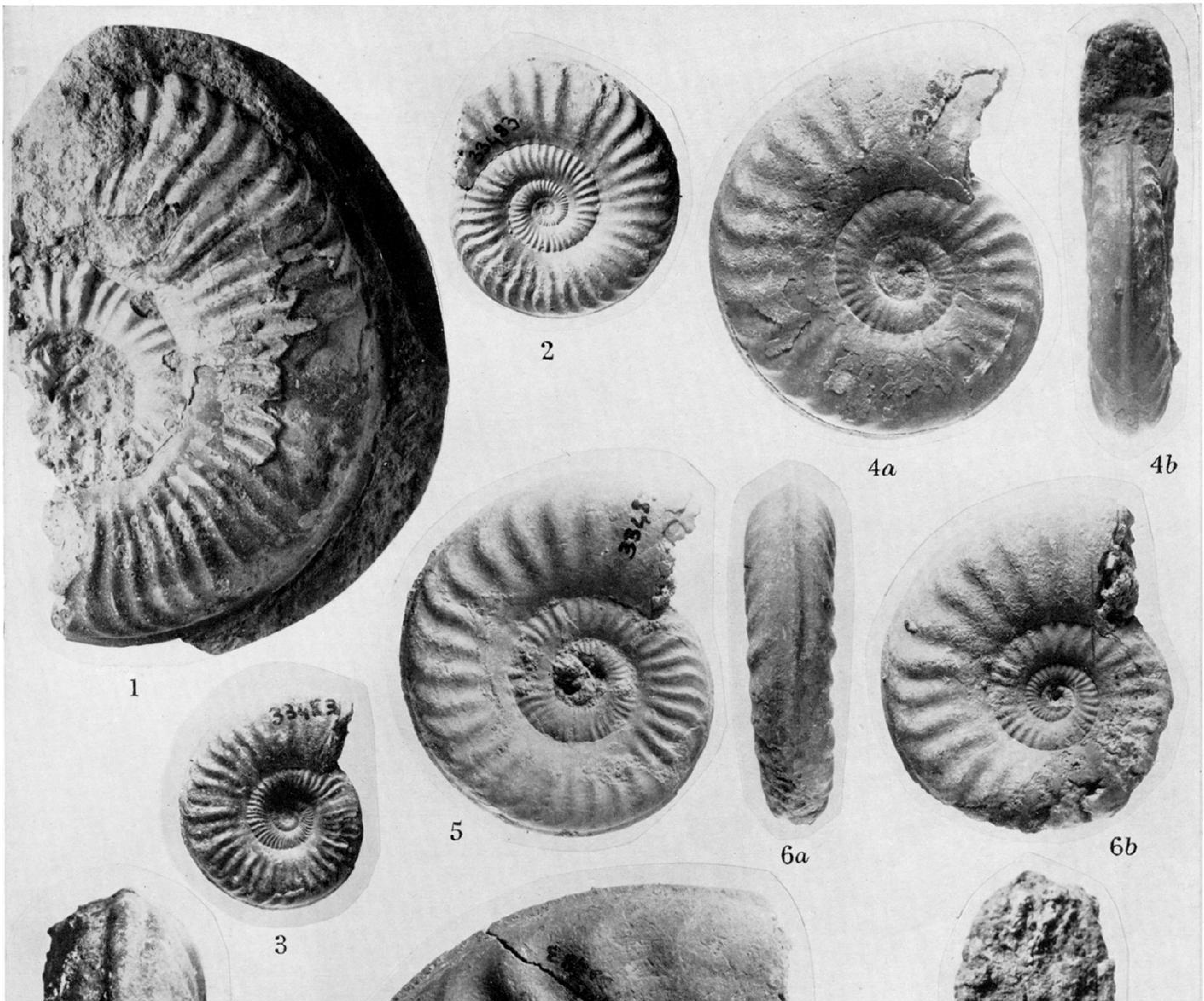


PLATE 27

FIGURES

1. *Sonninia playfordi* n.sp. Holotype, from well about 15 miles south-east of Bringo (964202) (p. 560).

2, 3. *Fontannesia clarkei* (Crick) or *F. fairbridgei* n.sp., at early stage when the two species are not distinct. Rabbit warrens at type locality of *F. fairbridgei* (p. 563).

4, (5?), 6, 7. *Fontannesia fairbridgei* n.sp. Rabbit warrens at and near type locality. Figure 7 holotype (784357). Figure 5 is as compressed as *F. clarkei* var. *etheridgei* (plate 29, figure 2*b*) (p. 563).

All figures natural size.

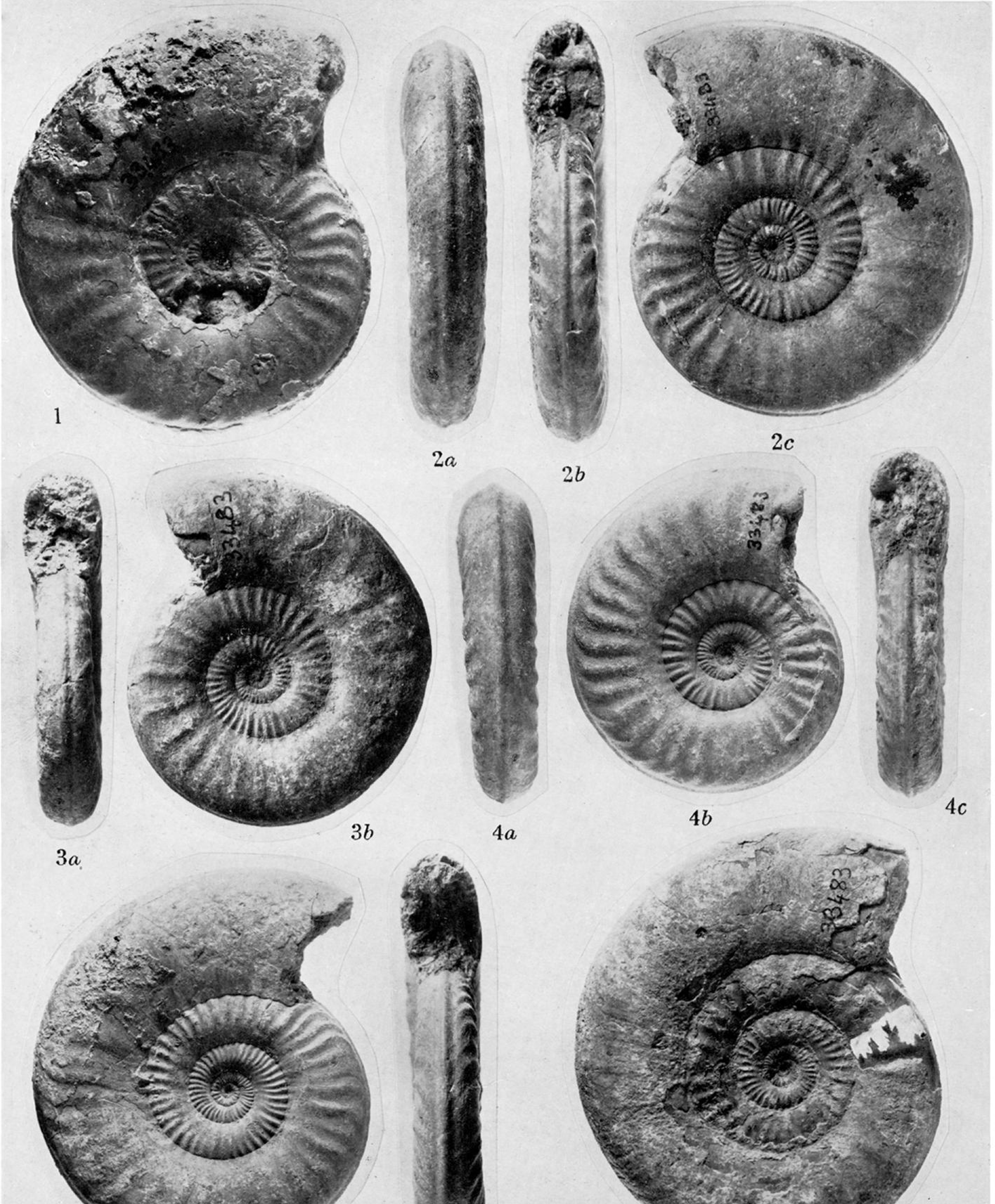


PLATE 28

1 to 6. *Fontannesia clarkei* (Crick). Typical specimens, all wholly septate with test complete except in figure 1, showing some of the variations. In figures 1 and 4 the ribbing persists longer than usual, in figure 6 it fades earlier. Of the specimens taken to London to compare with the type fragment, figure 3 was the most exact match. All from rabbit warrens at and near the type locality of *F. fairbridgei* (784357, 775352, 768356) (p. 565).

All figures natural size.

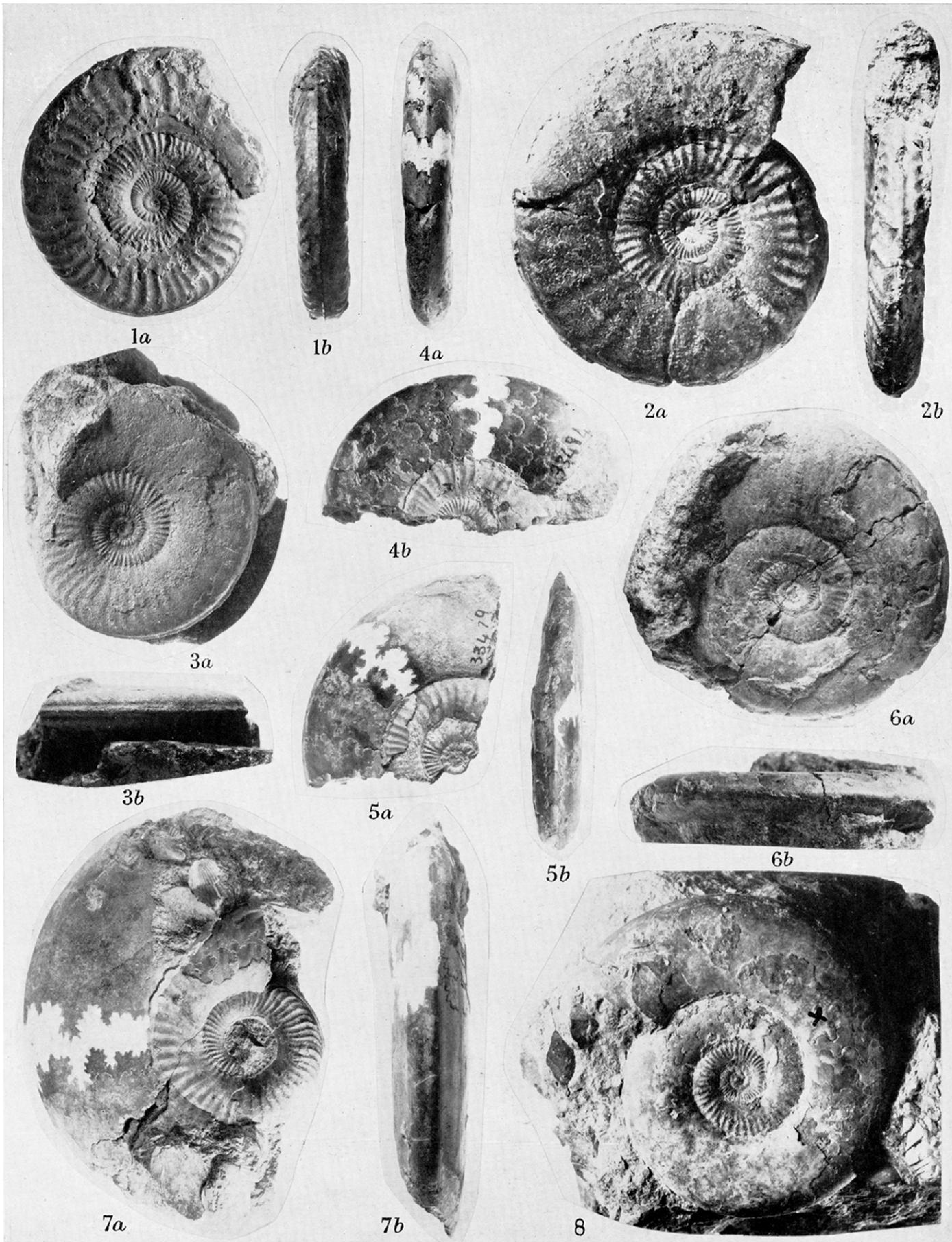


PLATE 29

1. *Fontannesia clarkei* (Crick) var. *etheridgei* (Whitehouse). F 21078 (p. 566).

2. *Fontannesia clarkei* (Crick) var. *etheridgei* (Whitehouse). Holotype of *Dorsetensia etheridgei* Whitehouse, figured by Etheridge, Tibraddon Station. The last quarter whorl (with test) may be body chamber (p. 566).

3 to 8. *Fontannesia whitehousei* n.sp. (p. 566).

3, involute, more shouldered variety, transitional to *F. clarkei*. Wholly septate. (718304.)

4, 5, fragments showing sutures. For enlarged view of the nucleus of 5, see plate 30, figure 6. (714309.)

6, original of Charles Moore's '*Ammonites aalensis* var. *moorei Lycett*'; Brit. Mus. (N.H.). C47366. Wholly septate.

7, variety with shouldered inner whorls as in figure 3 (but not so involute), transitional to *F. clarkei*, but acquiring venter of *F. whitehousei* on the outer whorl. The whitened area covers the last two camerae. (714309.)

8, holotype. Septation ceases at the cross. F 21081, very hard limestone matrix.

All figures natural size.

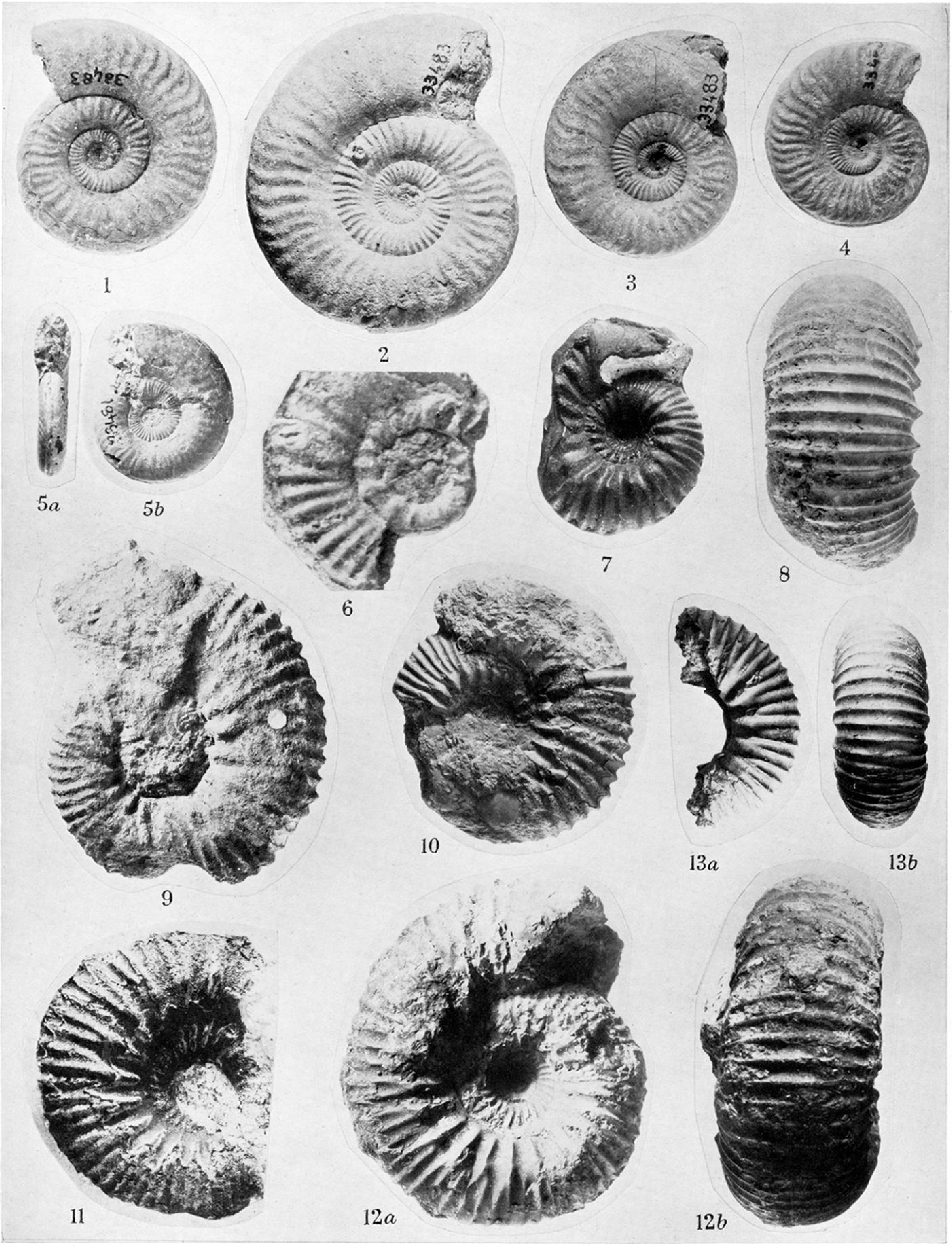


PLATE 30

FIGURES

1 to 4. *Fontannesia clarkei* (Crick). Closely-ribbed varieties (figure 2 var. *etheridgei* Whitehouse), showing the ribbing fading at different stages. Rabbit burrows, same locality and preservation as plate 28.

5. *Fontannesia whitehousei* n.sp. Wholly septate inner whorls. (710305) (p. 566).

. *Fontannesia whitehousei* n.sp. Nucleus of the specimen shown in plate 29, figure 5, magn. ×4 (p. 566).

7. *Otoites depressus* Whitehouse. Gutta percha squeeze (Sedgwick Museum F1880) of holotype (natural external mould), showing adult aperture with lappet. Well near Bringo railway-cutting (765366) (p. 570).

8. *Otoites antipodus* n.sp. Ventral view of specimen shown in plate 31, figure 5 (p. 570).

9 to 12. *Otoites woodwardi* (Crick) (p. 569).

9, holotype, internal cast with parts of aperture and of lappet (too crushed to show ventral view), Champion Bay. Brit. Mus. (N.H.) C30378.

10, slightly crushed specimen with some test. (714309.)

11, plaster cast of natural mould, Mt. Hill. F21089.

12, full-sized specimen, internal cast, with parts of aperture and of a lappet. F21091.

13. *Otoites* n.sp. Well-preserved half-whorl, internal cast, deceptively crushed (p. 570).

All figures natural size except figure 6.

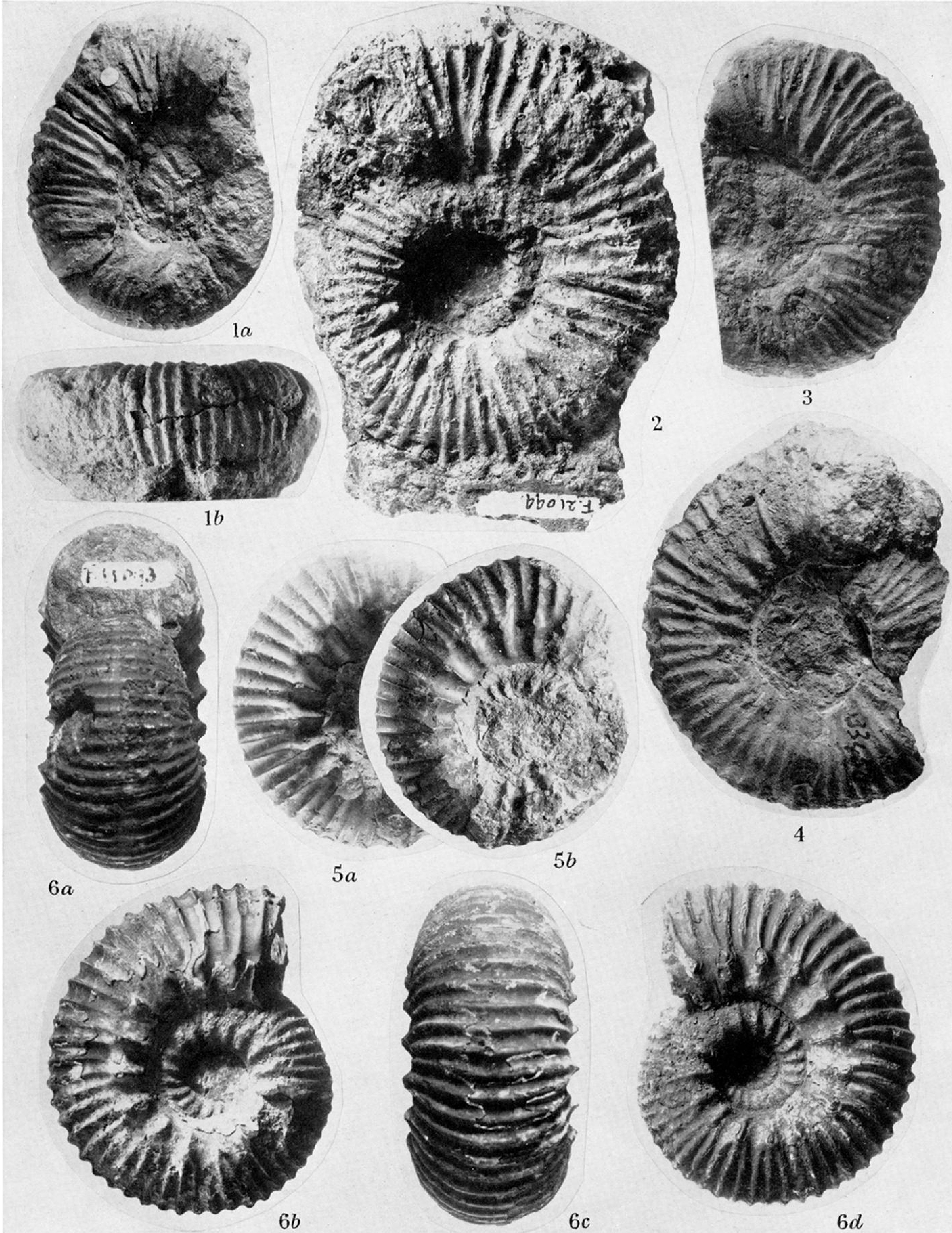


PLATE 31

1 to 4. ? *Otoites australis* (Crick) (p. 571).

1, holotype, crushed and distorted, Champion Bay. Brit. Mus. (N.H.) C30379.

2, largest specimen known. F21099.

3, 4, two imperfect specimens (691296), figure 3 with base of a lappet.

5. *Otoites antipodus* n.sp. Internal cast lit from two directions; for ventral view see plate 30, figure 8. (710305) (p. 570).

6. *Otoites antipodus* n.sp. Holotype, four views. Most of the test is preserved. Three-quarters of the last whorl is body-chamber. F21093, Mount Hill (p. 570).

All figures natural size.

PLATE 32

1. *Otoites* aff. *antipodus* n.sp. Depressed fragment agreeing with *Otoites* sp. indet. of Whitehouse, Bringo cutting (p. 570).
2. *Pseudotoites leicharti* (Neumayr). Typical specimen matching the type figures. (691296) (p. 573).
3. Believed inner whorls of *Pseudotoites leicharti* or *P. championensis*. F 21107.
4. *Pseudotoites championensis* (Crick). Holotype, Champion Bay. Brit. Mus. (N.H.) C 30385 (p. 574).

All figures natural size.

PLATE 33

1. *Pseudotoites championensis* (Crick), from (718335) (p. 574).
2. Believed inner whorls of *P. championensis* or *P. leicharti*. F 21108.
3. Cross-section of a *Pseudotoites leicharti* to show common style of crushing by rock pressure. Probably same locality as figure 4 (p. 573).
4. *Pseudotoites leicharti* (Neumayr). Largest specimen, with some uncrushed tumid outer whorl before stage of contraction; from (691296) (p. 573).

All figures natural size.

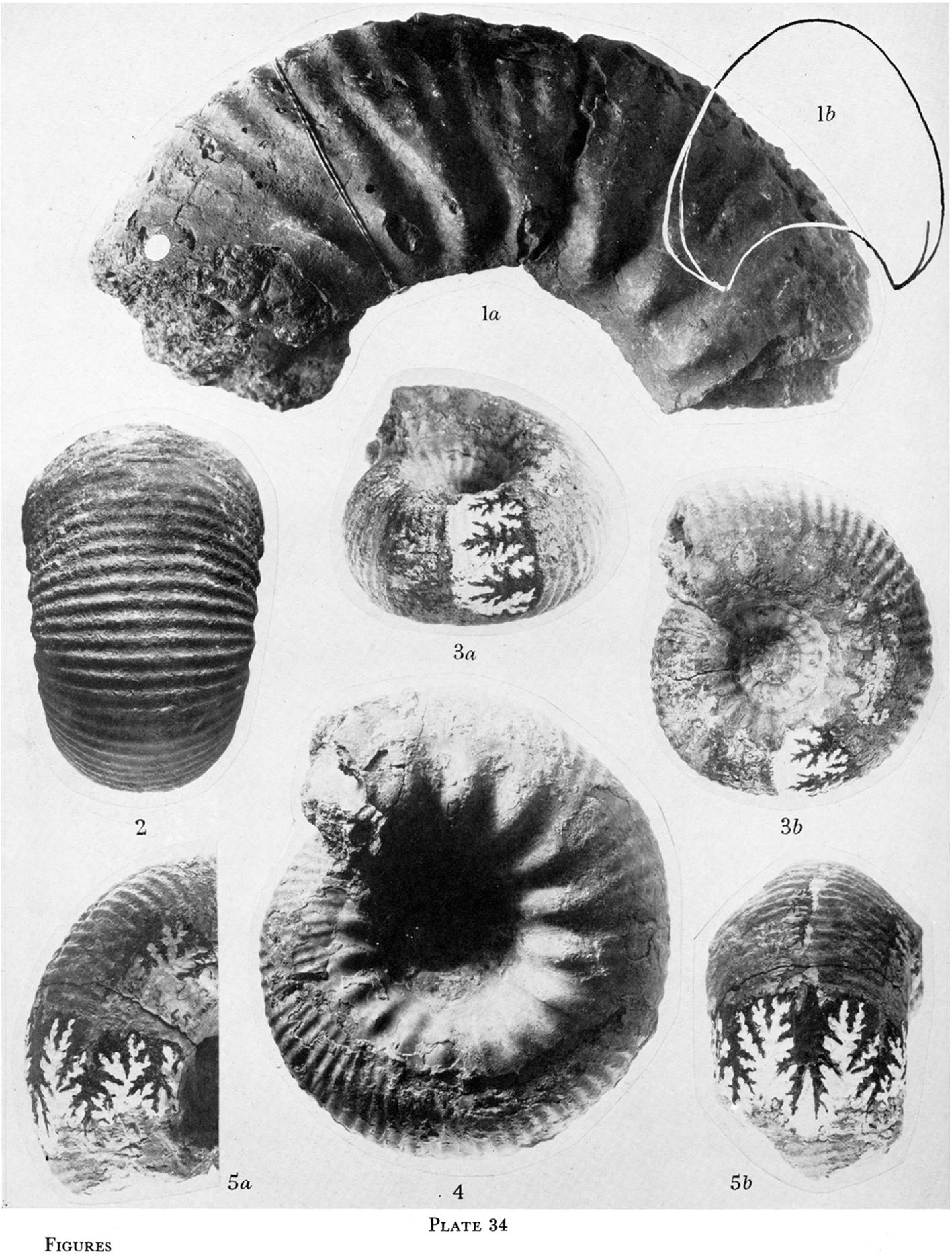


PLATE 34

FIGURES

1. *Pseudotoites robiginosus* (Crick). Holotype fragment of body-chamber, from Champion Bay. Brit. Mus. (N.H.) C30381. Compare plate 35, figure 1 (p. 574).
2. *Pseudotoites robiginosus* (Crick). Venter of specimen shown in plate 35, figure 2, from Mount Hill. F21110 (p. 574).
3. *Pseudotoites robiginosus* (Crick). Wholly septate specimen showing sutures, from (774351) (p. 574).
4. *Pseudotoites robiginosus* (Crick). Middle whorls, cadicone stage, from (714309) (p. 574).
5. *Pseudotoites emilioides* n.sp. Sutures of specimen from (714309) (p. 576).

All figures natural size.

1a

2a

2b

1b

PLATE 35

1, 2. *Pseudotoites robiginosus* (Crick) (p. 574).

1, Complete specimen from (725337) with weathered body-chamber, matching the holotype (see plate 34, figure 1).

2, Wholly septate specimen from Mount Hill. F 21110. For back view see plate 34, figure 2.

All figures natural size.

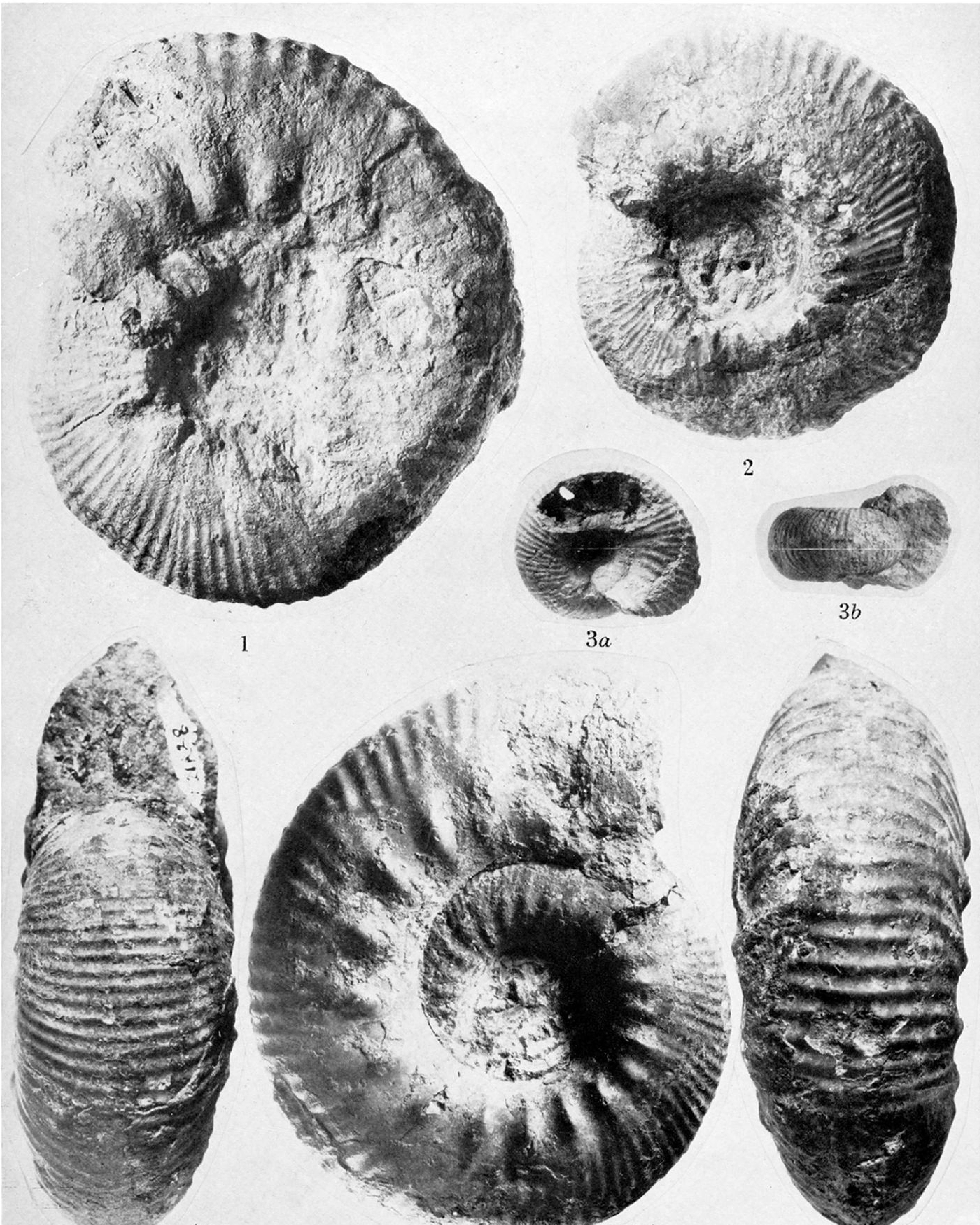


PLATE 36

1, 2. *Pseudotoites fasciculatus* n.sp. 1, Holotype, Fossil Hill (706333); 2, F21124 (p. 573).
3. *Pseudotoites brunnschweileri*? n.sp. (732343) (p. 576).
4. *Pseudotoites brunnschweileri* n.sp. Holotype, F21128 (p. 576).

All figures natural size.

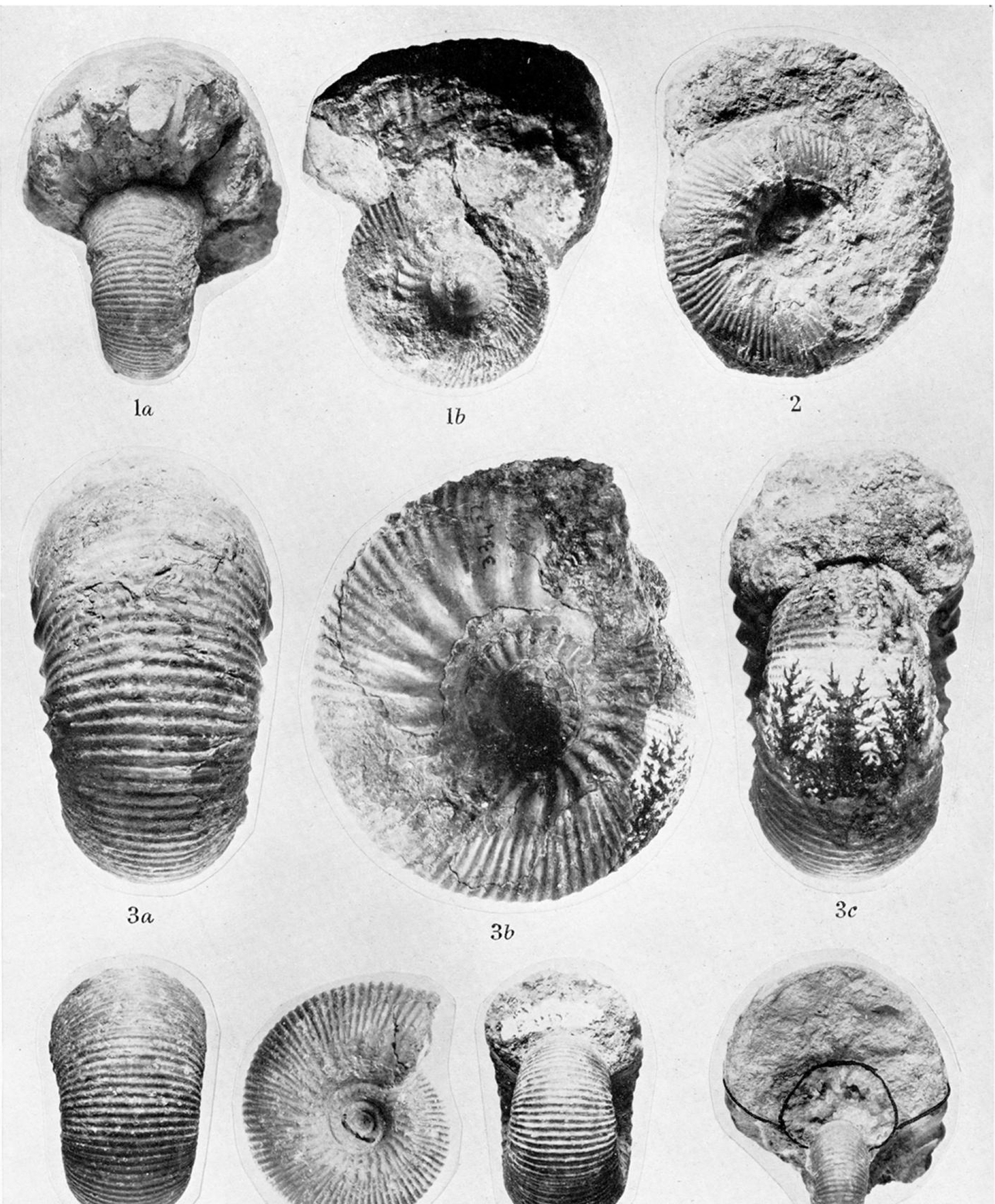


PLATE 37

1. *Pseudotoites* sp. indet., middle whorl-fragment as in *P. robiginosus*, inner whorls less inflated, appropriate to *P. leicharti* and *P. fasciculatus*. (714309) (p. 577).
2. *Pseudotoites fasciculatus* n.sp. (690296) (p. 573).
3, 4. *Pseudotoites emilioides* n.sp. 3, Holotype (714309), and 4, inner whorls, F21102 (p. 576).
5. *Pseudotoites robiginosus* (Crick), (691296) (p. 574).

All figures natural size.

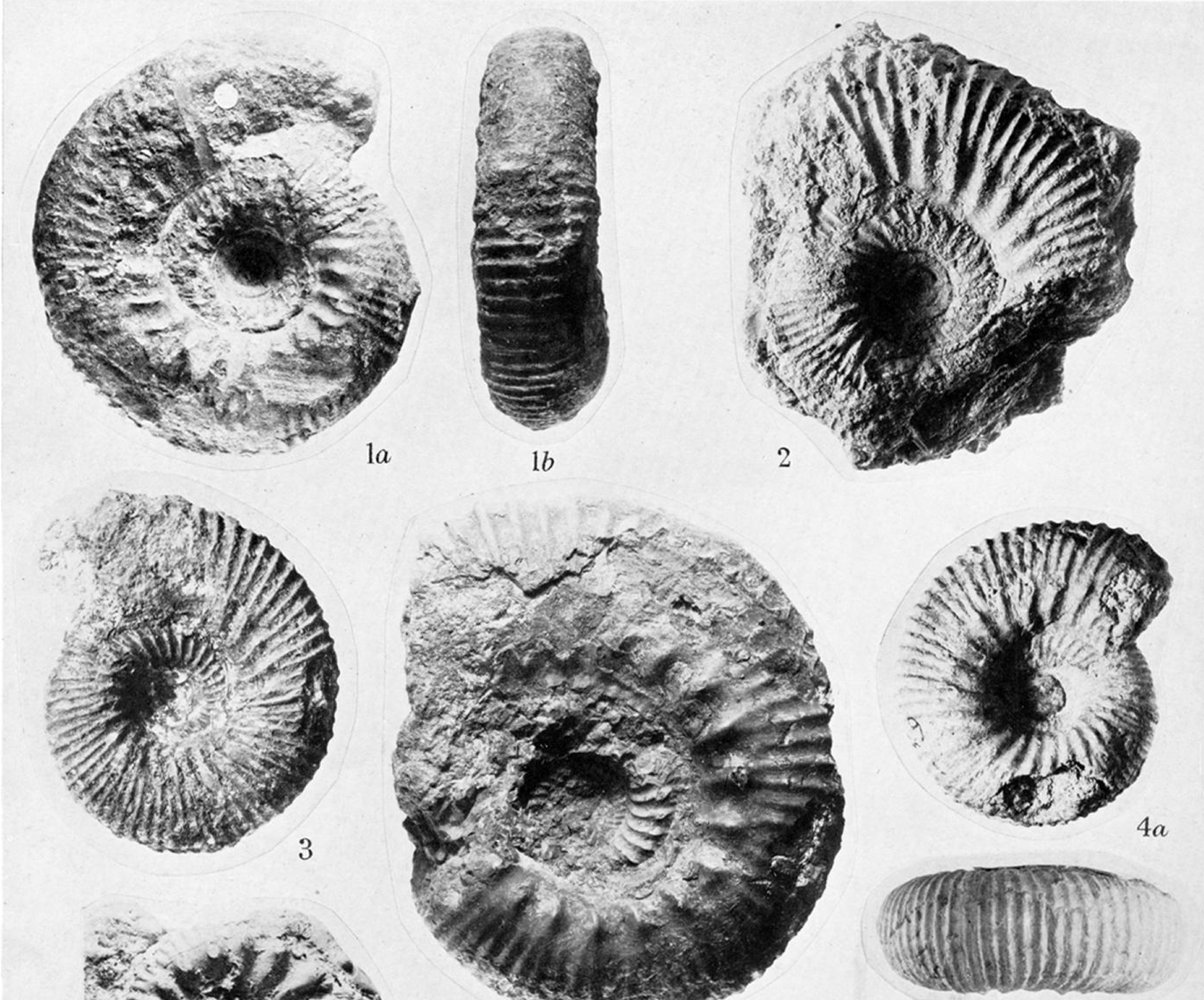


PLATE 38

1 to 6. *Pseudotoites semiornatus* (Crick) (p. 577).

1, Holotype, much worn natural cast, from Champion Bay, Brit. Mus. (N.H.) C30377.

2, 3, 4, sharply preserved specimens with test (691296).

5, complete natural cast with body-chamber, from well (964202).

6, from Doust Station, Hill River district (223528, Hill River one-mile military sheet).

7. *Stephanoceras* (*Stemmatoceras*) cf. *subcoronatum* (Oppel). Plasticene squeeze of natural mould from railway well (765366) (p. 582).

8. *Pseudotoites spitiformis* n.sp. Holotype (691296) (p. 577).

All figures natural size.

PLATE 39

1*a* to *c*. *Stephanoceras* (*Stemmatoceras*) aff. *triptolemus* (Morris & Lycett). Three fragments of a single specimen, each in ventral and lateral views; red ironstone (707304) (p. 582).

2, 3. *Zemistephanus corona* n.sp. 2, holotype, with test and peristome; 3, natural cast showing suture; both from (732343) (p. 578).

All figures natural size.

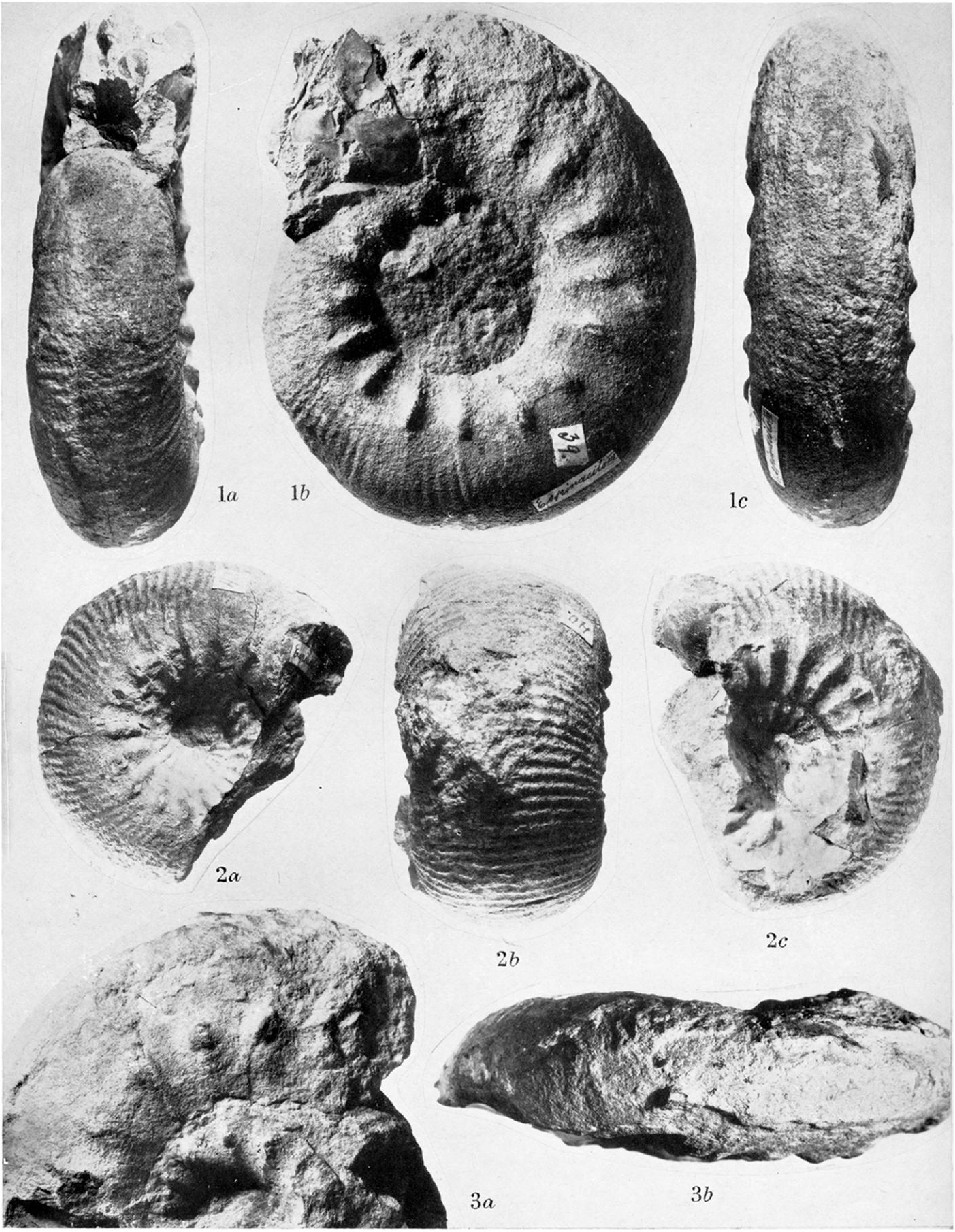


PLATE 40

FIGURES

1. *Pseudotoites argentinus* n.sp. Holotype (p. 592).

2, 3. *Pseudotoites sphaeroceroides* (Tornquist) (p. 592).

2, holotype (Tornquist, pl. vi, fig. 2).

3, original of Tornquist, pl. v, fig. 1 (different species?-much more compressed).

All from Espinazito Pass, Argentina, Bodenbender Coll., Geologisches Institut, Göttingen, kindly lent by Professor Hermann Schmidt.

All figures natural size.