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Autor(en): **Kugler, Hans G. / Jung, Peter / Saunders, John B.**

Objekttyp: **Article**

Zeitschrift: **Eclogae Geologicae Helvetiae**

Band (Jahr): **77 (1984)**

Heft 3

PDF erstellt am: **22.09.2024**

Persistenter Link: https://doi.org/10.5169/seals-165527

Eclogae geol. Helv.	Vol. 77	Nr. 3	Pages 675–705	Basel, December 1984

The Joes River Formation of Barbados and its fauna

By HANS G. KUGLER, PETER JUNG and JOHN B. SAUNDERS[1])

ABSTRACT

The depositional history of the Joes River Formation of Barbados, West Indies, is a complex one with various interpretations. In this paper we review the literature and discuss the field relations of the oligotypic assemblages of macrofossils. These are briefly discussed and figured and one new species, *Nuculana senni*, is described. Two oligotypic assemblages of agglutinated Foraminifera are also illustrated.

We consider that the Joes River sediments represent mobilized, overpressured Scotland clays. By diapiric action they spread out on the paleo-seafloor probably in latest Eocene times. Mud volcano activity is likely to have been associated. Possible remobilization of the unstable mass in the Late Tertiary may account for the fact that Barbados is the highest point on the accretionary prism today.

ZUSAMMENFASSUNG

Die Ablagerungsverhältnisse der Joes-River-Formation von Barbados, Westindien, sind komplex und haben Anlass zu verschiedenen Interpretationen gegeben. In dieser Arbeit werden die Literatur besprochen und die Feldbefunde der oligotypischen Makrofossil-Vergesellschaftungen diskutiert. Die Makrofossilien werden kurz beschrieben und abgebildet, und die neue Art *Nuculana senni* wird aufgestellt. Zwei oligotypische Vergesellschaftungen von agglutinierenden Foraminiferen sind ebenfalls abgebildet.

Wir betrachten die Joes-River-Sedimente als durch Überdrucke mobilisierte Scotland-Tone. Wahrscheinlich im spätesten Eozän breiteten sie sich durch diapirische Vorgänge auf dem Paläo-Meeresboden aus. Vermutlich war damit auch Schlammvulkanismus assoziiert. Es ist möglich, dass diese unstabile Masse im späten Tertiär remobilisiert wurde, und die Ursache dafür ist, dass Barbados heute den höchsten Punkt des Akkretionsprismas darstellt.

Introduction

Tertiary rocks are exposed below the Pleistocene coral cap of Barbados. Their main outcrop area is known as the Scotland District because of its rugged terrain. A considerable proportion of the southern half of this inlier is occupied by an incompetent, dark coloured, silty clay mass highly impregnated with oil. This constitutes a well defined, mappable unit, the Joes River Formation (Fig. 1). The mechanism by which it was formed is complicated and has evoked a number of different scenarios over the years. One point of disagreement has concerned the fossils found within the formation. Is there an autochthonous element? Are all the fossils allochthonous? It seems important to go back to the original field observations made mainly by Alfred Senn and Hans Kugler and to describe for the first time the megafossils found by them. This is done in the present paper where field relations are discussed and comments are made on the possible origin of the formation.

[1]) Natural History Museum, Augustinergasse 2, CH-4051 Basel.

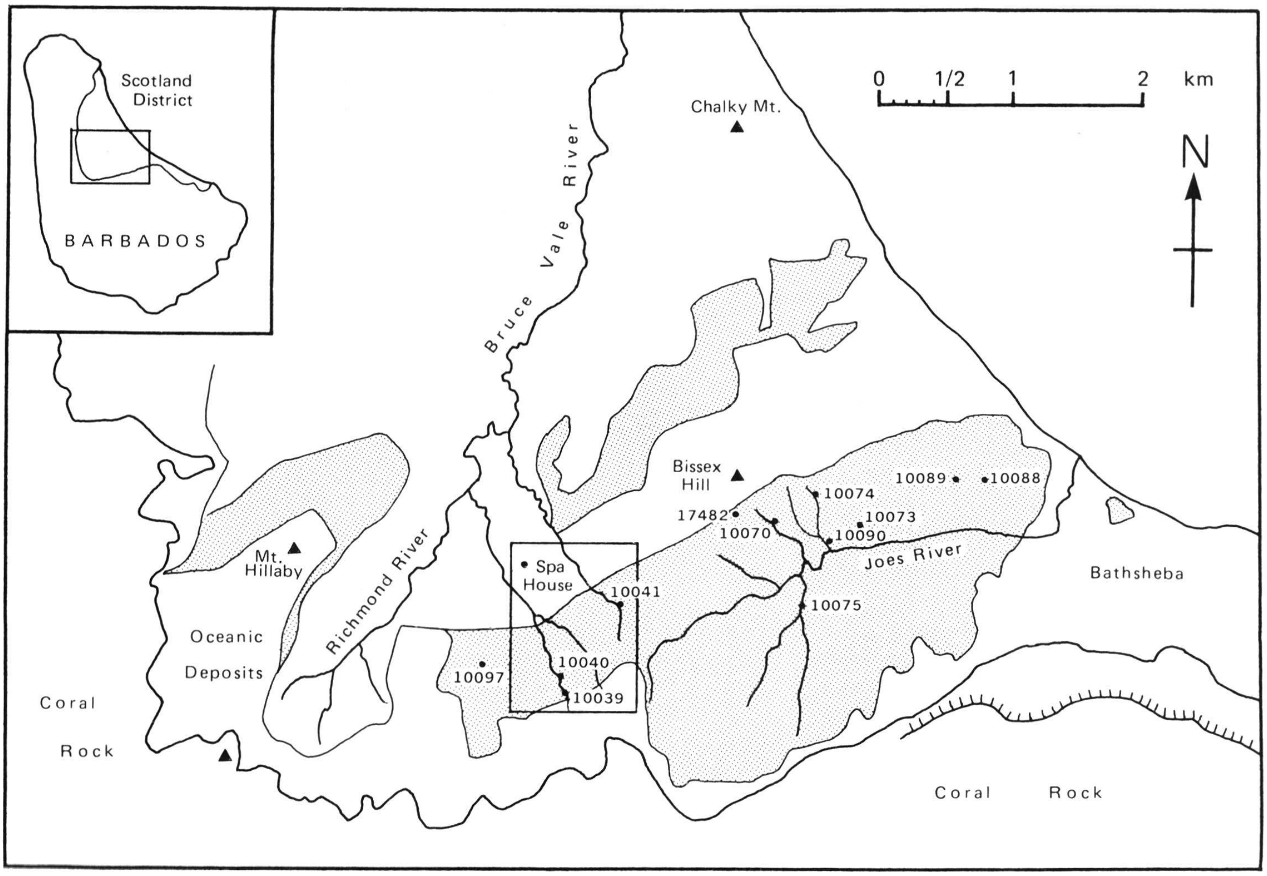

Fig. 1. The southern part of the Scotland District of Barbados showing the outcrop of the Joes River Formation and the position of localities. Outcrop taken from SENN (unpublished map at scale of 1:15,000) and POOLE & BARKER (1983).

References in the literature

The first clear reference to rocks that later came to be called the Joes River Formation is that by HARRISON & JUKES BROWN (1890) who considered this "thick bluish-grey clay containing small quantities of petroleum" as the top unit in their Scotland Rocks and noted that they were particularly prevalent on both sides of the Joes River.

BEEBY THOMPSON (1925) discussed the dead-black, oil soaked clays with sandstone blocks which he called "Joes River clay", a term that he had apparently taken from unpublished reports by A. MENZIES (see DAVIESS 1971). For the first time a mud volcano origin was proposed by BEEBY THOMPSON (1925, p. 396) who said: "From its nature and mode of occurrence there can be little doubt that it represents the debris from vast mud volcanoes, probably submarine, and probably due to the high gas pressure in the St. Andrews beds." The St. Andrews Beds were later taken as the "Lower Scotland Formation" by SENN (1940).

HESS (1938) considered the Joes River breccia to be a submarine landslide formed when the Scotland series were squeezed in the steep-sided, central trough of the developing West Indian tectogene.

It is in SENN (1940, p. 1572–1577) that the main published account of the Joes River beds is to be found and it is here that the occurrence of megafossils is first recorded.

BAADSGAARD, in an unpublished report (1959), noted a distinct gradation with a deeper, more shaley part becoming more silty and sandy upwards. He wrote that great erosion had taken place since SENN recorded distinct bedding and the presence of molluscs in the Spa River and said that he could find no evidence to support the idea of bedding. He did, however, record some crude lineations picked out by slide planes and by the alignment of elongated blocks. With regard to fossils, he stated "they do certainly occur very locally, but in large inclusions in the Joes River rather than as fossils deposited in the unit itself". He illustrated in his report molluscs collected from "a large inclusion of Bruce Vale type silty sandstone near the head of Spa River". Though BAADSGAARD (1959, 1960) acknowledged that the Joes River Unit had some of the characteristics of a mud volcano deposit or an olistostrome, he preferred to consider it as representing a number of mobilized shear zones.

HERRERA & SPENCE (unpublished report, 1964) suggested that the Joes River beds are "a mass of Lower Scotland sediments, mainly Morgan Lewis formation, thrust over the crumpled, concertina-folded Upper Scotland Group". In their stratigraphic table they show the Joes River as of Paleocene age and place it between the Walkers and Morgan Lewis formations. The reason they did not favour a mud volcano origin is that several of their sections (Scott's Gully west of Bissex Hill and Monkey Hill south of Chalky Mount) had considerable undisturbed bedding with sandstone inclusions up to 300 m long and 40 m wide. Much of the confusion in bedding seen today in Joes River outcrops is attributed by them to the present cycle of erosion with its considerable surface slumping. They say that in a few places, at the bottom of deep gullies, bedding is so good that the rocks are indistinguishable from the Morgan Lewis Formation. The problem is whether some of the outcrops are, in fact, Lower Scotland type beds and not Joes River Formation at all.

DAVIESS (1971) observed bedding in the upper part of the Joes River outcrop near the contact with the overlying Oceanic Series. He stated that the only autochthonous fossils known in the unit are present in oil-saturated sands interbedded with pebbly silts and siltstones. He equated these with the *"Leda"* beds of SENN and considered that they represent "reworking under shallow-water marine conditions". His conclusion was that the striking similarity to the argille scagliose of Italy and Sicily means that the Joes River beds represent olistostroma.

POOLE & BARKER (1982) regarded the Joes River Beds as intrusive sediments that are products of the Miocene–Pliocene Andean compression, their age being proved to be post Eocene by their intrusion into Oceanics. They dismiss the megafossils as being allochthonous though here they are only quoting from BAADSGAARD'S report.

PUDSEY & READING (1982) took the view that overpressured, deep water shales rose as mud diapirs locally culminating in extrusion of hydrocarbon-rich mud onto the seafloor. They remarked on the close comparison between the Barbados examples and those described from Trinidad.

New views on the structure and geologic history of Barbados in relation to its position on the accretionary prism in front of the West Indian Volcanic Arc are being provided by the extensive studies of R.C. SPEED and his coworkers (SPEED 1981; SPEED & LARUE 1982). These are relevant to any interpretation that is to be made on the origin of the Joes River Formation. An age overlap between the continentally derived Scotland and Joes River sediments (the terrigenous and debris flow suites of Speed) and the Oceanic sediments (abyssal pelagites of Speed) has now been demonstrated (see, for example, SPEED & LARUE 1982, Fig. 4). Their present juxtaposition (as shown on SPEED 1981, Fig. 3 and 4) is due to later stacking of fault slices on the accretionary prism. SPEED (1981, p. 262) stated "the pioneering geologic study of Barbados (SENN 1940) assumed that stratigraphic continuity exists among rocks of the Scotland district. However, new work indicates that stratigraphic successions cannot be correlated between packets and that age ranges of rocks in at least some of the four suites overlap. Depositional contacts between rocks of different suites are apparently absent except for two occurrences..." "Thus it is apparent that the four suites are not derived from a depositional succession, and some contemporaneous lithotypes may not even have been depositionally contiguous." He continued: "The debris flow (?) suite is predominantly foliated diamictite (melange), an assembly of well-oriented angular blocks of terrigenous sandstone and clay ironstone, soft green mudstone granules, and minor pelagite lenses in a scaly cleaved terrigenous mudstone and muddy turbidite. The age range of deposition of such rocks is unknown. The provisional interpretation of accumulation of debris flow is based on vague stratification by clay clast size and orientation locally within the diamictite and by the inclusion of thin-bedded muddy rocks and mud clasts which may have been slope deposits. The strong lithic affiliation of the rock clasts to rocks of the terrigenous suite suggests the latter suite underlaid the slope that supplied the debris flows." His interpretation is that the Joes River beds represent a debris flow that moved downslope on the paleo-seafloor in a lower slope basin and this situation is illustrated by him in a schematic cross section of the accretionary prism (SPEED 1981, Fig. 6).

In the present paper we continue to use the term "formation" for the Joes River sediments as they represent a clearly mappable unit in the field.

The field relations in the Spa area

Spa River West Branch (Fig. 2)

As recorded by SENN (1940, p. 1573), the first megafossils in a bedded series within the Joes River Formation were found by H. G. Kugler when they were together in the Spa River in 1939. The following notes made by both geologists at the time give the field relations of the fossils. The original sketch has been incorporated into Figure 2. The photograph of Figure 3 shows the deeply eroded gullies of the Spa, Cane Garden and Richmond rivers.

Senn 362 (also recorded as K 4371) was situated on the steep slope of a minor divide between two tributaries of the west branch of the Spa River. The matrix was of shaley silt with green clay pebbles. Joints were full of inspissated oil and the rock as a whole smelt strongly of oil. Scattered bivalves, many of them broken, were thought to belong to the genus *"Leda"*. This form is herein described as *Nuculana senni* JUNG n.sp. with Senn 362 (NMB 10039) as its type locality. Lenses of claystone with *"Thyasira"* were also recorded and the remark made by H. G. Kugler: "for the first time clearly defined as being equivalent in age to mudflow".

At *Senn 363* (= K 4372) lenticular lenses of silty clay with bivalves were recorded together with a 1.8 m thick layer of tar sand the top of which was rich in *Leda* and other molluscs. A dip of 45° was given by SENN.

Senn 388 and *Senn 389* are recorded as pebbly silts particularly rich in green clay pebbles and small clasts. Grains of manjak and small agglutinated Foraminifera are noted.

SENN's summary of the Spa River localities (1940, p. 1573) was as follows: "The fossils, among which a large long-tailed *Leda* is most common, occur in layers of tar sand, as well as in the pebbly silts and in lenses of gray knobbly marlstone containing free oil. The fossiliferous zone in the western branch of the Spa River is about 60 meters thick, beginning at about 300 meters above the base of the Joes River beds and overlain by about 90 meters of non-fossiliferous pebbly silts." The total thickness of the Spa River section was thus considered by SENN to be in the order of 450 m.

Cane Garden River (Fig. 2)

Senn 364 is recorded as pebbly silt with green clay pebbles, brown claystone and marlstone, manjak pebbles and oil sand in layers and blocks. Shell fragments rather rare. Senn noted one block of Chalky Mount Grit with oysters.

JS 1616 sampled in 1964 is recorded as a silt heavily impregnated with oil and with a light paraffinic smell. Angular fragments of light green silt and of dark brown sandstone. Many small, slickensided surfaces between grains. The agglutinated assemblage is illustrated on Plate 1.

JS 1617 is a 3 m block of friable, poorly sorted brown sandstone. Such blocks could have broken down rather easily to form bedded sand layers if exposed to erosion.

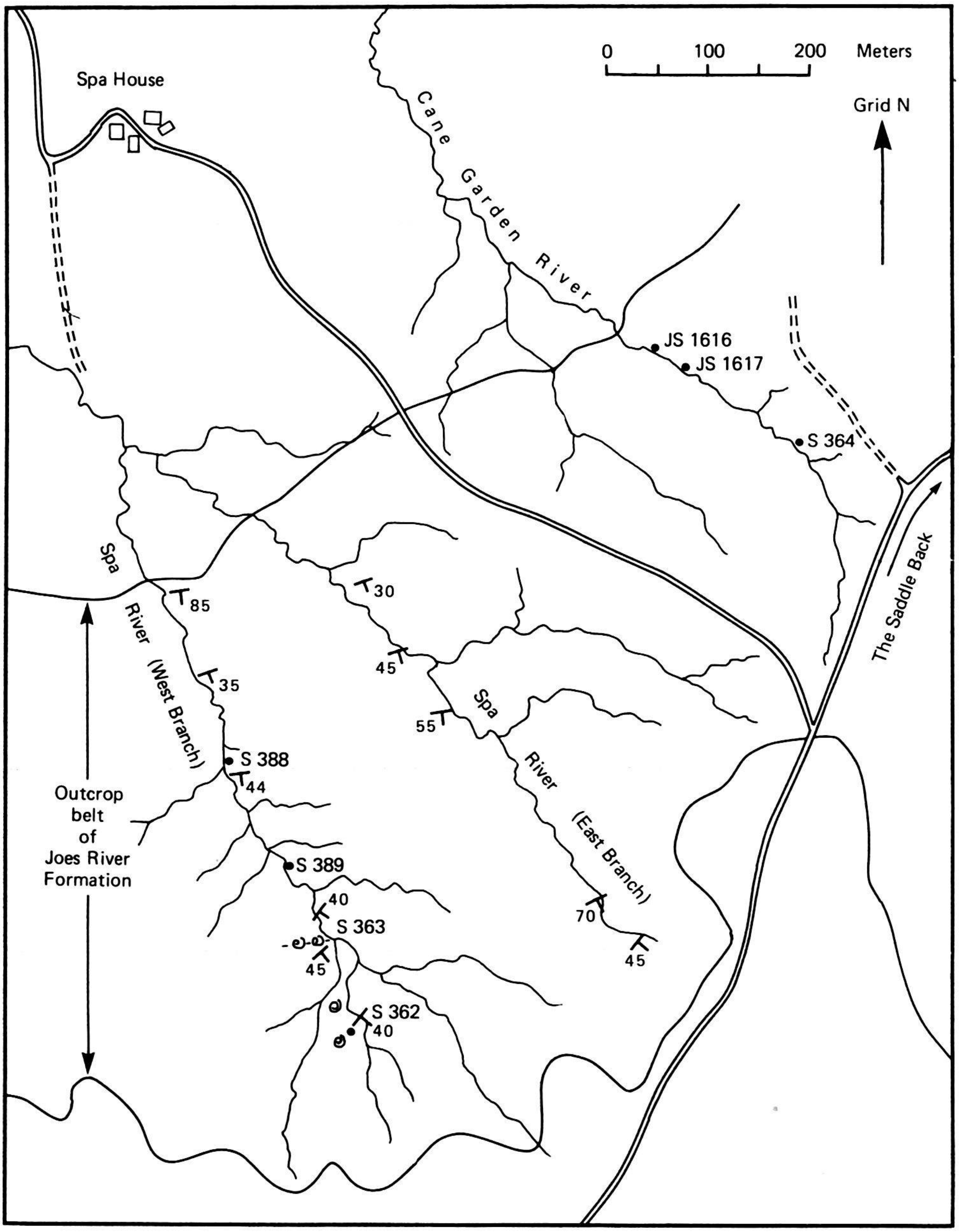

Fig. 2. Detailed map of Spa and Richmond area (position given on Fig. 1). Shows field samples with particular reference to position of molluscan assemblages collected in 1939.

Richmond River (Fig. 1)

Senn 1147 is recorded as pebbly silts with tar sand blocks and with a layer of bedded pebbly silt dipping 35° SE. *Leda* is noted.

A number of Kugler localities exist in the Richmond River close to Senn 1147 but are not exactly plotted on the original maps. They are included here for the additional information that they give on the presence of a bedded series.

K 4373 has a sketch in the fieldbook showing mudflow with blocks followed upwards by a thin oil sand, a thicker slickensided mudflow with pebbles, a thin marlstone with fossils *(Thyasira)* and a thick mudflow interval with angular and subangular blocks.

K 4374 is a block 4 × 3 × 3 ft of yellow weathering sandy mudstone with large bivalves, ?*Melania* and other gastropods. The rock was noted as being different from the *Thyasira* marlstone of K 4373.

K 4375–K 4377. Large blocks of oil sand in mudflow. Bivalves *(Leda)* common in clay breccia. Shells always broken into many pieces which have usually become disarticulated; infilled with oil sand with pieces of clay. Lenses of Chalky Mount Grit with characteristic blue quartz grains. Manjak veins. Agglutinated Foraminifera noted.

Foraminiferal assemblages

Plate 1 illustrates Foraminifera from two Joes River Formation samples. Both assemblages consist of agglutinated forms and, like the macrofossil assemblages, are oligotypic.

Plate 1, Figures 1–12, illustrate the assemblage from JS 1616 (NMB 17484). This sample from Cane Garden River is plotted on Figure 2 and referred to in SAUNDERS (1968, field trip guide, Stop 15).

Plate 1, Figures 13–18, are from JS 3230 (NMB 17485), a sample from the bank of the Joes River north of Mellows; it is plotted on Figure 1.

No attempt has been made to assign species names to these forms and even the generic designations given in the figure captions are sometimes uncertain.

Agglutinated foraminiferal faunas are widespread in the Joes River Formation but they are usually exceedingly poor.

In Barbados, agglutinated faunas occur relatively frequently in the shale/sandstone sequences of the Scotland Group. Extensive sampling has been carried out particularly in the thicker shales in what SENN (1940) called the Walkers and Morgan Lewis beds of his Lower Scotland Formation (St. Andrews beds). More than 30 localities have produced relatively rich agglutinated foraminiferal faunas. The assemblages are very similar to those found in the Joes River but are more diverse. There is a strong dominance of *Bathysiphon* with subordinate *Trochammina, Glomospira, Bolivinopsis, Hormosina* and rare limonitic casts of *Chilostomella.* It is still uncertain whether the almost total lack of a calcareous component to the fauna is an original feature or is due to later leaching. Similar problems are known from widespread localities around the world where flysch-type faunas are found. In Trinidad similar assemblages are known from the Chaudiere Formation (Paleocene), Pointe-à-Pierre Formation (Eocene), Nariva

Formation (Oligo-Miocene), Cipero Formation (Miocene) and Cruse Formation (Miocene–Pliocene). We favour the interpretation that the agglutinated faunas in many instances contained almost no calcareous forms from the beginning and were the result of the particular bottom water and sediment conditions.

The Joes River faunas cannot be reliably distinguished from the Scotland faunas. The only exception is that of JS 1616 (NMB 17484) where the walls of most specimens are constructed of particularly coarse grains and where unusual branching forms of *?Dendrophyra* are found. Those illustrated on Plate 1, Figures 6 and 7, are most similar to forms described as *Dendrophyra excelsa* Grzybowski from flysch deposits of Late Cretaceous and Eocene age in the Carpathians.

Molluscan assemblages

The Joes River Formation has yielded an oligotypic molluscan assemblage of ten different forms. The following 7 bivalves and 3 gastropods are recognized:

Nuculana (Nuculana) senni Jung n.sp.
Lucinid indet.
Large lucinid?
Venerid indet.
Tellinid indet.
Bivalve 1
Bivalve 2
Calliotropis sp.
Cerithid indet.
Diastoma sp.

As can be seen, identification has been possible only to the family level in several cases. Two bivalves cannot be identified at all, but are prominent enough to be listed and figured here. All the fossils are oil impregnated and their state of preservation is poor. Their occurrence as fragments adds to the difficulty of their identification.

Despite these circumstances it seems worthwhile reporting on this faunule. On the one hand marine Mollusca in the Joes River Formation have been mentioned (but never described) decades ago (Senn 1940, p. 1573), on the other hand Poole & Barker (1982, p. 649) say that "it is evident that these fossils occur in erratic blocks of Scotland rocks", and therefore deny the presence of autochthonous fossils in the Joes River Formation.

It seems likely that the faunule is of Eocene age. Affinities to related species are given in the comments to each form. However, a more precise age determination is not possible with the material at hand.

The Joes River assemblage probably lived in shallow water. The only species that might suggest a deeper water environment is *Calliotropis* sp. According to the depth information given for 5 species of *Calliotropis* (Quinn 1979, p. 7–15) the range is from 18 m to 1863 m. Quinn specifies that most specimens were taken in depths of several hundred meters.

The assemblages at individual localities are as follows:

10039: *Nuculana senni* n.sp.
Venerid indet.
Bivalve 1
Bivalve 2
Cerithid indet.
Diastoma sp.

10040: Numerous fragments of unidentifiable bivalves

10041: *Nuculana senni* n.sp.

10070: *Nuculana senni* n.sp.
Bivalve 2
Calliotropis sp.
Cerithid indet.

10073: *Nuculana senni* n.sp.
Fragments of bivalves

10074: *Nuculana senni* n.sp.
Venerid indet.
Lucinid indet.
Large lucinid?
Tellinid indet.
Cerithid indet.

10075: *Nuculana senni* n.sp.
Bivalve 2

10088: *Nuculana senni* n.sp.

10089: *Nuculana*?

10090: Cerithid indet.

10097: *Nuculana*?

17482: *Nuculana senni* n.sp.

Localities

The Natural History Museum Basel (NMB) localities plotted in Text Figures 1 and 2 are the following (S stands for A. Senn, K for H.G. Kugler, and JS for J.B. Saunders):

10039 = S 362 = K 4371: western branch of Spa River.
10040 = S 363: western branch of Spa River.
10041 = S 364: head waters of Cane Garden River.
10070 = S 737: in branches of river south of Bissex Hill.
10073 = S 759: easternmost ravine on south slope of Bissex Hill.
10074 = S 760: south slope of Bissex Hill; uppermost part of western ravine.
10075 = S 762: ravine south of Mellow ridge.
10088 = S 1039: railway line to Joes River bridge; mudflow ravine.
10089 = S 1049: slope southwest of Cattlewash.
10090 = S 1060: north side of Joes River Valley.
10097 = S 1147: eastern branch of Richmond River.
17482 = JS 4259: near Bissex Hill.

Molluscan fauna

Nuculana (Nuculana) senni Jung n.sp.

Pl. 2, Fig. 1–8; Pl. 3, Fig. 1–6; Pl. 4, Fig. 1–3

Description. – Shell large. Beaks subcentral. Anterior margin evenly rounded, posterior margin somewhat pointed. Mid ventral area of shell somewhat concave. Escutcheon distinct. Lunule smaller and less well defined than escutcheon. Posterior row of teeth longer than anterior row. Surface of shell disc sculptured by accentuated, concentric growth lines.

Holotype. – NMB No. G 16972.

Dimensions of holotype. – Length 45.1 mm (incomplete), height 24.8 mm, convexity 14.4 mm.

Type locality. – NMB locality 10039: western branch of Spa River. Joes River Formation.

Remarks. – This is an unusually large species of *Nuculana* which had already been recorded by Senn (1940, p. 1573) under the name of *Leda*. It is the most common species of the oligotypic fauna from the Joes River Formation, but none of the specimens is complete. In addition all the specimens are double-valved, and therefore the hinge cannot be studied properly. There are only a few fragments showing small parts of the hinge (Pl. 3, Fig. 4).

No other species of *Nuculana* reaches the dimensions of *N. senni*. It is therefore not possible to make comparisons with known species of *Nuculana*. There is one exception, however: the Chalky Mount beds of the Scotland Formation have yielded a number of specimens of a large species of *Nuculana*. It had been briefly described and poorly figured by Trechmann (1925, p. 500, Pl. 23, Fig. 35) as *Leda* sp. Although rolled, those specimens are quite well preserved, but there are no complete valves. It is not impossible that they represent *N. senni*, although they do not attain the size of the material from the Joes River Formation.

Replying to a request for paleoenvironmental implications of such a large *Nuculana* Dr. John A. Allen of the University Marine Biological Station Millport, Isle of Cumbrae, Scotland, made the following comments in a letter dated 4 February 1983: "... I find that the shallow concave outline of the mid ventral margin is interesting. I expect that it is related to the size of the animals and to the large anteriorly directed foot and to the development of a posterior siphon and a specialized feeding area at the posterior mantle margin ventral to the siphon. One would assume then that this is a vertically oriented animal buried in the sediment but feeding on the surface deposits and capable of active burrowing. It is true that in most deep waters Recent nuculanids dominate the fauna, but they are small (< 1 cm) and there is a high diversity of species. I think that it is very likely that this species lived in eutrophic and/or possibly anoxic muds, because of the problem of low diversity. I would expect that you might find lucinids (thyasirids?) in the same assemblage."

Occurrence. – NMB localities 10039, 10041, 10070, 10073, 10074, 10075, 10088, 17482.

Distribution. – So far *N. senni* is known only from the Joes River Formation of Barbados.

Venerid indet.

Pl. 3, Fig. 7; Pl. 4, Fig. 4–7

Remarks. – Only a few fragmentary specimens of this form are available. The shells are sculptured concentrically and must have reached a considerable size. One fragment shows part of the left hinge (Pl. 4, Fig. 5). The lunule is deeply sunken.

Whether this form should be compared with what TRECHMANN (1925, p. 502, Pl. 23, Fig. 2) reported as *Dosinia* sp. from the Chalky Mount beds of the Scotland Formation, is uncertain.

Occurrence. – NMB localities 10039 and 10074.

Lucinid indet.

Pl. 5, Fig. 5–7

Remarks. – There is a single, double-valved specimen with subcentral beaks and fine concentric sculpture. Its lunule is deeply sunken. The shell itself is thin.

TRECHMANN (1925, p. 500, Pl. 22, Fig. 13) recorded a similar form from the Chalky Mount beds of the Scotland Formation under the name *Cyrenoida*(?) sp. The specimen he figured has about the same dimensions as that figured here.

Occurrence. – NMB locality 10074.

Large lucinid?

Pl. 5, Fig. 1–2; Pl. 7, Fig. 1–2

Remarks. – This is a thick-shelled form, which is represented by numerous fragments. The shell must have attained considerable dimensions. The hinge is not known. The sculpture consists of coarse, concentric lines. On the inner side of the ventral margin there are coarse radial ridges or sometimes pustules, which extend from the pallial line upwards for a short distance.

This latter characteristic can be observed indistinctly in large lucinids from the Eocene of the Island of St. Bartholomew as well. A similar feature can be seen in *Lucina pandata* from the middle Eocene Claiborne Group of Alabama as described and figured by HARRIS (1919, p. 121, Pl. 39, Fig. 6, 7). *L. pandata* CONRAD has been referred to *Miltha (Eomiltha)* by BRETSKY (1976, p. 290, Pl. 33, Fig. 4–7).

Under the name of *Cyrena* spp. TRECHMANN (1925, p. 500, Pl. 22, Fig. 14) reported on the occurrence of a large bivalve in the Chalky Mount beds of the Scotland Formation. Whether this form is the same as that from the Joes River Formation cannot be determined at the moment.

Occurrence. – NMB localities 10039 and 10074.

Tellinid indet.

Pl. 6, Fig. 3

Remarks. – A single crushed, double-valved specimen is available. Its hinge is not visible. The sculpture of the shell consists of rather fine, concentric lines. Due to the bad state of preservation it is not possible to point out affinities.

Occurrence. – NMB locality 10074.

Bivalve 1

Pl. 5, Fig. 3–4

Remarks. – A single thick-shelled fragment with fine, concentric sculpture is available. Although its affinities cannot be determined, it is figured here for the sake of completeness.

Occurrence. – NMB locality 10039.

Bivalve 2

Pl. 6, Fig. 1–2, 4–7

Remarks. – This is an extremely thick-shelled bivalve with inconspicuous concentric sculpture. The hinge is too incomplete to be described. A shallow depression running from just below the beaks in a posteroventral direction seems to be a characteristic feature, although deformation during the life of the animal cannot be excluded.

The collections from the Chalky Mount beds of the Scotland Formation in the Basel Natural History Museum contain a few fragments of apparently the same bivalve. Although rolled those specimens show a somewhat more pronounced concentric sculpture. They had not been recorded by TRECHMANN (1925).

Occurrence. – NMB localities 10039, 10070, 10075.

Calliotropis sp.

Pl. 7, Fig. 3–5

Description. – Shell small. Protoconch not preserved. Preserved whorls almost 3½. Sculpture consists of a regular, cancellate pattern. There are 3 narrow spirals on late whorls, which are crossed by regularly spaced, prosocline axials. At the intersections there are small knobs. The axials do not continue below the periphery. Base sculptured by 3 spirals. Nature of umbilicus concealed by matrix.

Remarks. – The above description is based on a single specimen. Recently QUINN (1979) has redescribed several species of *Calliotropis* occurring mostly in deep water of the Straits of Florida. The specimen from the Joes River Formation is larger than these species, and its sculpture differs at the specific level.

Occurrence. – NMB locality 10070.

Cerithid indet.

Pl. 7, Fig. 6–8

Description. – Of medium size, moderately slender. Protoconch not preserved. Preserved whorls up to 4. Profile of whorls straight to slightly convex. Sculpture consists of prominent, opisthocline axials, which may become slightly sigmoid and inconspicuous on late whorls. Base sculptured by a few spirals.

Remarks. – This form is represented by a number of poorly preserved fragments. The type of sculpture is reminiscent of two species described from the Eocene of Peru: *Faunus* (?) *lagunitensis* WOODS (1922, p. 86, Pl. 10, Fig. 4–6) and *Cerithium iddingsi* OLSSON (1928, p. 68, Pl. 15, Fig. 4). However, this comparison remains unsatisfactory.

Occurrence. – NMB localities 10039, 10070, 10074, 10090.

Diastoma sp.

Pl. 7, Fig. 9–10

Description. – Shell small. Profile of whorls somewhat convex. There are 14 prominent, opisthocline axials per whorl; their interspaces and the slopes of the axials are sculptured by fine spirals. Base sculptured by several spirals.

Remarks. – The only available specimen consists of two whorls. From the Eocene of Peru a similar species has been described as *D. americanum* Woods (1922, p. 92, Pl. 12, Fig. 1, 2). The sculptural details are practically identical, but the specimen from the Joes River Formation is too incomplete for positive identification.

Occurrence. – NMB locality 10039.

Notes on the faunas of the Joes River Formation

Heavy erosion of the unstable gullies in the Spa and Richmond areas (Fig. 3) has caused marked deterioration in the Joes River Formation outcrops over the years and,

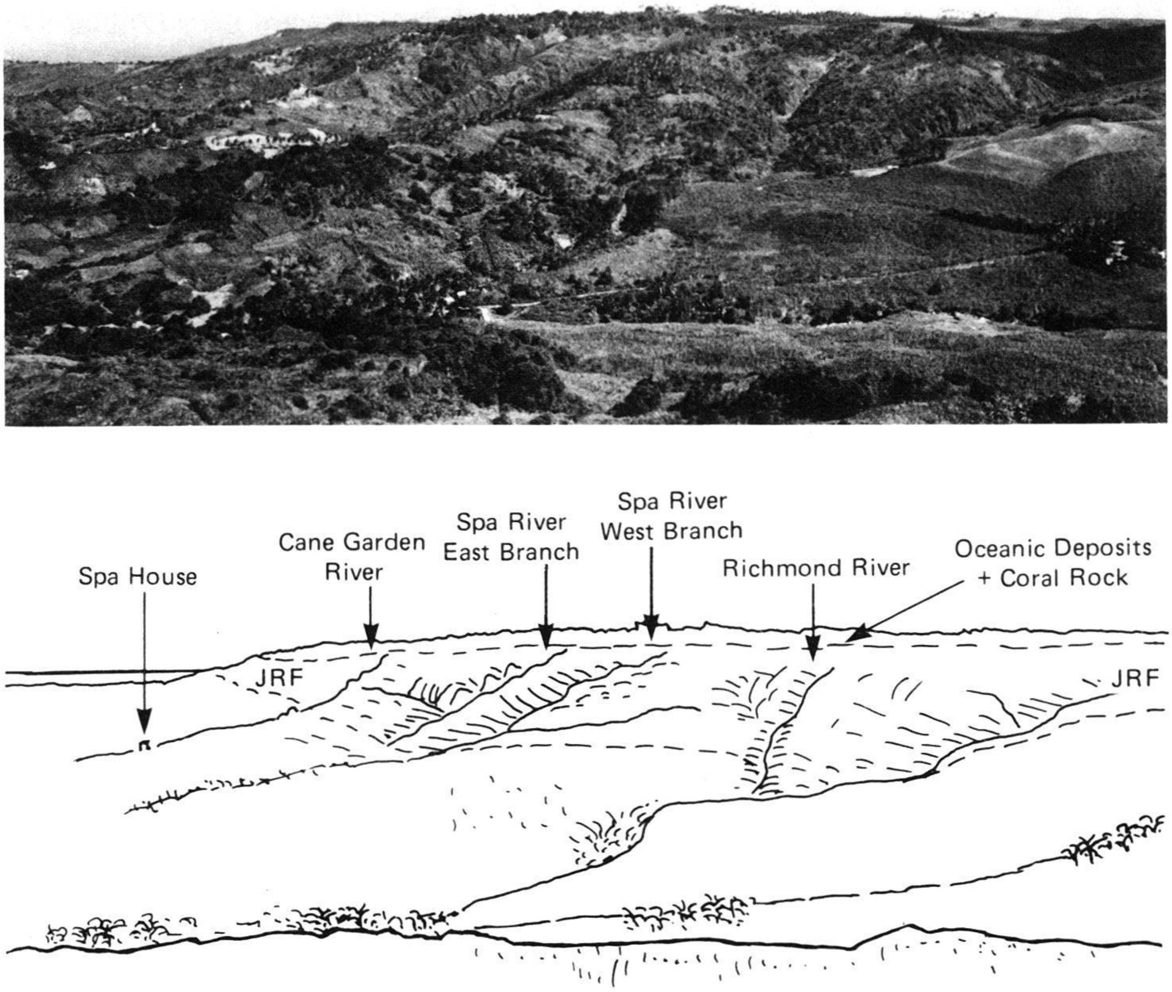

Fig. 3. Photograph of deep gullying in the Spa and Richmond area. JRF = outcrop of Joes River Formation.

for this reason, the foregoing descriptions of field relations as seen particularly by A. Senn and H. G. Kugler have been given in considerable detail.

The analysis of the molluscan assemblages has demonstrated an oligotypic fauna with a new species of *Nuculana* being particularly prevalent. Study of the original field books shows that, without doubt, a large number of shells occurred as autochthonous fauna in bedded, pebbly silts and in sand layers. Some shells are found today in indurated marlstone and mudstone masses though evidence suggests that these are of secondary origin.

The molluscan occurrences south of Bissex Hill are less easy to relate to the formation as they were all loose surface finds embedded in selectively harder masses. However, wherever matrix has remained attached or within the fossils we have examined this closely and find that in a number of instances it is a pebbly silt with green clay pellets and with scattered large quartz grains; the whole being indistinguishable from the Joes River Formation lithology and unlike that known from the Scotland Group. As a number of these instances are of Nuculanas that have both valves still articulated it would be virtually impossible for them to have been reworked empty and filled with later matrix. Such examples have been found in localities NMB 10039 and 10040 from Spa and NMB 10070 and 10074 from south of Bissex Hill. Thus we judge the Nuculanas, at least, to be certainly autochthonous.

The matrix within the small gastropods is harder to relate to formations being either siltstone, often with scattered large quartz grains and with manjak filling any open spaces, or packed quartz grains. An allochthonous origin for these shells cannot be discounted.

The evidence provided by the agglutinated Foraminifera is less clear. As we consider the Joes River sediments to have been derived in the first instance by mobilization of clays of Walkers and Morgan Lewis type, and as these are known to have carried similar faunas, these could have been allochthonously introduced along with the matrix and much of the fauna is most likely to have been derived this way. Species identical to those found in NMB 17484 have not been found so far in Scotland sediments. It is a rather strange, oligotypic assemblage suggesting unusual bottom conditions and, as it is found at an equivalent level to those carrying autochthonous molluscs, there is a possibility that the foraminiferal fauna is also autochthonous.

As regards the age of the macrofossils, the closest correspondence is with the Scotland faunas, mainly from Senn's Chalky Mount beds. Although these have also been introduced into the deep-water environments in which they are now found, such introduction is thought to have been penecontemporaneous and the fauna of Eocene age. Some comparisons can also be made with Eocene faunas from elsewhere in North and South America and the Caribbean. However, it must be borne in mind that the fauna appears to be a specialized one, perhaps requiring an unusual environment for its existence. The paucity of examples at other stratigraphic levels (for instance, the Oligocene) might reflect this fact rather than a restriction in age of the Joes River macrofauna.

Comparison can be made between the agglutinated foraminiferal fauna and Barbados examples that are at present considered to be of Paleocene or Eocene age but, as pointed out above, such faunas are known in flysch-type assemblages through a wide time range from at least Paleocene to Pliocene.

The origin of the Joes River Formation

We have always agreed with SENN (1940) that the close comparison of the Joes River Formation with diapiric silty clays associated with mud volcanoes that we have had the opportunity to study in Trinidad is so close as to suggest a similar origin (KUGLER 1961; SAUNDERS 1968; HIGGINS & SAUNDERS 1974). It is our opinion that the formation represents mobilized clays of Scotland type and that the latter now occur as wedges of Paleocene to Eocene age incorporated in an accretionary prism that owes its existence to the collision between the Atlantic and Caribbean plates. Studies carried out in recent years on the Barbados Ridge and on the geology of Barbados itself are crucial to the understanding of the overall picture (SPEED 1981; BIJU-DUVAL et al. 1982; WESTBROOK 1982; SPEED & LARUE 1982).

We believe that the muds and sands of the Lower Scotland series (part of Speed's terrigenous suite) were deposited rapidly and in pulses on the distal part of a deep-sea fan (SAUNDERS 1980; PUDSEY & READING 1982).

During the later part of the Eocene the fan deposits began to be piled as slices on the growing accretionary prism. Original entrapment of water and organic matter (later to be converted to hydrocarbons) due to fast deposition and burial caused the Lower Scotland muds to become overpressured in the accretionary prism and a combination of tectonic force and fluid and gas pressure mobilized the clays which formed a diapiric mass containing entrained blocks of the interbedded sandstones. Breakthrough to the paleo-seafloor took place and, due to the presence of gas, submarine mud volcanoes would almost certainly have resulted. Such recent and fossil diapiric movements have been documented in Trinidad (KUGLER 1933; HIGGINS & SAUNDERS 1967, 1974) while diapirs surmounted by mud volcanic cones active today have almost certainly been found on submarine parts of the Barbados Ridge (BIJU-DUVAL et al. 1982). The Joes River sediments at surface are still heavily impregnated with both light paraffinic oil and heavy, inspissated oil. In addition, manjak[2]) occurs as veins, as fillings in pore spaces such as the chambers of fossils and as pebbles and grains. The presence of discrete grains must mean that some manjak was hard enough to be broken and rolled during movement of the sediment mass.

We suggest that the mobilized mass broke out on the paleo-seafloor and that its surface was repeatedly winnowed by current action. The effect of winnowing and erosion of the soft matrix of a mud volcanic extrusion at sea level have been rather fully documented by HIGGINS & SAUNDERS (1967) for the Chatham Mud Island that made a sudden appearance in August 1964 off the south coast of Trinidad. The mud, which was highly charged with gas, broke up exceedingly rapidly and as a result of wave action and longshore currents, soon produced a plume of fine sediment extending for some miles to the west (HIGGINS & SAUNDERS 1967, Fig. 3, 4). The beaches of the island showed selective retention of the coarser sand and also of numerous sandstone boulders that had come up in the matrix. The fact that continuity of a single lithologic unit could, in some cases, remain during movement of the diapiric mass was demonstrated by the presence on the island of two parallel bands of white sand and friable sandstone (HIGGINS & SAUNDERS 1967, Fig. 13).

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[2]) A variety of solid bitumen or glance pitch with a brilliant conchoidal fracture.

Mud diapirs in considerable numbers have now been mapped on reflection seismic profiles east of Trinidad in all water depths from 100 m to 3000 m (CASE & HOLCOMBE 1980). Many of these can be seen to have broken through to the present sea bed.

There is no evidence requiring that the Joes River diapir came above sea level. However, relatively shallow water is suggested by the Nuculanas. The agglutinated foraminiferal faunas should be deeper but may be allochthonous. Even if the seafloor was well below wave base, the heterogeneous mud matrix and some of the more friable sandstone inclusions could have been subject to considerable sorting by deep current action.

The timing of events in the geologic history of the accretionary prism of which the Barbados Ridge forms a part is still under discussion in the light of new structural and stratigraphic results. It is now known that a simple succession as suggested by SENN and accepted by many of us with modifications cannot be maintained. For example, there is very considerable time overlap between the deep-sea oozes (Oceanic Formation of SENN and pelagic and hemipelagic suites of SPEED) and terrigenously derived sediments (Scotland Formation of SENN and terrigenous suite of SPEED: see, for example, SPEED 1981, Table p. 261). Their present day close structural relationship would be difficult to understand without the concept of slices of sediment being stacked during the development of the accretionary prism at the convergent boundary between the Atlantic and Caribbean plates.

Summary of possible sequence of events:

1. Formation of deep-sea fans of terrigenous material derived from northern South America. Paleocene and Eocene.
2. Incorporation of fan sediments into the accretionary prism during the Eocene.
3. Mobilization of some overpressured beds in the prism with diapiric movement, breakthrough to the paleo-seafloor and possible release of gas and fluids as mud volcanic manifestations. If the eruption took place on a slope, then debris flow and slumping would have resulted. ?Latest Eocene.
4. Incorporation of contemporaneous pelagic deposits (deep-sea oozes) into the structure of the prism. These beds may have been laid down in forearc basins. Some incorporation took place as late as the Middle Miocene (for example, Bissex Hill Nappe of SPEED & LARUE 1982).
5. Later mobilization of the diapiric beds seems very likely as such masses remain incompetent at least until all lubricating fluids have been expelled; a situation that still has not happened for the Joes River Formation. Injection of mudflow into the Oceanic Nappe that now lies above Joes River rocks would have been one result. Late movements of the incompetent mass might explain why Barbados is the highest point in the accretionary prism today.

Acknowledgments

The authors would like to thank Wolfgang Suter and Edith Müller-Merz for the photographs of fossils and Urs Marrer for preparation of the figures and plates.

REFERENCES

BAADSGAARD, P. H. (1959): Barbados Geological Review and Evaluation. – Unpubl. Rep. Gulf Oil Company.

— (1960): Barbados, W. I.: Exploration results 1950–1958. – Rep. 21st Sess. int. geol. Congr., Norden (Copenhagen), p. 21–27.

BEEBY-THOMPSON, A. (1925): Oil-Field Exploration and Development (vol. 1–2, p. 394–399). – Crosby Lockwood & Son, London.

BIJU-DUVAL, B., LE QUELLEC, P., MASCLE, A., RENARD, V., & VALÉRY, P. (1982): Multibeam Bathymetric Survey and High Resolution Seismic Investigations on the Barbados Ridge Complex (Eastern Caribbean): A Key to the Knowledge and Interpretation of an Accretionary Wedge. – Tectonophysics *86*, 275–304.

BRETSKY, S. S. (1976): Evolution and classification of the Lucinidae (Mollusca: Bivalvia). – Palaeontographica amer. *8*/50, 215–337.

CASE, J. E., & HOLCOMBE, T. L. (1980): Geologic-Tectonic Map of the Caribbean Region. – Misc. Invest. Ser. U. S. geol. Surv., Map I-1100.

DAVIESS, S. N. (1971): Barbados: A Major Submarine Gravity Slide. – Bull. geol. Soc. Amer. *82*/9, 2593–2601.

HARRIS, G. D. (1919): Pelecypoda of the St. Maurice and Claiborne Stages. – Bull. amer. Paleont. *6*/31, 1–268.

HARRISON, J. B., & JUKES-BROWN, A. J. (1890): The geology of Barbados. – Bennett Brothers, Salisbury, England.

HERRERA, R. C., & SPENCE, J. (1964): The Geology and Oil Prospects of the Scotland Group Sediments of Barbados. – Unpubl. Rep. Sinclair and B. P. Explorations Ltd.

HESS, H. H. (1938): Gravity Anomalies and Island Arc structure with particular reference to the West Indies. – Proc. amer. phil. Soc. *79*/1, 71–96.

HIGGINS, G. E., & SAUNDERS, J. B. (1967): Report on 1964 Chatham Mud Island, Erin Bay, Trinidad, West Indies. – Bull. amer. Assoc. Petroleum Geol. *51*/1, 55–64.

— (1974): Mud Volcanoes – their Nature and Origin. – Verh. natf. Ges. Basel *84*/1, 101–152.

KUGLER, H. G. (1933): Contribution to the knowledge of sedimentary volcanism in Trinidad. – J. Inst. Petroleum Technol. Trinidad *19*/119, 743–760.

— (1961): Tertiary of Barbados, W. I. – Geol. Mag. *98*/4, 348–350.

OLSSON, A. A. (1928): Contributions to the Tertiary Paleontology of Northern Peru: Part I, Eocene Mollusca and Brachiopoda. – Bull. amer. Paleont. *14*/52, 1–154.

POOLE, E. G., & BARKER, L. H. (1982): The geology of the Scotland District of Barbados. – Trans. 9th Carib. geol. Conf. Santo Domingo, Dominican Repub. (1980) *2*, 641–656. This was published in late 1982, although it is dated as 1980.

— (1983): Geology of Barbados, map at scale of 1:50,000. – Directorate Overseas Surv. Gov. U. K.

PUDSEY, C. J., & READING, H. G. (1982): Sedimentology and structure of the Scotland Group, Barbados. In: LEGGETT, J. K. (Ed.): Trench-Forearc Geology. – Spec. Publ. geol. Soc. London *10*, 291–308.

QUINN, J. F. (1979): Biological results of the University of Miami deep-sea expeditions. 130. The systematics and zoogeography of the gastropod family Trochidae collected in the Straits of Florida and its approaches. – Malacologia *19*/1, 1–62.

SAUNDERS, J. B. (1968): Field Trip Guide: Barbados. – Trans. 4th Carib. geol. Conf. (1965), p. 443–449.

— (1980): The development of the Caribbean with special reference to the Southern margin and the Venezuela basin. – Mém. Bur. Rech. géol. min. *115*, 237–243.

SENN, A. (1940): Paleogene of Barbados and its bearing on history and structure of Antillean–Caribbean region. – Bull. amer. Assoc. Petroleum Geol. *24*/9, 1548–1610.

SPEED, R. C. (1981): Geology of Barbados: implications for an accretionary origin. – Oceanologica Acta, Suppl. *4*, 259–265.

SPEED, R. C., & LARUE, D. K. (1982): Barbados: Architecture and implications for accretion. – J. geophys. Res. *87*/35, 3633–3643.

TRECHMANN, C. T. (1925): The Scotland beds of Barbados. – Geol. Mag. *62*/737, 481–504.

WESTBROOK, G. K. (1982): The Barbados Ridge Complex: tectonics of a mature forearc system. In: LEGGETT, J. K. (Ed.): Trench-Forearc Geology. – Spec. Publ. geol. Soc. London *10*, 275–290.

WOODS, H. (1922): Mollusca from the Eocene and Miocene deposits of Peru. In: BOSWORTH, T. O.: Geology and palaeontology in the north-west part of Peru (p. 51–113). – Macmillan, London.

Plate 1

All figures ×30 except where indicated.

Assemblage from JS 1616 (NMB Locality 17484), Cane Garden River.

Fig. 1–2	?*Dendrophyra* sp. NMB No. C 35894. Two views. Open tube divides into four.
Fig. 3	?*Dendrophyra* sp. NMB No. C 35895. Open tube dividing into three.
Fig. 4	?*Dendrophyra* sp. NMB No. C 35896. Open tube dividing into two.
Fig. 5	?*Dendrophyra* sp. or ?*Bathysiphon* sp. NMB No. C 35897.
Fig. 6	?*Dendrophyra* sp. NMB No. C 35898.
Fig. 7	?*Dendrophyra* sp. NMB No. C 35899.
Fig. 8	?*Dendrophyra* sp. or ?*Bathysiphon* sp. NMB No. C 35900.
Fig. 9	*Bathysiphon* sp. NMB No. C 35901.
Fig. 10	?*Trochamminoides* sp. NMB No. C 35902. Flattened specimen. ×48.
Fig. 11	*Glomospira* sp. NMB No. C 35903.
Fig. 12	?*Haplophragmoides* sp. NMB No. C 35904. Very small, flattened specimen. ×96.

Assemblage from JS 3230 (NMB Locality 17485), Joes River.

Fig. 13	*Bathysiphon* sp. NMB No. C 35905.
Fig. 14	*Bathysiphon* sp. NMB No. C 35906.
Fig. 15–16	*Bathysiphon* sp. NMB No. C 35907. A thick-walled form with the internal cavity almost flattened.
Fig. 17	*Hormosina* sp. NMB No. C 35908. Specimen crushed almost flat.
Fig. 18	?*Trochammina* sp. NMB No. C 35909. Crushed, distorted specimen.

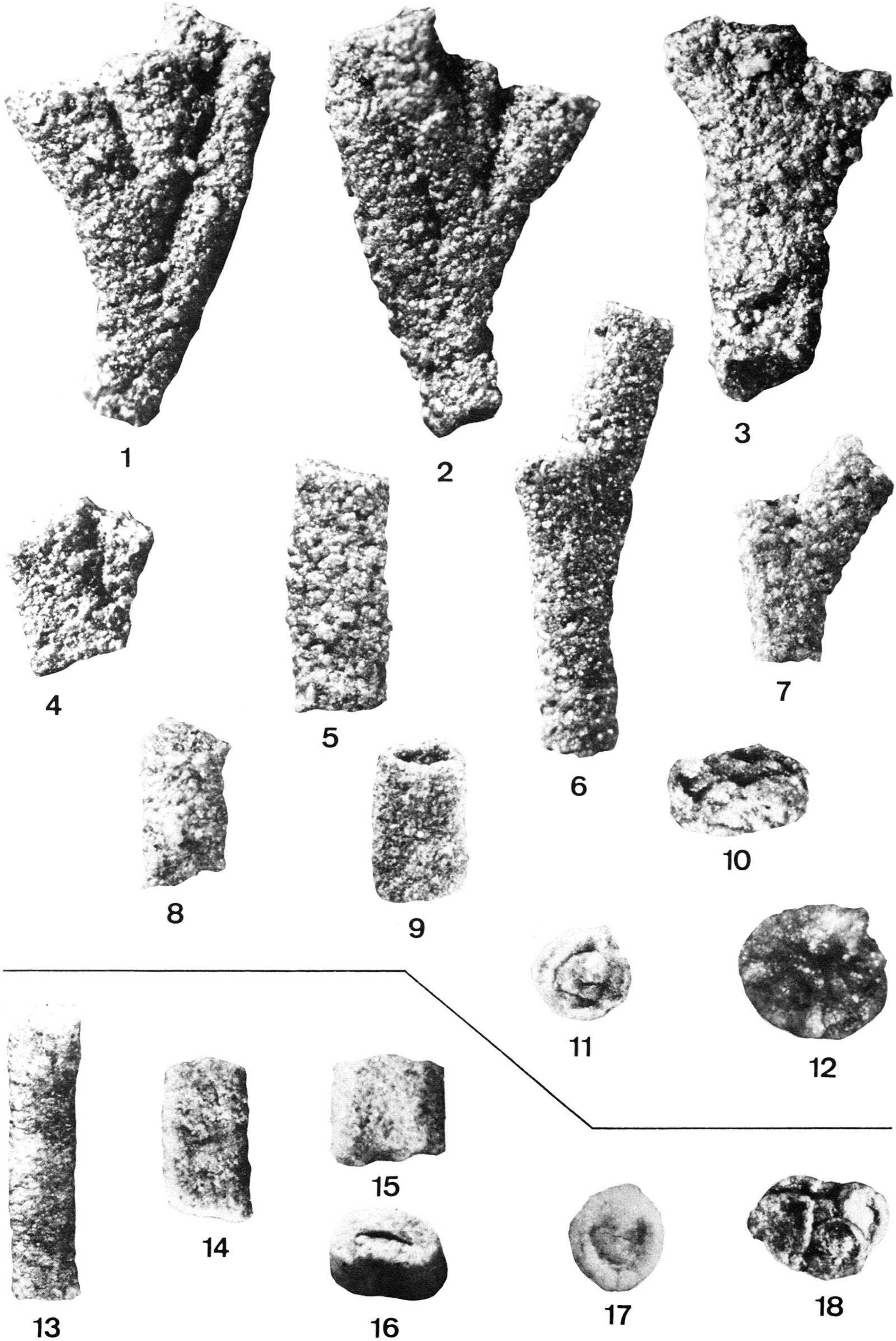
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Plate 2

Fig. 1–8 *Nuculana (Nuculana) senni* JUNG n.sp.
1–3: Holotype NMB No. G 16972. Locality 10039. 1: left valve; 2: right valve; 3: top view. Length 45.1 mm, height 24.8 mm, convexity 14.4 mm.
4–6: Paratype, NMB No. G 16973. Locality 10039. 4: left valve; 5: right valve; 6: top view. Length 46.5 mm, height 27.0 mm, convexity 17.0 mm.
7–8: Paratype, NMB No. G 16975. Locality 10073. 7: left valve; 8: top view. Length 59.4 mm, height 33.6 mm, convexity 23.6 mm.

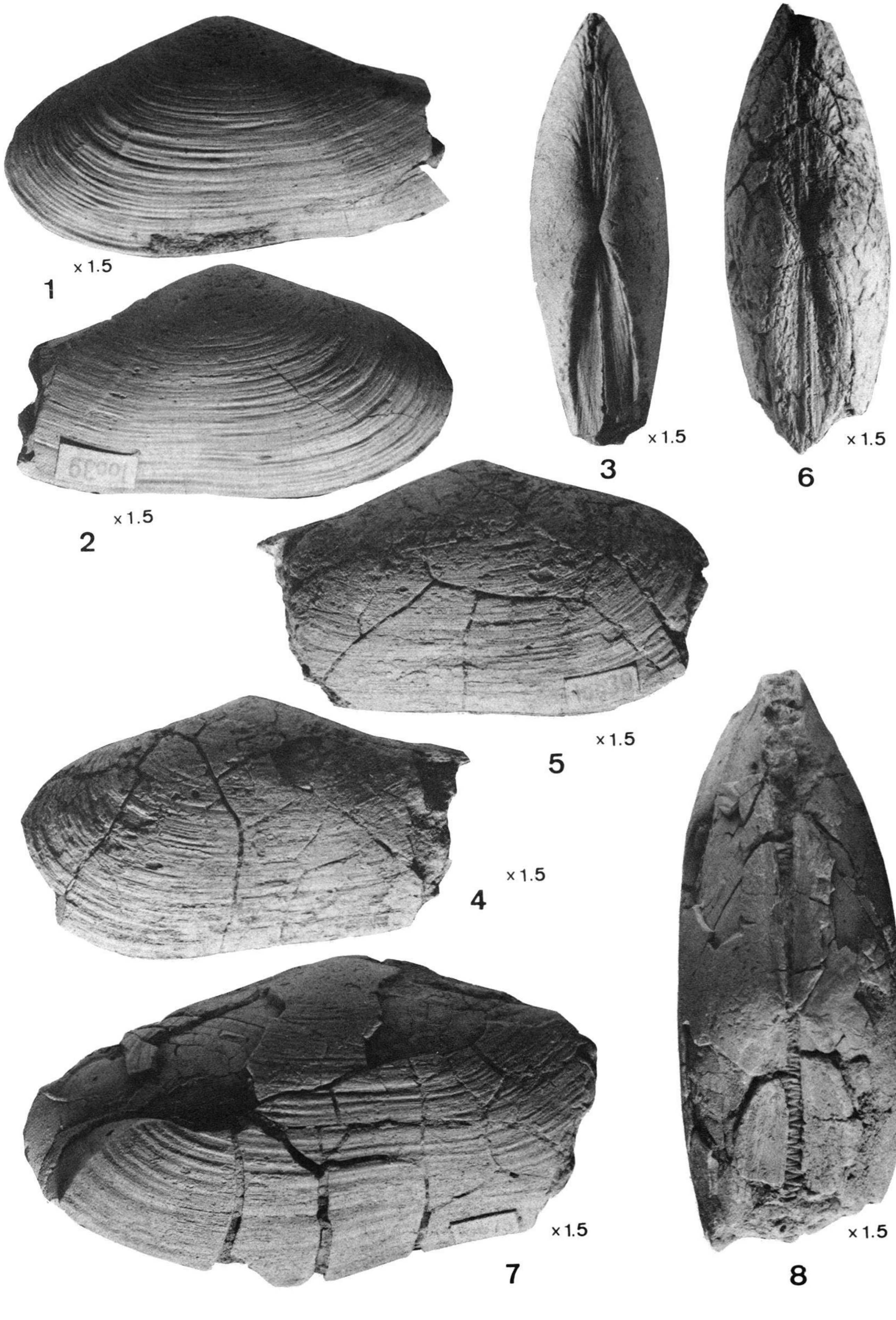
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Plate 3

Fig. 1–6

Nuculana (Nuculana) senni JUNG n.sp.
1–3: Paratype, NMB No. G 16974. Locality 10070. 1: left valve; 2: right valve; 3: top view. Length 55.6 mm, height 28.2 mm, convexity 17.7 mm.
4–5: Paratype, NMB No. G 16978. Locality 10039. 4: left valve, parts of right hinge visible; 5: right valve. Length 54 mm, height 36.7 mm.
6: Paratype, NMB No. G 16976. Locality 10073. Top view. Length 40.0 mm, convexity 16.3 mm.

Fig. 7

Venerid indet.
NMB No. G 16979. Locality 10039. Right valve.
Length 33.3 mm, height 25.7 mm.

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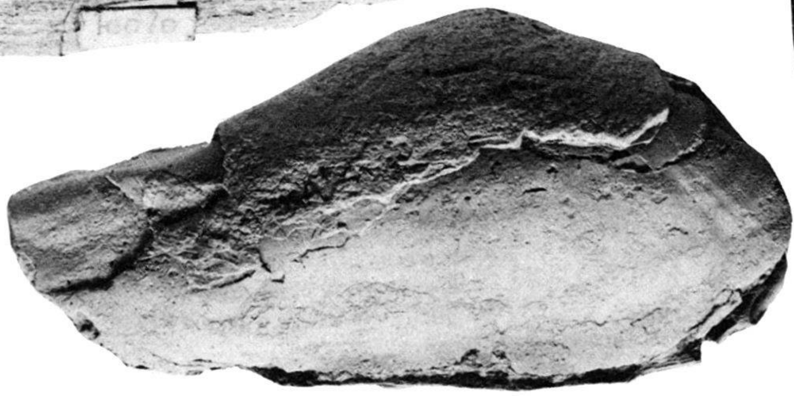

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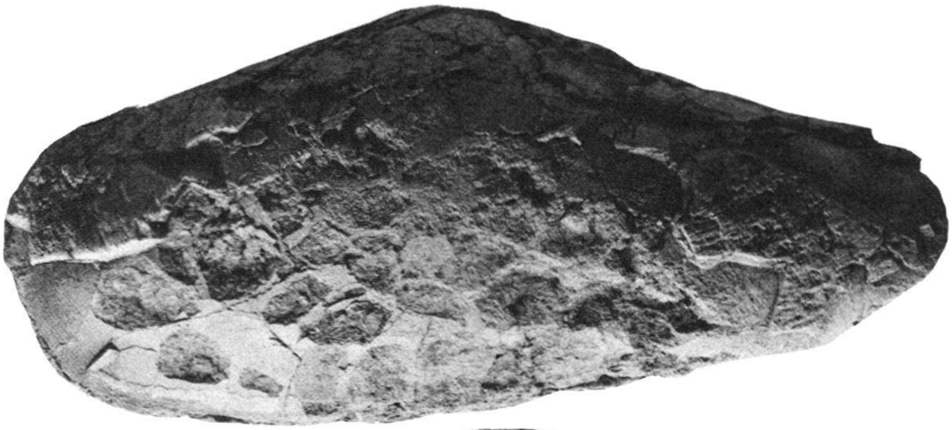
Plate 4

Fig. 1–3 *Nuculana (Nuculana) senni* JUNG n.sp.
Paratype, NMB No. G 16988. Locality 10073. 1: left valve; 2: right valve; 3: top view. Length 66.5 mm, height 30.0 mm, convexity 21.6 mm.

Fig. 4–7 Venerid indet.
4–5: NMB No. G 16982. Locality 10074. 4: top view; 5: oblique top view. Length 34.6 mm, convexity 15.5 mm.
6–7: NMB No. G 16983. Locality 10074, 6: top view; 7: right valve. Length 60 mm.



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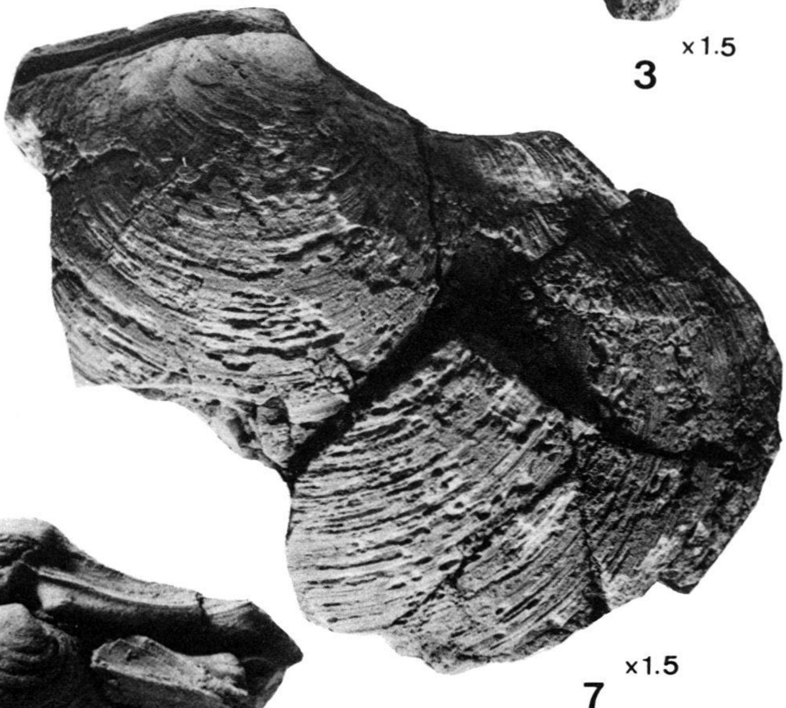

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Plate 5

Fig. 1–2 Large Lucinid?
NMB No. G 16987. Locality 10074. 1: interior; 2: exterior of fragment. Length 68.3 mm.

Fig. 3–4 Bivalve 1.
NMB No. G 16977. Locality 10039. 3: interior; 4: exterior of fragment. Length 56 mm, height 33.2 mm.

Fig. 5–7 Lucinid indet.
NMB No. G 16981. Locality 10074. 5: left valve; 6: right valve; 7: top view. Length 40.5 mm, height 35.5 mm, convexity 18.7 mm.

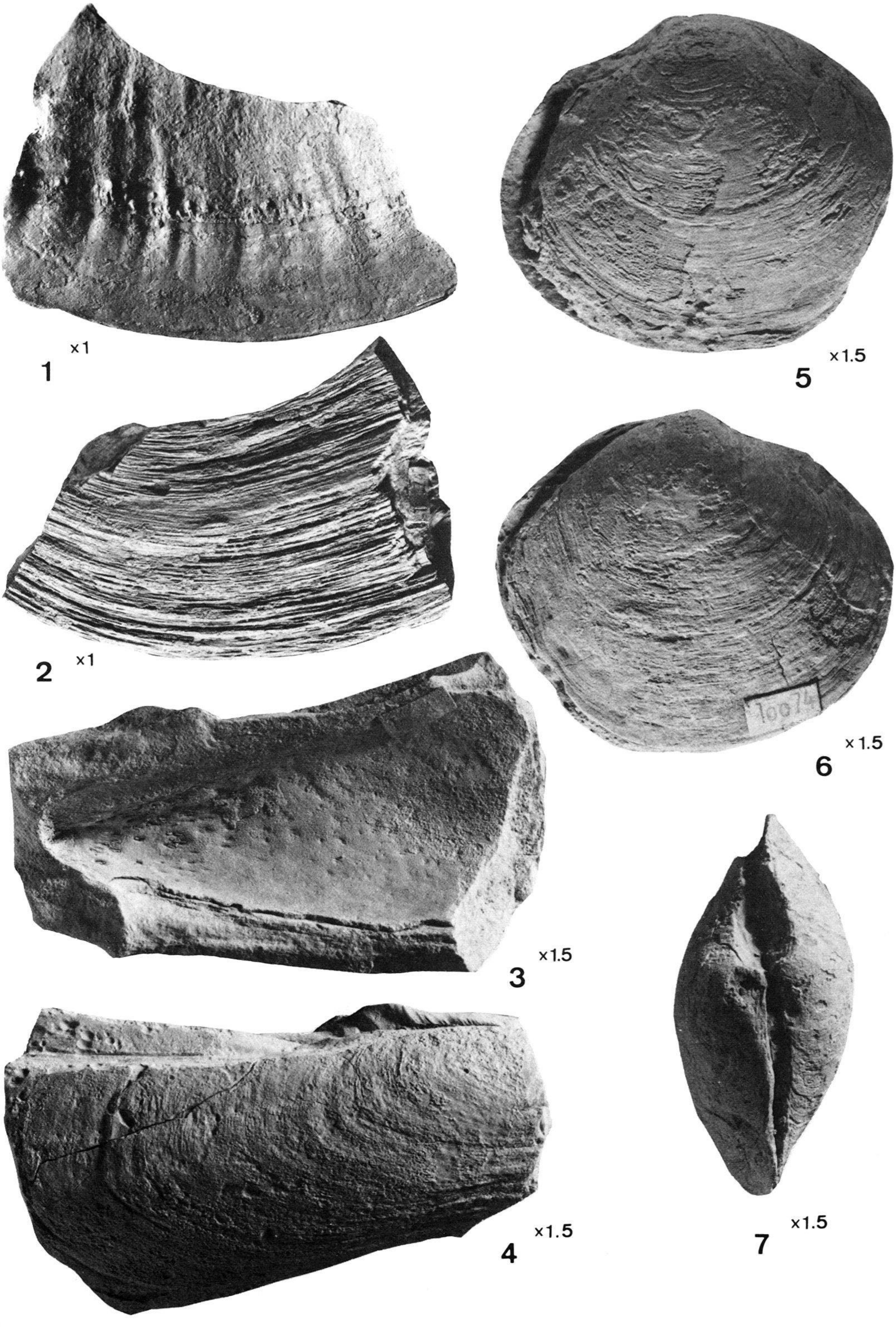
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Plate 6

Fig. 1–2, 4–7

Bivalve 2.
1–2: NMB No. G 16980. Locality 10039. 1: exterior; 2: interior of fragment. Length 78.5 mm.
4–7: NMB No. G 16985. Locality 10070. 4: view showing thickness of valve; 5: top view; 6: exterior; 7: interior of fragment. Length 62.6 mm, height 44 mm.

Fig. 3

Tellinid indet.
NMB No. G 16984. Locality 10074. Right valve. Length 40 mm, height 28 mm.

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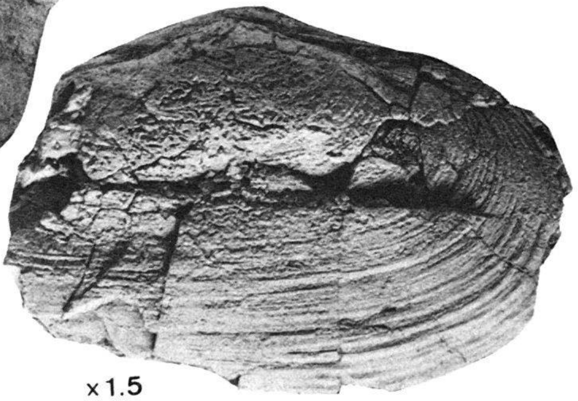

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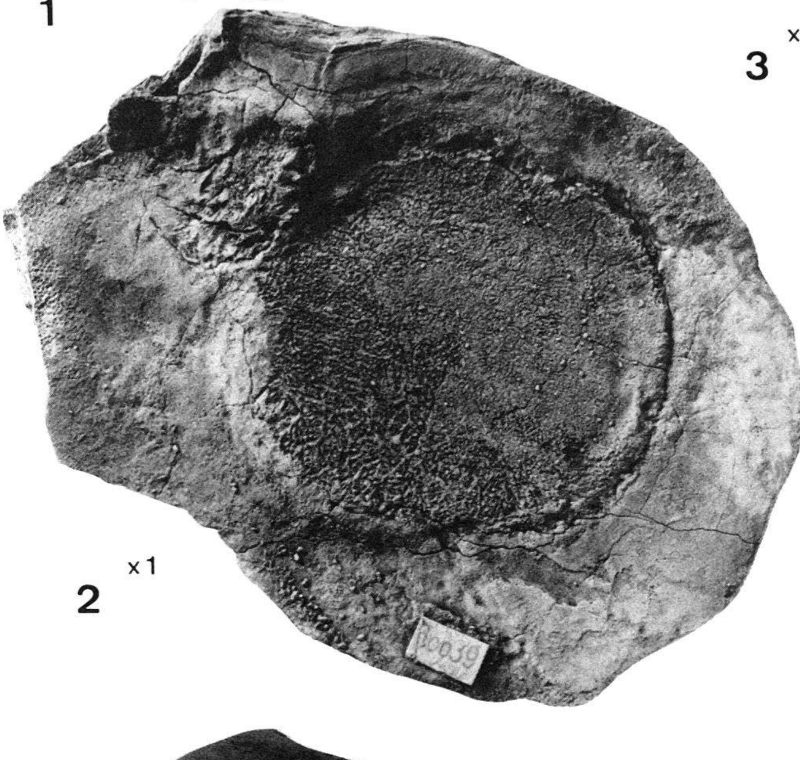

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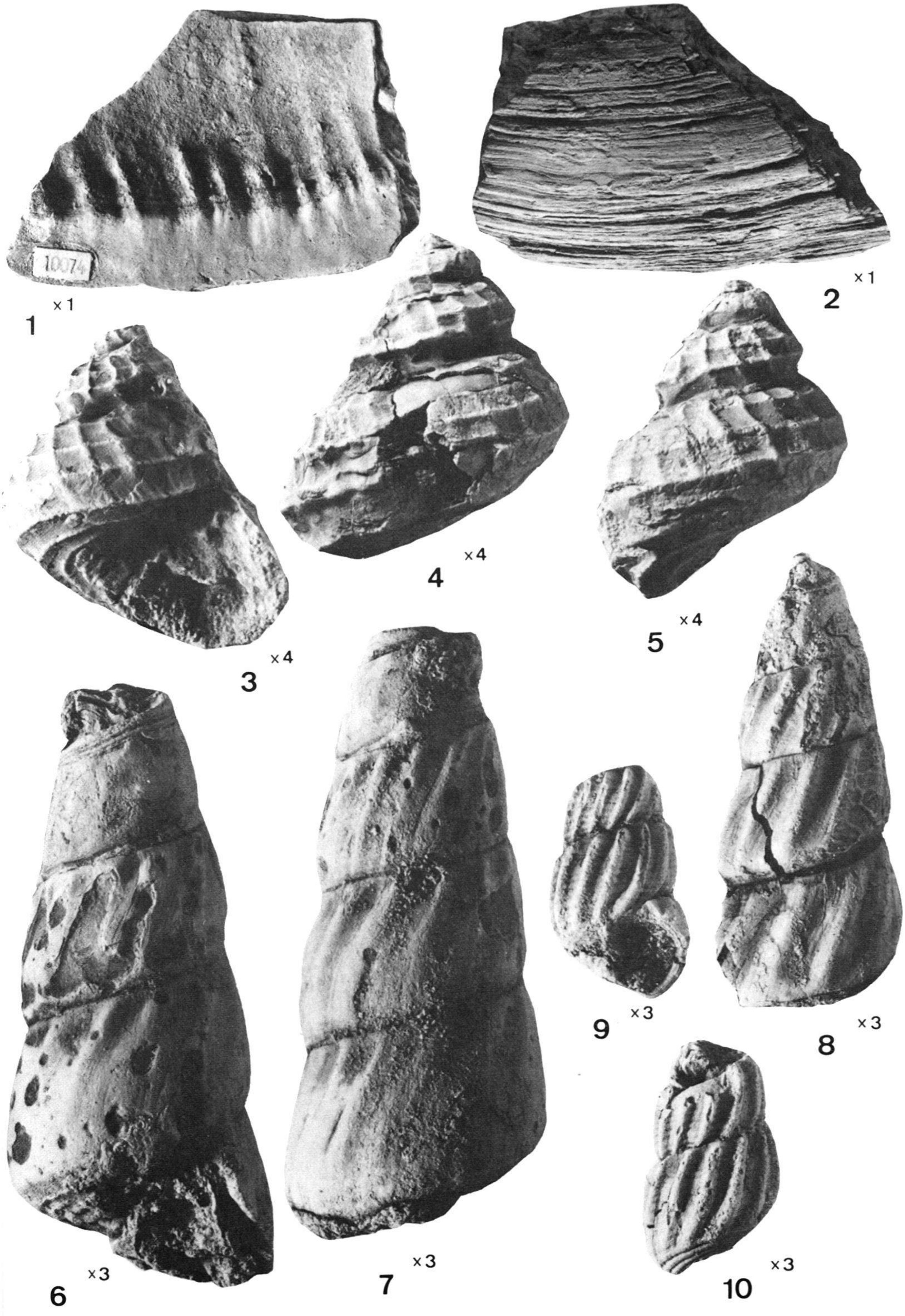
Plate 7

Fig. 1–2 Large lucinid?
NMB No. G 16986. Locality 10074. 1: interior; 2: exterior of fragment. Length 64.5 mm.

Fig. 3–5 *Calliotropis* sp.
NMB No. H 17144. Locality 10070. 3: front; 4: rear; 5: left side. Height 13.1 mm, width 11.7 mm.

Fig. 6–8 Cerithid indet.
6–7: NMB No. H 17143. Locality 10070. 6: front; 7: rear. Height 31.3 mm, width 14.1 mm.
8: NMB No. H 17142. Locality 10039. Height 22.7 mm.

Fig. 9–10 *Diastoma* sp.
NMB No. H 17141. Locality 10039. 9: front; 10: rear. Height 11.6 mm, width 7.2 mm.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