

A Cretaceous Ammonite from the Island of Curaçao, Netherlands Antilles : With Appendix. Stratigraphic position and age of a Cretaceous ammonite from Curaçao, Netherlands Antilles

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A Cretaceous Ammonite from the Island of Curaçao, Netherlands Antilles

By

Tatsuro MATSUMOTO

(With Appendix. Stratigraphic position and age of a Cretaceous
ammonite from Curacao, Netherlands Antilles by D. J. BEETS)

Abstract

An ammonite first discovered from Curaçao is described as *Parapuzosia* n. sp. (?) which is allied to *P. daubreei* (GROSSOUVRE), from the Santonian of France, on one hand and to *P. boesei* SCOTT and MOORE, from the Campanian of Mexico and Texas, on the other. On this occasion remarks are given on *Parapuzosia* with some revision of the species concerned. *Austiniceras* is separated as a distinct genus from *Parapuzosia*.

Introduction

While D. J. BEETS was engaged in a geological field work in the island of Curaçao, Netherlands Antilles, he found an ammonite in a shaly formation, which otherwise is quite poor in megafossil contents. The specimen was sent through Professor H. J. MACGILLAVRY, Amsterdam, to Professor Keith YOUNG, Austin, who, in turn, kindly transferred it to me for study.

The rare occurrence of ammonite from Curaçao is stratigraphically worthwhile to be reported. I had, furthermore, an opportunity to study the related species in other regions, with a result of getting some improvement in the palaeontological knowledge of the group. This paper gives new information with respect to both palaeontology and stratigraphy.

Acknowledgements.—Before going further, I wish to thank Professor H. J. MACGILLAVRY for his arrangements to render me an opportunity of studying an interesting specimen, Professor Keith YOUNG for his generosity, Mr. D. J. BEETS who has contributed note on stratigraphy as an appendix of this palaeontologic description, and Dr. Itaru HAYAMI and Miss Tomoko MIYAZAKI of our Department who have assisted me in the laboratory work.

I am also much indebted to Dr. J. P. LEHMAN and Dr. Jacques SORNAY of Laboratoire de Paléontologie, Muséum National d'Histoire Naturelle, Paris, who rendered facilities for studying there some of the ammonite specimens.

Notes on genus *Parapuzosia*

The ammonite in question is to be named "*Parapuzosia* sp. nov. (?) aff.

P. daubreei (DE GROSSOUVRE).” To explain this identification first the concept of genus *Parapuzosia* ought to be made clear and then follows the description of the particular specimen.

Genus *Parapuzosia* NOWAK, 1913

Type-species.—*Sonneratia daubreei* DE GROSSOUVRE, 1894 (from the Santonian of France), as designated subsequently by SPATH, 1922 (p. 126).

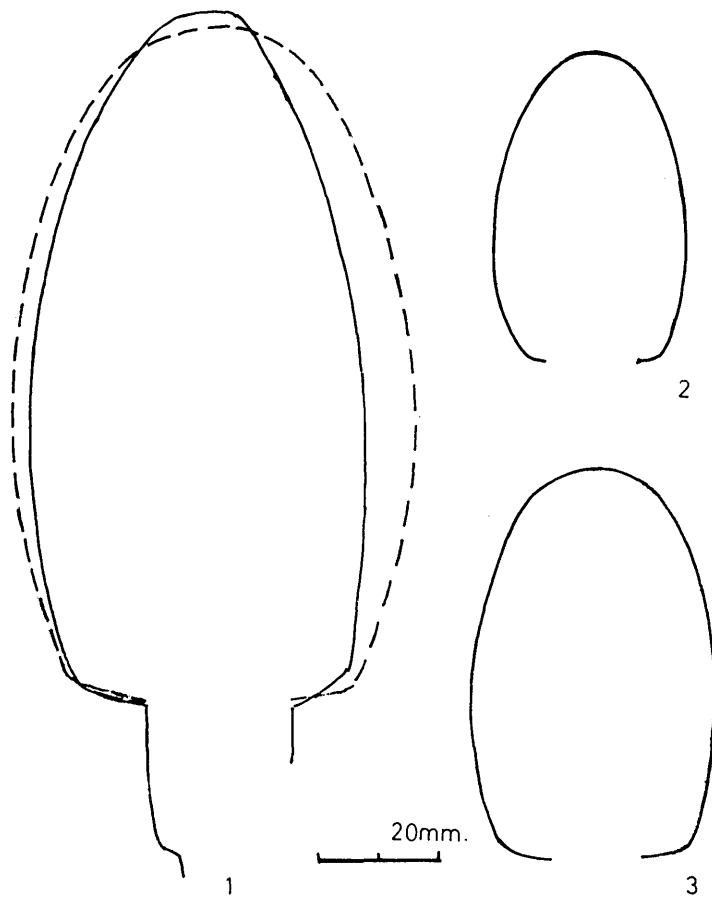
Generic diagnosis.—The full-grown shell is considerably large and sometimes attains an enormous size. The immature shell is similar to that of *Puzosia* or *Mesopuzosia*. In more or less late growth-stages the whorl becomes fairly involute and the umbilicus is somewhat narrower than typical *Puzosia*, being more than 20 and less than 30 percent of the entire shell-diameter. The whorl is higher than broad and oval or subelliptical in cross-section, with the maximum width at about or somewhat below the middle of the flank. The venter is moderately or gently arched, passing gradually to the gently inflated flanks.

On the inner whorls constrictions are distinct and fairly frequent and fine subcostae are developed mainly on the venter, although some of them extend down to or even beyond the middle of the flank. In the adolescent stage the ornament is differentiated into major and minor ribs. Namely on the outer whorl there are numerous, external, shorter and weaker ribs and less numerous, lateral, longer, broader and stronger ribs. The minor ribs cover the ventral area with uniform strength and forward projection. The major rib starts at or slightly above the umbilical margin, being rather rectiradiate or gently flexiradiate on the main part of the flank and normally branched to a few minor ribs at or near the ventrolateral part but occasionally simply extended to a minor rib, with intercalation of several minor ribs. The umbilical end of the long rib may be slightly more elevated than other parts, if not forming a distinct node or bulla. This character, however, is not always seen. In a giant shell the last whorl may be smoothish.

The suture is of typical *Puzosia* pattern, having a ventral lobe (E), which is much shallower than L, a large, expanding, asymmetrically tripartite lateral lobe (L) and obliquely descending auxiliaries.

Remarks.—The holotype, by original designation, of *Sonneratia daubreei* DE GROSSOUVRE (1894, p. 154, pl. 28), the type-species of *Parapuzosia*, is somewhat secondarily compressed. The illustration in the GROSSOUVRE's monograph is very good, but it gives only a side view. The whorl section of the holotype is illustrated here (Text-fig. 1), showing the actual, deformed shape and also a restored outline (in a broken line).

Three specimens, of different size (with diameters over 195 mm., about 120 mm., and 76 mm. respectively), of the same species in the subsequent collection from Aude, France, are available in the Institut de Paléontologie, Muséum National d'Histoire Naturelle, Paris. They furnish us some supplemental knowledge about the characters of this species. As can be judged from one of them (of moderate size) (Text-fig. 2; Pl. 31, Fig. 2), the narrowness of the venter in



Figs. 1-3. Whorl sections of three specimens of *Parapuzosia*.

1. *Parapuzosia daubreei* (DE GROSSOUVRE), holotype. Restored outline in broken line.
2. *Parapuzosia daubreei* (DE GROSSOUVRE), a specimen of moderate size illustrated on Pl. 31, Fig. 2.
3. *Parapuzosia corbarica* (DE GROSSOUVRE), holotype.

the holotype is obviously due to the secondary deformation and the venter is presumed to have been originally more evenly rounded. The flanks in all of these specimens, including the holotype, are gently inflated, showing the maximum breadth of a whorl at a point somewhat below the mid-height (at about two-fifth of the height).

A small specimen of them probably represents an immature stage. It has fairly distinct constrictions, five per whorl, showing a concave and prorsiradiate curvature with a considerable ventral projection. Its external ribs are numerous, narrow and of unequal length, some appearing in the ventrolateral part, others near the middle of the flank and still others near the umbilical margin, running on the flank with a gentle flexuosity. Thus the character of the immature shell

is similar to that of *Mesopuzosia*.

The suture is very incompletely impressed on the holotype. It is partly exposed in a large specimen and more completely so in another (of moderate size) of the subsequent collection (Pl. 31, Fig. 2). It is finely and deeply incised and belongs to the typical pattern of the *Puzosia* suture, as described in the diagnosis.

I have had no access to a Polish example identified by NOWAK (1913, p. 363, pl. 43, fig. 32; pl. 44, fig. 40) with *Parapuzosia daubreei*. His figure of the whorl section shows more flattened flanks and more rounded (gradually sloping) umbilical shoulder than the French examples, but this might be due to secondary compression. His figure of suture is again somewhat unusual, but I hesitate to give appropriate comments without seeing the actual specimen.

In addition to the type-species, from the Santonian of France, *Puzosia corbarica* DE GROSSOUVRE (1894, p. 174, pl. 27, fig. 1a, b), from the same Santonian of Aude, France, is another good example of *Parapuzosia*. Its holotype is somewhat deformed but the secondary compression does not seem great. A drawing of its whorl section is presented here (Text-fig. 3) and the measurements follow:

	Diameter	Umbilicus(%)	Height	Breadth	B./H.	
Near the end	150.0	39.3 (0.23)	65.0	40.5	0.62	0.65
— $\frac{1}{4}$ vol.	118.5	27.5 (0.23)	53.8	36.5	0.68	(average)

This may be helpful for understanding the shell form of a *Parapuzosia*.

Ammonites leptophyllus SHARPE (1857, p. 48, pl. 21, pl. 22, fig. 1), from the British Lower Senonian zone of *Micraster coranguinum*, and *Ammonites tannenbergensis* FRITSCH and SCHLOENBACH (1872, p. 37, pl. 9), from the Lower Senonian of Bohemia, and probably *Pachydiscus seppenradensis* LANDOIS (1895, p. 7, pls. 1 and 2), a giant ammonite from the Santonian of North Germany, are other examples of *Parapuzosia* from Europe.

Several species of huge ammonites have been reported from North America under the generic name *Parapuzosia*. They are (1) *Parapuzosia boesei* SCOTT and MOORE (1928, p. 274, pl. 36, figs. 1–3; pl. 37, fig. 2), from the Austin Chalk of Texas, (2) *Parapuzosia americana* SCOTT and MOORE (1928, p. 275, pl. 37, figs. 1, 3), from the same locality as (1), (3) *Parapuzosia bradyi* MILLER and YOUNGQUIST (1946, pl. 73, figs. 1, 2; pl. 74, figs. 1, 2; pl. 75, figs. 1–3), from the Lower Campanian Eagle Sandstone of Montana, (4) *Parapuzosia (Austiniceras) sealei* CLARK (1960, p. 235, pl. 34, figs. 1–3; text-figs. 1, 2), from the Upper Turonian upper Briton Member of the Eagle Ford, northern Texas, (5) *Parapuzosia terryi* YOUNG (1963, p. 53, pl. 10, figs. 2–4), from a Campanian clay member above the Gober Chalk, Texas, and (6) *Parapuzosia paulsoni* YOUNG (1963, p. 53, pl. 11, figs. 3–5; pl. 12, figs. 1–4; pl. 15, fig. 10; pl. 17, fig. 9; pl. 19, figs. 3, 4; text-figs. 8ab, 9gjr), from the Lower Campanian of Texas. YOUNG furthermore reported more examples of *Parapuzosia boesei* SCOTT and MOORE (YOUNG, 1963, p. 50, pl. 7, fig. 1; pl. 8, figs. 1, 3, 4; pl. 9, fig. 2; pl. 19, fig. 1; text-figs. 7jgr), revising its age as Campanian, and also *Parapuzosia* sp. aff. *P. bradyi* MILLER and YOUNGQUIST

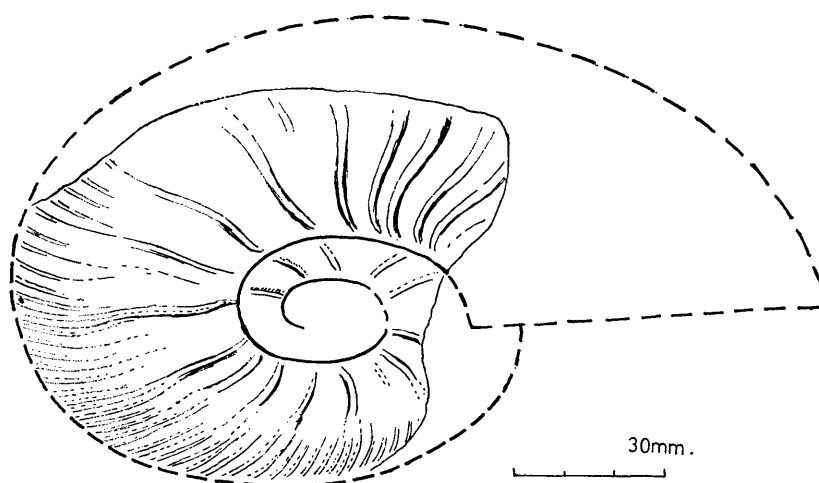


Fig. 4. A sketch of *Parapuzosia* sp. nov. (?) aff. *P. daubreei*, from Curaçao.
Restored but deformed outline of the whorl in broken line.

(YOUNG, 1963, p. 52, pl. 7, figs. 2, 3; pl. 9, figs. 1, 3, 4; pl. 11, fig. 1; text-fig. 8d), from the Lower Campanian of Texas. Of these species the second (*P. americana*) is, in my opinion, an example of *Austiniceras*, as is the fourth (*A. sealei*), for a reason to be discussed below. The sixth species (*P. paulsoni*) resembles certain species of *Pachydiscus* (such as *Pachydiscus buckhami* USHER, 1953, as redefined by MATSUMOTO, 1959). Although I have not yet examined the suture of the original specimens, the photograph of the holotype (YOUNG, 1963, pl. 11, fig. 4) seems to show a suture of *Pachydiscus* pattern. I would, however, refrain from giving a definite conclusion until I could get an opportunity of studying the actual specimens.

More species of *Parapuzosia* are known from South Africa and Madagascar. *Parapuzosia haughtoni* SPATH (1922, p. 128, pl. 8, fig. 1), from the Campanian (possibly Upper Santonian) of Pondoland and Zululand, and *Parapuzosia mozambica* COLLIGNON (1961, p. 48, pls. 18 and 19), from the Lower Campanian of Madagascar, are good examples. On examining the specimen from the Lower Campanian of Madagascar which was at one time described as *Parapuzosia indopacifica* (KOSSMAT) by COLLIGNON (1932, p. 18, pl. 9 [6], fig. 1)*, I have noticed that it has nothing to do with the named Indian species and that it is really a species of *Parapuzosia* fairly close to *Parapuzosia haughtoni* SPATH. Its outer whorl has somewhat inflated flanks, on the inner two thirds of which fairly broad major ribs are well developed.

Puzosia indopacifica KOSSMAT (1898, p. 117, pl. 17, fig. 2; pl. 18, fig. 3), from the Trichinopoly Group of India and from the Turonian of Japan and California, is referred to *Mesopuzosia* and not to *Parapuzosia* (see MATSUMOTO, 1954, 1959b).

* COLLIGNON's (1932) pl. 9[6], fig. 1 is reduced to a half ($\times \frac{1}{2}$) instead of two thirds ($\frac{2}{3}$) of natural size.

On the other hand the holotype and paratype of *Mesopuzosia bererensis* COLLIGNON (1961, p. 52, pl. 21, fig. 1; pl. 22), from the Lower Campanian of Madagascar, are better transferred to *Parapuzosia*, because they have frequent major ribs which are more elevated and more rectiradiate than other ribs.

In Japan I have recently found an example of *Parapuzosia* from the Santonian of the Hobetsu area, Hokkaido, although it has not yet been fully described. Several species from California which were described by ANDERSON (1958) under *Parapuzosia* are not truly referred to the named genus. Some are *Mesopuzosia*, others are *Pachydesmoceras* or other genera, as I discussed previously (MATSUMOTO, 1959a, b).

There are some other species from Europe which were once referred to *Parapuzosia* but have actually proved to be pachydiscids (see MATSUMOTO, 1954).

Distribution.—On the basis of the above reexamination it may be concluded that *Parapuzosia* had an extensive geographical distribution. The known species in Europe are mostly of Santonian age but in other regions numerous species are recorded as occurring in the Lower Campanian. No unmistakable example of *Parapuzosia* has been reported from the Maastrichtian.

Affinities.—*Parapuzosia* resembles *Austiniceras* SPATH, 1922, in the mode of coiling and ornamentation. The resemblance is so close that I (MATSUMOTO, 1954, p. 81) suggested the possibility to treat *Austiniceras* as a subgenus of *Parapuzosia*. WRIGHT (1957, p. L367) in fact put *Austiniceras* under *Parapuzosia* as a subgenus, but COLLIGNON (1961) treated them as independent genera. This may be a matter of difference in judgement between authors. Anyhow, more species have been described since I (MATSUMOTO, 1954) published a paper on the Puzosiinae. As a result of the restudy of them as well as older ones, I am now inclined to treat *Parapuzosia* and *Austiniceras* as independent genera on the following grounds. The principal difference between them is in the shape of the whorl. Namely *Parapuzosia* has an evenly rounded venter and an oval or subelliptical whorl section. Its flanks are gently inflated (often in the outer whorl) or subparallel (often in the inner whorl). *Austiniceras* has a remarkably narrow, if not fastigate, venter and a convergent whorl section. There is of course variability in the shell-form and a few species of *Parapuzosia* has a comparatively narrowly rounded venter than the typical ones, approaching to some extent to *Austiniceras*. The presence of a minority of such a form does not make a great objection against the separation. There may be, furthermore, some difference in the ornamentation, seeing that the type-species of *Austiniceras*, *Ammonites austeni* SHARPE (1855, p. 28, pl. 17, fig. 1), and its allies have flexuous major ribs while type-species and many other species of *Parapuzosia* have more rectilinear major ribs. The minor external ribs commonly show a more or less strong ventral projection in both genera. The available evidence at the date of my previous paper (1954) showed that species of *Austiniceras* occurred in the Cenomanian and Turonian and that those of *Parapuzosia* occurred in the Senonian (Coniacian to Campanian). In our present knowledge *Austiniceras* ranges from Cenomanian to Campanian. It follows that *Parapuzosia* and *Austini-*

ceras are diverging. In fact the Campanian examples of *Austiniceras* from Madagascar are unmistakably distinct from the contemporary species of *Parapuzosia* from the same area, as has been demonstrated by COLLIGNON's (1961) monograph.

Parapuzosia is allied to *Mesopuzosia* MATSUMOTO, 1954. They are very similar in the immature stage. In more or less late stages, however, stronger, broader major ribs are well developed in *Parapuzosia*, while in *Mesopuzosia* ribs are of equal intensity, although they are of unequal length. The thick major ribs which diverge into minor ribs are not developed in *Mesopuzosia*, but it has periodic constrictions.

Parapuzosia was sometimes misidentified with *Pachydesmoceras* SPATH, 1922. *Pachydesmoceras* has in its late growth-stages more inflated and roundish whorls than *Parapuzosia* and the ribs become uniformly coarse, consisting of alternating longer and shorter ribs, without showing such a differentiation of ornament as in *Parapuzosia*.

Parapuzosia was often confused with *Pachydiscus* GROSSOUVRE, 1894. The resemblance is in the similarly compressed whorl, gently inflated flanks, suboval or subelliptical whorl section and the differentiation of ventral minor ribs and umbilical to lateral major ribs. The difference in the pattern of suture is one of the best criteria to distinguish the two genera. The constriction on the inner whorl of *Parapuzosia* may be another criterion. The similarity in this case is a homoeomorphy, since one belongs to the Puzosiinae (of the Desmoceratidae) and the other to the Pachydiscidae.

Description of an ammonite from Curaçao

Parapuzosia sp. nov. (?) aff. *P. daubreei* (DE GROSSOUVRE)

Pl. 31, Fig. 1

Material.—A single specimen, an impression on a black slaty shale. The illustration in this paper is a photograph of a plaster cast. The original specimen is preserved in Geological Institute, University of Amsterdam, with register number X6001, and the illustrated cast in the Type-Specimen Room, Department of Geology, Kyushu University, with register number of GK. H9285.

Description.—The specimen is highly deformed and the ventral part of the last quarter whorl was destroyed away. As a trial I have drawn a restored outline of the shell under the deformed condition (Text-fig. 4). From this presumption the following approximate dimensions (in millimeters) of the specimen would be obtained:

	Diameter	Umbilicus	U./D.	Height	Breadth
At the presumed end	160	45	0.28	70	—
½ vol. earlier	103	28	0.27	43	—

This is indeed a rough estimation but can be well comparable with the better preserved (but still somewhat deformed) specimens of *Parapuzosia daubreei* (DE GROSSOUVRE), from the Santonian of France, as measured below:

	Diameter	Umbilicus	U./D.	Height	Breadth	B./H.
Holotype	271.8	73.3	0.27	115	56 (sec. comp.)	
" (restored)				112	67	0.6
A large example	192.4	55.0	0.28	79.5	39 (sec. comp.)	
A moderate example	118.0	83.0	0.28	51.5	33.2	0.64
" ($-\frac{1}{4}$ vol.)	—	—	—	44.5	28.8	0.63
A small example	75.7	19.8	0.26	29	21	0.72

As the specimen in question is much compressed secondarily, its breadth of whorl cannot be estimated. The flank is, however, gently inflated even in the compressed condition.

The ornament on the outer whorl is very characteristic. It consists of less numerous, thicker, umbilical to lateral, major ribs and numerous, much finer, ventrolateral to ventral, minor ribs. The major ribs are disposed rather at irregular intervals, but they tend to be more distant in the early part and more frequent in the visible last part. They are mostly thick, but a few of them are less so. They start from the umbilical margin, are most pronounced at or near the umbilical shoulder, run radially on the main part of the flank, and are much weakened on the upper lateral part where each of which diverges into two or three minor ribs. There are also a few intercalated minor ribs. Consequently four or five minor ribs are disposed for each major rib, but this may be modified according to the interval between major ribs. The minor ribs are fairly crowded, especially in the earlier part, and show a considerable ventral projection.

On the inner whorl distant major ribs are discernible in association with constrictions.

The suture is hardly visible on this specimen, but for incomplete impression of a portion of the finely incised elements.

Comparison.—In the mode of coiling and ornamentation this specimen considerably resembles the holotype and other examples of *Parapuzosia daubreei* (DE GROSSOUVRE, 1894), the type-species of *Parapuzosia*, from the Santonian of France. It is not, however, quite identical with the holotype and other examples of that species in that it has finer and more crowded minor ribs. A specimen of moderate size from Saubourcu, near Rennes les Bains (Aude), France (Pl. 31, Fig. 2) has somewhat finer minor ribs than the holotype, being probably within the extent of variation, but the specimen from Curaçao has still finer minor ribs. In this respect the Curaçao specimen is somewhat similar to *Parapuzosia corbarica* (DE GROSSOUVRE), from the Santonian of France. The latter species, however, has a narrower umbilicus and less numerous, much more distant, weaker and narrower major ribs, which extend to finer ventral ribs singly or with a few indistinct splitting.

The hitherto established species of *Parapuzosia* from the Gulf Coast and the Interior Province of the United States are mostly based on specimens of large or huge size. Therefore it is rather difficult to do an adequate comparison of the Curaçao specimen with any of them. YOUNG has recently illustrated a smaller, probably inner whorl of *Parapuzosia boesei* SCOTT and MOORE (YOUNG,

1963, p. 50, pl. 8, fig. 3; text-fig. 7r), from the Lower Campanian of Texas. I would agree with YOUNG in regarding "*Parapuzosia corbarica*" of RENZ (1936, p. 5, pl. 4, figs. 1, 2), from northeastern Mexico, as identical with *P. boesei*. The Mexican specimens also represent septate stages. The specimen from Curaçao resembles these inner whorls of *Parapuzosia boesei* in its fine, crowded, numerous minor ribs, but differs in its major ribs, which are on the lower part of the flank not so flattened as, but stronger and more frequent than, those of the latter species. YOUNG has noticed that in *P. boesei* major ribs remain larger over the venter than do the minor ones. Such a character is not seen in the Curaçao specimen, on the venter of which the ribs splitted from the major ones are nearly as fine as the intervening shorter ones, although, strictly speaking, there may be insignificant irregularity in the intensity of minor ribs.

The Curaçao specimen is much apart from the species from Madagascar, South Africa and Japan in various respects.

When the suture is not well exposed, it is fairly difficult to distinguish species of *Parapuzosia* from certain species of *Pachydiscus* (s. s.). Therefore a possibility that the Curaçao specimen could be a *Pachydiscus* should be taken into consideration. *Pachydiscus gollevillensis* (D'ORBIGNY), as illustrated by DE GROSSOUVRE (1894, p. 214, pl. 29, fig. 4; pl. 31, fig. 9), from Europe, *Pachydiscus* sp. cf. *P. gollevillensis* (D'ORBIGNY) of YOUNG (1963, p. 57, pl. 14, figs. 2, 3), from Texas, and of SPATH (1925, p. 30, pl. 1, fig. 3d, e) and *P. aff. stallauensis* (IMKELLER) of SPATH (1923, p. 29, pl. 1, fig. 3a-c), from Jamaica, have comparatively compressed whorls on which numerous external ribs and less numerous umbilical or major ribs are distinguished. The Curaçao specimen, like many species of *Parapuzosia*, has much finer, more numerous and more projected external ribs than these examples of *Pachydiscus*. It seems to have weak constrictions on the inner whorl. It is, thus, dissimilar to any known species of *Pachydiscus*. To find any example which shows sutures is essential for a definite identification.

To sum up the ammonite from Curaçao probably belongs to a species of *Parapuzosia* which is allied to but distinct from *P. daubreei*, from the Santonian of France, and *P. boesei*, from the Lower Campanian of Texas and Mexico. As it is poorly preserved, I call it provisionally *Parapuzosia* sp. nov. (?) aff. *P. daubreei* (DE GROSSOUVRE).

Occurrence.—The specimen was found by D. J. BEETS in an outcrop of the Mameter Formation at loc. lat. 12°16'10.5" N. and long. 69°06'19" W., in Curaçao (see *Appendix* for further details). As is discussed in full detail by BEETS in *Appendix*, the age of the Mameter Formation is within the range of Campanian and Maastrichtian. The hitherto described species of *Parapuzosia* occur in Santonian and Lower Campanian, while those of *Pachydiscus* (s. s.) in Campanian and Maastrichtian. Since the described specimen probably belongs to a new species, it could be younger than Lower Campanian. The reworking of the ammonite from an older formation to the Mameter could be considered as another possibility, although this may be improbable.

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Tatsuro MATSUMOTO

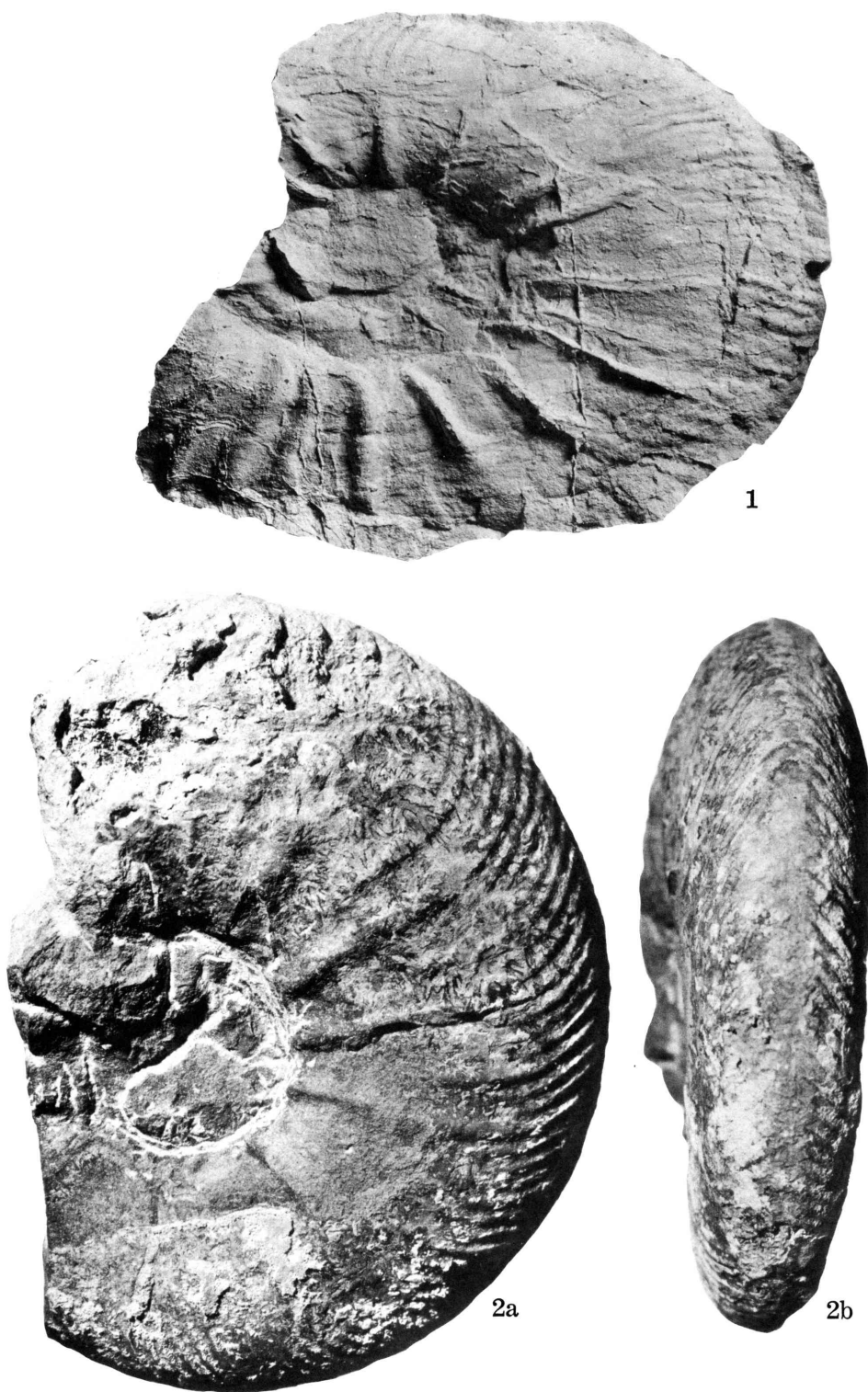
A Cretaceous Ammonite from the Island of Curaçao,
Netherlands Antilles

Plate 31

Explanation of Plate 31

- Fig. 1. *Parapuzosia* sp. nov. (?) aff. *P. daubreei* (DE GROSSOUVRE)
Plaster cast, GK.H9285, of the imprint, X6001, of ammonite from the
Mameter Formation, Curaçao, Netherlands Antilles. (Kyushu University
photo.)
- Fig. 2. *Parapuzosia daubreei* (DE GROSSOUVRE)
A specimen of moderate size in the collection of the Muséum National
d'Histoire Naturelle, Paris, from the Santonian of Saubourcu, near Rennes
les Bains (Aude), France. Lateral (a) and ventral (b) views. (Muséum
photo.)

Figures are of natural size, except for a slightly reduced Fig. 2b.



Appendix

Stratigraphic Position and Age of a Cretaceous Ammonite from Curaçao, Netherlands Antilles

By
D. J. BEETS

Abstract

The stratigraphic position and age of the first ammonite found on the island of Curaçao (Netherlands Antilles) are discussed. In spite of tectonic and stratigraphic complications, it is concluded that the ammonite bearing formation is of Campanian or Maastrichtian age, subject to the correctness of the age assignments of Pseudorbitoididae as given in the literature.

Introduction

During fieldwork carried out on the island Curaçao (Netherlands Antilles) between April 1961 and June 1962, a deformed imprint of an ammonite was found in rocks belonging to a local unit, the Mameter Formation. To the author's knowledge this is the first ammonite found on the island.

Through Professor K. YOUNG of the University of Texas, Austin, the fossil was sent to Professor T. MATSUMOTO of the Kyushu University of Fukuoka, Japan, who was so kind to identify it. The results of his investigation are described in the paper to which this appendix is added.

Curaçao is situated in the southern part of the Caribbean area between the latitudes $12^{\circ}2'$ and $12^{\circ}23'30''$, and the longitudes $68^{\circ}44'30''$ and $69^{\circ}10'$, and has an area of approximately 425 square kilometers.

The island consists of an eugeosynclinal sequence of Upper Cretaceous and Lower Tertiary age, which was strongly folded and faulted in the interval between the Danian and the Upper Eocene. The resulting structure roughly consists of two anticlinoria, forming the northwestern and the southeastern part of the island, separated by a synclinorium in the central part. The sequence is unconformably overlain by younger deposits, mainly of Quaternary age. These younger rocks are chiefly found in a zone of varying width along the coastline (Fig. 5).

The author's investigations were limited to the eugeosynclinal sequence. The results will be published as a Ph. D. thesis in 1966.

Previous work of various geologists provided the base for the author's investigations. Especially MARTIN (1888), MOLENGRAAFF (1929), and Professor L. M. R. RUTTEN with a group of students from the Utrecht University (VERMUNT & RUTTEN, 1931; PIJPERS, 1931; and MAC GILLAVRY, 1932), have to be mentioned.

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Diagnostic fossils are scarce in the eugeosynclinal sequence, and, where found, are often limited to isolated limestone lenses. Moreover, in the Mameter Formation from which the ammonite in question was collected, no other diagnostic fossils were found. Its Campanian–Maastrichtian age is based on data derived from adjacent formations. It will, therefore, be necessary to give a short outline of the stratigraphy of the sequence, and of the principles on which it is based, before we can enter into the question of the age assignment.

Stratigraphy

Three main lithostratigraphic units could be distinguished, viz., from base to top:

(i) The Curaçao Lava Formation, which mainly consists of basic volcanics. Lavas are the dominant constituent and often show typical pillow-structure. Locally one also finds water-lain tuffs and tuffites. The formation, which covers a large part of the island, is mainly exposed in the cores of the two large anticlinoria (Fig. 5).

(ii) The Knip Group, which consists almost exclusively of sediments. The Group is characterized by a high silica-content: cherts and siliceous rocks of various nature predominate. With the exception of a few intercalations of basic lavas in the lowermost part of the Group, volcanics consist of tuffs and tuffites of intermediate composition, found at various levels. The Group has its most extensive development in the northwestern part of the island, where it is found as a wide garland forming the flanks of the NW-plunging anticlinorium. In the central and southeastern part of the island the Group is exposed as a rather thin strip along both flanks of the central-Curaçao synclinorium (Fig. 5).

(iii) The Midden-Curaçao Formation, a turbidite sequence found in the core of the aforementioned synclinorium.

On the basis of lithology the Knip Group is subdivided into 8 formations, which are partly time-equivalent. The Mameter Formation, in which the ammonite in question was found, belongs to this Group. Owing to rapid changes in thickness and facies the Knip Group varies strongly from one part of the island to another. The general tendency is a rapid thinning from the northwest to the southeast, accompanied by lateral facies changes. Thinning is thought to be mainly the result of southeastward condensation, accompanied, in the central and southeastern part of the island, by non-deposition and perhaps some erosion during the early part of Knip Group time.

Because of faults, fault systems and thrusting, the island is divided into a number of more or less isolated areas, so that lateral facies changes have been obliterated to a considerable extent. Correlation within the Knip Group is mainly based on lithology.

The Mameter Formation is exposed in the central part of the island, where it forms a belt of varying width, which can be followed from Santa Martabaai to the ESE over a distance of approximately 8 km (Figs. 5 and 6). Between

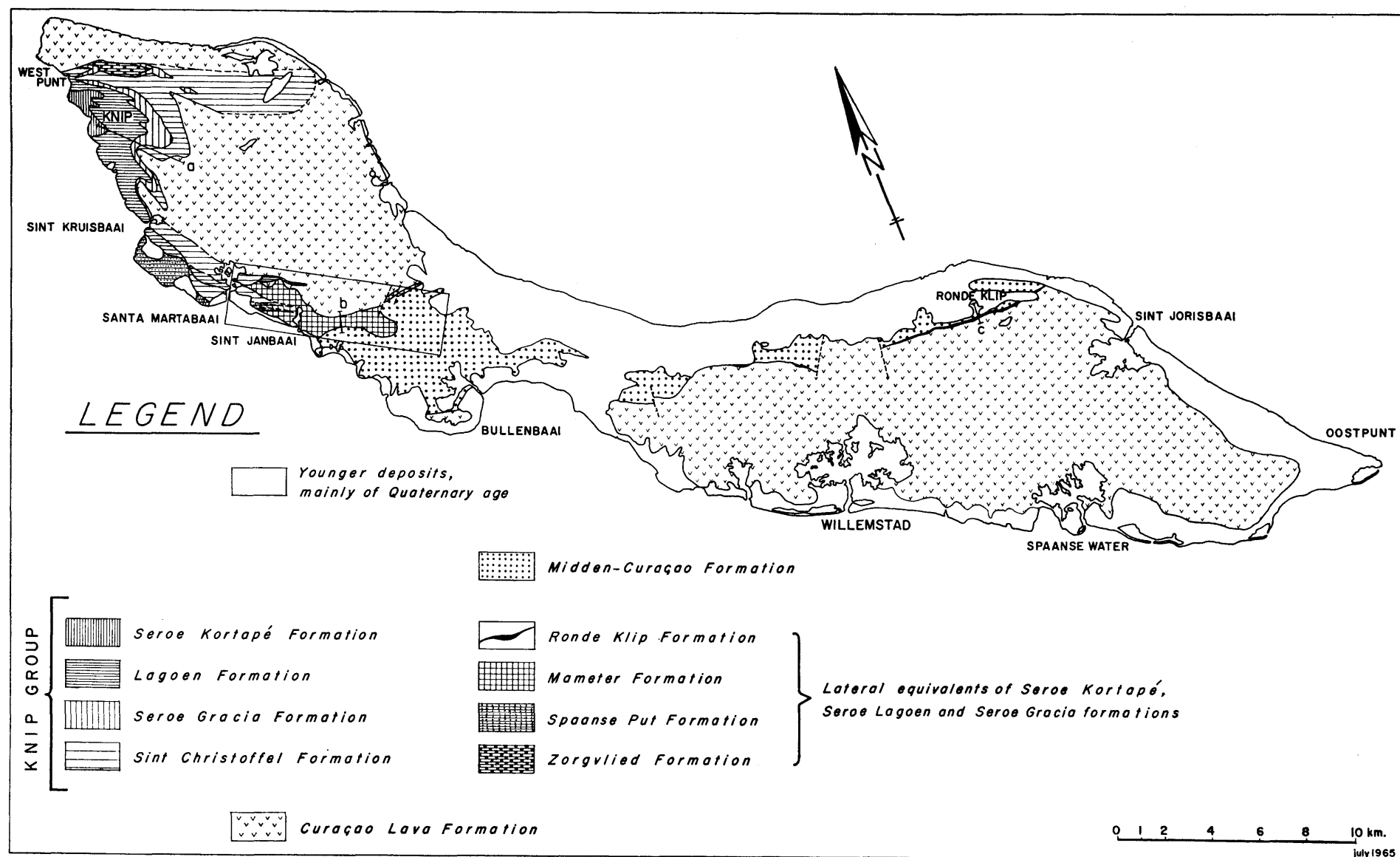


Fig. 5. Simplified geologic map of Curaçao (Netherlands Antilles). The inset is given in more detail in Fig. 6. The lines a, b and c indicate the approximate position of the columnar sections given in Fig. 7.

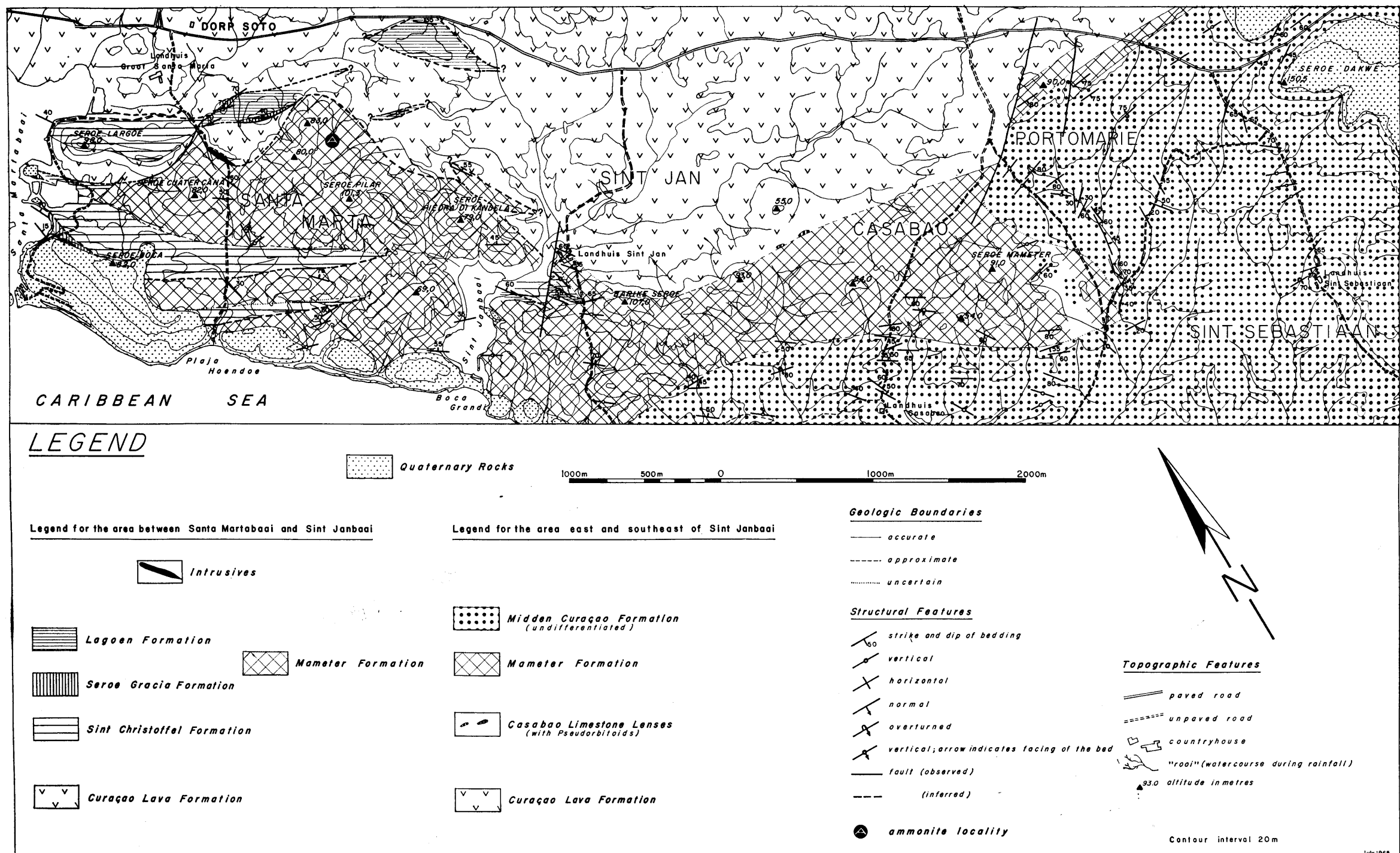


Fig. 6. Detailed geologic map of the Santa Marta-Sint Jan-Casabao-area (inset of Fig. 5), indicating the ammonite locality.

Santa Martabaai and Sint Janbaai the formation is intricately imbricated with other units (left side of Fig. 6). East of Sint Janbaai it is found in normal succession between the Curaçao Lava Formation in the north and the Midden-Curaçao Formation in the south (right side of Fig. 6).

The Mameter Formation consists of a monotonous succession of dark coloured sandy, silty and clayey rocks with a varying admixture of chert and carbonate. They often have the appearance of siliceous mudstones. The detritus is mainly of volcanic origin. Fine-grained volcanic sandstones with a matrix of chert and carbonate, and sandy calcareous cherts are the most prominent rock types. Crystal tuffs and calciferous cherts are found locally. A distinct bedding is often absent, but occasionally lamination, due to the intercalation of thin sandstone beds in more cherty rocks, can be seen. Radiolaria and sponge spicules were frequently observed, whereas gumbelinids and smaller benthonic Foraminifera are much scarcer in thin-section.

Although it is difficult to draw any definite conclusions on the depositional environment, I am inclined to assume rather deep water conditions for the greater part of the formation. The high matrix-content of the sandstones in any case points to deposition below wave base.

The imprint of the ammonite was found in an outcrop situated about 1250 m SE of the country-house "Groot Santa Marta" and 1750 m NW of the country-house "Sint Jan" (Fig. 6). Latitude and longitude of the locality are $12^{\circ}16'10.5''$ and $69^{\circ}06'19''$. Owing to complex tectonic imbrication no information about the stratigraphic position of the Mameter Formation could be obtained from this area. However, some kilometers to the southeast, along the N-flank of the central-Curaçao synclinorium, the formation is found in normal stratigraphic succession. In this section the Mameter Formation is bounded at both sides by fossil-bearing rocks, from which the age can be inferred. Additional evidence is obtained by correlation of the formation with the Knip Group as developed in the northwestern and southeastern parts of the island.

In Figure 7 columnar sections are given from various parts of the island. Section *a* represents the sequence in the northwestern part of the island in the surroundings of the country-house "Knip". The two remaining sections are from the north and from the south flank of the central-Curaçao synclinorium, respectively. Section *b* is taken about two kilometers east of Sint Janbaai (Fig. 6) and is situated near the ammonite locality; section *c* represents the surroundings of the country-house "Ronde Klip" (Fig. 5).

As appears from the three sections, the Knip Group has the most complete development in the NW-area, where, at least locally, a continuous transition between the Curaçao Lava Formation and the Knip Group may exist. Here the Group is subdivided on the basis of lithology into four successive formations, viz., from base to top: the Sint Christoffel Formation, the Seroe Gracia Formation, the Lagoen Formation and the Seroe Kortapé Formation. Time-sequence in this section is expressed in: i) a change of grain-size and composition of the detritus; ii) a decrease, and a change in the nature of the volcanism.

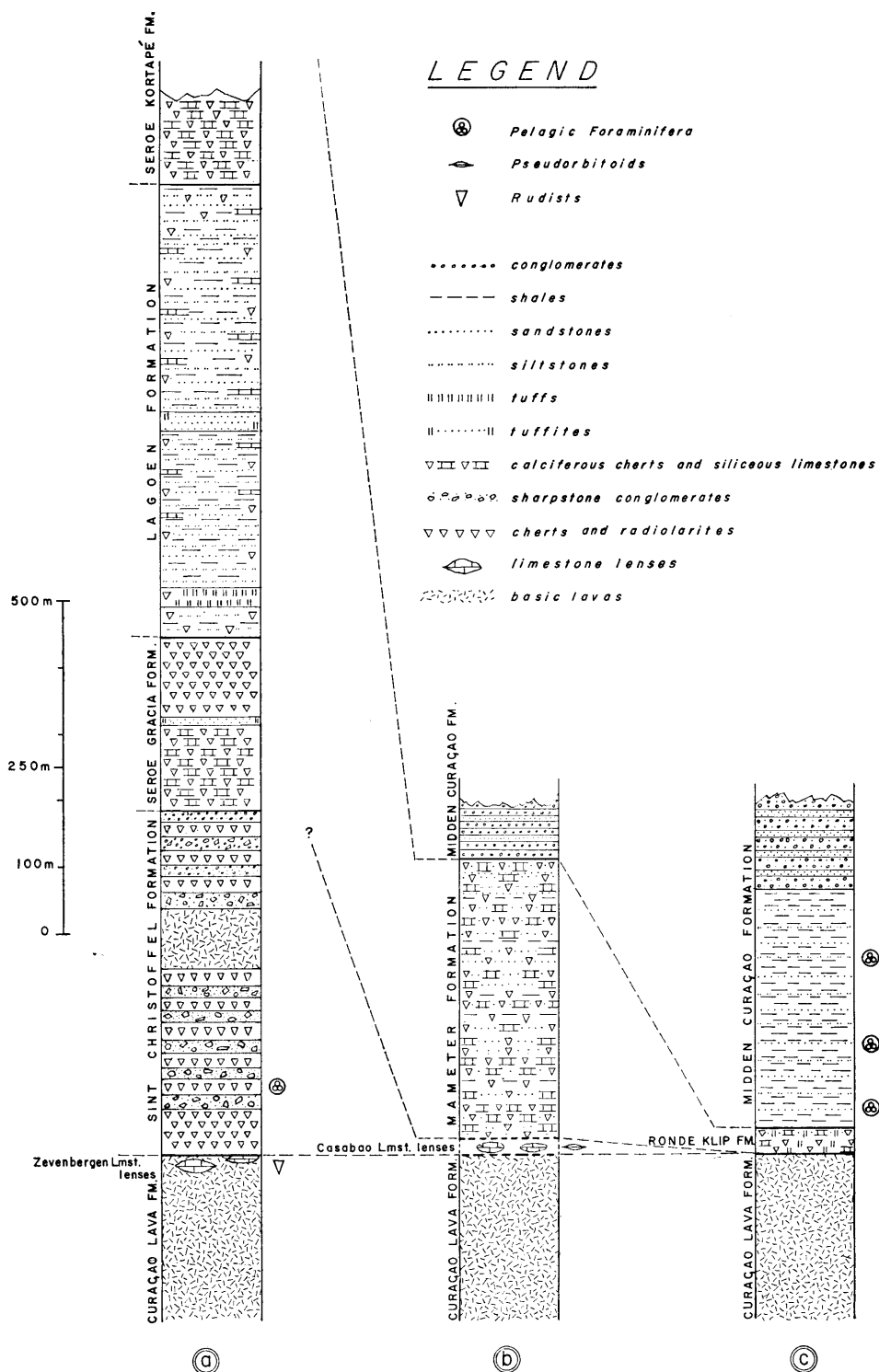


Fig. 7. Simplified columnar sections of the Upper Cretaceous and Lower Tertiary sequence of Curaçao. The approximate geographic positions of the sections are given in Fig. 5.

In this area fossil-bearing limestone lenses are found at various levels near the base of the Knip Group. Stratigraphically lowest are the Zevenbergen limestone lenses, found in the upper part of the Curaçao Lava Formation, directly below or at the boundary with the Knip Group (Fig. 7a). Fragments of rudists were sampled from these limestones and were provisionally identified by Professor H. J. MAC GILLAVRY of the Geological Institute of the University of Amsterdam as *Radiolites* sp., *Plachioptychus* sp. and *Torreites tschoppi* MAC GILLAVRY.

Many small limestone lenses, intercalated between rocks of the Sint Christoffel Formation, are found directly northeast of the Knip area. The exact stratigraphic level of these lenses is not known, and they are therefore omitted from the columnar section. Two species of rudistids, *Vaccinites martini* MAC GILLAVRY and *Durania curasavica* (MARTIN) were collected from three limestone lenses and described by MAC GILLAVRY (1932). The rudist material was mainly collected from the two larger outcrops, exposed at two small hills, Seroe Teintje and Seroe Bomba Boea. In the literature the limestone lenses are referred to as the Seroe Teintje limestone.

The affinity of *Vaccinites martini* with the group of *Vaccinites inaequicostatus*, in particular *V. oppeli*, known from the Campanian of the Gosau basins of Austria (TOUCAS, 1904), led MAC GILLAVRY (1932) to assume the same age for the fauna of the Seroe Teintje limestone. KÜHN (1934), in a review of MAC GILLAVRY's paper, considered a Campanian age for the Seroe Teintje fauna almost certain.

Torreites tschoppi is known from Loma Yucatan, Camaguey Province, Cuba, where it is associated with *Vaccinites inaequicostatus macgillavryi* (PALMER), *Durania curasavica* (MARTIN), and *Durania lopez-trigo* (PALMER). MAC GILLAVRY (1937) considered the Loma Yucatan fauna of Cuba to be probably of the same as the Seroe Teintje fauna of Curaçao.

As the age of these rudist limestones is mainly based on the affinity of these fossils with *Vaccinites inaequicostatus* from Europe, it is interesting to note that, according to KOLLMANN (1964), this form may range down into the Upper Santonian in the Gosau basin of Gams (Austria). Moreover, in view of the absence of larger Foraminifera of the family Pseudorbitoididae, which are now believed to range down into the Campanian (BRÖNNIMANN, 1955; SEIGLIE & AYALA-CASTANARES, 1963), the rudist limestones in question may be older than Campanian.

On the other hand, in a thin-section of a sample from the lower part of the Sint Christoffel Formation, Professor J. J. HERMES of the Geological Institute of the University of Amsterdam, found a fauna, consisting of gumbelinids, *Hedbergella*, and single- and double-keeled *Globotruncana*, indicating an Upper Senonian age. The sample was taken from a stratigraphically slightly higher level than the Zevenbergen limestone lenses, but cannot differ much in age from the Seroe Teintje limestone.

Summarizing the above evidence, an Upper Santonian to Lower Campanian

age for the rudist-bearing limestone lenses seems most likely, whereas a Campanian age for the major part of the Sint Christoffel Formation is almost certain.

The Knip Group as developed in the northwestern part of the island, thins gradually in a southeasterly direction, but can be followed as far as the area between Santa Martabaai and Sint Janbaai (Figs. 5 and 6). Here, because of faulting, field relations are not quite clear. In a general way it can be said that the Sint Christoffel Formation is found halfway down this belt, and then disappears, whereas the remaining part of the facies succession of the northwest is restricted to the northern part of the fault belt and is replaced further to the south by the Mameter Formation.

On the basis of lithology, mainly grain-size and composition of the detritus, the Mameter Formation is correlated with the middle and upper part of the NW-section, in particular with the Lagoen Formation. Lateral facies transitions between the Lagoen Formation and the Mameter Formation were actually observed in the neighbourhood of Santa Martabaai. Contemporaneous deposition of part of the Mameter Formation and the Sint Christoffel Formation is unlikely, because of too great differences in lithology.

East and southeast of the country-house "Sint Jan" no formations of the NW-facies succession are found any more. Here, for the main part, the Mameter Formation rests directly upon the Curaçao Lava Formation. A similar situation is found along the south flank of the central-Curaçao synclinorium, where the Ronde Klip Formation, which is thought to be contemporaneous with the Mameter Formation, directly overlies the Curaçao Lava Formation (Figs. 5 and 7c). Since the Sint Christoffel Formation is absent in this part of the island, a hiatus is thought to separate the Curaçao Lava Formation from the Mameter Formation and the Ronde Klip Formation, respectively.

About 1500 m SE of the country-house "Sint Jan", two small limestone lenses are found at the boundary of the Curaçao Lava Formation and the Mameter Formation (Figs. 6 and 7). These lenses, which were named after the plantation Casabao, contain a rich fauna of larger Foraminifera, belonging to the family Pseudorbitoididae. The fauna, which is being studied by Mr. J. KRIJNEN of the Geological Institute of the University of Amsterdam, contains *Sulcoperculina* sp., *Sulcorbitoides pardo* BRÖNNIMANN, *Pseudorbitoides* sp. and *Aktinorbitoides* sp. A separate paper on this fauna will be published by Mr. KRIJNEN. Basing himself mainly on data of BRÖNNIMANN and SEIGLIE & AYALE-CASTANARES, KRIJNEN considers the age of this fauna as almost certainly Campanian or Lower Maastrichtian, and perhaps even Upper Campanian or Lower Maastrichtian.

Both the Mameter and the Ronde Klip Formations are overlain by the Midden-Curaçao Formation. Pelagic Foraminifera from the Midden-Curaçao Formation, identified by Professor J. J. HERMES, indicate a Tertiary, probably Danian age for this sequence.

Conclusions

Assuming that BRÖNNIMANN's age assignments of the Pseudorbitoididae involved are correct, the age of the Mameter Formation would be Upper (?) Campanian or Maastrichtian.

Independent evidence for a Campanian or Maastrichtian age, based on rudists and a pelagic fauna in thin-sections, is obtained by correlation of the Mameter Formation with the sequence in the NW-part of the island.

Unless reworking of the ammonite from an older formation had happened, a similar age range is adopted for this fossil.

Acknowledgements

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