

Lower Cenomanian Mollusks from Diégo-Suarez, Northern Madagascar*

By

Yasumitsu KANIE

Yokosuka City Museum, Yokosuka 238

Hiroimichi HIRANO** and **Kazushige TANABE**

Department of Geology, Kyushu University, Fukuoka 812

As a part of paleontological reconnaissance survey in Madagascar by the National Science Museum, Tokyo, the Diégo-Suarez area was surveyed by UJIIÉ and KANIE in September of 1973. They surveyed several localities in the Diégo-Suarez area, and then sampled abundant molluscan fossils especially from Loc. Dg 2, Betahitra Valley.

Previously pyritized ammonite fossils from the Betahitra Valley were reported by BOULE *et al.* (1906–1907) and subsequently by COLLIGNON (1928–1929, 1931).

In this paper, we illustrate the geological outline of the Diégo-Suarez area and re-examine characteristics of the molluscan fauna, particularly in paleontological points of view. Along with geological outline of the Diégo-Suarez area, geological age, faunal composition and presumable paleoecology of mollusks are shown by KANIE in Part I. In Part II, HIRANO compares the growth modes of *Anagaudryceras sacya* (FORBES) from Diégo-Suarez with those of Japan, supplement the morphological information on *A. sacya* from Diégo-Suarez and consider the geographic variation between the two regions. In Part III, TANABE describes two species of *Scaphites* from Loc. Dg 2 along with some biometric examinations. Genus *Scaphites* is one of the most important ammonites in the Cenomanian deposits of this area. Previously COLLIGNON (1928–1929, 1931) described eleven species of *Scaphites* from several localities. However, the details of intraspecific variation of each species have not yet been clarified to our satisfaction. On the occasion of the field work, 162 individuals of *Scaphites* were collected, together with a large quantity of other marine molluscan fossils at Loc. Dg 2. In this part, he gives the systematic descriptions of the two species of *Scaphites* based on this collection.

All maragasy specimens examined are registered as a part of the collections of the National Science Museum, although they will be returned to the Malagasy Republic in the near future.

Acknowledgments. We express our sincere gratitude to Professor Tatsuro MATSUMOTO of Kyushu University for critical readings of the manuscript and suggestion on taxonomic problems, to Dr. Hiroshi UJIIÉ of the National Science Museum

* Contribution to the Paleontology of Madagascar, II.

** Present address: Institute of Earth Sciences, School of Education, Waseda University, Tokyo.

for his kind cooperation in the field work and critical readings of the typescript, to Dr. Ikuwo OBATA of the museum for giving kind advice and fruitful discussion, to Dr. Akira KATO and Mr. Satoshi MATSUBARA of the museum for the X-ray powder analysis of mineral compositions of fossils and spherulites. The field work was carried out with the facilities afforded by the Geological Survey, Department of Mines and Energy, Malagasy Republic. The study was supported by the Grant in Aid for Overseas Scientific Survey difrated from the Ministry of Education, and Science and Culture.

PART I FAUNAL ANALYSIS OF THE LOWER CENOMANIAN MOLLUSKS FROM DIÉGO-SUAREZ

Yasumitsu KANIE

The Cretaceous fauna of the Diégo-Suarez area has been studied mostly by French paleontologists. BOULE *et al.* (1906–1907) reported 74 species of fossil cephalopods including 10 new species from the environs of Diégo-Suarez. Among them, *Acanthoceras subvicinale*, *A. prenodosoides*, *Phylloceras forbesianum*, *P. diegoi*, *Scaphites aequalis*, *Belemnites fibula* and *Ostrea fosseyi* were shown as the Middle Cenomanian elements from the Betahitra Valley.

In 1910 HAUG assigned the age of the fauna containing *Scaphites aequalis-obliquus*, *Baculites baculoides*, *Turrilites morrissi*, *Gaudryceras sacya*, *Latidorsella latidorsata*, *Cottreautes subvicinale* and *Serpula ootatorensis* to the Middle to Upper Cenomanian.

COLLIGNON (1928–1929) described 92 species of cephalopods, among which 32 were designated as new “varieties” or “mutations”. Subsequently he (1931) added 65 species of invertebrates and 5 species of vertebrates to the fossil list which previously had shown, and then the fauna was composed of 120 cephalopod species (Scaphitidae 60%, Acanthoceratidae 17%, Turrilitidae 13%), 2 pelecypod species, 16 gastropod species, 12 coral species, and few species of crinoids, echinoids, annelids, decapods and pisces. As a result, he concluded that the fauna has a close relationship with the Cenomanian fauna of Algeria, Tunigia and also southern Europe. In 1964 COLLIGNON published an atlas of the Cenomanian ammonites from various localities in Madagascar including the Diégo-Suarez area.

Geological Outline of the Diego-Suarez Area

The paleontological reconnaissance survey of the Diégo-Suarez area was summarized in a Japanese preliminary report of the First Paleontological Expedition to Madagascar (1975). The geological sketch map of the Diégo-Suarez area indicating localities of our materials is shown in Fig. 1. The columnar sections are illustrated in Fig. 2. The lithofacies, the collected fossils, and the geological age of each locality are summarized in Table 1.

The outcrops of Locs. Dg 2–5, 6 and 8 are mostly composed of greyish green

Table 1. Locality list.

LOC.	LITHOLOGY	COLLECTED FOSSILS	AGE	ALTITUDE
Dg 1	calcareous mudstone	pelecypod fragments foraminifers	Cenomanian ?	ca.80m
Dg 2	mudstone	many mollusks, see text foraminifers	Cenomanian	ca.80m
Dg 3	mudstone	foraminifers	Cenomanian	
Dg 4	mudstone	<i>Picnodonte fosseyi</i> <i>Trochus</i> sp. <i>Tetragonites</i> sp. <i>Scaphites</i> cf. <i>perouini</i> foraminifers	Cenomanian	ca.123m
Dg 5	mudstone	foraminifers	Cenomanian	
Dg 6	mudstone	foraminifers	Cenomanian	ca.200m
Dg6'	chalk	foraminifers	Campanian ?	ca.200m
Dg 7	limestone (pebble)		Eocene	
Dg 8	calcareous mudstone		Cenomanian	ca.142m
Dg8'	chalk		Campanian ?	ca.142m
Dg 9	mudstone	<i>Mantelliceras susanna</i> <i>Scaphites</i> sp. <i>Mariella</i> sp. foraminifers	Cenomanian	ca.5m
Dg10	fine-grained sandstone	<i>Mantelliceras</i> cf. <i>caertianum</i>	Cenomanian	ca.40m

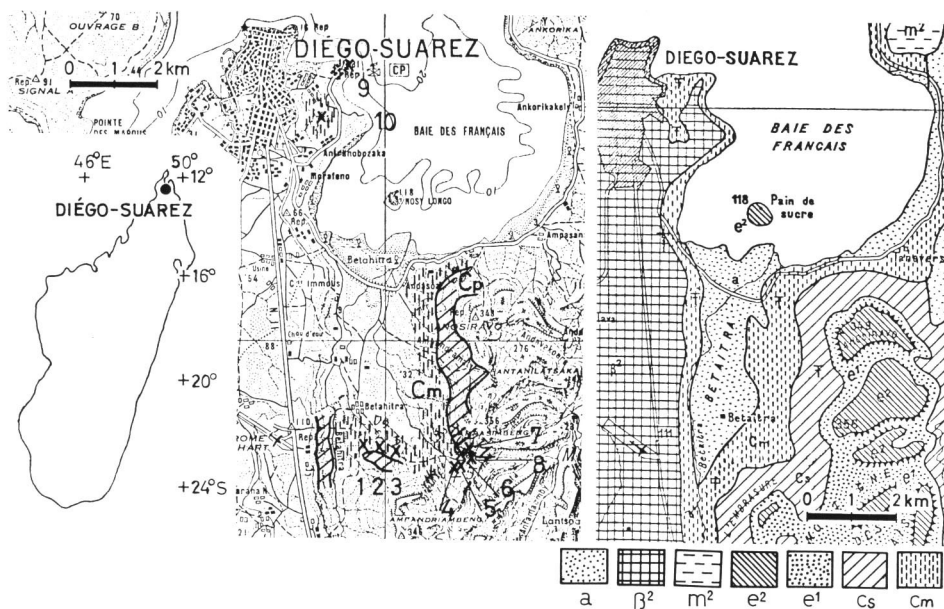


Fig. 1. Geological sketch maps of the studied area, showing localities (numerals and Dg 2). Right from RERAT (1963). Cm: "Cenomanian", Cp: "Campanian". a: Alluvium, β^2 : Recent basalt flows, m^2 : Aquitanian-Burdigarian, e^2 : Lutetian, e^1 : Infra-Lutetian, Cs: Coniacian-Campanian, Cm: Albian-Turonian.

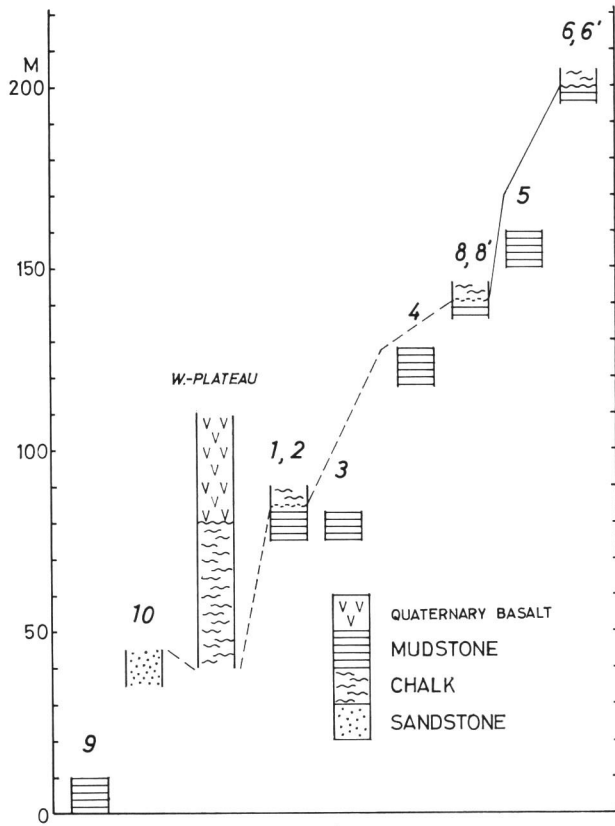


Fig. 2. Geological columnar sections of localities arranged by their approximate altitudes. All the mudstones are of the "Lower Cenomanian".

massive mudstone. The sediments often contain a number of molluscan fossils and gypsum crystals. At Loc. Dg 2 abundant small-sized mollusks are scattered on the earth composed of weathered mudstone containing goethite-spherulites 1 to 2 cm across.

Loc. Dg 9 in Diégo-Suarez City shows massive mudstone yielding small specimens of *Mantelliceras* sp., *Mariella* (*Mariella*) sp., *Scaphites* sp., similarly to Loc. Dg 2, associated with gypsum crystals and goethite-spherulites. A fragment of *Mantelliceras* cf. *cantianum* SPATH occurred in the calcareous fine-grained sandstone bed at Loc. Dg 10 which lies about 35 m above the Loc. Dg 9 in altitude. Loc. Dg 1 is mostly composed of probable Cenomanian calcareous sandstone or siltstone bearing pelecypod fragments.

The probable Campanian bed with westward dipping unconformably overlies Cenomanian deposits as seen at Loc. Dg 6. Quaternary basalt layer almost horizontally covers Cretaceous deposits at higher altitude than 80 m, as seen on plateau west of the Betahitra Valley for example.

Material

I treated about five hundreds specimens from Loc. Dg 2 and discriminated 13 genera and 22 species as follows:

CEPHALOPODA

- Neophylloceras seresitense* (PERVINQUIÈRE)
N. sp.
Phyllopachyceras diegoi (BOULE, LEMOINE & THEVENIN)
P. whiteavesi KOSSMAT
Anagaudryceras sacya (FORBES)
Tetragonites kiliani jacobi COLLIGNON
T. timotheanus (PICTET)
Gabbioceras jaubertianum jacobi (COLLIGNON)
 Gaudryceratidae gen. et sp. indet.
Sciponoceras aff. *baculoides* (MANTELL)
S. sp.
Anisoceras aff. *armutum* (SOWERBY)
A. subcompressum FORBES
Mariella (*Mariella*) n. sp. aff. *M. (Mariella) lewesiensis* (SPATH)
M. sp.
Scaphites dailyi WRIGHT
S. bassei COLLIGNON
S. sp.
Uhligella? *walleranti jacobi* COLLIGNON
Puzosia (?) sp.
Mantelliceras (Mantelliceras) saxbii (SHARPE)
M. (Mantelliceras) suzanna (PERVINQUIÈRE)
M. (Cottreautes) waterloti COLLIGNON
M. (?) sp.
Sharpeiceras cf. *falloti* (COLLIGNON)
Utaturiceras (?) *subvicinale* (BOULE, LEMOINE & THEVENIN)
Stoliczkaia (Stoliczkaia) aff. *texana* (GRAGIN)
 “*Mammites*” *prenodosoides* BOULE, LEMOINE & THEVENIN

PELECYPODA

- Picnodonte fosseyi* (LEMOINE)
Macoma sp.

GASTROPODA

- Cerithium* sp.
Rostellaria (?) sp.
Trochus waterloti COLLIGNON
T. cf. *crucianum* PICTET & CAMPICHE
Soloarium cf. *berthoni* PERVINQUIÈRE

HEXACORAL

- Cycloseris diegoensis* COLLIGNON

Although BOULE *et al.* (1906–1907) reported 74 species, and COLLIGNON (1928–1929, 1931) 157 species from the Diégo-Suarez area, several “species” described by them may have to be suppressed as variations or objective synonyms, according to my preliminary examination. Figure 3 indicates the frequency of occurrence at

generic level. Heteromorph ammonoid species belonging to *Scaphites*, *Mariella*, *Sciponoceras* etc. occupy 62% of total ammonite individuals. The remnant contains such *Neophylloceras* and *Phyllopachyceras* (10%) as ammonites stated as “smooth, involute, and obese shells with subcircular whorl section” by SCOTT (1940), and such *Mantelliceras*, *Stoliczkaia* and *Utaturiceras* (?) (11%) as the ones stated as “sculptured evolute shell with quadrate whorl section”.

The maximum diameter of coiled, scaphitid and turrilitid ammonites are 3, 1.6 and 3 cm, respectively, and maximum length of the straight ammonites is 3 cm. The specimens were mostly preserved only as phragmocones. Pelecypods and gastropods are less than 2.5 and 2 cm in height, respectively.

Faunal Analysis

Taxonomic Notes on Selected Species. This brief notes concern the species shown in Table 2, where representative cephalopod species common between Loc. Dg 2 and various regions in the world are listed.

Neophylloceras seresitense (PERVINQUIÈRE), which was reported from the Diégo-Suarez area by BOULE *et al.* (1906–1907) under the name of *Phylloceras velledae* MICHELIN and revised to the named species by MATSUMOTO (1959), has broader whorl, and more complicated suture-line with more finely and deeply incised elements than *Phyllopachyceras diegoi* (BOULE, LEMOINE & THEVENIN).

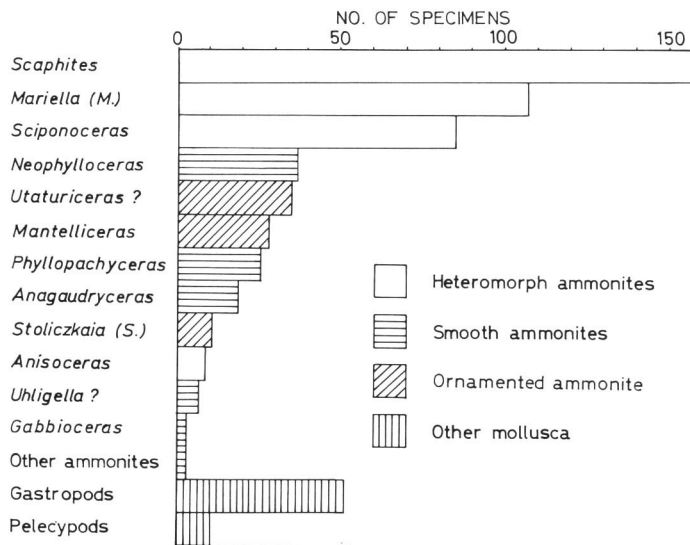


Fig. 3. Abundance of ammonite genera gastropods and pelecypods observed at Loc. Dg 2.

Table 2. Geographical distribution of the selected ammonite species from Loc. Dg 2, same as (X) or similar to (*) those from various places of the world.

	1 Nigeria, Cameroon	2 Southeast Africa	3 South India	4 Algeria, Tunisia	5 Southwest Europe	6 New Zealand, Australia	7 Japan, Sakhalin
<i>Neophylloceras seresitense</i>	x Ab		x	x	x	x M	x
<i>Phyllophyceras diegoi</i>							
<i>P. whiteavesi</i>			x	x			
<i>Anagaudryceras sacya</i>			x Ab		x		x Ab-U
<i>Tetragonites kiliani jacobi</i>					* Ab		* Ab
<i>T. timotheanus</i>		* L	x Ab		x		* Ab
<i>Gabbioceras jaubertinum jacobi</i>					* Ab		* Ab
<i>Sciponoceras aff. baculoides</i>			*		* M	* M	*
<i>Antisoceras aff. armatum</i>					*		
<i>A. subcompressum</i>		x	*				
<i>Mariella aff. lewesiensis</i>							
<i>Scaphites dailyi</i>			x			x M-U	x L
<i>S. bassei</i>							
<i>Uhligella (?) walleranti</i>		*	*	x Ab-M			
<i>Mantelliceras saxbii</i>				* Ab	* Ab		
<i>M. suzanna</i>			x	x L	x L		
<i>M. waterloti</i>				x L			
<i>Sharpeioceras cf. falloti</i>		x L		* Ab	* Ab		
<i>Utaurioceras (?) subvicinale</i>			*		* U		
<i>Stoliczkaia aff. tezana</i>	* Ab	* Ab	* Ab	* Ab-L	* Ab		* Ab?-L
" <i>Mammites</i> " <i>prenodosoides</i>							

1: Reyment, 1955, 2: Collignon, 1928-1929; Kennedy & Klinger, 1975, 3: Matsumoto, 1942c; Matsumoto *et al.*, 1966, 4: Pervinquierre, 1907; Collignon, 1928, 1929, 1931; Sornay, 1955, 5: Jacob, 1908; Collignon, 1928-1929; Kennedy, 1971; Kennedy & Hancock, 1971, 1977, 6: Wright, 1963 — northern Australia; Henderson, 1973 — New Zealand, 7: Matsumoto, 1942b, 1942-1943. Ab: Alban, L: Lower Cenomanian, M: Middle Cenomanian, U: Upper Cenomanian

The growth mode of *Anagaudryceras sacya* (FORBES) is shown in Part II by HIRANO. The other small specimens of tetragonitids are tentatively identified to *Tetragonites kiliani jacobi* (COLLIGNON), *T. timotheanus* (PICTET) and *Gabbioceras jaubertianum jacobi* (COLLIGNON).

Sciponoceras aff. baculoides (MANTELL) abundant at Loc. Dg 2 seems to differ somewhat from the typical species described by MATSUMOTO and OBATA (1963) in having an elliptical whorl section and slightly prorsiradiate regular ribbing.

Mariella is next to *Scaphites* in the individual numbers (Fig. 3). *M. (Mariella)* n. sp. aff. *lewesiensis* (SPATH) is characterized by spire angle of about 30°, two narrowly spaced rows of tubercles on the bulge, and two widely spaced ones on the flank. Sometimes the two kinds of rows make oblique ribs. *M. (Mariella)* n. sp. aff. *lewesiensis* (not yet described but now being prepared for description by MATSUMOTO and INOMA*) was originally found from the Lower Cenomanian deposits of the Shumarinai-Soeushinai area of Hokkaido and the *Graysonites*-bearing bed in Kyushu, Japan. This new species is characterized by three rows of tubercles on the external side and another masked row of tubercles on the base, normally with a rib extending from the upper tubercle.

Scaphites is most abundant at Loc. Dg 2, where two species are discriminated by TANABE as shown in Part III. While *S. dailyi* C. W. WRIGHT is distributed in the

* I express many thanks to Dr. MATSUMOTO and Dr. Akitoshi INOMA for offering me unpublished data of this new species.

Middle to Upper Cenomanian of northern Australia and southern India, *S. bassei* COLLIGNON occurs in the Upper Albian to Middle Cenomanian of Algeria.

Among acanthoceratids fairly common at Loc. Dg 2, cosmopolitan *Mantelliceras* (*Mantelliceras*) *saxbii* (SHARP), which is a synonym of *M. martimpreyi* (COQUAND), is less common compared with the other species of *Mantelliceras*. *M. (Mantelliceras) suzannae* (PERVINQUIÈRE) is common between Madagascar and Tunisia and *Sharpeicer* *cf. falloti* (COLLIGNON) common between Madagascar and southeastern Africa, whereas *M. (Cottreauites) waterloti* COLLIGNON, *Utaturiceras* (?) *subvicunale* (BOULE, LEMOINE & THEVENIN) and "*Mammites*" *prenodosoides* BOULE, LEMOINE & THEVENIN are endemic species in Madagascar as pointed out by COLLIGNON (1928–1929).

Stoliczkaia (Stoliczkaia) aff. texana (GRAGIN) from Loc. Dg 2 has broader whorl section (B/H: 0.96–1.17) than that of lectotypes of *S. (Stoliczkaia) texana* from Texas (MATSUMOTO and INOMA, 1975).

Decapods, gastropods excluding *Solarium cf. berthoni* PERVINQUIÈRE, and hexacorals are regarded as endemic species. The name of "*Ostrea*" *fosseyi* LEMOINE was transferred to *Picnodonte fosseyi* after STENZEL (1971).

Table 2 seems to suggest that the fauna from Loc. Dg 2 is characterized by the Indo-Pacific elements and the Tethys ones. The fauna has few common species with "chalk or conglomerate facies" of Zululand of South Africa (KENNEDY and KLINGER, 1971) but nothing with the Lower Cenomanian of Morocco (COLLIGNON, 1966). A cosmopolitan species, *Neophylloceras seresitense*, was also reported from Nigeria (REYMENT, 1955).

Geological Age. Judging from the occurrence of several species of *Mantelliceras* with *Sciponoceras aff. baculoides* (MANTELL) and *Mariella (Mariella) aff. lewesiensis* (SPATH) from the same bed, the horizon may be included in the Lower Cenomanian (cf. KENNEDY and HANCOCK, 1977). *M. (Mantelliceras) saxbii* is associated with such relatively long ranged species as *Anagaudryceras sacya*, *Tetragonites kiliani jacobi*, *Gabbioceras jaubertianum jacobi*, *Uhligella* (?) *walleranti* COLLIGNON at various places of the world as well as at Loc. Dg 2. But certain species somewhat similar or related to the Diégo-Suarez materials have been recognized in the Upper Albian faunas of the other countries as summarized in Table 2. The range of *Scaphites dailyi* probably extends to the Lower Cenomanian in Madagascar.

Suggested Paleoenvironment. On the basis of the faunal composition from Loc. Dg 2, a presumable ecological condition may be suggested as follows:

(1) Individual numbers of certain restricted species are very large at Loc. Dg 2. This suggests that they lived in schools.

(2) Almost all the ammonite individuals are small as preserved as only phragmocones. On the other hand, larger adult specimens of *Mantelliceras cf. cantianum* SPATH occurred from Loc. Dg 10, which is at somewhat higher stratigraphic level than Loc. Dg 2.

The surface of molluscan fossils were replaced by goethite, probably because of the oxidization of pyrite, while chamber space of ammonite is occupied by barite.

The other examples of pyritized micromorphic invertebrates fauna were reported from the Albian to the Cenomanian mudstone of Algeria, Tunisia and Texas (KENNEDY and COBBAN, 1976). Spherulites of 1 to 2 cm in diameter often occur along with molluscan fossils at Loc. Dg 2. Surface of the spherulite is also replaced by goethite, and the internal portion is occupied by gypsum. According to EDWARD and BAKER (1951), pyrite is an indicator of a neutral or alkaline sea waters. Sulphur source of the pyrite may be ascribed to the decay of organisms, in a great deal of ammonite soft bodies, under anaerobic condition in some enclosed environment.

(3) SCOTT (1940) reported ammonite specimens under similar state of preservation from the Upper Albian "Upper Duck Creek Bed" of Texas, where the shells are replaced by pyrite and marcasite. The ammonite fauna is represented principally by several species of *Mortoniceras* and *Prohysteroceras*, and few species of *Desmoceras* and *Uhligella*. *Scaphites*, *Worthoceras*, *Hamites* and *Crioceras*, which constitute important elements of the fauna, are all of small individuals and are associated with many small gastropods and pelecypods.

Partially adopting SCOTT's (1940) estimation on the bathymetric distribution of the Upper Duck Creek fauna, the fauna from Loc. Dg 2 could be regarded as a representative of infra-neritic to epibathyal type. According to MATSUMOTO's (1965) scheme of ammonite biofacies, Dg 2 fauna is assignable to the intermediate facies between off-shore mud and near-shore shelf facies.

Suggested Early Cenomanian Paleogeography of Madagascar.

A paleogeographic map (Fig. 4) of the western coast of Madagascar in Early Cenomanian is tentatively drawn based on the previously published data (particularly, BESAIRIE, 1972; COLLIGNON, 1936).

Pyritized ammonites like those at Loc. Dg 2 of the Diégo-Suarez area were also reported from the southern region; *i.e.* Mahaboboka (e in Fig. 4) 100 km north of Tuléar (BESAIRIE, 1972, p. 364) and Betsioky (f) 80 km southeast of Tuléar (COLLIGNON, 1936). Both the two faunas are also characterized by heteromorph ammonites, indicative for the "intermediate facies". Along the western coast region between Diégo-Suarez and Tuléar, ornamented ammonites occur characteristically at four localities; namely, Befotaka (a) about 200 km northeast of Majunga, Manja (b) 120 km south of Morondava, southern bank of the Mangoky River 170 km north of Tuléar, and Ankomaka (c) 60 km north of Tuléar (d). "Near-shore facies" (MATSUMOTO, 1965) indicated by the occurrence of ornamented ammonites coincides with more sandy lithofacies of the four localities. It must be mentioned that the Lower Cenomanian equivalents between Befotaka and Manja are represented by non-marine deposits sparingly intercalated with marine beds.

Consequently we can imagine such paleoenvironment as the sea under the "intermediate facies" around Diégo-Suarez and Tuléar becoming shallower and nearer to land towards the central region. Although the shore-line may have extended somewhat westward, the Early Cenomanian sea passage may have never been blocked by a land mass at the central region because of very close similarity between the Diégo-

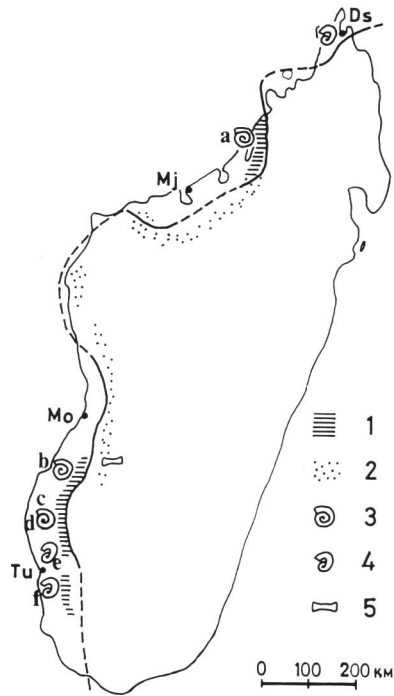


Fig. 4. Early Cenomanian paleogeographic map on the western coast of Madagascar. 1: mudstone, 2: sandstone, 3: ornamented ammonite, 4: heteromorph ammonite, 5: reptile bone. Ds: Diégo-Suarez, Mj: Majunga, Mo: Morondava, Tu: Tuléar. a-f: see the text.

Suarez and the Tuléar faunas. Since the age the Mozambique Channel might have been opened.

Concluding Remarks of Part I

28 species of ammonite, two of pelecypod, five of gastropod and one of hexacoral were collected from Loc. Dg 2, south of Diégo-Suarez. This fauna is assigned to the Lower Cenomanian because of *Mantelliceras* (*Matelliceras*) species, especially *M. (Mantelliceras) saxbii*. The Diégo-Suarez fauna is characterized by the Indo-Pacific and Tethys elements despite of estrangement from western Africa elements.

The dominant occurrence of such heteromorph ammonites as *Scaphites*, *Sciponoceras*, *Mariella*, etc. at Loc. Dg 2 indicates the “intermediate facies” between the “off-shore facies” and the “near-shore facies” of MATSUMOTO (1965), “*Bculites* facies” of MATSUMOTO and OBATA (1962), or “infraneritic—epibathyal facies” of SCOTT (1940).

Pyritized shells partly replaced by goethite and their small, immature size suggest a muddy bottom environment in a somewhat enclosed bay, followed with the post-mortem anaerobic condition.

On the basis of ammonite biofacies and lithology, I proposed an Early Cenomanian paleogeography of the western coast of Madagascar. The sea was shallower and nearer to shore toward the central region from the north around Diégo-Suarez and also from the south around Tuléar, probably because of the westward extending of shore-line between Majunga and Morondava. However, no land mass obstructed the sea passage between Diégo-Suarez and Tuléar since the Lower Cenomanian ammonite faunas from the two regions have a close relation from each other.

PART II NOTE ON *ANAGAUDRYCERAS SACYA* FROM THE DIÉGO-SUAREZ AREA

Hirokich HIRANO

Ammonites sacya FORBES was established along with *Ammonites buddha* by FORBES (1846, pp. 112–113, pl. 14, figs. 9, 10). The former is represented by a small specimen with diameter 32.8 mm (MATSUMOTO measured at British Museum) and the latter is by a fragmentary ribbed specimen with whorl-height 42.5 mm (MATSUMOTO measured). Those two specimens were collected from Verdachellum, southern India. STOLICZKA (1865) regarded these two incomplete specimens, growth stages of which are perhaps different from each other, as one species based on his three specimens collected from the neighbourhood of Odium and Moraviatoor, southern India. He used the name *A. sacya* and rejected *A. buddha*. Whether his step is correct or not is uncertain. The detailed state of this problem was mentioned by MATSUMOTO (1959, p. 73).

On the other hand, BOULE *et al.* (1906) described *Lytoceras (Gaudryceras) cf. sacya* based on small specimens from Diégo-Suarez. COLLIGNON (1928, 1931) identified small specimens from Diégo-Suarez with *L. (Gaudryceras) sacya*. 19 specimens at my hands are much similar to those specimens of *cf. sacya* and *sacya* of these two authors, and then I identified them with *Anagaudryceras sacya*.

Japanese specimens of *Anagaudryceras sacya* has hitherto been called by the name although the detailed report has not been published yet.

From these reasons, the holotypes of *A. sacya* and *A. buddha* and topotypes should be studied in detail again, although tentatively I regard here the step of STOLICZKA (1865) as correct and follow the redefinition of KOSSMAT (1895).

Morphology of *A. sacya* from Diégo-Suarez

I. *Material.* 19 specimens from Loc. Dg 2, south of Betahira, Diégo-Suarez. NSM. PM 9163–9173.

II. *Description.* The volution of the whorl is moderate in the lateral view. The shell is rarely preserved and the surface is coated by goethite. Although the surface ornamentation is not observable in detail, so far as I observe, the whorl is devoid of ribbing. The construction is somewhat prorsiradiate and somewhat flexuous. The flank is flat and the venter is fairly wide. The average growth pattern of the

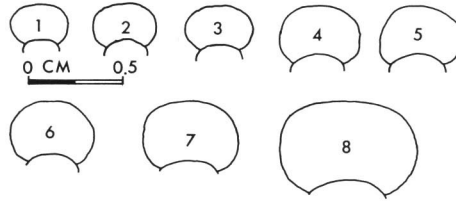


Fig. 5. Ontogenetic change of the whorl section of *Anagaudryceras sacya* (FORBES) from Loc. Dg 2. 1: Diameter 6.60 mm, NSM. PM 9173 2: D. 7.55 mm, NSM. PM 9172 3: D. 8.20 mm, NSM. PM 9171 4: D. 9.80 mm, NSM. PM 9164 5: D. 10.25 mm, NSM. PM 9170 6: D. 10.45 mm, NSM. PM 9169 7: D. 12.40 mm, NSM. PM 9168 8: D. 17.55 mm, NSM. PM 9165.

whorl section is shown in Fig. 5, and this pattern indicates that the width of the whorl is larger than the height through the observed growth stages. The body chamber is not preserved. The sample of Loc. Dg 2 is composed of very small specimens for the size of *A. sacya* and the statistic of the maximum diameter is given as follows: N: 19; observed range: 6.65–17.40 mm; mean: 11.49 mm; coefficient of variability:

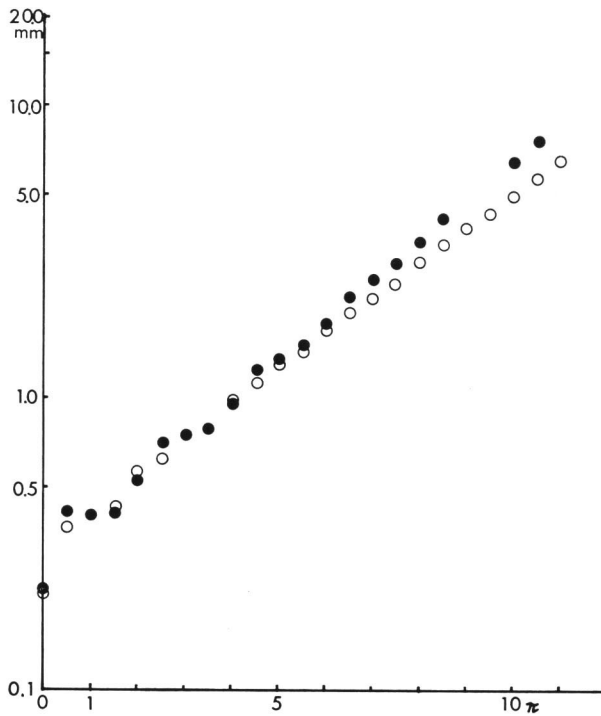


Fig. 6. Growth pattern of the radius length to the spiral of *Anagaudryceras sacya* from Loc. Dg 2. Open circle: NSM. PM 9163; black circle: NSM. PM 9166.

24.65; standard deviation: 2.83 mm

I consider that they are not dwarf but immature, because the observable last septa are not approximated, ribs are not yet arisen and the suture is of the same complexity as that of similarly small immature examples of *A. sacya* from Japan.

The size distribution does not show the significant difference from the normal distribution in the chi-square test ($\chi^2=2.551 \ll \chi^2_{0.05}(\nu=3) = 9.488$).

Concerning the growth pattern of radius length to the spiral in cross section, two specimens are available for the measurements. The critical point is at about the 2.0π growth point and there is no critical point after that at least until about the 11.0π point (Fig. 6). The growth ratio in the stage from 2π to 11π is from 0.135 to 0.120. The mean is 0.128, the coefficient of variability is 8.417 and the standard deviation is 0.011.

As the sample is on loan from the Malagasy Republic, I did not disassemble the whorls from the outer to the protoconch. Therefore I cannot figure out the details

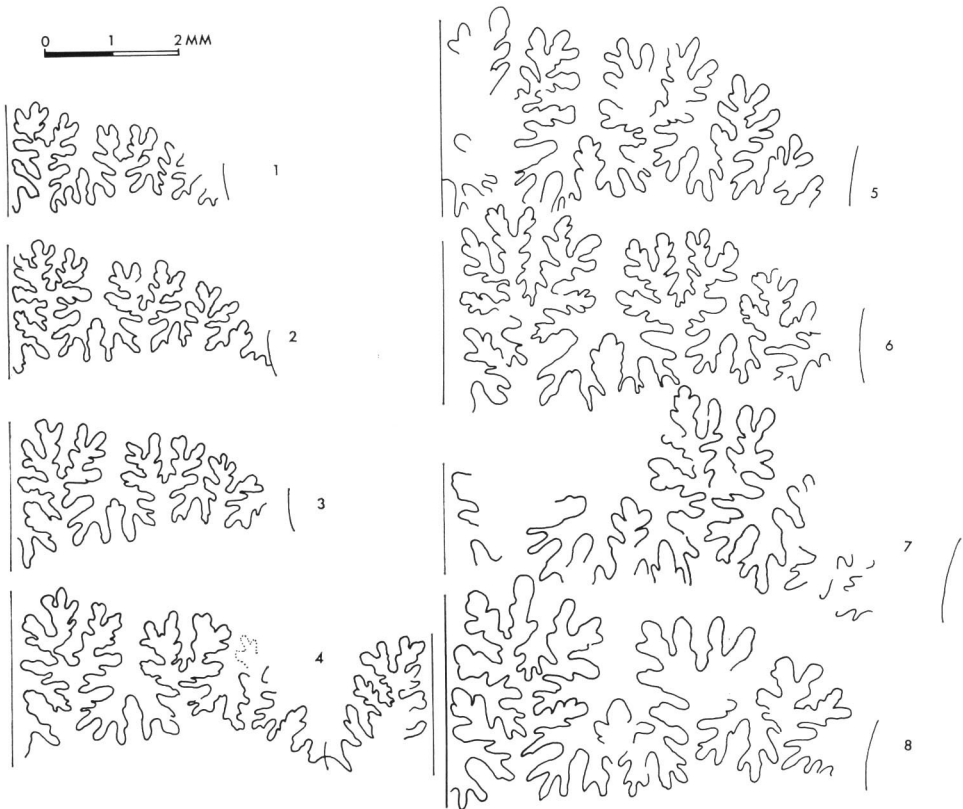


Fig. 7. Sutural ontogeny of *Anagaudryceras sacya* from Loc. Dg 2. 1: diameter ca. 6 mm, 2: 8 mm, 3: ca. 10 mm, 4: 10.4 mm, 5: ca. 11 mm, 6: 13.8 mm, 7: 14.7 mm, 8: ca. 15 mm; 1, 2: NSM. PM 9167; 4, 6: NSM. PM 9164; 5, 7: NSM. PM 9166; 8: NSM. PM 9165.

of successive pattern in sutural ontogeny, but the patterns at eight growth points from the diameter 0.6 cm to 1.5 cm of the four specimens are obtained (Fig. 7). The observed patterns do not conflict with $ELU_2U_1Is(U_1 \text{ suspensive})$ -pattern of the Gaudryceratinae (MATSUMOTO, 1942a, fig. 1; KULLMANN and WIEDMANN, 1970, fig. 14h).

Morphology of *A. sacya* from Japan

Material. Three specimens, GK. G. 5860–5862, from the River Kanajiri-zawa, Obira, Rumoi-gun, Hokkaido (Loc. R5403 pl, see TANABE *et al.*, 1977), one, GK. G. 5863, from the Kiritachitoge, Tomamae-gun, Hokkaido (Loc. R107, see MATSUMOTO and OKADA, 1973), one, GK. H. 5864, from the River Hakkin-zawa, Oyubari, Hokkaido (Loc. Y5286w, see HIRANO *et al.*, 1977) and one, GK. H. 5865 from the River Hikage-zawa, Shiyubari, Hokkaido (Loc. Y650c, see MATSUMOTO, 1942–1943). All of these localities are of a Cenomanian age and the stratigraphy around them is described respectively in the papers indicated above.

Description. Concerning *Anagaudryceras* from Japan, a successive occurrence of *A. sacya*, *A. limatum* (YABE) and *A. yokoyamai* (YABE) have been known since MATSU-

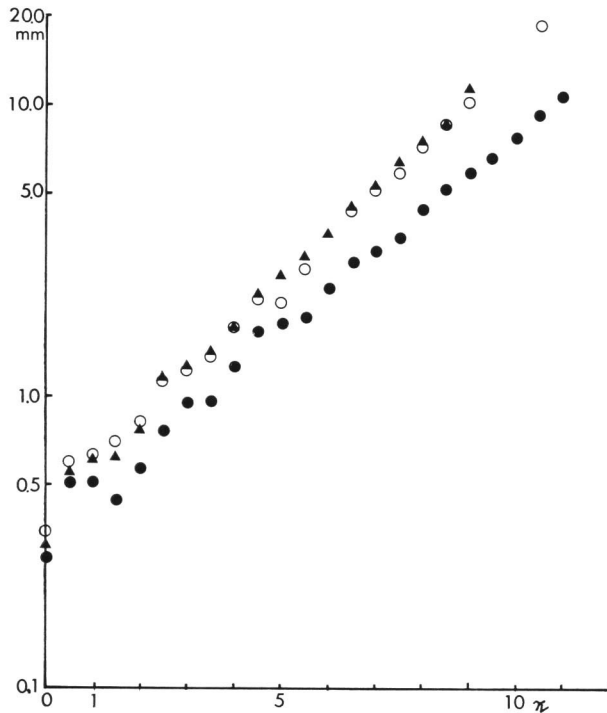


Fig. 8. Growth pattern of the radius length to the spiral. *Anagaudryceras sacya* from Hokkaido, Japan. Open circle: GK. G. 5860, black circle: GK. G. 5863, black triangle: GK. G. 5861.

MOTO (1941) pointed out the interesting mutual relation among them. Here I omit to state repeatedly that point and the general morphology and illustrate the growth pattern of the radius length to the spiral in the cross section and also the suture.

Three cut and polished specimens are available for the growth analysis of radius length to the spiral. The patterns show one critical point at about the 2.0π point and no other critical points after that (Fig. 8). The statistic of the growth ratio in the growth stage from about 2π point to about 11π point is as follows.

N: 3; $\bar{\alpha}$: 0.149; coefficient of variability: 7.652; standard deviation: 0.011.

The sutural patterns in the immature stages are yet insufficiently obtained and here I illustrate two patterns at the growth points of the diameters 1.7 cm and 5.0 cm (Fig. 9). Although the patterns are not traced successively in one and the same specimen, the observed patterns do not conflict with the $ELU_2U_1Is(U_1 \text{ suspensive})$ -pattern.



Fig. 9. Sutural patterns of *Anagaudryceras sacya* from Hokkaido, Japan. Upper: diameter 17 mm, GK. G 5863; Lower: diameter. 50 mm, GK. G. 5864.

Comparison between Samples of Japan and Madagascar

Growth Pattern of Radius Length to the Spiral. I compare the growth ratios of the radius length to the spiral between the samples from the two regions. The results

from the above described data are as follows.

$$F=1.135 < F_{0.05}(\nu=1/2)=199.50 \quad \text{Not significant}$$

$$t=2.125 < t_{0.05}(\nu=3)=2.776 \quad \text{Not significant}$$

$$\text{Coefficient of difference}=0.977$$

From these results it follows that there is no significant geographic variation on the growth mode of radius length in the growth stage up to about the 11π point between the two samples. This character seems to be very stable in this species.

Suture: No clear difference is detected in the main elements of the similar growth stage between the two samples. Although the suture has been regarded as the highly stable character, it is necessary to examine further the favourably preserved adult specimens from Madagascar.

Concluding Remarks of Part II

Anagaudryceras sacya from Diégo-Suarez (Loc. Dg 2) is represented by 19 small specimens with mean diameter of 11.49 mm. From the facts that the preserved septa are not approximated, the rib does not yet appear and the suture is not fully grown up, I conclude that they are immature.

As the sutural pattern has hitherto been rarely illustrated, here I illustrate some. Although the detailed developmental history of the suture is not traced, the obtained patterns do not conflict with the $ELU_2U_1Is(U_1 \text{ suspensive})$ -pattern of the Gaudryceratinae.

The suture and the growth mode of radius length are compared between two samples of the species from Japan and Madagascar, and no clear differences are detected. For example, the growth modes of the two samples show only one critical point at about the 2.0π growth point. Although the adult specimens from Madagascar are necessary for further analysis, these characters also seemed to be geographically fairly stable at least in the observed growth stages.

PART III LOWER CENOMANIAN SCAPHITES FROM DIÉGO-SUAREZ

Kazushige TANABE

The fossil locality Dg 2 is shown in Fig. 1. 162 individuals of *Scaphites*, to be discussed in this paper, were collected from a single bed which belongs to the Cm Formation of RERAT (1963).

After having examined the sample collected, *Scaphites dailyi* C. W. WRIGHT (159 individuals including 25 adult forms) and *Scaphites bassei* COLLIGNON (3 adult individuals) are distinguished.

The body chamber of adult specimens of both species are all imperfect and

secondarily deformed. The shell layer of every specimen is completely eroded away. With respect to the septa, they have been diagenetically replaced by geothite. For that reason, the present material is not suitable for the analysis of ontogenetic shell growth. However, the septate whorls of almost every specimen are not deformed, and the details of surface ornamentation can be observed.

Systematic Descriptions

Order AMMONOIDEA

Superfamily Scaphitaceae MEEK, 1876

Family Scaphitidae MEEK, 1876

Genus *Scaphites* PARKINSON, 1811

Type-species. *Scaphites equalis* J. SOWERBY, 1813

Scaphites dailyi C. W. WRIGHT

Pl. 4, figs. 1–12; fig. 13–(1)–(6)

Scaphites obliquus SOWERBY: STOLICZKA 1865, p. 168, pl. 81, figs. 1–3.

Scaphites aequalis SOWERBY: BOULE, LEMOINE, and THEVENIN 1907, pl. 13, fig. 6.

Scaphites aequalis-obliquus SOWERBY: COLLIGNON 1929, p. 49, pl. 5, figs. 1–6, —COLLIGNON 1964, p. 9–10, pl. 319, fig. 1376.

Scaphites hugardianus D'ORBIGNY: COLLIGNON 1929, p. 53, pl. 5, fig. 12.

Scaphites falloti COLLIGNON 1929, p. 54, pl. 5, fig. 14.

Scaphites dailyi C. W. WRIGHT 1963, p. 602, pl. 81, fig. 6.

Scaphites (Scaphites) yonekurai YABE: WIEDMANN 1965, p. 421–422, pl. 56, fig. 7; text-fig. 3d.

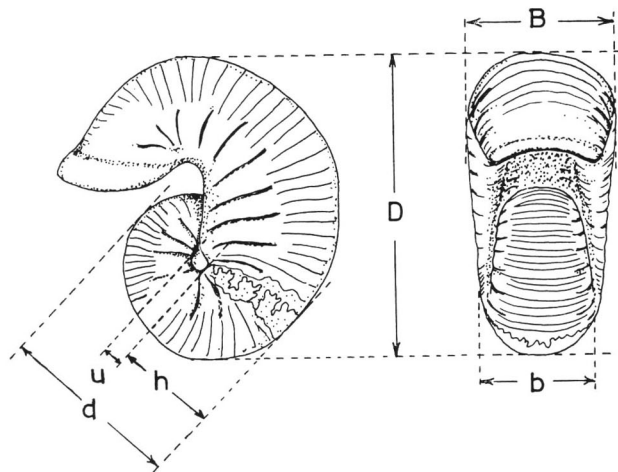


Fig. 10. Basic morphology and measurements of *Scaphites*. D: maximum size of an adult shell B: maximum breadth of an adult shell, d: maximum size of a spiral portion, h: maximum whorl height of septate whorls, b: maximum whorl breadth of septate whorls, u: umbilicus of a spiral portion.

Material. 159 individuals (NSM.PM 9001–9159) from Loc. Dg 2.

Description. Shell medium sized for the genus, stout, more or less inflated; at the adult stage, body chamber tightly enrolled with well-developed lateral bulges at its base; septate whorls evolute with subcircular cross section at the early to middle stages, up to a shell diameter of approximately 7–8 mm, but later become embracing so that the adult shell narrowly umbilicate with semilunate whorl section; surface ornamented by straight or somewhat adapically concave primary, and fine and dense secondary ribs; secondaries bifurcate from primaries at mid-flank; coarseness of both ribs tend to be coarser from the last septate whorl; tubercles absent; suture characterized by its asymmetric L and a deep lobule in the middle of saddle E L.

Variation of Adult Shells. The variation of four characters, namely maximum size of a spiral preion (d), maximum whorl height of septate whorls (h), maximum whorl breadth of septate whorls (b), and umbilicus of a spiral portion (u) was examined in the 22 adult specimens. The basic morphology and measurements of *Scaphites* are diagrammatically illustrated in Fig. 10. The dimensions (in mm) of examined adult specimens are tabulated as follows: (for abbreviations see Fig. 10).

NSM.PM	d	h	b	u	h/d	b/d	u/d
9001	13.0	7.8	11.4	0	0.60	0.88	0
9002	15.3	9.5	11.0	0.8	0.62	0.72	0.05
9003	11.2	7.2	10.0	0.8	0.64	0.89	0.07
9005	13.4	7.4	11.8	0	0.55	0.88	0
9006	12.7	9.0	9.3	0	0.71	0.73	0
9007	12.3	9.0	9.3	0.6	0.73	0.76	0.05
9008	12.1	8.0	8.6	0	0.66	0.71	0
9009	11.0	7.0	7.0	0.5	0.64	0.64	0.05
9014	12.1	8.1	8.8	0.5	0.67	0.73	0.04
9015	11.3	5.9	8.5	0	0.52	0.75	0
9019	15.0	7.6	12.0	0	0.51	0.80	0
9021	12.1	8.8	9.9	0.8	0.73	0.82	0.07
9024	12.1	7.5	10.5	0	0.62	0.87	0
9027	12.9	8.1	8.8	0.5	0.63	0.68	0.04
9028	13.3	7.5	9.1	1.0	0.56	0.68	0.08
9052	15.8	11.2	13.4	0	0.71	0.85	0
9065	14.3	8.8	8.7	0.9	0.62	0.61	0.06
9073	12.1	8.2	8.1	0.6	0.68	0.67	0.05
9074	13.2	8.2	9.4	0	0.62	0.71	0
9077	12.1	7.9	8.5	1.1	0.65	0.70	0.09
9084	11.4	6.9	8.7	0.7	0.61	0.76	0.06
9091	11.8	8.0	7.9	0.5	0.68	0.67	0.04

The sample mean (\bar{X}), coefficient of variation (V), and standard deviation (s) of each character are summarized as follows:

$$d: \bar{X}=12.75 \text{ mm}, V=10.45, s=1.33 \text{ mm}$$

$$h: \bar{X}= 8.07 \text{ mm}, V=13.27, s=1.07 \text{ mm}$$

$$b: \bar{X}= 9.58 \text{ mm}, V=16.11, s=1.54 \text{ mm}$$

$$u: \bar{X}= 0.42 \text{ mm}, V=92.61, s=0.39 \text{ mm}$$

The coefficient of variation of *u* is extremely large as compared with those of other three characters. The variance-covariance matrix of these four characters is

$$\begin{bmatrix} 1.77 & 0.95 & 1.48 & -0.88 \\ & 1.14 & 0.74 & 0.01 \\ & & 2.37 & -0.25 \\ & & & 0.15 \end{bmatrix}$$

, and the sample correlation matrix is given as

$$\begin{bmatrix} 1.00 & 0.67 & 0.72 & -0.16 \\ & 1.00 & 0.45 & 0.22 \\ & & 1.00 & -0.42 \\ & & & 1.00 \end{bmatrix}$$

The coefficients of correlation between *u* and the remaining three characters are not significant with 95% confidence.

Variation of Sutures. The variation of sutures was examined in the selected seven specimens. Although the suture of the present species is expressed by the formula, E L p Uv Ud I, the complexity varies from specimen to specimen (see Fig. 11). No relationship is observed between the length of whorl section and that of ex-

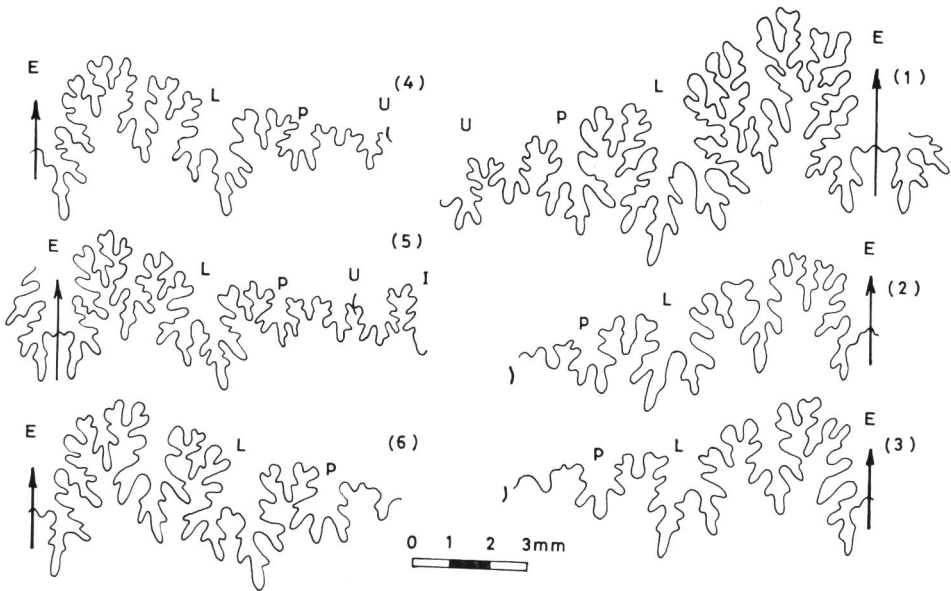


Fig. 11. Variation of sutures in *Scaphites dailyi* C. W. WRIGHT from Loc. Dg 2. (1): NSM. PM 9058, *b*=13.7 mm, *h*=5.5 mm, (2): NSM. PM 9062, *b*=8.8 mm, *h*=6.0 mm, (3): NSM. PM 9053, *b*=9.5 mm, *h*=4.7 mm, (4): NSM. PM 9016, *b*=8.7 mm, *h*=4.9 mm, (5): NSM. PM 9068, *b*=10.7 mm, *h*=5.6 mm, (6): NSM. PM 9079, *b*=8.7 mm, *h*=4.5 mm.

ternal suture, but as shown in Fig. 12, there is an intimate correlation between the sutural complexity (=external sutural length/length of whorl section) and the ratio of b to h. Namely the sutural complexity increases with the increase of the ratio of b to h. However, if we attempt to discuss the sutural complexity in relation to other shell characters, the growth of septal and shell wall thickness, and septal spacing should be taken into consideration. Unfortunately, this cannot be done for the reason of unfavourable preservation.

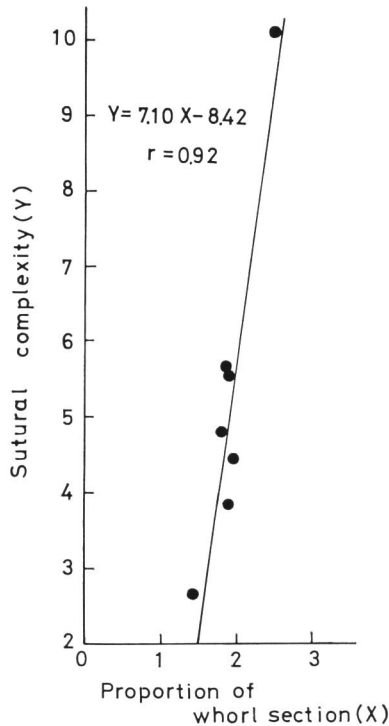


Fig. 12. Double scatter diagram showing the relation between the sutural complexity (Y) and the proportion of whorl section (X) in the selected seven specimens of *Scaphites dailyi*. X and Y are expressed as the ratio of whorl breadth to whorl height, and that of external sutural length to whorl sectional length, respectively.

Relative Growth. The average relative growth of whorl height and breadth in relation to shell diameter of a spiral portion was examined in the well-preserved 93 individuals with an aid of the reduced major axis method. The results are summarized in Fig. 13. The slope for the growth of whorl height indicates strong positive allometry, and that of whorl breadth slight positive allometry.

Comparison. In the inflation of septate whorls and surface ornament, the present species completely coincides with *Scaphites aequalis-obliquus* SOWERBY by COLLIGNON

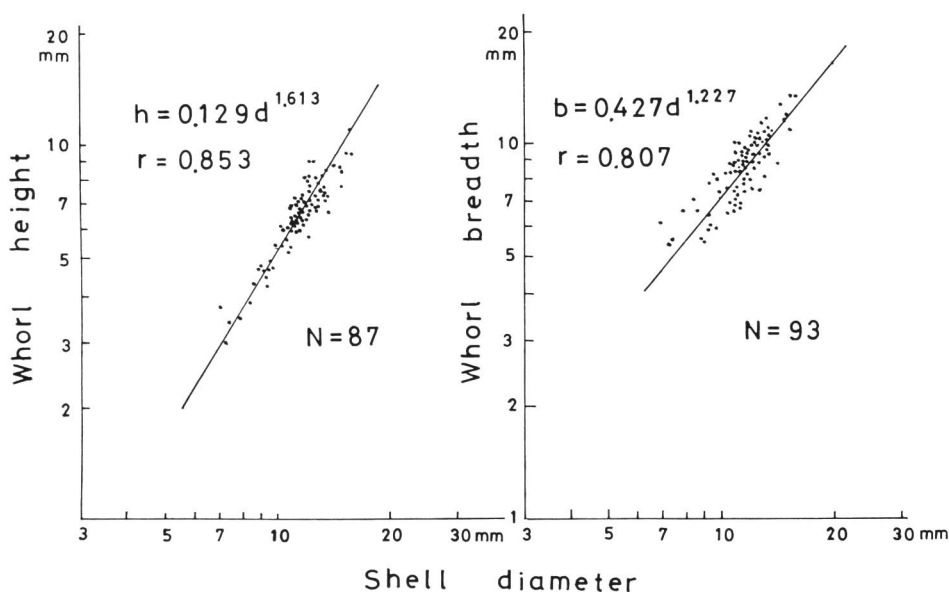


Fig. 13. Double logarithmic scatter diagram with the reduced major axis showing the average relative growth of whorl height and breadth in relation to shell diameter of a spiral portion in the sample of *Scaphites dailyi*. N is the sample size, r: correlation coefficient.

(1929) from the same locality as the present material. However, as WRIGHT (1963) has already pointed out, the present species is readily marked off from *Scaphites equalis* J. SOWERBY (1813, p. 53, pl. 18, figs. 1–3) and *Scaphites obliquus* J. SOWERBY (1813, p. 54, pl. 18, figs. 4–7) from the Cenomanian of England in the more inflated septate whorls and the presence of pronounced lateral bulges.

The present species is allied to *Scaphites vellai* HENDERSON (1973, p. 95, fig. 9b–d; fig. 10, no. 1a–c, 2, 3a, b) from the Lower Ngaterian (approximately the Uppermost Albian to the Lowermost Cenomanian according to HENDERSON) of New Zealand, in the tightly enrolled shaft, more or less inflated spire, sutural pattern and the presence of lateral bulges at the base of body chamber. The latter, however, differs from the former in its finer ornament on the spire and shaft.

The present species is similar to the European Late Albian species, *Scaphites meriani* PICTET and CAMPICKE (1861, p. 16, pl. 44, figs. 1–4, 8) in the inflated globose septate whorls, fairly complicated adult sutures and the presence of lateral bulges, but the latter has pronounced lateral tubercles on the spire and shaft which are absent in the former.

Scaphites hugardianus and *S. falloti*, described by COLLIGNON (1929), from the same locality as the present species, are doubtful species. Indeed, the surface ornament and inflation of septate whorls of these two species are closely similar to those of the present species. At present, the precise comparison among these three species

is difficult, because the diagnostic characters including adult sutures of *S. hugardianus* and *S. falloti* have not been realized.

Discussion. WIEDMANN (1965) subdivided the Middle Cretaceous (Albian to Turonian) *Scaphites* into the three stocks, namely, the *equalis* main, *similaris* and *meriani* stocks. According to him, the diagnosis of each stock is summarized as follows.

The *equalis* main stock: This stock is represented by the evolutionary series from *S. simplex* JUKES-BROWNE through *S. equalis* to *S. obliquus*. These species have untubercled primary ribs, rounded to oval whorl section and small umbilicus without lateral bulges at the base of body chamber. The *similaris* stock: This is represented by the evolutionary series from *S. hilli* ADKINS and WINTON to *S. similaris* STOLICZKA through "*S. yonekurai* YABE". It is characterized by a smaller adult shell than that of the *equalis* stock, and the presence of pronounced lateral bulges which cover the umbilicus. The *meriani* stock: This is represented by *S. hugardianus* D'ORBIGNY, *S. meriani* and *S. collignoni* WIEDMANN. Its adult shell has conical ventrolateral tubercles, closed umbilicus and asymmetrically bifid L. The three species restrictedly occur in the Upper Albian.

In the presence of pronounced lateral bulges at the base of body chamber and the absence of lateral tubercles, the present species may belong to the *similaris* stock of WIEDMANN (1965). WIEDMANN treated the present species as a synonym of *Scaphites yonekurai* YABE (1910, p. 165, pl. 15, figs. 4-7) from the Turonian of Hokkaido, Japan. However, the latter species has a narrower umbilicus even in youth, more globose septate whorls and finer ornament on the shaft, and much simpler adult suture than those of the present species (TANABE, 1977, p. 14, pl. 1, figs. 12-13; fig. 3-(5), (6)). In Hokkaido and south Sakhalin, *S. yonekurai* limitatively occurs in the Lower to Middle Turonian.

Geographic Distribution. The present species is one of the characteristic Indo-Pacific faunal elements, being distributed in the Cenomanian of Madagascar, northern Australia (Bathurst Island; WRIGHT, 1963) and southern India (STOLICZKA, 1865).

Scaphites bassei COLLIGNON

Pl. 4; Figs. 13-14; Fig. 15-(1), (2)

Scaphites Bassei COLLIGNON 1929, p. 51, pl. 5, figs. 8-9.—COLLIGNON 1931, p. 46, pl. 5, fig. 6.

Scaphites bassei COLLIGNON: SORNAY, 1955, p. 10, text fig. 3, pl. 10, figs. 7, 11.

Scaphites hilli ADKINS and WINTON: WIEDMANN, 1965, p. 421.

Material. 3 adult individuals (NSM.PM 9160-9162) from Loc. Dg 2.

Description. The shell small in size, more or less inflated; body chamber, short, tightly enrolled with a distinct pair of lateral bulges at the base; septate whorls involute, depressed with a depressed subcircular cross section; surface ornament consists of fine and dense primary and secondary ribs; secondaries intercalated between two primaries on flank; suture rather simple for the genus, characterized by its bifid L (see Fig. 14); sutural formula probably expressed as E L U I.

Measurements in mm.

NSM. PM	D	B	d	h	b	u	h/d	b/d
9160	?	?	7.0	3.4	4.9	0	0.49	0.70

9161	ca. 13	7.8	7.8	4.1	6.4	0	0.53	0.82
9162	?	?	7.9	4.6	7.2	0	0.58	0.91

Comparison. The present species fairly resembles *Scaphites hilli* ADKINS and WINTON (1920, p. 37, text-fig. 3; pl. 7, figs. 3–6; ADKINS, 1920 p. 79–84, pl. 2, figs. 1–12; figs. 6–8; 1928, p. 257, pl. 20, figs. 1–3, 7) from the Upper Albian Pawpaw Formation of Texas, in the small-sized adult shells with tightly enrolled and inflated body chamber, and prominent lateral bulges. The latter, however, has a longer saddle E L, and a distinct lobe incision (=p) in the middle of the saddle L U, which is absent in the former.

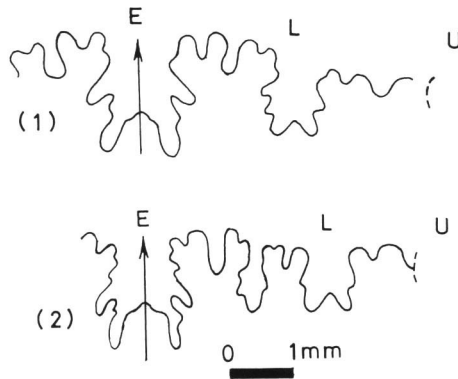


Fig. 14. Adult sutures in *Scaphite bassei* COLLIGNON from Loc. Dg 2. (1): NSM. PM 9161, (2): NSM. PM 9160.

Geographic Distribution. The present species is distributed in the Cenomanian of Madagascar and Algeria (SORNAY, 1955).

Concluding Remarks of Part III

Two species of the Genus *Scaphites*, *S. dailyi* C. W. WRIGHT and *S. bassei* COLLIGNON, from a single bed of the Lower Cenomanian deposits at the Betahitra Valley, Diégo-Suarez area, northern Madagascar, have been described in this paper. As the sample size of *S. dailyi* is large (159 individuals), the intraspecific variation of a certain shell characters has also been analysed with some biometric examinations. The sample of this species shows a considerably large variation in the shell proportion of adult shells. However, there is an intimate correlation between the sutural complexity and the proportion of whorl section. The two species characterize the Indo-Pacific faunal elements, as other ammonoids from the same bed (see p. 114).

References

- ADKINS, W. S., 1920. The Weno and Pawpaw Formations of the Texas Comanchean. *Univ. Texas Bull.*, (1856): 1–192, pls. 1–11.
- ADKINS, W. S., 1928. Handbook of Texas Cretaceous fossils. *Ibid.*, (2838), 1–303, pls. 1–37.
- ADKINS, W. S. and W. M. WINTON, 1920. Paleontological correlation of the Fredericksburg and Washita Formations in North Texas. *Ibid.*, (1945), 1–84, pls. 1–21.
- BESAIRIE, H., 1972. Géologie de Madagascar. I. Les terrains sédimentaire. *Ann. Géol. Serv. Mines Mad.*, **35**: 1–463, pls. 1–89.
- BOULE, M., P. LEMOINE & A. THEVENIN, 1906, 1907. Céphalopodes crétaçes des environs de Diégo-Suarez. I. *Ann. Paléont.*, **1**: 173–192, pls. 14–20, (1906); **2**: 21–77, pls. 8–15 (1907).
- COLLIGNON, M., 1928, 1929. Les céphalopodes du Cénomaniens pyriteux du Diégo-Suarez. I. *Ibid.*, **17**: 139–160, pls. 15–19 (1928); **18**: 25–81, pls. 6–7 (1929).
- COLLIGNON, M., 1931. La fauna du Cénomaniens à fossiles pyriteux du nord de Madagascar. *Ibid.*, **20**: 43–104, pls. 5–9.
- COLLIGNON, M., 1936. Ammonites cénomaniennes du sud ouest de Madagascar. *Ann. Géol. Serv. Mines, Mad.*, **8**: 31–69, pls. 1–11.
- COLLIGNON, M., 1964. Atlas des caractéristiques de Madagascar (Ammonites). 11, Cénomaniens.: 1–152, pls. 318–375. Tananarive, Serv. Géol.
- COLLIGNON, M., 1966. Les céphalopodes crétaçes du bassin cotier de Tarfaya. Relations stratigraphiques et paléontologiques. *Notes et Mém. Serv. Géol. Maroc.*, (175): 1–78, pls. 1–35.
- EDWARDS, A. B., & G. BAKER, 1951. Some occurrences of supergene iron sulphides in relation to their environment of deposition. *Jour. Sed. Petrol.*, **21**: 34–46.
- FORBES, E., 1846. Report on the fossil Invertebrata from southern India, collected by Mr. KAYA and Mr. CUNLIFFE. *Trans. Geol. Soc. London, Ser. 2*, **7**: 97–174, pls. 7–19.
- HAUG, E., 1910. Une vue d'ensemble de nos connaissances sur le Cénomaniens du Nord de Madagascar a été donnée. *Traité Géol.*, **2** (2): 1286–1287.
- HENDERSON, R. A., 1973. Clarence and Raukumura Series (Albian-? Santonian) Ammonoidea from New Zealand. *Jour. Royal Soc. New Zealand*, **3** (1): 71–123.
- HIRANO, H., T. MATSUMOTO & K. TANABE, 1977. Mid-Cretaceous stratigraphy of the Oyubari area, central Hokkaido. In: KANMERA, K. ed., Mid-Cretaceous Events–Hokkaido Symposium, 1976. *Palaeont. Soc. Japan, Spec. Paps.*, (21): 1–10.
- JACOB, C., 1908. Étude sur quelques ammonites de Crétacé moyen. *Soc. Géol. France, Mém. Paléont.*, **15** (38): 1–64, pls. 1–9 (1907).
- KENNEDY, W. J., 1971. Cenomanian ammonites from southern England. *Spec. Paps. Palaeont.*, (8): 1–133, pls. 1–64.
- KENNEDY, W. J. & W. A. COBBAN, 1976. Aspects of ammonite biology, biogeography, and biostratigraphy. *Ibid.*, (17): 1–94, pls. 1–11.
- KENNEDY, W. J. & J. M. HANCOCK, 1971. *Mantelliceras saxbii*, and the horizon of the Martimprey Zone in the Cenomanian of England. *Palaeontology*, **14**: 437–454, pls. 79–82.
- KENNEDY, W. J. & J. M. HANCOCK, 1977. Towards to correlation of the Cenomanian sequences of Japan with those of Northwest Europe. In: KANMERA, K. ed., Mid-Cretaceous Events–Hokkaido Symposium, 1976. *Palaeont. Soc. Japan, Spec. Paps.*, (21): 127–141.
- KENNEDY, W. J. & H. KLINGER, 1971. A major intra-Cretaceous unconformity in eastern South Africa. *Jour. Geol. Soc. London*, **217**: 183–186.
- KENNEDY, W. J. & H. KLINGER, 1975. Cretaceous faunas from Zululand and Natal, South Africa. Introduction and Stratigraphy. *Bull. Brit. Mus. (Nat. Hist.)*, ser. geol., **25** (4): 265–351, 1 pl.
- KOSSMAT, F., 1895. Untersuchungen über die südindische Kreideformation I. *Beitr. Paläont. Geol. Österr.-Ungarns u. Orients*, **9**: 97–203, pls. 15–25.
- KULIMANN, J. & J. WIEDMANN, 1970. Significance of sutures in phylogeny of ammonoidea. *Univ.*

- Kansas Paleont. Contr.*, (47): 1–32.
- MATSUMOTO, T., 1941. A study on the relation between different species, with special reference to the problems on the range of fossil species. *Jour. Geol. Soc. Japan*, **48**: 17–37. [In Japanese].
- MATSUMOTO, T., 1942a. A note on the Japanese ammonite belonging to the Gaudryceratidae. *Proc. Imp. Acad. Japan*, **18**: 666–670.
- MATSUMOTO, T., 1942b. A short note on the Japanese Cretaceous Phylloceratidae. *Ibid.*, **18**: 674–676.
- MATSUMOTO, T., 1942c. Correlation of the Cretaceous deposits of southern India and Japan. *Jour. Geol. Soc. Japan*, **49** (584): 149–164. [In Japanese].
- MATSUMOTO, T., 1942, 1943. Fundamentals in the Cretaceous stratigraphy of Japan. *Mem. Fac. Sci., Kyushu Imp. Univ., ser. D*, **1** (3): 129–380, pls. 5–20 (1942); **2** (1): 98–237 (1943).
- MATSUMOTO, T., 1959. Cretaceous ammonites from the Upper Chitina Valley, Alaska. *Mem. Fac. Sci., Kyushu Univ., ser. D.*, **8** (3): 49–90, pls. 12–29.
- MATSUMOTO, T., 1965. Faunal changes in Cretaceous cephalopods. *Fossils*, (9): 24–29. [In Japanese].
- MATSUMOTO, T. & A. INOMA, 1975. Mid-Cretaceous ammonites from the Shumarinai-Soeushinai area, Hokkaido. Part I. *Mem. Fac. Sci., Kyushu Univ., ser. D*, **23** (2): 263–293, pls. 38–42.
- MATSUMOTO, T. & I. OBATA, 1962. On the *Baculites* facies. *Fossils*, (3): 57–63. [In Japanese].
- MATSUMOTO, T. & I. OBATA, 1963. A monograph of the Baculitidae from Japan. *Mem. Fac. Sci., Kyushu Univ., ser. D*, **13** (1): 1–116, pls. 1–27.
- MATSUMOTO, T., M. V. A. SASTRY & S. S. SASKAR, 1966. Notes on some Cretaceous ammonites from southern India. Part I. *Utaturiceras vicinale* (STOLICZKA) from southern India (by MATSUMOTO & SASKAR). *Ibid.*, **17** (3): 295–309, pls. 32–33.
- PERVINQUIÈRE, L., 1907. Études de paléontologie tunisienne I. Céphalopodes des terrains secondaires: 428 pp., 21 pls. Carte Géol. Tunisie.
- PICTET, F. J. & G. CAMPICHE, 1861. Description des fossiles du terrain crétacé des environs de Sainte-Croix. II. *Meteor. Paléont. Suisse, 3e sér.*, **2**: 1–144, pls. 44–57.
- RERAT, J. C., 1963. Carte géologique 1/100,000 “Diego-Suarez”. Serv. Géol. Madagascar.
- REYMENT, R. A., 1955. The Cretaceous ammonoidea of southern Nigeria and the southern Cameroons. *Bull., Geol. Surv. Nigeria*, (25): 1–107, pls. 1–24.
- SCOTT, G., 1940. Paleontological factors controlling the distribution and mode of life of Cretaceous ammonoids in Texas area. *Jour. Paleont.*, **14**: 299–323.
- SORNAY, J., 1955. Ammonites nouvelles du Crétacé de la région des Monts du Mellegue, Constantine. *Publ. Serv. Carte Géol. Algérie, Mém. Paléont.*, (18): 1–41, pls. 1–2.
- SOWERBY, J., 1813. The mineral conchology of Great Britain, 1: 234 pp., 102 pls., London.
- STENZEL, H. B., 1971. Oysters. In: MOORE, R. C. ed., *Treatise on Invertebrate Paleontology*, Part N, 3: N953–N1224. Geol. Soc. Amer. & Univ. Kansas Press.
- STOLICZKA, F., 1865. The fossil cephalopoda of the Cretaceous rocks of southern India. *Mem. Geol. Surv. India, Palaeont. Indica, Ser. 3*: 107–154, pls. 55–75.
- TANABE, K., 1977. Mid-Cretaceous scaphitid ammonites from Hokkaido. In: KANMERA, K. ed., *Mid-Cretaceous Events—Hokkaido Symposium, 1976. Palaeont. Soc. Japan, Spec. Paps.*, (21): 11–22, pl. 1.
- TANABE, K., H. HIRANO, T. MATSUMOTO & MIYATA., 1977. Stratigraphy of the Upper Cretaceous deposits in the Obira area, northwestern Hokkaido. *Sci. Repts. Dept. Geol., Kyushu Univ.*, **12** (3): 181–202. [In Japanese with English abstract].
- WIEDMANN, J., 1965. Origin, limits, and systematic position of *Scaphites*. *Palaeontology*, **8**, (3): 397–453, pls. 53–60.
- WRIGHT, C. W., 1963. Cretaceous ammonites from Bathurst Island, northern Australia. *Ibid.*, **6** (4): 597–614, pls. 81–89.
- YABE, H., 1910. Die Scaphiten aus der Oberkreide von Hokkaido. *Beitr. Päläont. Geol. Österr.-Ungarns u. Orients*, **23**: 159–174, pl. 15.

Explanation of Plates

Every specimen illustrated from the Lower Cenomanian deposits at Locality Dg 2, Betahitra Valley, Diégo-Suarez, northern Madagascar.

Plate 1

(All figures $\times 2$)

- Figs. 1, 2. *Neophylloceras seresitense* (PERVINQUIÈRE). 1. NSM. PM 9174; 2. NSM. PM 9175.
 Figs. 3, 4. *Phyllopachyceras whiteavesi* KOSSMAT. 3. NSM. PM 9176; 4. NSM. PM 9177.
 Figs. 5, 6. *Phyllopachyceras diegoi* BOULE, LEMOINE and THEVENIN). 5. NSM. PM 9178; 6. NSM. PM 9179.
 Fig. 7. *Sciponoceras* aff. *baculoides* (MANTELL) NSM. PM 9180.
 Fig. 8. *Mariella* (*Mariella*) n. sp. aff. *M. (Mariella). lewensis* (SPATH). NSM. PM 9181.
 Fig. 9. *Uhligella* (?) *walleranti jacobii* COLLIGNON. NSM. PM 9182.
 Fig. 10. *Utaturiceras* (?) *subvicinale* (BOULE, LEMOINE and THEVENIN). NSM. PM 9183.
 Photos, with whitening, by KANIE.

Plate 2

(All figures $\times 2$)

- Fig. 1. *Mantelliceras (Mantelliceras) saxbii* (SHARPE). NSM. PM 9184.
 Fig. 2. *Sharpeiceras* cf. *falloti* (COLLIGNON). NSM. PM 9185.
 Fig. 3. *Mantelliceras (Cottreauities) waterloti* COLLIGNON. NSM. PM 9186.
 Fig. 4. *Mantelliceras (Mantelliceras) suzanna* (PERVINQUIÈRE). NSM. PM 9187.
 Fig. 5. *Stoliczkaia (Stoliczkaia) aff. texana* (GRAGIN). NSM. PM 9188.
 Fig. 6. "*Mammites*" *prenodosoides* BOULE, LEMOINE and THEVENIN. NSM. PM 9189.
 Fig. 7. *Picnodonte fosseyi* (LEMOINE). NSM. PM 9190.
 Photos, with whitening, by KANIE.

Plate 3

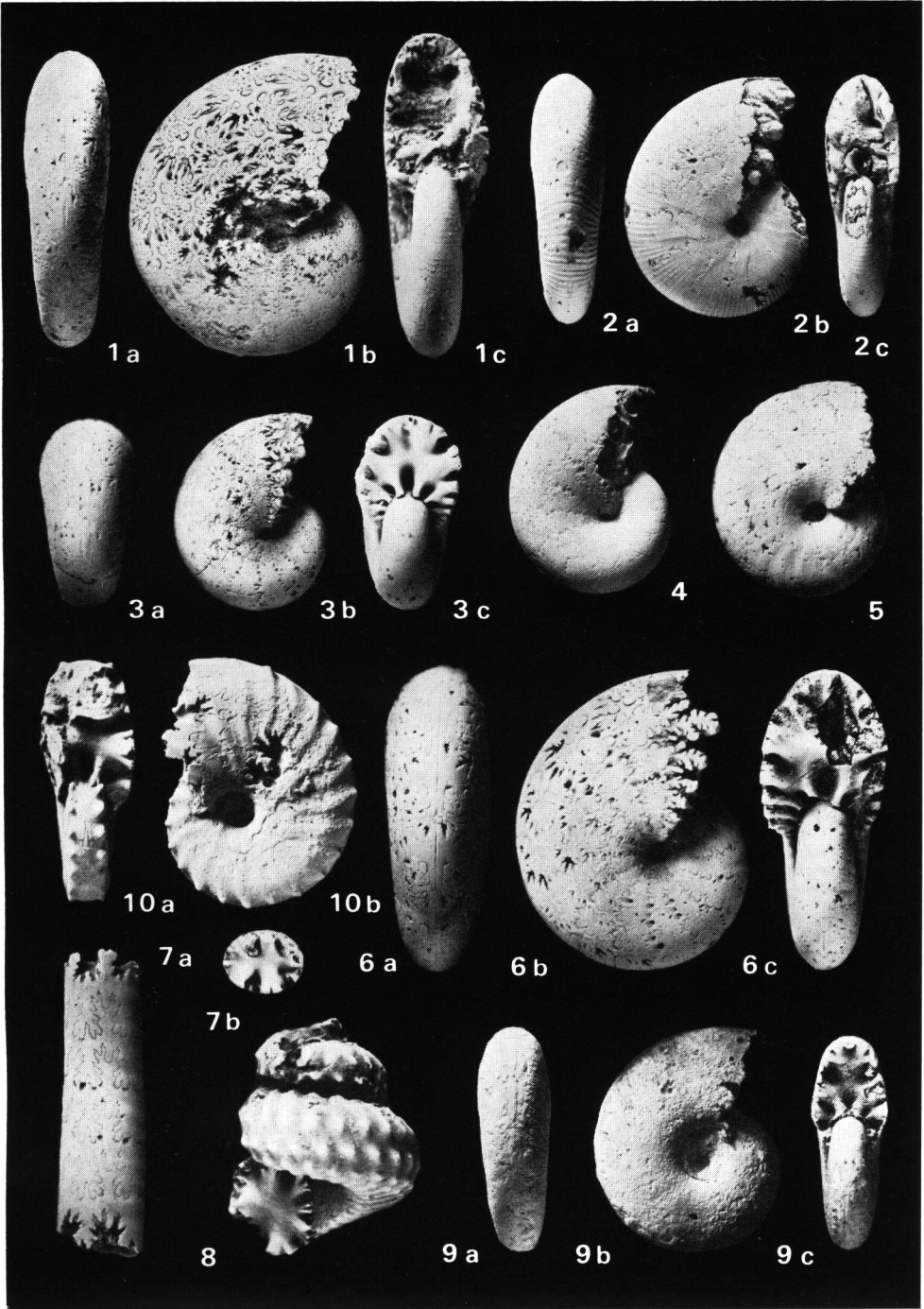
(All figures $\times 2$)

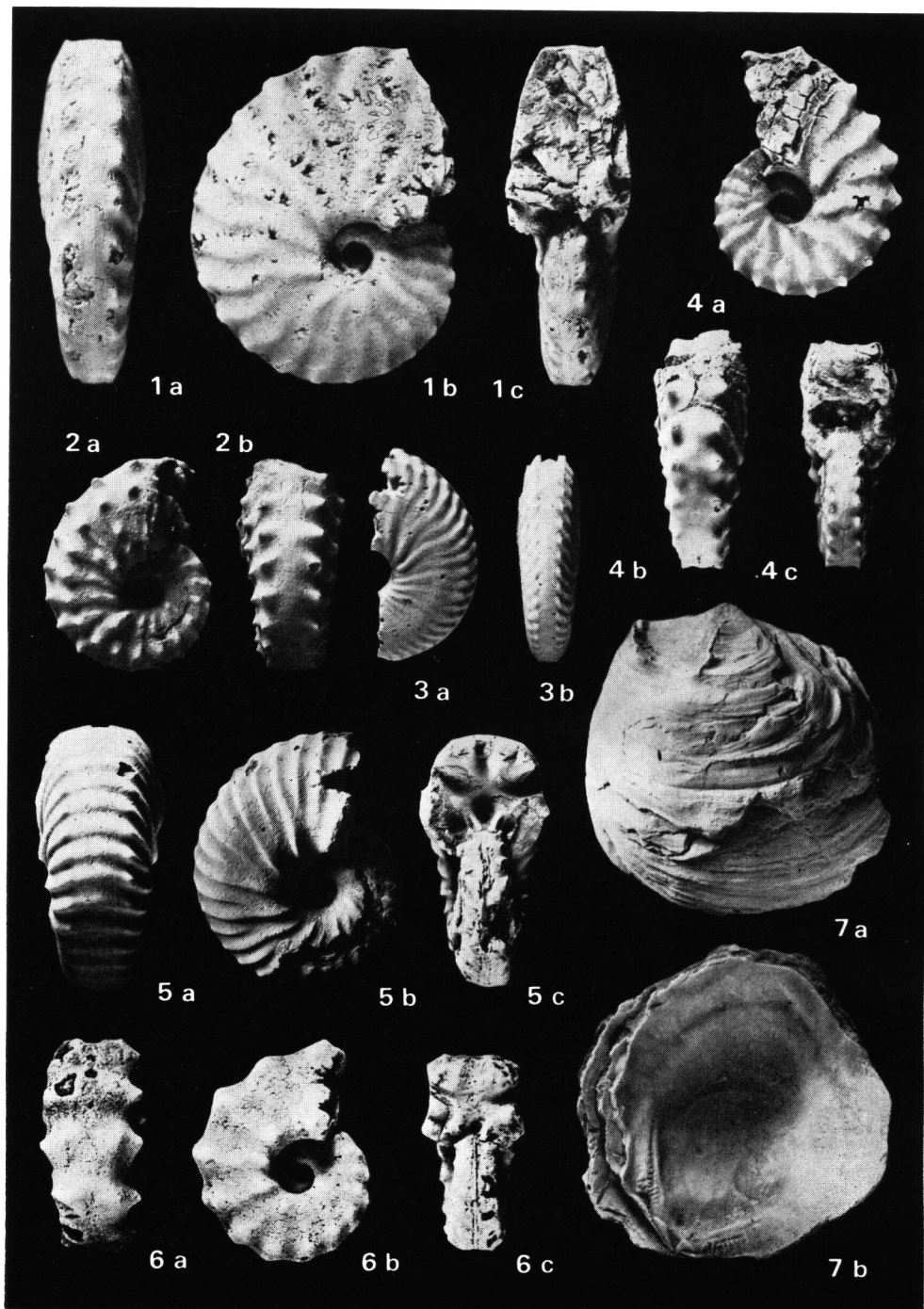
- Figs. 1–10. *Anagaudryceras sacya* (FORBES)
 1. NSM. PM 9166, a: cross section, b: lateral view; 2. NSM. PM 9163, a: cross section, b: lateral view; 3. NSM. PM 9165, a: lateral view, b: ventral view; 4. NSM. PM 9173, a: lateral view, b: ventral view; 5. NSM. PM 9172, a: lateral view, b: frontal view; 6. NSM. PM 9171, a: lateral view, b: frontal view; 7. NSM. PM 9173, a: lateral view, b: frontal view; 8. NSM. PM 9169, a: lateral view, b: ventral view; 9. NSM. PM 9168, a: lateral view, b: ventral view; 10. NSM. PM 9170, a: lateral view, b: ventral view; 11. NSM. PM 9167, a: lateral view, b: ventral view.
 Photos by HIRANO

Plate 4

Two lateral (b, d), ventral (a) and frontal (c) views are shown on each specimen, except as otherwise stated.

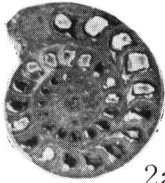
- Figs. 1–12. *Scaphites dailyi* C. W. WRIGHT ($\times 1.5$)
 1. NSM. PM 9002, adult specimen; 2. NSM. PM 9006, adult specimen; 3. NSM. PM 9008, adult specimen; 4. Lateral (a) and frontal (b) views of NSM. PM 9005, adult specimen; 5. Two lateral (a, c) and ventral (b) views of NSM. PM 9009, adult specimen; 6. NSM. PM 9064, young specimen; 7. NSM. PM 9061, young specimen; 8. NSM. PM 9083, young specimen; 9. NSM. PM 9042, young specimen; 10. NSM. PM 9074, young specimen; 11. NSM. PM 9063, young specimen; 12. NSM. PM 9058, adult specimen.
 Figs. 13, 14. *Scaphites bassei* COLLIGNON ($\times 2$)
 13. NSM. PM 9160, adult specimen; 14. NSM. PM 9161, adult specimen.
 Photos, with whitening, by TANABE.



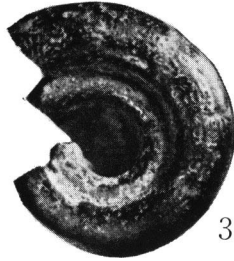




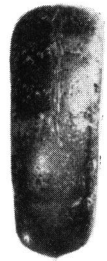
1a



2a



3a



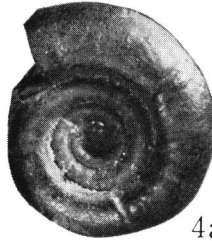
3b



1b



2b



4a



4b



5a



5b



9a



8a



8b



6a



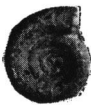
6b



9b



11a



7a



7b



10a



10b



11b

