

Cretaceous ammonites from Fuerteventura, Canary Islands

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Abstract – Mesozoic deep-water sediments occurring on the island of Fuerteventura were deposited near the continent–ocean boundary adjacent to the African margin. During Tertiary times, they were uplifted and intruded by ultramafic, mafic and alkaline plutons and dykes and are now exposed as part of the ‘Basal Complex’ of the island. These sediments reflect more or less continuous hemipelagic and turbiditic deposition during most of Jurassic and Cretaceous times. Two ammonites, described in this paper, document a Valanginian to Hauterivian age for part of the Lower Cretaceous siliciclastic turbidites, and a latest Albian to early Cenomanian age for part of the Upper Cretaceous hemipelagic limestones.

1. Introduction

On the Canary Island of Fuerteventura, Mesozoic deep-water sediments occur (Fig. 1; Rothe, 1968; Robertson & Stillman, 1979*a*; Robertson & Bernoulli, 1982). These sediments were deposited near the continent–ocean boundary adjacent to the African margin; they were uplifted in Tertiary times and are now exposed as part of the ‘Basal Complex’ of the island (Fig. 2; Fuster *et al.* 1968; Stillman *et al.* 1975; Le Bas, Rex & Stillman, 1986). The Basal Complex is a lithologically diverse assemblage. It is dominated by an extensive dyke-in-dyke swarm which was closely associated with the emplacement of ultramafic to mafic and alkaline plutons. Where visible, the host rocks to the dykes comprise Mesozoic and minor Lower Tertiary sediments and submarine volcanic rocks (Fuster *et al.* 1968; Robertson & Stillman, 1979*a,b*) which were affected by thermal metamorphism of low greenschist grade (chlorite–epidote–quartz–albite) during the intrusion of the dykes and plutonic bodies.

The Mesozoic deep-water sediments document more or less continuous hemipelagic and turbiditic deposition on the deep Atlantic sea floor adjacent to the African margin. Fossils date the sediments as early Cretaceous and younger; however, in this part of the Atlantic oceanic sediments could be as old as late early or middle Jurassic. Indeed, if confirmed, the impressions of ‘*Posidonia*’ reported by Rothe (1968) from Barranco de Ajui (Unit B below) would extend the age of the sequence to the middle or early Jurassic. Earliest volcanic activity on Fuerteventura is documented by basaltic breccias, pillow lavas and volcanoclastic sandstones which overlie with apparent conformity and intercalate with Upper Cretaceous chalks and marls (Robertson & Stillman, 1979*a*; Le Bas, Rex & Stillman, 1986). Available radiometric age data

suggest that the main phases of intrusion and build-up of the island took place over a period of over 40 m.y., from late Cretaceous to early Miocene (Le Bas, Rex & Stillman, 1986). Previous to the extension connected with the emplacement of the main dyke complex in Oligocene time, the Mesozoic sediments were folded and partly overturned. Unroofing of some of the plutons in Oligocene times is suggested by the occurrence of reworked plutonic rocks in Oligocene bioclastic limestones (Le Bas, Rex & Stillman, 1986). These limestones, which are part of the Basal Complex, document the proximity of areas of photic shallow-water carbonate deposition on a seamount or offshore shoal fringing an emergent volcanic edifice (Robertson & Stillman, 1979*a*; Robertson & Bernoulli, 1982). A thick pile of subhorizontal Neogene, post-early Miocene plateau basalts unconformably overlies the Basal Complex (Fuster *et al.* 1968).

The lithostratigraphy and sedimentology of the Mesozoic and early Tertiary sediments are relatively

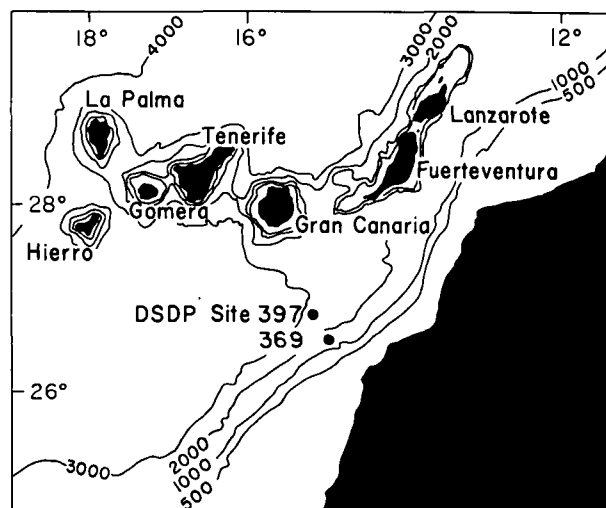


Figure 1. Location map of Fuerteventura, Canary Islands.

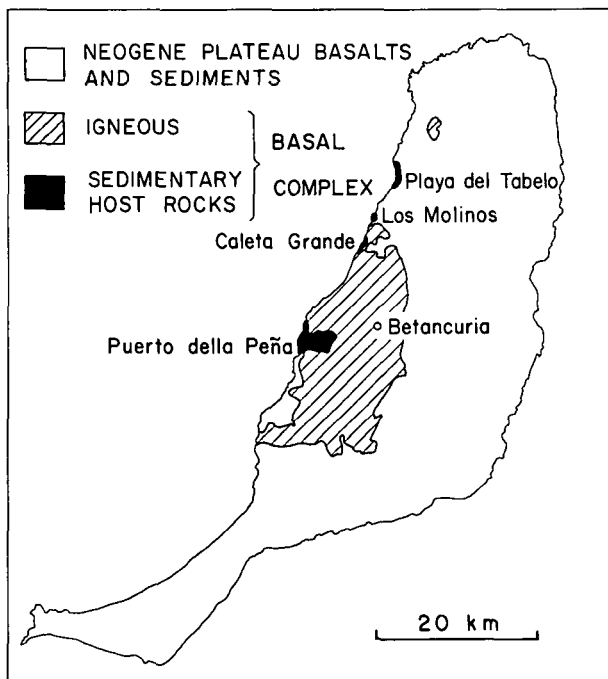


Figure 2. Simplified geological map of Fuerteventura.

well known (Robertson & Stillman, 1979*a*; Robertson & Bernoulli, 1982), but dating is poor. In this paper we document the occurrence of Cretaceous ammonites, mentioned in an earlier paper (Robertson & Bernoulli, 1982), from the Mesozoic sequence of the Basal Complex. The sedimentary evolution of Fuerteventura has been discussed in detail by Robertson & Bernoulli (1982), the early volcanic evolution by Le Bas, Rex & Stillman (1986), and we refer to these papers for details and more extensive discussion.

2. Stratigraphy of the Mesozoic sequence

The Basal Complex is exposed in the western part of the island (Fig. 2). The Mesozoic stratigraphy has been established in the area between Puerto della Peña and Caleta della Peña Vieja along the barrancos near the western coast of the island (Fig. 3). Rothe (1968) stated that the Mesozoic sequence in this area was disposed in a major east–west-trending isoclinal overturned syncline. In contrast, Robertson & Stillman (1979*a*), while confirming that the beds were predominantly overturned, established that the succession becomes uniformly younger towards the north, on the basis of sedimentary structures in redeposited sediments. Grunau *et al.* (1975) for their part did not recognize the overturned nature of the sequence between Puerto de la Peña and Caleta della Peña Vieja and thought the sequence to young to the south. This is clearly contradicted by sedimentological and fossil evidence (Robertson & Bernoulli, 1982).

Robertson & Stillman (1979*a*) and Robertson & Bernoulli (1982) subdivided the Mesozoic sequence into seven lithological units (A to G). No base to the

pre-volcanic sedimentary sequence is known, until now, from Fuerteventura. The oldest unit exposed, Basal Unit A, comprises epidotized black shales, grey siltstones, sandstones and marbles. It is overlain by a Calcarenite–Sandstone–Shale Unit (B) consisting of amalgamated bioclastic calcarenite turbidites and thin-bedded fine- to medium-grained yellow to pale grey turbiditic quartzarenites to quartzlutites.

Unit B passes gradually upwards into several hundred metres of dark grey to black silty shales interbedded with massive or weakly laminated thin-bedded calcilutites (Unit C: Calcilutite–Siltstone–Shale Unit). Units A to C are not dated palaeontologically; however, Rothe (1968) mentions ‘impressions’ of *Posidonia* from Unit B and infers a Liassic to late Jurassic age for Units A to C.

Up-section, the limestone interbeds gradually thin and give way to siliciclastic arenites and rudites interbedded with black shales and siltstones. Thick bedded quartzarenites often show complete Bouma-cycles whereas thinner-bedded sandstones show C–D–E or D–E divisions. The sandstones are arranged in thickening- and coarsening-upward sequences. Flute-casts show a prevailing sediment transport from the northeast or east. In the lower part of Unit D (Barranco della Peña), the finding of *Neocomites* sp., described below, indicates a Valanginian to Hauterivian age for part of the formation. A general Valanginian to Hauterivian age of Unit D is supported by lithological correlation with the Lower Cretaceous sequence at Site 370/416 of the Deep Sea Drilling Project (Lancelot *et al.* 1980).

In Unit E (Homogeneous Siltstone Unit), the sandstones become finer and thinner up-section and give way to finely laminated quartzlutites, siltstones and black shales. A Barremian to Aptian age is tentatively assigned to this unit.

Units F and G (Marl–Calcarenite Unit and Thicker Bedded Marl and Chert Unit) consist of pelagic, partly redeposited limestones (Series 5 of Rothe, 1968). The lower part of the sequence comprises about 30 m of white to light grey foraminiferal/radiolarian chalks and marls with lesser calcarenites and a few calcirudites becoming more frequent up-section. The calcarenites are graded and contain in their lower parts clasts of siltstone, mudstone, black shale and chert from the underlying formations, phosphatic and shell fragments, fish teeth and intraclasts of pelagic chalk set in a pelagic limestone or chalk matrix (Robertson & Bernoulli, 1982, fig. 8). Most of the chalk sequence is redeposited by slumping and mass flow processes. Up-section there is a relatively abrupt change to 30 m of still paler, more homogeneous marls and chalks with nodules of replacement chert and lesser redeposited beds.

In Units F and G two different faunal associations can be distinguished. From Caleta de la Peña Vieja, Rothe (1968) mentioned ‘*Globotruncana*’ of possibly

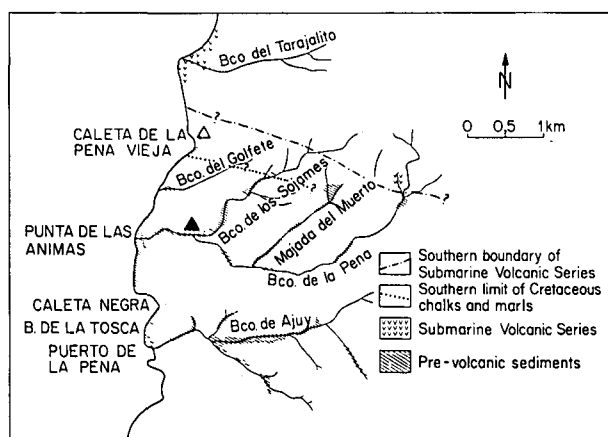


Figure 3. Map of the Mesozoic sedimentary sequences of the southern coastal exposures, Fuerteventura. After Robertson & Stillman (1979a). Open triangle: fossil locality at Caleta della Peña Vieja; closed triangle: fossil locality at Barranco della Peña.

Albian age, without giving specific determinations. Lehmann (*in* Mitchell-Thomé, 1976) and Grunau *et al.* (1975) identified a number of planktonic foraminifera (*Globigerina*, *Hedbergella*, *Globigerinelloides*, *Ticinella*) and calcispherulids (*Pithonella*), also suggesting an Albian age. More specifically, a late Albian to early Cenomanian age can be assigned to the lower part of the sequence. This is based on an ammonite (*Partschiceras* cf. *whiteavesi* (Kossmat), described below) and on the following foraminiferal taxa: *Schakoina gandolfii* Reichel, *Rotalipora* sp., *Hedbergella* sp., and *Gabonella* sp. (Hottinger *in* Robertson & Bernoulli, 1982). The upper part of the sequence is clearly younger: a pre-Maastrichtian Coniacian to Campanian age is indicated by double-keeled globotruncanids, rare Heterohelicidae and benthonic foraminifera of the genera *Stensiöina*, *Gavelinella*, *Polymorphina* and *Reussella* (Hottinger *in* Robertson & Bernoulli, 1982). The relations between the sediments

containing these different associations are obscured by dyke intrusions and no Turonian fauna has been found thus far. A stratigraphical hiatus between the Upper Albian–Lower Cenomanian and the Coniacian–Campanian successions is suggested by analogy with a similar hiatus associated with slumping and soft sediment deformation observed at Site 369 of the Deep Sea Drilling Project (Lancelot *et al.* 1977).

The Upper Cretaceous sediments of Unit G are overlain to the north by submarine volcanic rocks which locally alternate with chalks and marls, presumably still of late Cretaceous age (Le Bas, Rex & Stillman, 1986). The relations between these volcanics and the Oligocene limestones at Caleta Grande (Robertson & Bernoulli, 1982) are again obscured by dyke intrusions.

3. Systematic palaeontology

Subclass AMMONOIDEA

Material. The two ammonites found on Fuerteventura cannot be fully determined specifically because of their poor preservation. The stratigraphically older specimen comes from Unit D and was found at Barranco de la Peña (Fig. 3). It consists of a mould which has been preserved on the bottom surface of a turbidite bed. It belongs to the family Neocomitidae (genus *Neocomites*). The younger ammonite comes from Unit F at Caleta de la Peña Vieja (Fig. 3) and occurs in a light-brown micritic limestone. It represents the juvenile stage of a representative of the genus *Partschiceras* which first appears in early Jurassic and extends into late Cretaceous time. Many species of the genus are distinguished by their longevity which makes an accurate age determination problematic.

The ammonites described are deposited in the Museum of Natural History, Basel, Switzerland under the numbers J 31312 to J 31318. The *Partschiceras*(?) *whiteavesi* from southern India used for comparison in

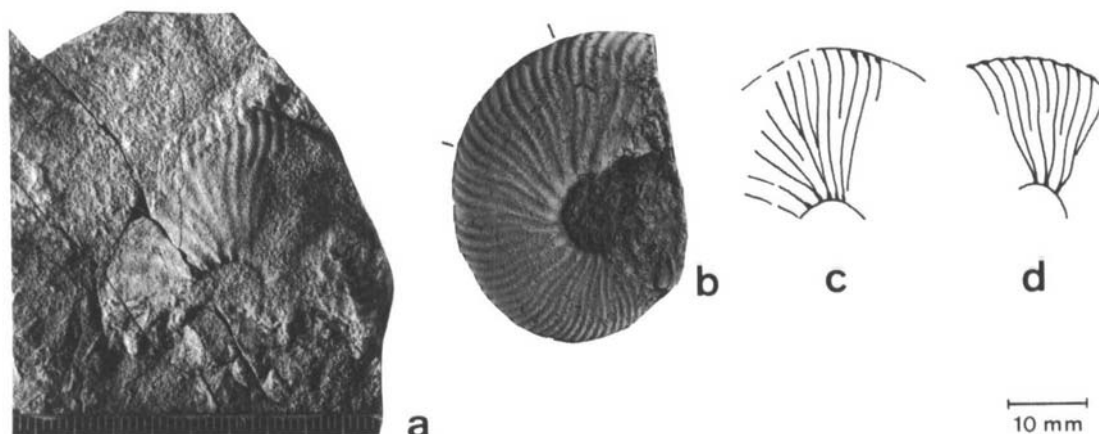


Figure 4. (a) ?*Neocomites* from stratigraphical Unit D, Barranco de la Peña, Fuerteventura (Canary Islands). Museum of Natural History, Basel, no. J 31312. (b) *Neocomites neocomiensis* (d'Orbigny), Gemsmättli-Schicht (Valanginian), Mount Pilatus, Switzerland. Museum of Natural History, Basel, no. J 31313. (c, d) Rib patterns of (a) and (b) (c reversed for easier comparison).

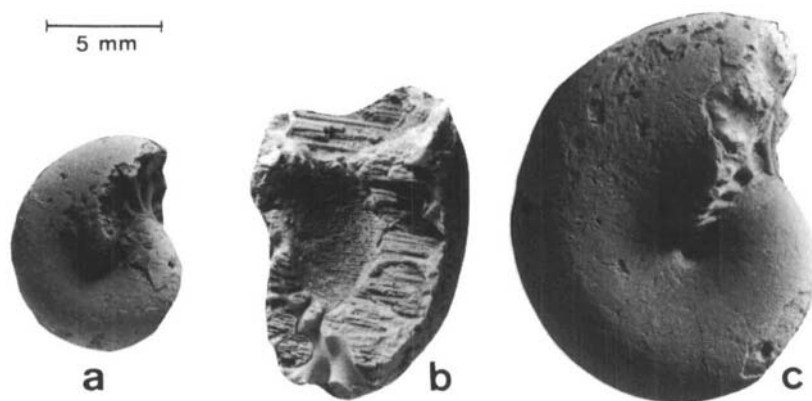


Figure 5. *Partschiceras baborensis* (Coquand) from the Upper Aptian of San Telmo (Mallorca) showing a fine ribbing on the test. (a) The outer whorl has been removed (specimen illustrated in b). Museum of Natural History, Basel, no. J 31314. (b) Detached whorl fragment of specimen illustrated in (a) showing the fine ribs. (c) On this specimen, the test is mostly preserved but badly worn. The ribbing is faintly preserved on the right half. Museum of Natural History, Basel, no. J 31315.

Figure 6 has been described by Wiedmann (1963, p. 249, fig. 58) and is deposited under the number Wi 'UAM'/3 in the Museum of Natural History in Geneva.

Family NEOCOMITIDAE Salfeld, 1921
Subfamily NEOCOMITINAE Salfeld, 1921
Genus *Neocomites* Uhlig, 1906
(Fig. 4a–d)

Description. Seven rather fine, closely spaced, markedly flexuous prorsiradiate ribs, branching in small bunches from feeble umbilical tubercles are preserved. These ribs branch again towards the middle of the flank or higher up on the whorl, terminating in small, apparently slightly oblique bullae. The coiling seems to have been rather involute and the umbilical edge pronounced (Fig. 4a,c). The venter is not preserved.

Discussion. The aspect of the ribs suggests a comparison with some forms belonging to the genus *Neocomites*, as figured by Sayn (1901) from the Valanginian of southeastern France. The specimens figured on his plate 7, figures 10 and 11 (*Neocomites neocomiensis* (d'Orbigny)) have all of the features of the present specimen.

For a further comparison we have chosen a *Neocomites neocomiensis* from the Valanginian of the Helvetic sequence of the Swiss Alps. The whorl segment corresponding to the specimen from Fuerteventura is marked by two lines on Figure 4b. The identity of the morphological features of the two segments (according to Fig. 4c,d) can hardly be doubted.

Based on the occurrence of this ammonite which most probably belongs to the genus *Neocomites*, a Valanginian to Hauterivian age is suggested for the turbidites of Unit D.

Family PHYLLOCERATIDAE Zittel, 1884
Subfamily PHYLLOCERATINAE Zittel, 1884
Genus *Partschiceras* Fucini, 1923

Discussion. Before discussing the specimen from Unit F, a few additional remarks concerning the species *Partschiceras baborensis* (Coquand) are relevant. The genus *Partschiceras* has been redefined and redescribed by Wiedmann (1963, pp. 229–51) while Schindewolf (1961, p. 76, fig. 36) investigated the ontogenetic development of the suture line of a *P. aff. subobtusum* (Kudernatsch).

Species *Partschiceras baborensis* (Coquand)
(Fig. 5a–d, 6b, 7d–e)

- 1880 *Ammonites Baborensis* Coquand, p. 26.
- 1912 *Phylloceras infundibilum* var. *Baborensis* Coquand; Joleaud, p. 110, pl. 1, figs 1–3.
- 1937 *Phylloceras baborensis* Coquand; Collignon, p. 8, pl. 1, figs 4–6.
- 1963 *Partschiceras baborensis* (Coquand); Wiedmann, p. 243, pl. 14, figs 2, 4, 5; pl. 16, figs 1, 2; fig. 59 (cum synon).

Material. The material available for comparison was collected by W. Bodmer (Museum of Natural History in Basel) from the Upper Aptian of Mallorca in the vicinity of San Telmo, on the western end of the island, at Punta Negra.

Discussion. Besides other cephalopods indicating a late Aptian age, Bodmer's collection contains numerous specimens of well-preserved *Partschiceras baborensis*. Their preservation is comparable to those described by Wiedmann (1963) from the Upper Aptian of the Province of Alicante and Cala Blanca on Mallorca. The ammonites consist predominantly of limonite, but some chambers are filled with calcite crystals. The thin test has generally been eroded or dissolved from most of the specimens. One specimen, however, has some fragments of the test preserved (Fig. 5a,b). Here, a fine, dense ribbing, as known in *Phylloceras* (*Hypophylloceras*), can be clearly seen. These fine ribs begin on the dorsal third of the flank and cross over the venter. In order to verify this

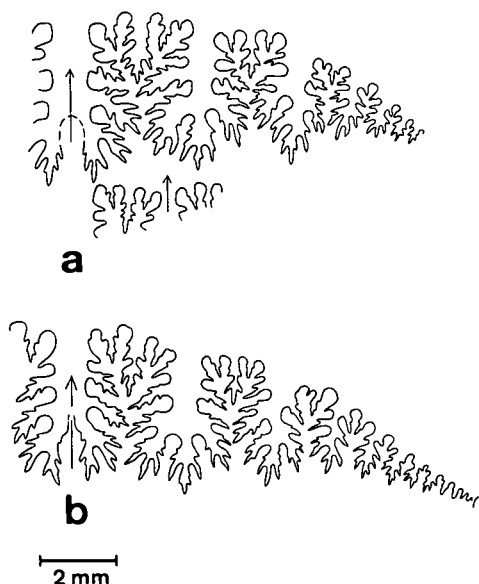


Figure 6. (a) External suture line of *Partschiceras whiteavesi* (Kossmat), Utatur Group, Odium, southern India (at diameters 15 (above) and 10 mm (below)). Museum of Natural History, Geneva, Wi 'UAM' /3. (b) External suture line of *Partschiceras baborensis* from San Telmo, Mallorca (at diameter 15 mm). Museum of Natural History, Basel, no J 31316.

observation, part of the outer whorl was removed from some specimens. The ribbing is well preserved on the venter of the adjoining inner whorl, where parts of the test remained attached (Fig. 5b,c). This confirms an observation made already by Collignon (1937, p. 9) on material of *P. baborensis* from the Aptian of Madagascar: 'Aucune ornementation, sauf sur quelques rares échantillons encore munis du test, de très fines costules ordonnées en faisceaux à partir de la fosse ombilicale est parfois visible à la loupe.' This ribbing on *P. baborensis* had not been considered by previous workers, and its assumed absence led to the view that a relationship between supposedly smooth *Partschiceras* of the Aptian and ribbed forms from the Cenomanian was doubtful (Wiedmann, 1963, p. 259).

The present observation confirms the relationship between *P. baborensis* from the Upper Aptian and the younger representatives of the genus *Partschiceras* occurring in the Cenomanian. This mainly concerns *Partschiceras whiteavesi* (Kossmat) from the Utatur Group of Odium (southern India) of Cenomanian age (as figured by Wiedmann, 1963, p. 249). Figure 58 of Wiedmann (1963) shows the fine ribbing present on the test of this species. *P. whiteavesi* cannot be

distinguished by adult morphological features from *P. baborensis*: it has an equally broad-oval to subcircular whorl section, fine ribbing on the test, and even the suture line, when fully developed in the adult stage, appears very much alike in the two species (Fig. 6a, b; compare Fig. 6a also with Wiedmann, 1963, p. 251, fig. 59).

An important difference, separating *P. baborensis* from *P. whiteavesi* has been found in the ontogenetic development of the suture line of the juvenile stages: the innermost suture line exposed on a *P. whiteavesi* from India (Fig. 6a below), at a diameter of 10 mm and a whorl height of 5.5 mm, displays a much more pronounced tetraphyllic pattern than that found in *P. baborensis* at an equal whorl height (Fig. 7e; diameter 11 mm, whorl height 6 mm). This, according to our present knowledge, represents the only difference separating *P. baborensis* (Upper Aptian) from *P. whiteavesi* (Cenomanian).

A description of the suture of the *Partschiceras* from Fuerteventura (which in our opinion should be compared with *P. whiteavesi* from southern India) is given below.

Species *Partschiceras* cf. *whiteavesi* (Kossmat)
(Fig. 6a, 7a–c)

- 1895 *Phylloceras Forbesianum* d'Orbigny; Kossmat, p. 109, pl. 15, fig. 1a–c.
1898 *Phylloceras whiteavesi* Kossmat, pp. 124, 142.
1963 *Partschiceras* (?) *whiteavesi* (Kossmat); Wiedmann, p. 249, fig. 58.

Description and discussion. The measurements in Table 1 differ within narrow limits only. No traces of test are preserved, but the suture lines are remarkably well exposed. Conspicuous is the more advanced tetraphyllic pattern of the external saddle on the specimen from Fuerteventura than that of *P. baborensis* from Mallorca at similar diameters. At a diameter of about 6 mm, the external saddle of *P. baborensis* is still clearly biphyllid and develops towards a tetraphyllic pattern only between diameters of 7.5 and 11 mm (Fig. 7d,e). In contrast, *P. cf. whiteavesi* already displays a fully developed tetraphyllic pattern from a diameter of 5 mm onwards (Fig. 7c). At that size, the suture compares well with that of a much larger *P. baborensis*, as illustrated by Wiedmann (1963, p. 251, fig. 59a).

We conclude that at progressively younger stratigraphical levels the appearance of the tetraphyllic

Table 1. Measurements of *Partschiceras* specimens

	Specimen no.	Age/location	Dm (mm)	Wh (mm)	Ww (mm)	Ww/Wh
<i>P. baborensis</i>	J 31318	Aptian/Mallorca	11.5	7 (0.61)	6.3 (0.54)	0.90
<i>P. whiteavesi</i>	'UAM' /3	Cenomanian/India	22	13.6 (0.62)	12.1 (0.55)	0.89
<i>P. cf. whiteavesi</i>	J 31317	Fuerteventura	8	4.5 (0.56)	4 (0.50)	0.89

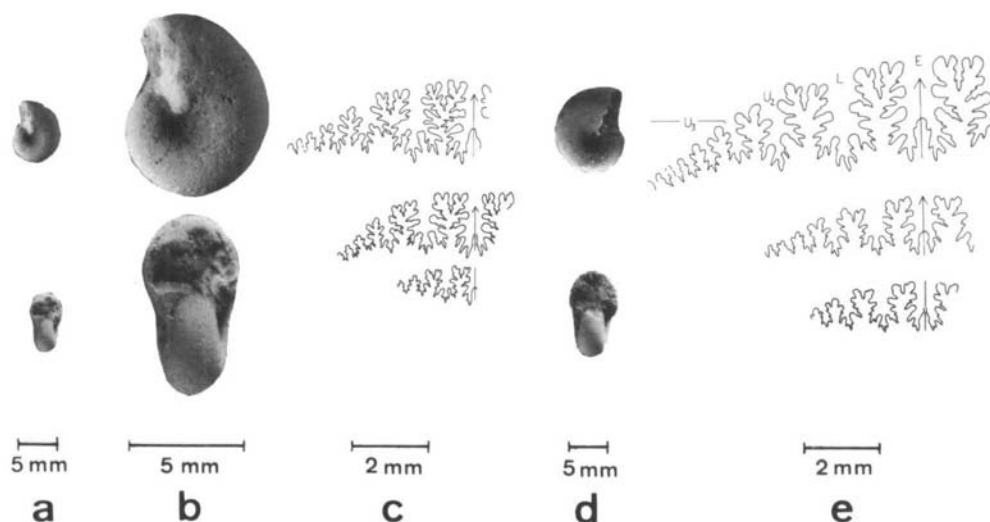


Figure 7. (a, b) *Partschiceras* cf. *whiteavesi* (Kossmat) from stratigraphical Unit F, Caleta de la Peña Vieja, Fuerteventura (Canary Islands). Museum of Natural History, Basel, no. J 31317. (c) Suture lines of *P.* cf. *whiteavesi* (specimen illustrated in a, b) at diameters of 3.6, 5.2 and 6 mm. Museum of Natural History, Basel, no. J 31317. (d) *Partschiceras baborense* (Coquand) from the Upper Aptian of San Telmo, Mallorca. Museum of Natural History, Basel, no J 31318. (e) Suture lines of *P. baborense* (specimen illustrated in d) at diameters of 6, 7.5 and 11 mm. Museum of Natural History, Basel, no. J 31318.

pattern occurs at successively earlier ontogenetic stages. Based on this observation, we propose a latest Albian to early Cenomanian age as most likely for the *Partschiceras* under discussion. This age is in line with the foraminiferal assemblage (*Schackoina gandolfii* Reichel, *Rotalipora* sp., *Hedbergella* sp., *Gabonella* sp.) co-occurring with the ammonite.

4. Conclusions

Neocomites found in Unit D dates this turbidite sequence as Valanginian to Hauterivian, and shows it to be a deep-water equivalent of the Wealden-type 'Sables de Tantan' of the Aaiun (Tarfaya) Basin of the African mainland. In a larger context, these Lower Cretaceous turbidites reflect an interval of warm and humid climate, favouring the accumulation of siliciclastics during times of global sea-level highstands (Robertson & Bliefnick, 1983; Weissert, 1990), and are well documented along the western Atlantic–Tethyan seaway (von Rad & Sarti, 1986; Weissert, 1990). Interestingly *Neocomites* is also reported from comparable deposits of partly similar facies of the central Atlantic. An ammonite of the group of *Neocomites neocomiensis* (d'Orbigny) has also been described from deeper marine Hauterivian silt- and mudstones drilled at DSDP Site 397 on the continental slope south of Fuerteventura (Wiedmann, 1979), and a *Neocomites* sp., similar to our specimen, has been found in a silty deep-water limestone of the Blake-Bahama Formation (Valanginian) at DSDP Site 534 of the Blake-Bahama Basin (Renz, 1983).

Partschiceras cf. *whiteavesi* from Unit F confirms the late Albian to early Cenomanian age established for these pelagic limestones by planktonic foraminifera

(see above, Section 2). These limestones were deposited under high fertility and up-welling conditions, as shown by the abundance of radiolarians, fish teeth and phosphatized debris. An unstable slope environment of deposition is suggested by slumping and mass flow deposits (Robertson & Bernoulli, 1982). These observations are in line with the overall evolution of the northwest African continental margin during the late Albian–Cenomanian interval which was characterized by gravitational instability (e.g. Lancelot *et al.* 1980).

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References

- COLLIGNON, M. 1937. Paléontologie de Madagascar. XXII. Les ammonites pyriteuses de l'Aptien d'Antananamirafy. *Annales de Paléontologie* **26**, 107–32, 3 pls.
- COQUAND, H. 1880. Etudes supplémentaires sur la paléontologie algérienne. *Bulletin de l'Académie Hippone* **15**, 449 pp.
- FUCINI, A. 1923. Fossili domeriani dei dintorni di Taormina. Parte prima. *Palaeontografia Italica* **26** (1920), 75–116.
- FUSTER, J. M., CENDRERO, A., GASTESI, P., IBARROLA, E. & LOPEZ RUIZ, J. 1968. *Geología y volcanología de las Islas Canarias – Fuerteventura*. Madrid: Instituto Lucas Mallada, Consejo Superior de Investigaciones Científicas, 239 pp.
- GRUNAU, H. R., LEHNER, P., CLEINTUAR, M. R., ALLEN-

- BACH, P. & BAKKER, G. 1975. New radiometric ages and seismic data from Fuerteventura (Canary Islands), Maio (Cape Verde Islands) and São Tomé (Gulf of Guinea). In *Progress in Geodynamics* (eds G. J. Borradaile, A. R. Ritsema, H. E. Rondeel and O. J. Simon), pp. 89–108. Royal Netherlands Academy of Arts and Science. Amsterdam, New York: North Holland Publishing Co.
- JOLEAUD, L. 1912. *Etude géologique de la Chaîne Numidique et des Monts de Constantine (Algérie)*. Paris: Thèse, 436 pp., 8 pls.
- KOSSMAT, F. 1895. Untersuchungen über die südindische Kreideformation (Erster Teil). *Beiträge zur Paläontologie (Geologie) Oesterreich-Ungarns und des Orients* 9, 97–203, pls 15–25.
- KOSSMAT, F. 1898. Untersuchungen über die südindische Kreideformation (Dritter Teil). *Beiträge zur Paläontologie (Geologie) Oesterreich-Ungarns und des Orients* 11, 89–152, pls 14–19.
- LANCELOT, Y., SEIBOLD, E., DEAN, W. E., JANSÁ, L. F., EREMEEV, V., GARDNER, J., CEPEK, P., KRASHENINNIKOV, V. A., PFLAUMANN, U., JOHNSON, D., RANKIN, J. G. & TRABANT, P. 1977. *Initial Reports of the Deep Sea Drilling Project*, vol. 41. Washington: United States Government Printing Office, 1259 pp.
- LANCELOT, Y., WINTERER, E. L., BOSELLINI, A., BOUTEFÉU, A. G., BOYCE, R. E., CEPEK, P., DUANE, F., GALIMOV, E. M., MELGUEN, M., PRICE, I., SCHLAGER, W., SLITER, W., TAGUCHI, K., VINCENT, E. & WESTBERG, J. 1980. *Initial Reports of the Deep Sea Drilling Project*, vol. 50. Washington: United States Government Printing Office, 1079 pp.
- LE BAS, M. J., REX, C. D. & STILLMAN, C. J. 1986. The early magmatic chronology of Fuerteventura, Canary Islands. *Geological Magazine* 123, 287–98.
- MITCHELL-THOMÉ, R. C. 1976. *Geology of the Middle Atlantic Islands*. Berlin: Gebrüder Bornträger, 382 pp.
- RENZ, O. 1983. Early Cretaceous cephalopoda from the Blake Bahama Basin (Deep Sea Drilling Project Leg 76, Hole 534A) and their correlation in the Atlantic and Southwestern Tethys. In *Initial Reports of the Deep Sea Drilling Project*, vol. 76 (eds R. E. Sheridan *et al.*), pp. 693–744. Washington: United States Government Printing Office.
- ROBERTSON, A. H. F. & BERNOULLI, D. 1982. Stratigraphy, facies and significance of Late Mesozoic and Early Tertiary sedimentary rocks of Fuerteventura (Canary Islands) and Maio (Cape Verde Islands). In *Geology of the Northwest African Continental Margin* (eds U. von Rad *et al.*), pp. 498–525. Berlin: Springer.
- ROBERTSON, A. H. F. & BLIEFNICK, D. M. 1983. Sedimentology and origin of Lower Cretaceous pelagic carbonates and redeposited clastics, Blake-Bahama Formation, Deep Sea Drilling Project Site 534, Western Equatorial Atlantic. In *Initial Reports of the Deep Sea Drilling Project*, vol. 76 (eds R. E. Sheridan *et al.*), pp. 795–828. Washington: United States Government Printing Office.
- ROBERTSON, A. H. F. & STILLMAN, C. J. 1979a. Late Mesozoic sedimentary rocks of Fuerteventura, Canary Islands: implications for West African continental margin evolution. *Journal of the Geological Society, London* 136, 47–60.
- ROBERTSON, A. H. F. & STILLMAN, C. J. 1979b. Submarine volcanic and associated sedimentary rocks of the Fuerteventura Basal Complex, Canary Islands. *Geological Magazine* 116, 203–14.
- ROTHER, P. 1968. Mesozoische Flysch-Ablagerungen auf der Kanareninsel Fuerteventura. *Geologische Rundschau* 58, 314–32.
- SALFELD, H. 1921. Kiel- und Furchenbildung auf der Schalenaußenseite der Ammonoiten in ihrer Bedeutung für die Systematik und Festlegung von Biozonen. *Centralblatt für Mineralogie, Geologie und Paläontologie* 1921, 343–7.
- SAYN, G. 1901–1907. Les ammonites pyriteuses des marnes valangiennes du Sud-Est de la France. *Mémoires de la Société Géologique de France* 23, 66 pp., 6 pls.
- SCHINDEWOLF, O. H. 1961. Studien zur Stammesgeschichte der Ammoniten. *Abhandlungen der Akademie der Wissenschaften und Literatur, mathematisch-naturwissenschaftliche Klasse* 10, Lief. 1, 109 pp.
- STILLMAN, C. J., FUSTER, J. M., BENNELL-BAKER, M. J., MUÑOZ, M., SIEWING, J. D. & SAGREDO, J. 1975. Basal complex of Fuerteventura (Canary Islands) is an oceanic intrusive complex with rift-system affinities. *Nature* 257, 469–71.
- UHLIG, V. 1906. Einige Bemerkungen über die Ammonitengattung *Hoplites* Neumayr. *Sitzungsberichte der kaiserlichen Akademie der Wissenschaften (Wien), mathematisch-naturwissenschaftliche Klasse* 114/7 (1905), 591–636.
- VON RAD, U. & SARTI, M. 1986. Early Cretaceous 'events' in the evolution of the eastern and western North Atlantic continental margins. *Geologische Rundschau* 75, 139–58.
- WEISSERT, H. 1990. Siliciclastics in the Early Cretaceous Tethys and North Atlantic Oceans: documents of periodic greenhouse climatic conditions. *Memorie della Società Geologica Italiana* 44, 59–69.
- WIEDMANN, J. 1963. Unterkreide-Ammoniten von Mallorca. 2. Lieferung: Phylloceratina. *Abhandlungen der Akademie der Wissenschaften und Literatur, mathematisch-naturwissenschaftliche Klasse* 4, 151–264, pls 11–21.
- WIEDMANN, J. 1979. Early Cretaceous mollusks from DSDP Hole 397A off Northwest Africa. In *Initial Reports of the Deep Sea Drilling Project*, vol. 47(1) (eds U. von Rad *et al.*), pp. 283–7. Washington: United States Government Printing Office.
- ZITTEL, K. A. 1884. *Handbuch der Paläontologie, I. Abteilung, II. Band, 3. Klasse Cephalopoda. Kopffüßer*, pp. 329–522. München and Leipzig: R. Oldenburg (1881–1885).