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# STRATIGRAPHY AND RUDIST BIOZONATION OF THE CAMPANIAN AND THE MAASTRICHTIAN OF EASTERN OMAN

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ABSTRACT

A cartographic and stratigraphic study of the Upper Cretaceous series surrounding the Haushi-Huqf massif (eastern Oman) has allowed to subdivide it into lithostratigraphic formations and to refine their chronostratigraphic age. Moreover, a dozen or so of rudist banks, interbedded in the series, have been discovered and constitute the aim of a palaeontologic and biostratigraphic study.

The Upper Cretaceous series begins during the early Campanian, while it ends during the late Maastrichtian. From base to top, five rudist coenozones are distinguished. The Campanian-Maastrichtian rudists of eastern Oman show main palaeogeographic affinities with the Mediterranean Province. Thus, lots of new taxa—at the genus or species levels—were endemic in the Oman area and they provide new data for palaeobiogeographic interpretation and evolutionary trends of the group. New considerations are presented on the systematics of the genus *Tetravaccinites*.

Key words: Oman, rudists, Upper Cretaceous, early Campanian, late Maastrichtian, coenozones, chronostratigraphy, paleogeography, *Tetravaccinites*.

RESUMEN

Un estudio cartográfico y estratigráfico de la serie del Cretácico Superior que rodea el macizo Haushi-Huqf (al este de Omán), permitió subdividir la serie en formaciones litoestratigráficas y precisar la edad cronoestratigráfica. Además, se descubrió aproximadamente una docena de bancos de rudistas interestratificados en la serie, que constituye el objeto de un estudio paleontológico y bioestratigráfico.

La serie del Cretácico Superior se inicia durante el Campaniano temprano y termina durante el Maastrichtiano tardío. De la base a la cima se distingue cinco cenozonas de rudistas. Los rudistas del Campaniano-Maastrichtiano del este de Omán presentan sus principales afinidades paleogeográficas con la Provincia Mediterránea.

Muchos taxa nuevos (a nivel de género y especie) son endémicos del área de Omán y proporcionan nueva información para la interpretación palebiogeográfica y acerca de las líneas evolutivas del grupo. Se presenta nuevas consideraciones sobre la sistemática del género *Tetravaccinites*.

Palabras clave: Omán, rudistas, Cretácico Superior, Campaniano temprano, Maastrichtiano tardío, cenozonas, cronoestratigrafía, paleogeografía, *Tetravaccinites*.

## INTRODUCTION

During the last ten years, discovery of rudists has began to be pointed out in the Cretaceous formations of Oman. Their stratigraphic situations have gradually been pinpointed as work on the dating of their carbonate shelf habitat has advanced. In particular, it was in the course of regular geological mapping operations, undertaken by the BRGM for the Ministry of Petroleum and Minerals, Sultanate of Oman, in 1985 in Dhofar in the south of the country, and then in 1990-1991 in the Haushi-Huqf in the east (Figure 1), that most part of the rudists were collected, since they were the target of systematic research.

Fossil fauna of the Upper Cretaceous formations has revealed to be particularly rich and diverse, mainly for the Campanian and Maastrichtian of the Haushi-Huqf region, where numerous biostromes have been discovered at around 12 horizons in the succession, the species associations of which have enabled palaeontologic biostratigraphic studies to be undertaken. This has led to the presentation in this paper of a rudist coenozone biozonation, which on one hand shows the evolution of certain species within the same group, *i. e.*, *Vaccinites*, and genera within the same family, *i. e.*, *Torreites*; and on the other shows main affinities with the Mediterranean Province (different species of *Vaccinites*, the genus *Pseudopolyconites*), and less with the Caribbean Province (the genus *Torreites*).

## REGIONAL GEOLOGICAL CONTEXT

Located on the eastern edge of the Arabian Peninsula, Oman is a desert where most of the outcropping terrains that constitute the vast, monotonous central plain are Tertiary in age and hence exposure of older rocks is limited. Apart from in the northern alpine mountain chain, Cretaceous rocks occur in only two other regions: one in the province of Dhofar to the south, in a very narrow band stretching over a distance of 250 km; and the other in the Haushi-Huqf on the eastern coast of

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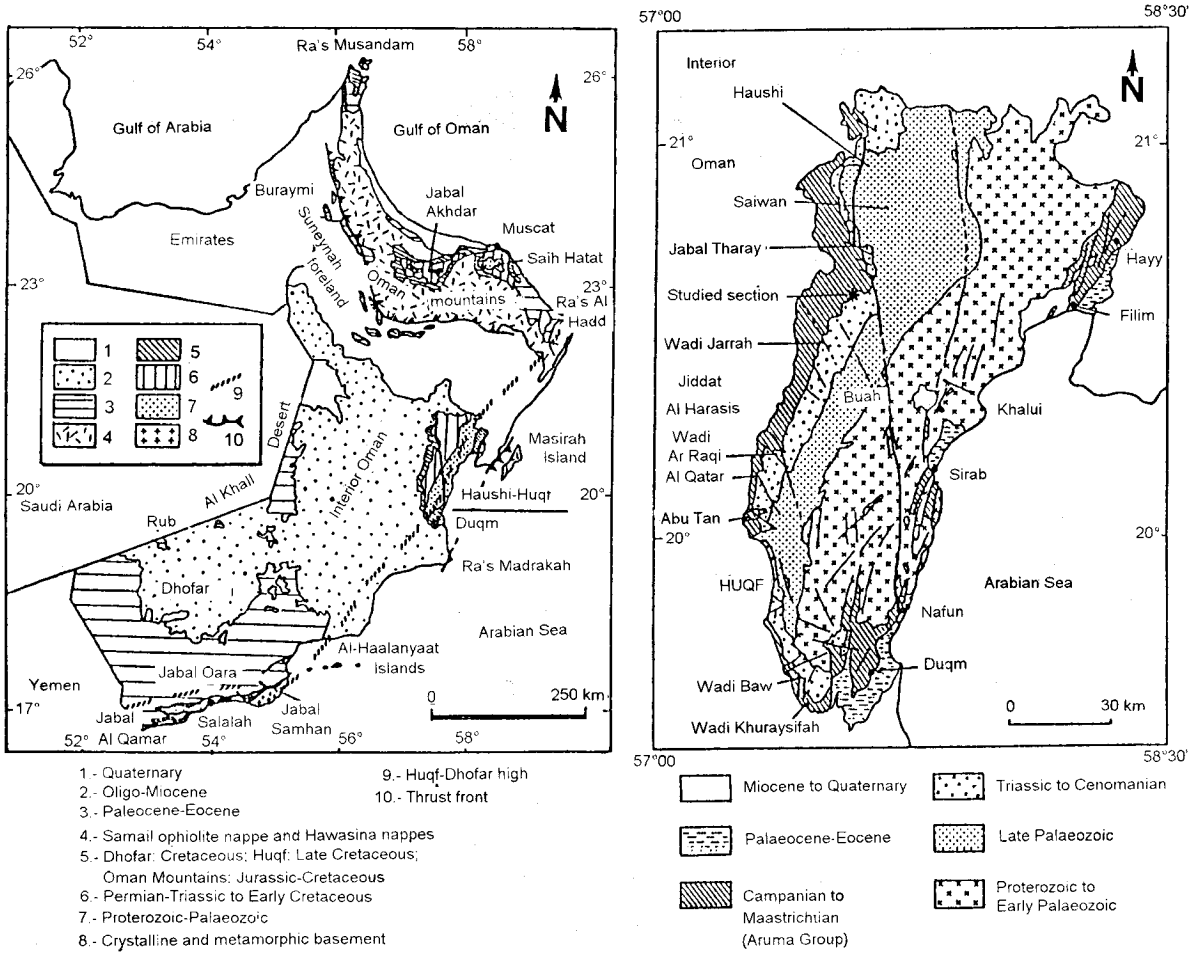



Figure 1. Geological sketch map of the Oman and Haushi-Huqf areas.

Oman, where, in an area 200 km long and 40 to 70 km wide, Cretaceous formations can be followed easily cropping out on either side of an anticlinorium structure with a Precambrian core (Figure 1). Whilst the ensemble of the successions in Dhofar, in places exceeding 1,500 m in thickness and almost always deposited in a neritic shelf environment, and extending from the Barremian-Aptian to the upper Maastrichtian with numerous hiatuses (Roger *et al.*, 1989, 1992), the Haushi-Huqf succession is more complete though commonly thinner (about 400 m), beginning with the Berriasian and including a thick and environmentally varied and deeper Campanian succession, which terminates at the same time as that of Dhofar (Platel *et al.*, 1992; Dubreuilh *et al.*, 1992).

During the Campanian and the Maastrichtian, deposition of the last four formations—Samhan, Fiqa, Filim and Simsima—took place both during and after the major tectonic event, *i. e.*, the emplacement of the Hawasina nappes and the Samail ophiolites which were thrust across northern Oman (Bechennec *et al.*, 1989). Corresponding to one of the highest levels of the sea during the Mesozoic, the Campanian transgression took place in several stages with a diversification of facies linked to the proximity of emergent zones. This succession of stages can be explained through the evolution of the regional geodynamic context in relation to the formation of the Suneinah foreland basin which led to the abrupt collapse of the shelf to the west of Haushi-Huqf (Platel *et al.*, 1994). A major regression then occurred progressively during the late Maastrichtian.

## PREVIOUS WORK ON THE UPPER CRETACEOUS SUCCESSION

### *GEOLOGICAL STUDIES*

It has only been over the last 20 years that the geology of Oman started to be established. Before this period, oil exploration had only sketched the main outline of the sedimentary history of the country. Most of this work involved determination of the facies types and the geometry of the formations, the geological ages of which often remained poorly defined.

Very little work on the Cretaceous of the Haushi-Huqf has been hitherto published. Recently, Hughes-Clarke (1988) mentioned briefly the Campanian lithostratigraphy with its deep-water chalky marl facies, which makes up the Fiqa Formation known subsurface in interior Oman, and which, accord-

ing to this same author, may extend into the Haushi-Huqf with rocks laid down in a shallow-water limestone environment. As far as the Maastrichtian is concerned, Hughes-Clarke (1988) only mentions scarce outcrops of pelagic carbonates in the eastern part of the area.

Recent work in the Haushi-Huqf supported by geological mapping, following systematic prospecting (Platel *et al.*, 1992; Dubreuilh *et al.*, 1992), has enabled the establishment of a complete and detailed stratigraphic succession of the Cretaceous with determination of the precise ages of the eight Formations which are distinguished locally and assembled into three groups—Thamama, Wasia and Aruma. The groups are commonly separated by major discontinuities corresponding in places to regional unconformities caused by major transgressions. In particular it has been possible to distinguish the characteristics of the great Campanian transgression at the base of the Aruma Group (Figure 2), the deposits of which are organised in a succession of shelf environments—Samhan and Filim Formations—where rudist biostromes became regularly established in littoral environments (Platel *et al.*, 1994).

The Upper Cretaceous transgression has also been studied in the northwestern part of the Oman Mountains—Al Buraymi—and in the UAE (Skelton *et al.*, 1990; Nolan *et al.*, 1990; Le Metour *et al.*, 1992). Here it began during the late Maastrichtian with the unconformable contact of the Qahlah and Simsima Formations across the Hawasina nappes and the Samail ophiolites.

*STUDIES ON THE RUDISTS*

From a palaeontological point of view, precise data were scarce until recent years and the associations of numerous groups of macrofauna remained poorly documented. This was particularly the case for rudist bivalves, the systematic collection and positioning of which in the lithostratigraphic succession, has only been undertaken in recent years.

At first in Dhofar, where rudist biostromes showing Caribbean rudist affinities (*Torreites milovanovici*) were described for the first time (Philip and Platel, 1987) occurring within proximal shelf limestones of the Samhan Campanian Formation.

At the same time, Skelton and Wright (1987) indicated the discovery of *Torreites* in the northern Haushi-Huqf and in the eastern UAE, considering that the neritic succession in which both occurred was of the Maastrichtian and that they were thus in the Simsima Formation.

In the Maastrichtian rocks—Qahlah and Simsima Formations—of the northwestern part of the northern Oman Mountains, Skelton and others (1990) indicated diverse associations comprising several species of *Vaccinites* and *Hippurites*, with *Dictyoptychus, Torreites, Pseudopolyconites, Vautrinia, Pironaea Sabinia, Durania, Bournonia* and various Radiolitidae.

Lastly, in the course of detailed study of the Campanian transgression across the Haushi-Huqf massif, Platel and others (1994) were able to describe a highly fossiliferous section to the south of Saiwan in the Samhan Formation, where gigantic hippuritid-bearing biostromes occur. This formation, which has been dated as early Campanian by microfauna and nannoflora, contains a rich rudist association, dominated by *Vaccinites vesiculosus,* with *Torreites milovanovici*, large *Durania* sp., *Bournonia* sp. and many Radiolitidae, particularly, several species of *Biradiolites*.

In addition, new forms—at species and genera levels—have been brought to light in the context of prospecting within Campanian-Maastrichtian rocks of the region and are still under study. A notable novelty is the description of *Praetorreites omanensis* n. gen., n. sp. occurring at the extreme base of the Samhan Formation (Philip and Platel, 1994).

## STRATIGRAPHY OF THE LATE CRETACEOUS SUCCESSION OF THE HAUSHI-HUQF

Around the Proterozoic cored anticlinorium of the Haushi-Huqf, various groups of Mesozoic rocks crop out well in successive aureoles which make up the monoclinal western

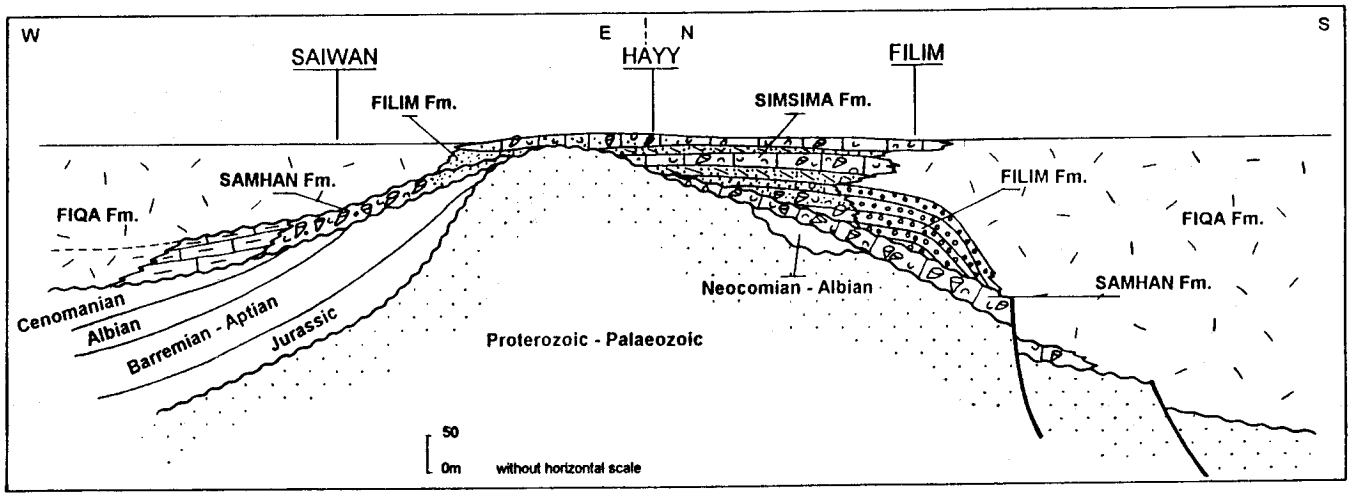



Figure 2. Schematic organization of the Campanian and Maastrichtian platforms lapping onto the Haushi-Huqf palaeohigh.

flank of the structure and occur, to a less extensive extent, in its northeastern part—Hayy, Filim. They are separated by unconformable contacts of varying amplitude. As is the case across the whole of the Arabian platform, one of the main unconformities separates the Albian-Cenomanian Wasia Group from the Campanian-Maastrichtian Aruma Group (Figure 3). This division is materialised by the continental Qitqawt Formation which is thin, probably Santonian in age, that occurs ubiquitously.

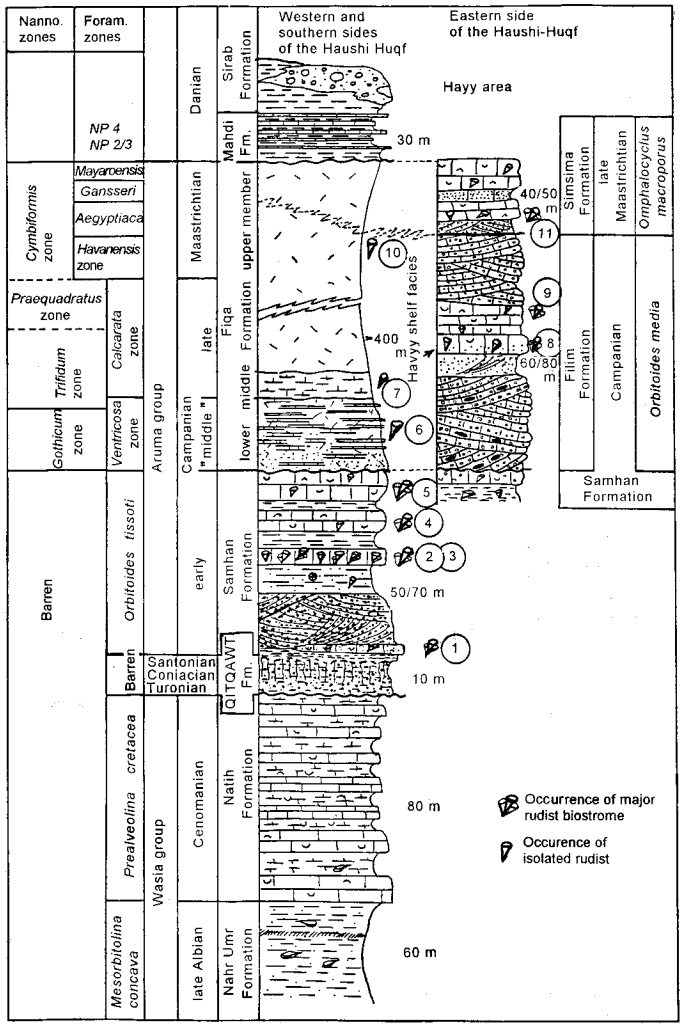



Figure 3. Lithostratigraphy of Upper Cretaceous formations in the Haushi-Huqf area.

In contrast to the earlier Palaeozoic and Mesozoic groups, the Aruma comprises a complex ensemble of superpositioned formations, but which grade laterally into one another as a function of the local geodynamic context which strongly influenced the palaeogeography. The major environmental variations, created by compart-forming tectonics which were still active during the greater part of deposition, and the main discontinuities, have enabled local distinction of four formations: in ascending order, the Samhan Formation with its shelf facies, which is clearly distinct from the chalky Fiqa Formation, which is overlain by the Simsima Formation, repeating the neritic shelf environment of deposition. In the northeast of the area, around Hayy and Filim, the Fiqa grades laterally into the Filim Formation, which is less distal in character (Platel *et al.*, 1992; Dubreuilh *et al.*, 1992). Generally speaking, the Fiqa replaces all other shelf formations in its subsurface expression to the west of the Haushi-Huqf and in the collapsed areas along the edge of the Indian Ocean.

### *SAMHAN FORMATION (LOWER CAMPANIAN)*

The sea began its new conquest of the continent during the early Campanian with deposition of the Samhan Formation. These neritic shelf facies best illustrate the beginning of this very significant transgression. A narrow carbonate shelf surrounded the rim of the Precambrian Haushi-Huqf massif which was under a strong emerged continental influence. The shelf was regularly fed with terrigenous sediments that disturbed the proliferation of the rich rudist colonies, from which the biostromes developed in strongly littoral palaeoenvironments at least five main levels (Platel *et al.*, 1994).

The Samhan Formation, the thickness of which may exceed 100 m, shows a fairly variable lithology both vertically and laterally, attesting to the same transgressive evolution (Figure 4). It is made up of three members, the first two of which begin with detrital sandy or marly facies and end with spectacular rudist biostromes, such as those near Saiwan in the north of the region (biostromes 1, 2 and 3). The upper member,

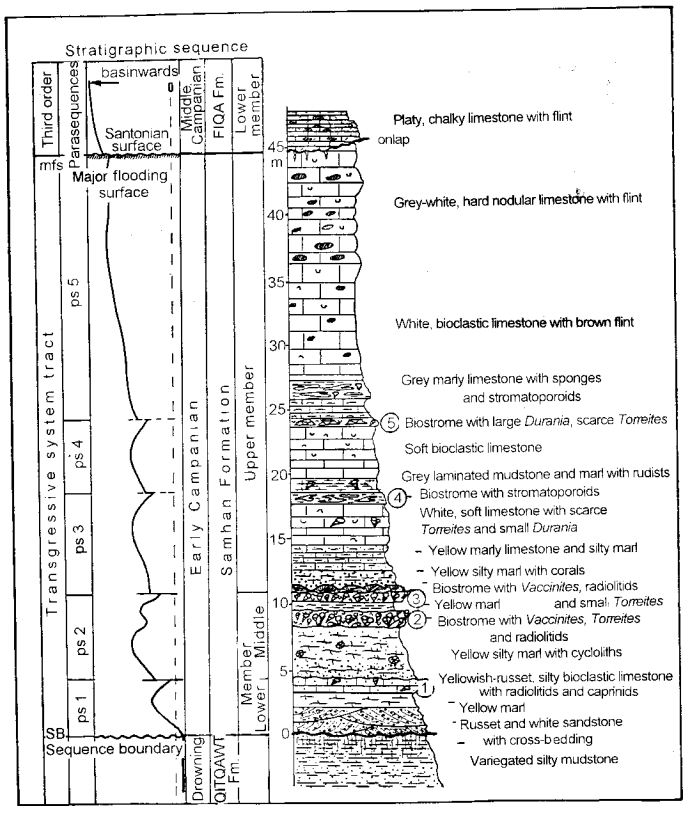



Figure 4. Lithostratigraphic column of the lower Campanian Samhan Formation, Saiwan area.

whose thickness exceeds 80 m where erosion has not removed the formation, is mostly made up of proximal carbonate shelf deposits which are alternately marly and bioturbated, variably bioclastic limestones with numerous small hippuritids and/or radiolitid biostromes, corals and stromatopora, on the western and central flanks of the Haushi-Huqf massif (biostromes 4 and 5). On the eastern flank, around Nafun and Sirab, the facies attest to greater opening to the sea with abundant pycnodonts and echinoids in layers and the almost total disappearance of rudists.

*FIQA FORMATION (MIDDLE CAMPANIAN TO LATE MAASTRICHTIAN)*

A major unconformity ends the first step of the transgression with an abrupt deepening of the sea caused by tectonic collapse of the shelf in the east of Oman. The second step, which took place from the beginning of the "middle" Campanian, was more pronounced with the establishment of the chalky facies of the Fiqa Formation in a basin of variable depth, deposited across major flooding surface—ferruginous hardground—attesting to strongly subsident zones around the massif. The rocks of the Fiqa Formation, which may attain a thickness 400 m to the east of the massif, though it is much thinner to the west, is made up of a homogeneous succession of white chalk and pale green marls. The lowest member is composed of 10 to 50 m of silty chalk; the overlying member is composed of 10 to 15 m of marl. Both are dated "middle" to earliest late Campanian (Platel *et al.*, 1994), on the basis of *Globotruncana ventricosa, Globotruncanita elevata* and *Quadrum gothicum*, and then higher up by the presence of *Q. trifidum.* The great chalk succession which constitutes the third and upper member corresponds to the third and uppermost member and is attributed to the late Campanian—with *Lithraphidites praequadratus*—and to the late Maastrichtian—with *Gansserina gansseri, Globotruncana aegyptiaca* and *Abathomphalus mayaroensis.*

The rudists, strongly represented by *Sauvagesinae*, are much less abundant in this formation and nowhere form biostromes, occurring in scattered manner at several levels in each member (levels 6, 7, and 10).

*FILIM FORMATION (MIDDLE TO LATE CAMPANIAN)*

Most part of the Fiqa Formation grades laterally in the northeastern area to the Filim Formation, the thickness of which is highly variable and may exceed 80 m. It is composed of thin, white calcarenite beds containing black chert and large-scale cross-bedding (Figure 5). These beds correspond to slope facies and are typical of this formation. The succession is affected by very numerous, very distinct truncations in the Filim area, and slumps can be observed locally. These slope facies only occur within an area of a few tens of square km to the north of Filim and grade toward the northeast, around

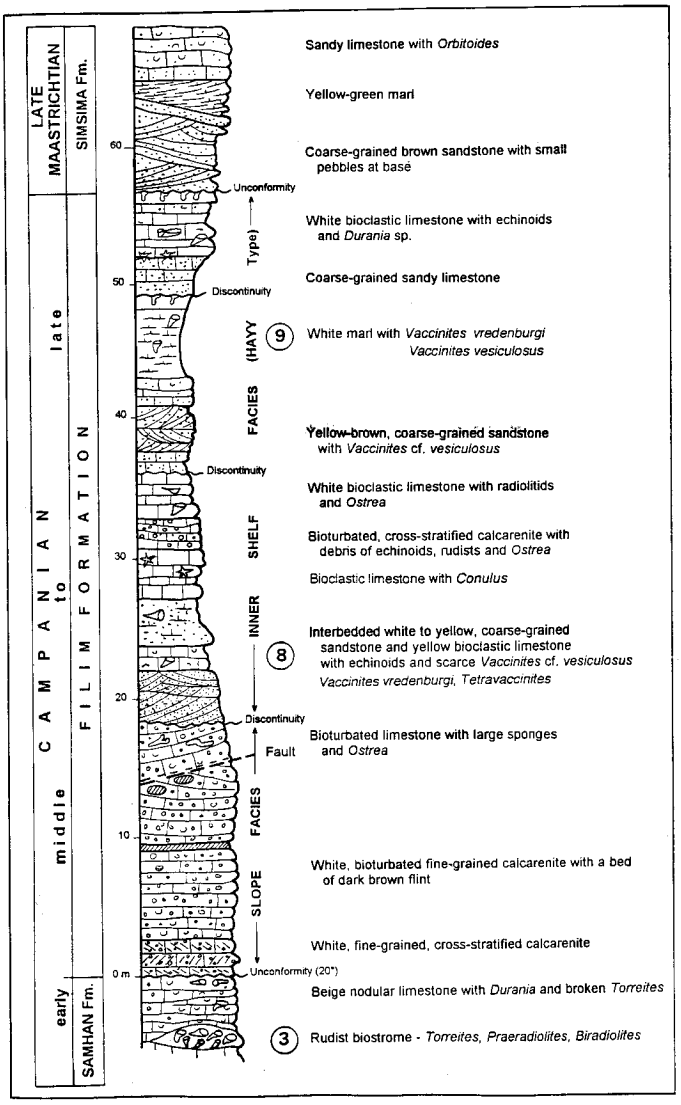



Figure 5. Type-section of the Campanian Filim Formation, north of the Haushi-Huqf area.

Hayy, into inner shelf facies. These latter facies occur most frequently showing thin sequences beginning with a few metres of yellow, bioclastic, calcareous sandstone and white, variably chalky marls containing the rudists *Vaccinites* and radiolitids with abundant *Orbitoides media* and *O.* cf. *concavatus* (levels 8 and 9).

To the north of Hayy (Wadi Halfayn), in a zone proximal to the narrow shelf, the rudists locally constitute fairly dense biostromes, whilst toward Filim they are more scarce in the advanced areas of shelf facies which are interstratified in layers roughly 15 m thick in the middle part of the slope calcarenites (Figure 5, levels 8 and 9).

*SIMSIMA FORMATION (UPPER MAASTRICHTIAN)*

The Aruma Group is concluded with yet another shelf formation, the Simsima, which only crops out extensively between Filim and Hayy, where it unconformably overlies the

Filim Formation or the Samhan Formation. It also occurs in the form of residual benches unconformably overlying and directly upon the Proterozoic rocks to the west of Khaluf. Where it is not too eroded, the thickness of the Formation remains constant at about 50 m. The Simsima Formation, which the authors have dated as late Maastrichtian on the basis of the macrofauna *Omphalocyclus macroporus, Loftusia elongata, L.* cf. *minor, Orbitoides media* amongst others, corresponds to the terminal Cretaceous regression, whilst the chalky, deep-water facies with planktonic foraminifera of the Fiqa Formation disappear up and into the late Maastrichtian in the collapsed areas of the eastern flank (Sirab). The Simsima Formation is divided into two transgression/regression sequences each of equal thickness and constituting members. These rocks form small cuestas to the south of Hayy and display very similar lithologic successions (Figure 6). The base of each member begins with a continuous layer of coarse-grained sandstone forming thin beds commonly displaying cross-bedding—2 to 8 m at Filim and 15 to 20 m at Khaluf. The successions continue with either a few metres of yellow marls which may contain rudist biostromes such as the lower member occurring to the north of Filim, or by bioturbated bioclastic limestones with more marly, fossiliferous intercalations. Both members end with a dozen or so metres of yellow, fine- to medium-grained calcarenites forming one-metre-thick beds and locally showing cross-bedding (Figure 7).

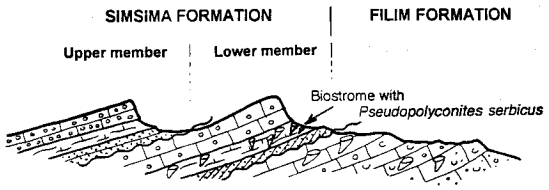



Figure 6. Cross-section of the upper Maastrichtian Simsima Formation overlying the Campanian Filim Formation, north of Filim.

Rudists occur at several horizons but are particularly abundant in the biostrome (level 11) of the lower member (**Sauvagesinae**, *Vaccinites, Pseudopolyconites, Pironaea*, **Caprinidae** n. sp., Radiolitids).

## RUDIST BIOZONATION

*SAMHAN FORMATION*

*Lower member (earliest Campanian?)*

*Vaccinites inaequicostatus* Munster
*Praetorreites omanensis* Philip and Platel
*Praeradiolites* aff. *hoeninghausi* (Des Moul.)
*Durania* sp.1
Caprinidae

*Middle member (early Campanian)*

*Vaccinites vesiculosus* Woodward
*Torreites milovanovici* Grubic
*Biradiolites* cf. *canaliculatus* d'Orb.

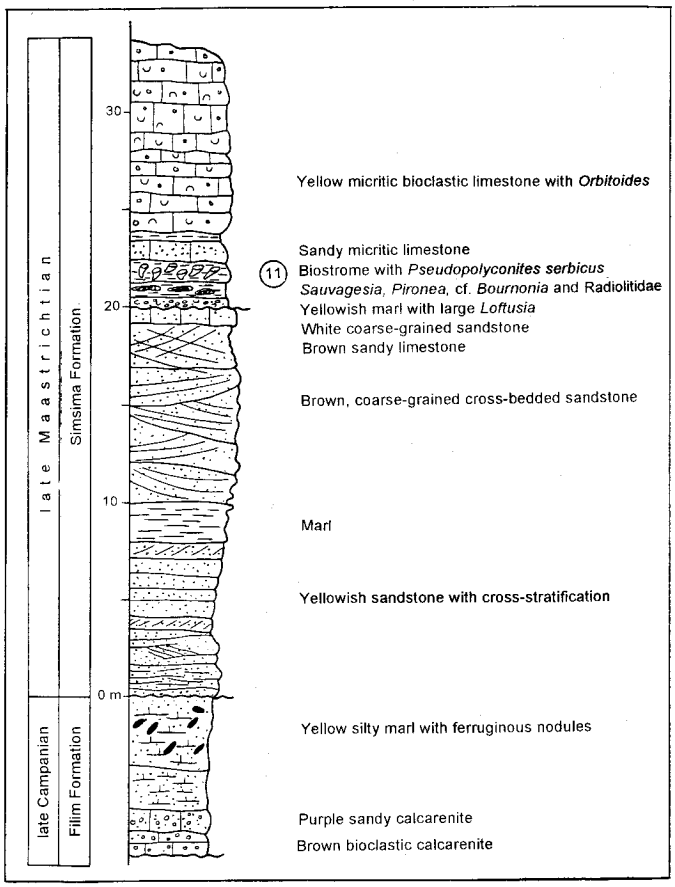



Figure 7. Base of the upper Maastrichtian Simsima Formation, north of the Haushi-Huqf area.

*Biradiolites* aff. *aquitanicus* Toucas
*Biradiolites* aff. *bulgaricus* Pamouktchiev
*Durania* sp.1
Caprinidae

*FILIM FORMATION, Hayy facies (early late Campanian)*

*Vaccinites vredenburgi* Kuhn
*Vaccinites vesiculosus* Woodward
*Tetravaccinites filimensis* nov. sp.
*Praeradiolites* aff. *hoeninghausi* (Des Moul.)
*Biradiolites* aff. *bulgaricus* Pamouktchiev
*Biradiolites* cf. *canaliculatus* D'Orb.
*Sabinia* sp.
*Durania* sp. 1
*Durania* sp. 2

*FIQA FORMATION, Upper part (earliest to early Maastrichtian)*

*Durania* sp.2
*Durania* sp.3
*Lapeirousia* sp.
Sauvagesinae

*SIMSIMA FORMATION - (late Maastrichtian)* (Plate 2)

*Vaccinites vesiculosus* Woodward
*Pseudopolyconites ovalis* Milovanovic

*Pseudopolyconites* sp.
*Praeradiolites* aff. *boucheroni* (Bayle)
*Pironea* sp.
*Bournonia* sp.
*Durania* sp.
**Caprinidae**

*SAMHAN FORMATION*

Rudists are very abundant in the lower and middle members (Figure 3). A rich rudist biostrome belonging to the lower member crops out at Wadi Khuraysifah, south of the Huqf massif (Figure 1). The rudist association is dominated by two forms: *Praetorreites omanensis* Philip and Platel, 1994 and *Vaccinites inaequicostatus* Munster. Radiolitids and Caprinids are more scarce.

In the Saiwan area (Figure 1) rudist biostromes of the middle member are well exposed (Figure 4) and provide a rich and diverse fauna (Platel *et al.*, 1994). By comparison with the first biostrome, it is worth to notice a renewal of the Hippuritids and the first appearance of *Vaccinites vesiculosus* Woodward (very abundant) and *Torreites milovanovici* Grubic (rare). Otherwise, the radiolitids are more diversified than in the lower member.

*FILIM FORMATION*

The two biostromes of the Hayy facies (Figure 5) afford: *Vaccinites vredenburgi* Kuhn and *V. vesiculosus* Woodward, while a new morphotype of the strange genus *Tetravaccinites* Bilotte occurs in the lower one. The Radiolitid association is quite comparable to the former biostromes of the Samhan Formation.

*FIQA FORMATION*

Rudists are very scarce in the Formation and are often represented by isolated specimens of Radiolitids (*Durania* and *Lapeirousia* sp.)

*SIMSIMA FORMATION*

The rudist association of this unit is characterized by the first appearance of *Pseudopolyconites* and *Pironaea*.

Table 1 displays a more complete list of the rudists identified in the Campanian and the Maastrichtian of the Haushi-Huqf and the biostratigraphical range of each taxon, through the stratigraphic interval here considered. Amongst the rudist coenozones represented in the overall biostromes (1 to 11), selected taxa can be considered as biostratigraphically significant. It is the case of the Hippuritids, which allow to separate distinctively the three lithostratigraphical units—Samhan, Filim, Simsima. A special mention can be done of the Torreitidae, a new family created by Philip and Platel (1994), that gathers the genera *Praetorreites* and *Torreites*. In the Haushi Huqf area, the Torreitidae are only present in the Samhan Formation. Lastly, the first occurrence of the genus *Pseudopolyconites* in the Simsima formation can be underlined. This occurrence indicates the palaeobiogeographic relationships which existed during the Maastrichtian between the Haushi Huqf carbonate platforms and the central Mediterranean platforms, where the genus was well represented (Milovanovic, 1937; Sladic-Trifunovic, 1983).

Table 1. Stratigraphic range of the rudists of the Campanian and Maastrichtian of the Haushi-Huqf massif.

| CAMPANIAN | | | | | | | | | | MAASTRICHTIAN | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Early | | | | | Middle to Late | | | | | Early to Late | Late | |
| FIQA Formation | | | | | | | | | | | | |
| SAMHAN Fm. | | | | | Lower Mb. | | FILIM Fm. | | | Upper Mb. | SIMSIMA Fm. | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | | 10 | 11 | Biostromes or rudist levels |
| xxx | | | | | | | | | | | | *Vaccinites inaequicostatus* Munster |
| | xxxxx | | | | | | xxxxxxxxxx | | | | xxxxxxx | *Vaccinites vesiculosus* Woodward |
| | | | | | | | xxxxxxxxxx | | | | | *Vaccinites vredenburgi* Kühn |
| | | | | | | | xxxxxxxxxx | | | | | *Tetravaccinites filimensis* nov. sp. |
| | | | | | | | | | | | xxxxxxx | *Pironea* sp. |
| xxx | | | | xxx | xxxxxxxxxx | | xxxxxxxxxx | | | xxxxxx | | *Durania* sp. |
| | | | | | | | | | | xxxxxx | | *Lapeirousia* sp. |
| | | | | | | | | | | | xxxxxxx | *Sauvagesia* sp. |
| | | | | | | | | | | xxxxxx | | Sauvagesiinae |
| | | | | | | | xxxxxxxxxx | | | | | *Sabinia* sp. |
| xxxxxxxxx | | | | | | | | | | | xxxxxxx | Caprinidae |
| xxx | | | | | | | | | | | | *Praetorreites omanensis* Philip and Platel |
| | xxxxx | | | | | | | | | | | *Torreites milovanovici* Grubic |
| | xxxxxxxxx | | | | | | xxxxxxxxxx | | | | | *Biradiolites* cf. *canaliculatus* d'Orb. |
| | xxxxxxxxx | | | | | | xxxxxxxxxx | | | | | *Biradiolites* aff. *bulgaricus* Pamouktchiev |
| | xxxxxxxxx | | | | | | | | | | | *Biradiolites* aff. *aquitanicus* Toucas |
| | | | | | | | | | | | xxxxx | *Praeradiolites* aff. *boucheroni* (Bayle) |
| xxx | | | | | | | xxxxxxxxxx | | | | | *Praeradiolites* aff. *hoeninghausi* (Des Moulins) |
| | xxxxxxxxx | | | | | | | | | | xxxxxxx | *Bournonia* sp. |
| | | | | | | | | | | | xxxxxxx | *Pseudopolyconites ovalis* Milovanovic |
| | | | | | | | | | | | xxxxxx | *Pseudopolyconites* sp. |
| | xxxxxxxxx | | | | | | xxxxxxxxxx | | | | xxxxxxx | Radiolitidae |

SYSTEMATICS

Genus *Tetravaccinites* Bilotte, 1981

***Tetravaccinites filimensis* n. sp.**
(Plate 1, figure 3)

***Holotypus***—JPP 535 C2.

***Derivatio nominis***—From Filim's locality.

***Locus typicus***—Filim (northeastern part of the Haushi massif) 20°38' N, 58°12' E.

***Stratum typicus***—Early late Campanian.

**Description**—The specimen is only represented by the right valve, that which is silicified. The outer shell layer is not well preserved and intensively bored. The *arête cardinale* is elongated, with a rounded tip. Pillars S and E are as long as the *arête cardinale* and are strongly pedunculate. The angle of arc between the *arête cardinale* and pillar E is of 130. The third, supernumerary pillar (pillar A of Bilotte [1981]) is elongated, 2-cm long, with a rounded tip; the angle of arc between the *arête cardinale* and the pillar A is of 210.

The angle made by the myocardinal array with the inner tip of the *arête cardinale* is of 75. The socket for the left valve posterior myophore (pms) is located in the vicinity of the tip of pillar S. The anterior adduction muscle scar forms an arcuate broad inclined shelf, in the antero-ventral part of the shell. A

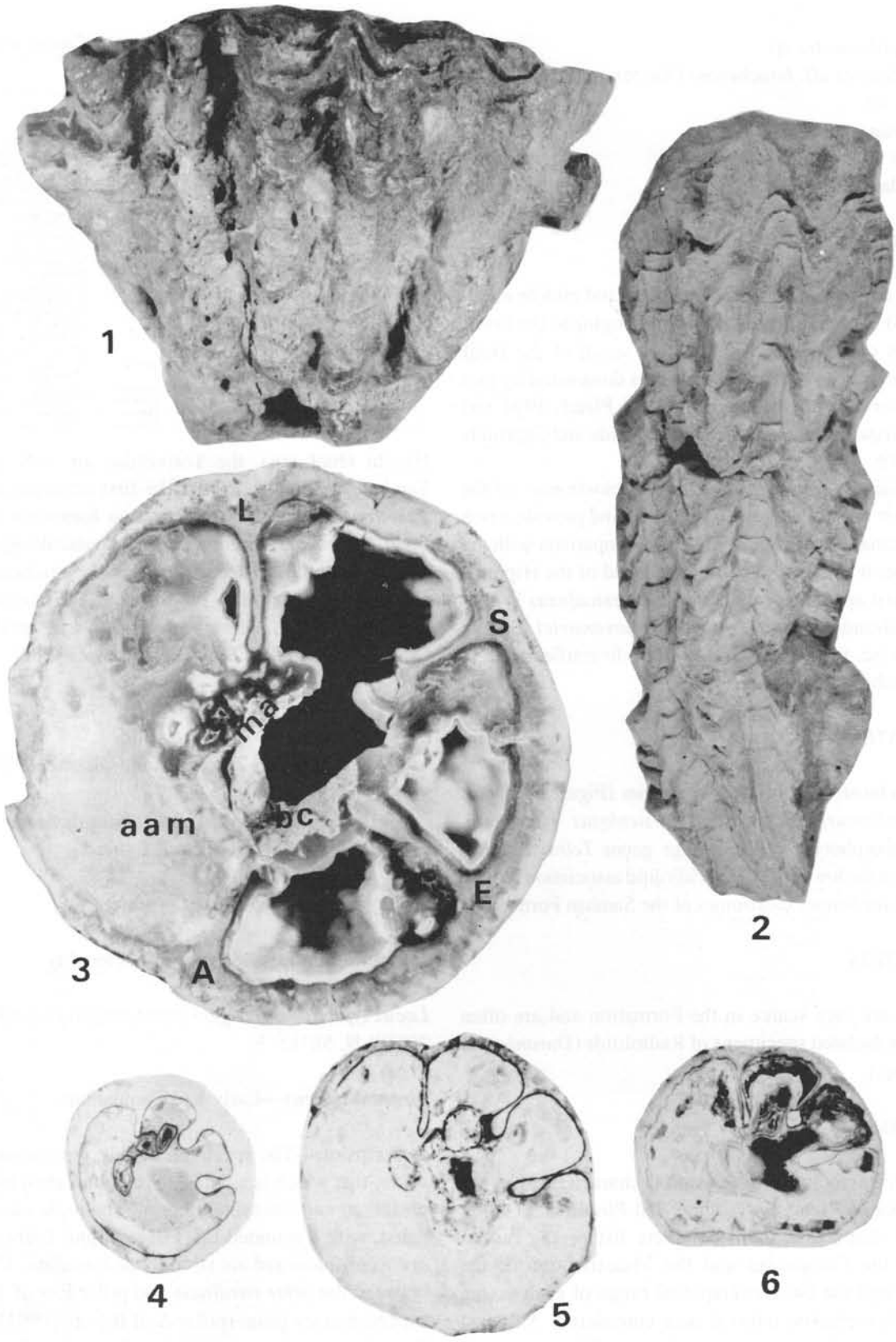
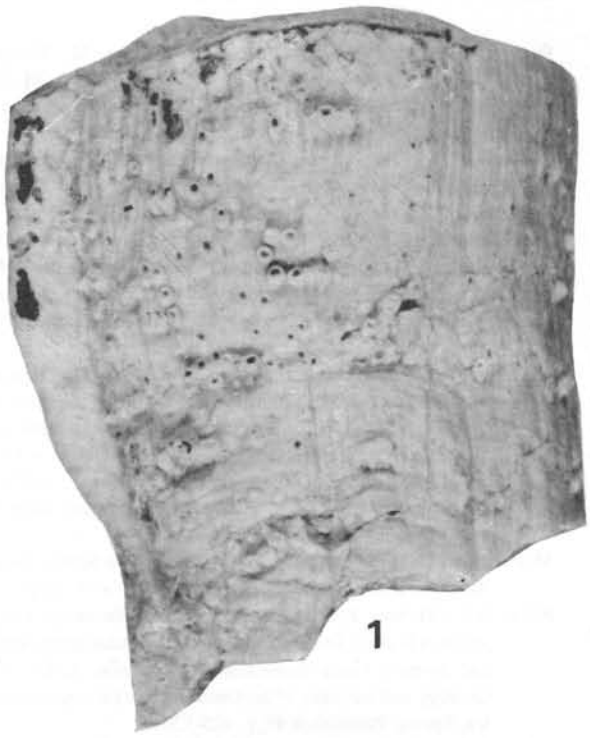
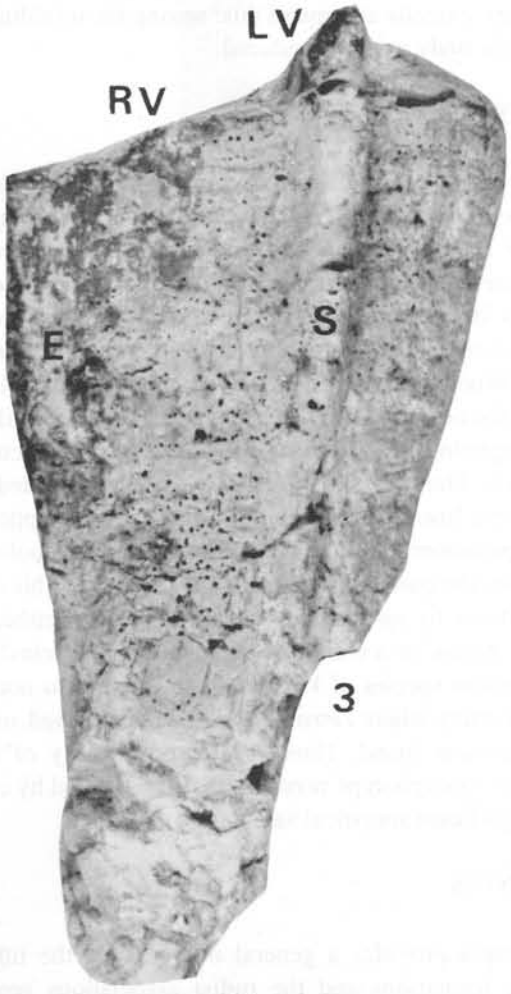
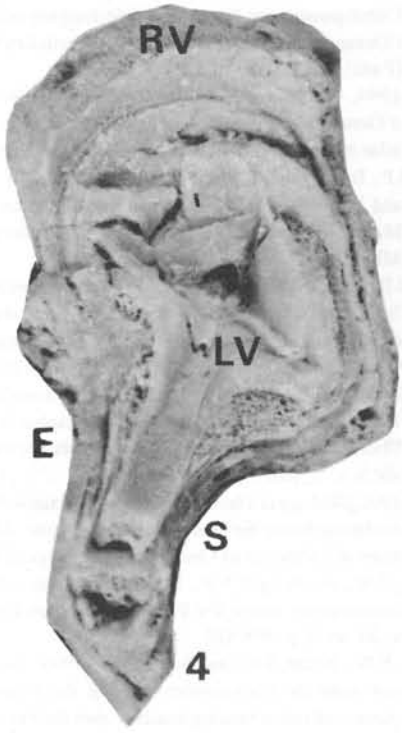



Plate 1. Figure 1—*Biradiolites* aff. *bulgaricus* Pamouktchiev. View of the siphonal side, Samhan Formation, lower Campanian, Saiwan, x 0,66, 405 A. Figure 2—*Biradiolites* aff. *aquitanicus* Toucas. View of the siphonal side, Samhan Formation, lower Campanian, Saiwan, x 0.45, JPP 320 N. Figure 3—*Tetravaccinites filimensis* nov sp. Section of the right valve. L = ligamental ridge; S and E = pillars; A = supernumerary pillar; a. a. m. = anterior adductor muscle; m. a. = myocardinal array; b. c. = body cavity; Filim Formation, middle Campanian, Filim, x 1, JPP 535 $C_2$. Figure 4—*Vaccinites inaequicostatus* Munster. Section of the right valve, Samhan Formation, lower Campanian, Wadi Khuraysifah, x 0.43. Figure 5—*Vaccinites vesiculosus* Woodward. Section of the right valve, Samhan Formation, lower Campanian, Saiwan, x 0.57. Figure 6—*Vaccinites vredenburgi* Kühn. Section of the right valve, Filim Formation, middle Campanian, Hayy, x 0.35.



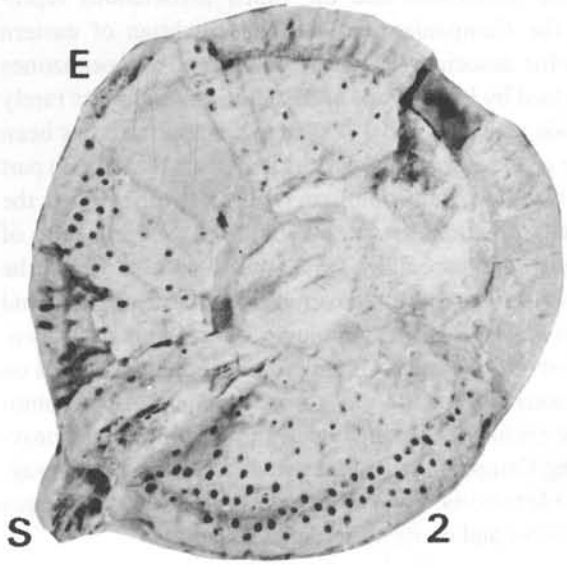




Plate 2. Figure 1—*Pseudopolyconites* sp. Lateral view of the right valve, showing the tubular excrescences, Simsima Formation, upper Maastrichtian, NW of Filim, x 1.5, JPP 503 $C_2$. Figure 2—The same. View of the left valve, S. and E. siphonal folds, x 1.7. Figure 3—*Pseudopolyconites ovalis* Milovanovic. Bivalve specimen, RV = right valve; LV = left valve; S. and E. siphonal folds, Simsima Formation, upper Maastrichtian, NW of Filim, x 1, JPP 503 $C_2$. Figure 4—*Bournonia* sp. Top view of a bivalve specimen, RV = right valve; LV = left valve; S. and E. siphonal bands, Simsima Formation, upper Maastrichtian, NW of Filim, x 2, JPP 503 $C_1$.

vesicular layer is broadly developed in the inner part of the right valve and extends all around this, among the infoldings. As a result, the body cavity is reduced.

## DISCUSSION

The new form differs from *Tetravaccinites collignoni* Bilotte (1981) in the morphology of pillars S and E and in the angle between the *arête cardinale* and pillar A. It differs from *Tetravaccinites macedoniensis* Lupu (*in* Kollmann *et al.*, 1985) mainly in the morphology of pillars S and E. *Tetravaccinites filimensis* n. sp. is probably derived from *Vaccinites vesiculosus* Woodward, which displays numerous characters described in the new form. Of particular interest is the similarity in the morphology of pillars S and E, as well as the vesicular inner structure. Thus, an evolutionary trend can be inferred in certain phyletic lineage of *Vaccinites*, leading to the appearance of a supernumerary pillar, whilst the overall morphology inherited from the parent species remains the same. This observation allows to suspect *Tetravaccinites* to be either a polyphyletic genus, or a morphologic (teratologic?) transformation of certain species of *Vaccinites*. It is worth to notice that in each locality where *Tetravaccinites* was described, only one specimen was found. Thus, the reproductibility of the *Tetravaccinites* morphotype needs to be demonstrated by collecting of significant statistical samples.

## CONCLUSIONS

This paper provides a general overview of the lithostratigraphic formations and the rudist associations represented in the Campanian and the Maastrichtian of eastern Oman. Rudist associations can be considered as coenozones mainly formed by Hippuritids and Radiolitids and more rarely by Caprinids and Torreitids. A systematic approach has been done at the genus and species levels. It appears that a main part of rudist taxa has palaeobiogeographic affinities with the Mediterranean realm. However, some forms are endemic of eastern Oman and especially the Torreitid species whilst the genus *Torreites* was both recovered from the Caribbean and Arabic provinces. The paleontologic description of the endemic rudists from eastern Oman provides interesting data on the evolutionary trend of the group and on the palaeobiogeographic exchanges among Oman and the other rudist provinces during Campanian and Maastrichtian times. In this way, new considerations have been presented on the genus *Tetravaccinites* and on its systematics meaning.

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## BIBLIOGRAPHICAL REFERENCES

Bechennec, F.; Le Metour, J.; Rabu, D.; Beurrier, M.; Bourdillon-Jeudy-de Grissac, C.; De Wever, P., Tegyey, M.; and Villey, M., 1989, Géologie d'une chaîne issue de la Téthys—Les montagnes d'Oman: Bulletin de la Société Géologique de France, v. 2, no. 8, p. 167-188.

Bilotte, M., 1981, *Tetravaccinites collignoni* n. gen., n. sp. et les autres rudistes du Santonien supérieur de l'Aude (France): Géobios, v. 14, no. 1, p. 123-139.

Dubreuilh, J.; Bechennec, F.; Berthiaux, A.; Le Metour, J.; Platel, J.P.; Roger, J.; and Wyns, R., 1992, Geological map of Oman at 1/250,000, Al Khaluf, sheet NF 40-15 and explanatory notes: Muscat, Oman, MPM Ed.

Hughes-Clarke, M.W., 1988, Stratigraphy and rock unit nomenclature in the oil-producing area of interior Oman: Journal of Petroleum Geology, v. 11, no. 1, p. 5-60.

Kollmann, H.A.; Lupu, D.; and Velitzelos, E., 1985, Rudisten aus der oberen kreide von Agios christophoros, östlich Ptolemais (Mazedonien, Griechenland): Annalen des Naturhistorichen Museums in Wien, Mineralogie und Petrographie, Geologie und Paläontologie, v. 87, A, p. 121-134.

Le Metour, J.; Bechennec, F.; Chevremont, P.; Roger, J.; and Wyns, R., 1992, Geological map of Oman at 1/250,000, Buraymi, sheet NG 40-14 and explanatory notes: Muscat, Oman, MPM Ed.

Milovanovic, B.,1937, Les nouveaux rudistes de la Serbie: Belgrade, Bulletin Acad. Sc. Math. et Naturelles, Bull. Sc. nat., v. 3 , 42 p.

Nolan, S.C.; Skelton, P.W.; Clissold, B.P.; and Sweming, J.D., 1990, Maastrichtian to early Tertiary stratigraphy and palaeogeography of the central and northern Oman mountains, *in* Robertson, A.H.F. *et al.*, eds., The Geology and tectonics of the Oman region: Geological Society of America, Special Publication 49, p. 425-520.

Philip, J.M., and Platel, J.P., 1987, Sur la présence du genre *Torreites* (Rudiste de la province Caraïbe) dans le Campanien du Dhofar (Sud de l'Oman)—Conséquences sur l'évolution paléobiogéographique du Pacifique et de l'Océan Indien au Crétacé: Comptes Rendus de l'Académie des Sciences (Paris), ser. 2, v. 304, no. 12, p. 679-684.

———1994, *Praetorreites*, un nouveau genre de rudiste du Campanien d'Oman—Conséquences sur la classification et l'évolution des Hippuritidae et des Caprinidae: Géobios, v. 27, no. 3, p. 303-319.

Platel, J.P.; Bechennec, F.; Berthiaux, A.; Dubreuilh, J.; Roger J.; Le Metour, J.; and Wyns, R., 1992, Geological map of Oman at 1/250,000, Duqm and Madraca, sheet NE 40-03/07 with explanatory notes: Muscat, Oman, MPM Ed.

Platel, J.P.; Philip, J.M.; Bourdillon-de-Grissac, Chantal; Babinot, J.F.; Roger, Jack; and Mercadier, Christopher, 1994, Modalités de la transgression campanienne sur le massif du Haushi-Huqf (Oman): Bulletin de la Société Géologique de France, v. 165, part 2, p. 147-162.

Roger, Jack; Platel, J.P.; Cavelier, Claude; and Bourdillon-de Grissac, Chantal, 1989, Données nouvelles sur la stratigraphie et l'histoire géologique du Dhofar (Sultanat d'Oman): Bulletin de la Société Géologique de France, sér. 8, v. 2, part 5, p. 265-277.

———1992, Geology of Dhofar (Sultanate of Oman)—Geology and geodynamic evolution during the Mesozoic and Cenozoic: Muscat, Ministry of Petroleum and Minerals of Oman, MPM Geological Documents, v. 1, 120 p.

Skelton, P.W., and Wright, V.P., 1987, A caribbean rudist bivalve in Oman—Island-hopping across the Pacific in the Late Cretaceous: Palaeontology, v. 30, no. 3, p. 505-529.

Skelton, P.W.; Nolan, S.C.; and Scott, R.W., 1990, The Maastrichtian transgression onto the northwestern flank of the Proto-Oman Mountains—Sequences of rudist-bearing beach to open shelf facies, *in* Robertson, A.H.F., *et al.*, eds., The Geology and tectonics of the Oman region: Geological Society of America, Special Publication, v. 49, p. 521-547.

Sladic-Trifunovic, M., 1983, Paleontological characteristics and biostratigrahic significance of *Pseudopolyconites*: Ann. Geol. Péninsule Balkanique, v. 47, p. 207-304.

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