

2.4. Palaeogeographic distribution of Cretaceous Tethyan non-rudist bivalves

By Annie V. DHONDT*)

Abstract

In the non-rudist bivalve faunas of Valanginian-Hauterivian age two distinct realms can be distinguished: Boreal and warm-Temperate Tethyan. From the Barremian stage onwards with the spreading of the carbonate platform Tethyan faunas become more marked, with a rudist and a non-rudist facies. In the Albian a strong northern influence is visible in the northern Tethys. The successive Cenomanian transgressions result in a diversification of faunas; in the Tethys this is best seen in the oyster-facies. The Turonian-Santonian interval was relatively brief, and the faunas appear as being more or less homogeneous during that period, but with a differentiation between northern and southern sides of the Tethys. Campanian Tethys faunas are varied, but only occur on the southern side of the Tethys, and are mainly seen in the oyster-facies. In the Upper Campanian-Maastrichtian specific widespread Tethys faunas no longer exist: the Atlantic influence is more important than the Tethys influence.

Résumé

Parmi les faunes de bivalves d'âge Valanginien-Hauterivien on distingue deux unités paléobiogéographiques: le domaine boréal et le domaine tempéré (chaud) / téthysien. A partir du Barrémien la plateforme carbonatée s'étend et les faunes téthysiennes diffèrent d'après qu'elles sont oui ou non associées au faciès à rudistes. Pendant l'Albien une forte influence nordique est présente dans les faunes de la bordure nord de la Téthys. Les transgressions cénomaniennes successives sont à l'origine d'une diversification des faunes. Dans le

*) Department of Palaeontology, Koninklijk Belgisch Instituut voor Natuurwetenschappen, Vautierstraat 29, B-1040 Brussels, Belgium.

domaine de la Téthys ceci se remarque surtout dans les faciès à ostracées. L'intervalle Turonien-Santonien, relativement court, est caractérisé par des faunes assez homogènes, mais différentes sur les bordures nord et sud de la Téthys. Au Campanien de vraies faunes de bivalves téthysiens ne se retrouvent qu'en Afrique et en Asie (Proche Orient, et son extension vers l'Asie Centrale), et encore une fois surtout en faciès à ostracées. Au Campanien supérieur-Maastrichtien les faunes à large répartition téthysienne ont disparu: l'influence atlantique est devenue plus importante que celle de la Téthys.

Introduction

The ocean pattern changed drastically during the Cretaceous. At the beginning of the era the North Atlantic was barely open, the South Atlantic non existing and the major waterway between America and Eurasia a very wide Tethys. By the end of the Cretaceous most landmasses of the Northern Hemisphere occupied positions comparable to those of to-day, the North Atlantic was wide, the South Atlantic well established, and the Tethys much reduced and subdivided into smaller entities.

These changes in the oceans, and especially the transgressions which accompanied them and resulted in wide epicontinental seas, strongly influenced the paleobiogeographic distribution of the Cretaceous shallow marine faunas. This has been demonstrated beautifully by SOHL (1987) for the Cretaceous gastropods.

Aspects of the paleobiogeographic distributions of Bivalvia during the Cretaceous have been discussed by KAUFFMAN in HALLAM (1973); KAUFFMAN has taken the global distribution of all Bivalvia into consideration but has subdivided the Cretaceous stratigraphically only in Lower and Upper Cretaceous.

The most characteristic and best known representatives of Cretaceous bivalves are rudists and inoceramids, two groups which no longer occurred above the K/T boundary. Inoceramids were adapted to deeper seas: both cold water and warm water species have been recognised (KAUFFMAN, 1975).

Rudists are considered as indicating warm seas and they were present in large numbers in the Tethys. They lived in shallow environments. As discussed by SOHL (1987) the Cretaceous distribution of algal-coral, coral-rudist or rudist dominated organic framework buildings (SOHL, *ibid.*, p. 1087, Fig. 1) shows the "... maximum extent of the Tethyan Realm during the Cretaceous" (SOHL, *ibid.*, p. 1086).

As discussed during the meetings of the IGCP 262 the distribution of rudists could be used (and has been used by some authors) to delimit the distribution of Tethys in the Cretaceous. Yet, this distribution varies widely during the Cretaceous, reaching *f. i.* in the Late Maastrichtian, Maastricht (Limburg, The Netherlands). The term Tethys has been interpreted in many different ways and I would like to refer for details on this problem to NAIDIN (1986).

In the present paper distribution patterns and changes in geographic distribution of non-rudist bivalves throughout the Cretaceous shall be discussed.

Material and Methods

Bivalves were very numerous in the shallow Cretaceous seas. According to MOORE (1969) 80 families of marine bivalves occurred in the Cretaceous: of these 21 (8 of which are rudists), have not been found in strata younger than Cretaceous, 1 died out in the Miocene, and 58 still occur to-day. Thus the composition of the Cretaceous faunas was similar but not identical with those of to-day.

For paleogeographic purposes, the best data are given by those groups which (a) were widely distributed, (b) are easily recognizable and/or generally well-preserved. Among Cretaceous bivalves, these criteria are found in most groups with a calcitic shell (Isognomidae, Oxytomidae, Plicatulidae, Pectinidae, Spondylidae, Limidae, Ostreacea . . .) but also in groups with a thin shell and/or strong ornamentation (Inoceramidae, Lucinidae, Mactromyidae, Thyasiridae, Pholadomyidae, . . .). It excludes most of the trioniids and many heterodonts.

Data have been assembled over many years concerning the distribution of bivalve species, based on type collections and general collections in many museums in Europe and North America. Emphasis has been on Pectinacea, Limacea and Ostreacea but other groups were also studied (list of collections as addendum).

Palaeobiogeographic Distributions of the species

At the beginning of the Cretaceous and up into the Hauterivian the faunal distribution resulted from a more or less stable ocean situation, similar to that known from the Upper Jurassic. Two distinct faunal biogeographic entities can be distinguished: a "Boreal realm" (CASEY & RAWSON, 1973) with bivalve faunas very similar to those from the Oxfordian-Volgian in the same regions, and a "warm temperate-Tethyan province" (KAUFFMAN in HALLAM, 1973) with old and new faunal elements. As an example of these different distributions I have chosen the typically Cretaceous pectinid genus *Neitheia*, with the species *N. atava* (ROEMER) and *N. valangiensis* (PICTET & CAMPICHE) typical for the Valanginian-Hauterivian of the Tethys (s. l.), and the pectinid *Mclearnia* with the species *Mc. cinctus* (SOWERBY) and related species typical for the Boreal realm (Text-Figure 1) (KELLY, DHONDT & ZAKHAROV, 1984). Similar distinctive distributions could be shown using oysters [*Aetostreon* and *Rastellum* (DHONDT & DIENI, 1988) versus *Deltoideum*, or with the presence/absence of *Buchia* (ZAKHAROV, 1981)].

The Valanginian-Hauterivian interval in the Tethys is characterized by a very rich and diversified bivalve fauna which occurs over wide areas. This distribution of faunas was already recognised f. i. by LANGE (1914), and a

similar distribution is accepted as a matter of course by ammonite workers today (KAKABADZE, 1981, 1983; KOTETISHVILI, 1970, 1983; THIEULOY, 1973, 1977; WIEDMANN, 1973). DHONDT & DIENI (1988, 1989) have discussed aspects of the bivalve distributions and shown that most species which are well-defined have a distribution ranging from South-America to Central Asia, and occasionally to Japan [Examples of such widely distributed taxa: *Grammatodon (Nanonavis) securis* (LEYMERIE), *Cucullaea (Noramya) gabrielis* LEYMERIE, *Pinna (Pinna) robinaldina* D'ORBIGNY, *Gervillaria alaeformis* (SOWERBY), *Gervillaria sowerbyana* (MATHERON), *Isognomon (Isognomon) ricordeanus* (D'ORBIGNY), *Mimachlamys robinaldina* (D'ORBIGNY), *Neithea (Neithea) atava* (ROEMER), *Aetostreon latissimum* (LAMARCK), *Ceratostreon boussingaulti* (D'ORBIGNY), *Trigonia carinata* (AGASSIZ), *Quadratrigonia nodosa* (SOWERBY), *Sphaera corrugata* (SOWERBY), *Ptychomya plana* AGASSIZ, *Panopea gurgitis* (BRONGNIART in CUVIER), *Pholadomya gigantea* (SOWERBY)]. These authors have shown that on the northern margin of the Tethys almost identical faunas can be found between the Paris Basin and the Caucasus, in strata of Valanginian-Hauterivian age, with about 80% of the species in common (Text-Figure 2).

From the Barremian onwards the spreading of the carbonate platforms and the presence of rudist build-ups is characteristic of the Tethys fauna. Among the non-rudist bivalves a differentiation can be made between those which lived in and around the rudist frameworks and those which lived in environments where rudists were rare. Rudist-associated bivalves in the Barremian-Aptian are f. i. the pectinid *Neithea deshayana* (MATHERON), the bakevelliid species *Turkmenia balkhanensis* KRIMHOLZ (Text-Figure 3).

The faunas which are not associated with rudists are very diverse (PELLAT & COSSMANN, 1907, COSSMANN, 1916) and contain new elements such as *Neithea (Neithea) syriaca* (CONRAD), *Pycnodonte* sp., *Gryphaeostrea* sp., etc.

Up to the Aptian the distribution of the Tethys fauna extends from the Caribbean to Japan via southern Europe and the Middle East (Text-Figure 4) [a few examples of such widely distributed taxa: *Grammatodon (Nanonavis) securis* (LEYMERIE), *Pinna (Pinna) robinaldina* D'ORBIGNY, *Gervillaria alaeformis* (SOWERBY), *Isognomon (Isognomon) ricordeanus* (D'ORBIGNY), *Neithea (Neithea) atava* (ROEMER), *N. (N.) syriaca* (CONRAD) etc. Occasionally extensions of the distribution of these species reach temperate regions, such as the Isle of Wight (UK).

The middle Cretaceous is stratigraphically well known, but because the type-localities of the stages are outside the Tethys some of the Tethyan faunas are not as well dated as most of the temperate faunas. Albian and Cenomanian were long stages, and transgressions and regressions, or at least changes in the sea level, occurred several times during that period, but the overall result was a progressive inundation of the land from the earliest Albian to the latest Cenomanian (HANCOCK & KAUFFMAN, 1979).

During the Albian the Northern Atlantic Ocean had become wider, and the sea level began to rise (HANCOCK & KAUFFMAN, 1979). In European Tethys faunas northern elements such as *Aucellina* are found (MORTER & WOOD,

1983) (Text-Figure 5). In Texas, Oklahoma and Mexico specific faunas are recognised which contain numerous pectinids [*Neithea* species and oysters (BÖSE, 1911; KNIKER, 1918; STANTON, 1947; SCOTT, 1970)]. An unusual pattern in which endemic faunas alternate with more widely spread faunas, can be seen (YOUNG, 1972) in the Texas basin.

A relatively widely distributed Tethyan fauna of Vraconian age has been recognised, but it also reached temperate parts of the Paris Basin, especially in localities with greensand facies of Albian and Cenomanian age [examples of species *Pseudoptera anomala* (SOWERBY), *Acesta subovalis* (SOWERBY), *Limaria ? elongata* (SOWERBY) (and closely allied species) . . .] (Text-Figure 5).

In the Albian and Cenomanian as in the Barremian a few species are associated with rudist frameworks – *Neithea roemeri* (HILL) from the Upper Albian and lowermost Cenomanian of Texas, *Neithea fleuriausiana* (D'ORBIGNY) from the Albian-Cenomanian of France, Spain, Portugal (possibly both species are identical!), *Chondrodonta* spp. in Texas and Southern Europe (Text-Figure 5 & 6).

The Cenomanian stage in its type-locality and in the area around Le Mans is stratigraphically very well known; the many transgressions of the stage are precisely documented. Le Mans lies outside the Tethys, but some of the typical bivalves from the Upper Cenomanian faunas are found over wide areas, partly in the temperate regions and partly on the northern margins of the Tethys. Faunas seem to be different on both sides of the Tethys (s. l.) among oysters, pectinids and plicatulids f. i. the Upper Cenomanian is characterized by *Pycnodonte biauriculatum* (LAMARCK), *Ceratostreon flabellatum* (GOLDFUSS), *Rhynchostreon suborbiculatum* (LAMARCK), *Neithea aequicostata* (LAMARCK), *N. alpina* (D'ORBIGNY) [= *N. texana* (ROEMER)] on the northern side of the Tethys and in warm Temperate areas; *Costagyra olisiponensis* (SHARPE), *Ilymatogyra africana* (LAMARCK), *Gyrostrea delectrei* (COQUAND), *Actinostreon syphax* (COQUAND), '*Curvostrea*' *rouvillei* (COQUAND) (and related species), *Neithea hispanica* (D'ORBIGNY), *N. dutrugei* (COQUAND), *N. coquandi* (PÉRON), *Plicatula auressensis* COQUAND, on the southern side of the Tethys (BOBKOVA, 1961) (Text-Figure 6). It must be stressed that in Portugal and in Spain both southern and northern side Tethys species occur, and this is also true to a lesser degree for localities around Marseille: it might well be that the Tethys in the Late Cenomanian was relatively easily crossed by bivalve larvae between the Iberian Peninsula and Northwest Africa. Some of the same species occurring in Texas (and occasionally reaching into the Western Interior) have sometimes a slightly different stratigraphic age.

KOLLMANN (1978) gave explanations for the varying gastropod distributions during the Cenomanian of western Europe, stressing the Tethys influences in the Upper Cenomanian.

A differentiation between northern and southern sides of the Tethys is also documented in ostracods of the same age (BABINOT, 1988).

The Cenomanian-Turonian transition is the time of strong regressions (HANCOCK & KAUFFMAN, 1979) and, probably related to this, of faunal

changes (DHONDT, 1981). Yet, in the Tethys deposits these changes are not so obvious as in the Temperate provinces, possibly:

a. because the stratigraphic boundary between the Cenomanian-Turonian stages was chosen in the Temperate Realm and the Tethyan equivalency was not easily found (result: the stratigraphic data indicated in collections for Tethyan bivalves are not always very precise);

b. the faunal break which is found between the Cenomanian and Turonian faunas in the Temperate province is probably not strongly present in the Tethys [f. i. many species continue into the Turonian and beyond in the Tethys (DHONDT, 1981), but this is relatively rare in the Temperate region].

As far as I know, specific Turonian Tethys non-rudist bivalves have not clearly been documented. Some of the uppermost Cenomanian Tethyan bivalves reach the Coniacian and are mainly Turonian – an interesting example is *Costagryra olisiponensis* (SHARPE) with a very wide Tethyan distribution (REESIDE, 1929; MORONI & RICCO, 1968; LEFRANC, 1983) (Text-Figure 7). More species might have similar distributions but few are as well documented.

From the same period a rudist-associated fauna is known containing *Neitheia zitteli* (PIRONA), and *Chondrodonta joannae* (CHOFFAT) (Text-Figure 7).

In the Coniacian and Santonian the shallow oyster facies of North Africa continues to be well developed; a few examples of species occurring in it: *Pycnodonte flicki* PERVINQUIÈRE, *P. (Costeina) costei* (COQUAND), ? *Acutostrea acutirostris* (sensu COQUAND, non NILSSON), *Rastellum dichotomum* (BAYLE), *Plicatula flattersi* COQUAND, *Pl. ferryi* COQUAND, *Veniella* spp. etc.

In north eastern Spain and in southern France similar species are found, but in the western and northwestern European white chalk facies – a totally different environment – another fauna existed (Text-Figure 8). The northern margin Tethys is not completely documented, but several consecutive faunas of Coniacian and Santonian age are known from the 'Gosau' deposits in Austria (SUMMESBERGER, 1985): they contain Tethys elements (mainly species known from SE France) combined with shallow more northern Temperate elements (DHONDT, 1987).

During the Campanian the wide transgressions over Europe and Africa reached a maximum extension (HANCOCK & KAUFFMAN, 1979). This influenced the faunas in as far that several somewhat deeper water faunas were present, which can clearly be seen in the faunas from near Bordeaux [northern Tethys margin- southern Temperate province (DHONDT, 1985)].

In the Tethys, oyster facies were present in North Africa and the Middle East. On an extensive material, with good stratigraphic control, from the Wadi Quena region (Egypt), MALCHUS (1990) has demonstrated that these faunas were changing quite rapidly, and that most species were short-lived. A different distribution in Upper Campanian and Maastrichtian Tethys strata is shown by *Merklimia perornata* (COTTREAU): Cuba to Oman and Madagascar (Text-Figure 9). Similar distributions are found for certain inoceramids, even if they reached somewhat further (*Trochoceramus* spp., Text-Figure 9) (DHONDT, 1983; ETAYO-SERNA, 1985).

Among the fossils from the Upper Campanian strata on the northern side of the Tethys, specific Tethyan elements are difficult to recognize: these faunas seem to contain more elements of the warm Temperate faunas. The extension of the warm Temperate faunas went even further in the Maastrichtian and the spreading of faunas from the north of Europe towards the Near East is shown f. i. in the distribution of the pectinid *Microchlamys acuteplicata* (ALTH) (Text-Figure 9).

Thus, towards the K/T boundary the palaeogeographic distribution of the bivalves in the Tethys has lost its homogeneous aspect. With the opening of the Atlantic Ocean, the Tethys and its faunas have lost their continuity. This is clearly visible in the Upper Maastrichtian, and the terminal Cretaceous regressions resulted in accentuating this fact in the Paleocene.

Discussion

The distributions indicated for the Tethys bivalve faunas are – because of the nature of the material used – only approximative at the stratigraphic level. To improve on this it would be necessary to have new collections of all the consecutive faunas, and then study all systematic groups from these collections together (including stratigraphically relevant groups such as ammonites, inoceramids and Foraminifera). In recent years in the Tethys such work has been done for the Upper Cretaceous in Eastern Egypt (Wadi Quena) by a group from German universities organized by BANDEL, in NE Spain by the group working in Barcelona organized by PONS, in the Gosau in Austria by a group in Vienna organized by KOLLMANN and SUMMESBERGER; for the Lower Cretaceous such work is under way for deposits near the carbonate platform in SE France organized by A. and H. ARNAUD from Grenoble in France, and has been done for the E. Sardinian outcrops by DIENI from Padova, to name but a few. When all the data of these and other projects in similar direction shall be assembled, the precise reconstruction of the faunas at each exact moment shall be possible, for the complete Tethys. The stratigraphic control of the Cretaceous has improved so much in the last 20 years that a very good resolution (reaching often the level of an ammonite zone) could be reached for these paleobiogeographic reconstructions.

At present the data on Tethyan non-rudist bivalves suffer from occasional stratigraphic inaccuracies at the Barremian/Aptian, Cenomanian/Turonian, Campanian/Maastrichtian, Maastrichtian/Danian boundaries (as result of interpretations often dating back to the beginning of this century), and from the problem of the correlation/position of the Turonian. Thus, except for the Cenomanian, it is difficult to reach beyond the stage level.

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Addendum

List of collections studied:

- Austin: Palaeontological Collections of the Texas Memorial Museum, The University of Texas at Austin.
- Basel: Naturhistorisches Museum Basel.
- Berlin: Naturkunde Museum, Humboldt Universität.
- Bonn: Paläontologisches Institut der Universität.

Brussels: Koninklijk Belgisch Instituut voor Natuurwetenschappen.
Budapest: Magyar Allami Földtani Intézet
Cambridge: Sedgwick Museum, University of Cambridge.
Denver: Paleontology and Stratigraphy Branch, US Geological Survey Coll.
Fukuoka: Kyushu University, Geology Dept.
Geneva: Muséum d'Histoire naturelle.
Hannover: Niedersächsische Landesanstalt.
Lausanne: Musée géologique.
Leningrad: Leningrad State University, Geology.
 All Union Geological Survey (VSEGEI).
Lisbon: Portuguese Geological Survey Coll.
London: British Museum (Natural History).
Marseille: Musée d'Histoire naturelle.
Moscow: Moscow State University, Geological Museum.
 Palaeontological Institute of the USSR Academy of Sciences (PIN).
Paris: Muséum national d'Histoire naturelle. Institut de Paléontologie.
Sendai: Tohoku University, Dept. Geology and Paleontology.
Sofia: University Kliment Ohridski, Geology.
Tbilisi: Tbilisi State University.
Tokyo: The University of Tokyo, University Museum.
Vienna: Naturhistorisches Museum Wien.
Washington DC: Paleobiology, US National Museum of Natural History, Smithsonian Institution.

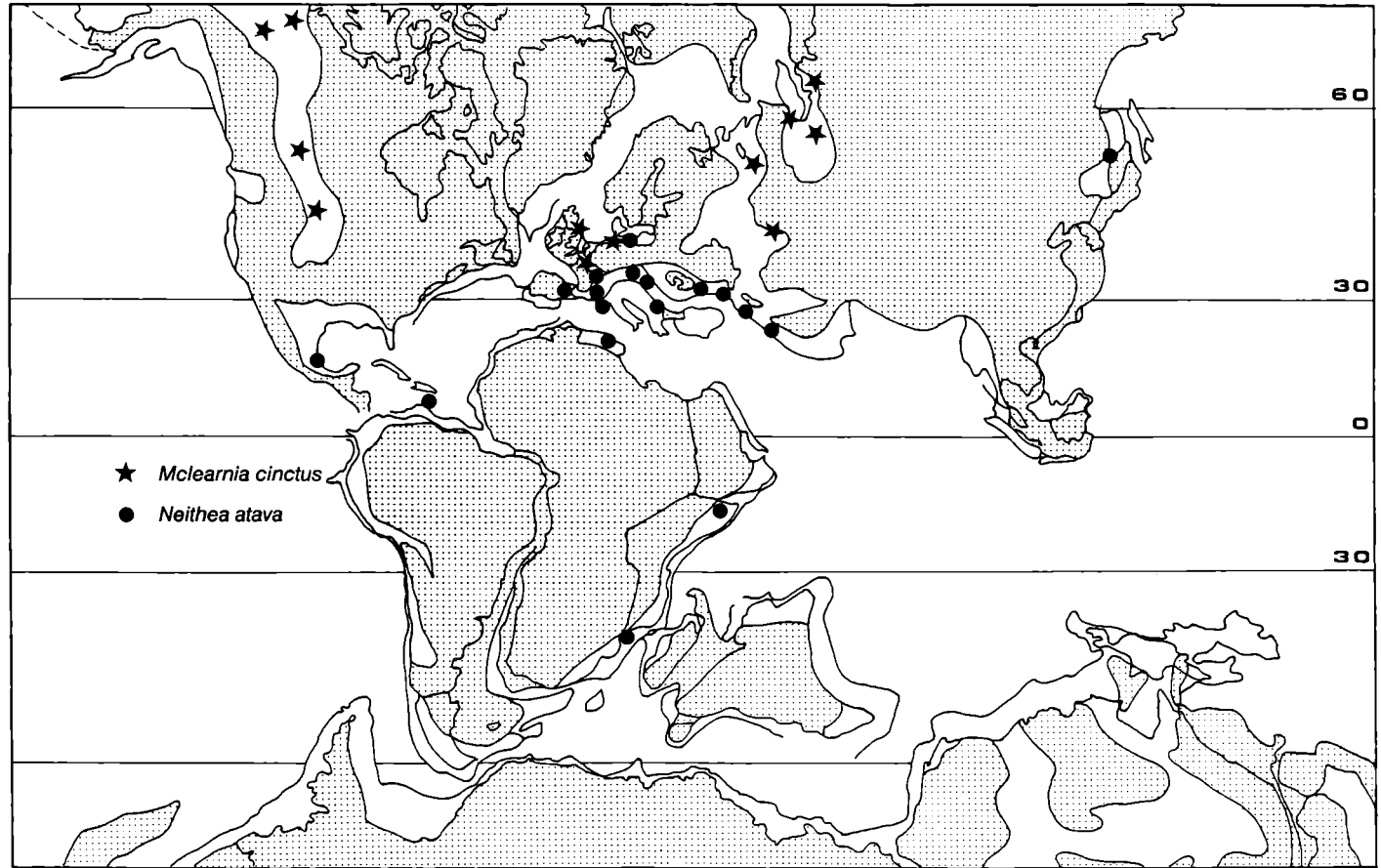


Fig. 1: Map at 120 million years (from BARRON et al., 1981) showing the distribution of *Neithea atava* (ROEMER) and *Mclearnia cinctus* (SOWERBY) in Valanginian-Hauterivian times. *N. atava* occurs in warm Temperate and in Tethys provinces, whereas *Mc. cinctus* is typical for Boreal (i. e. cold Temperate) provinces.

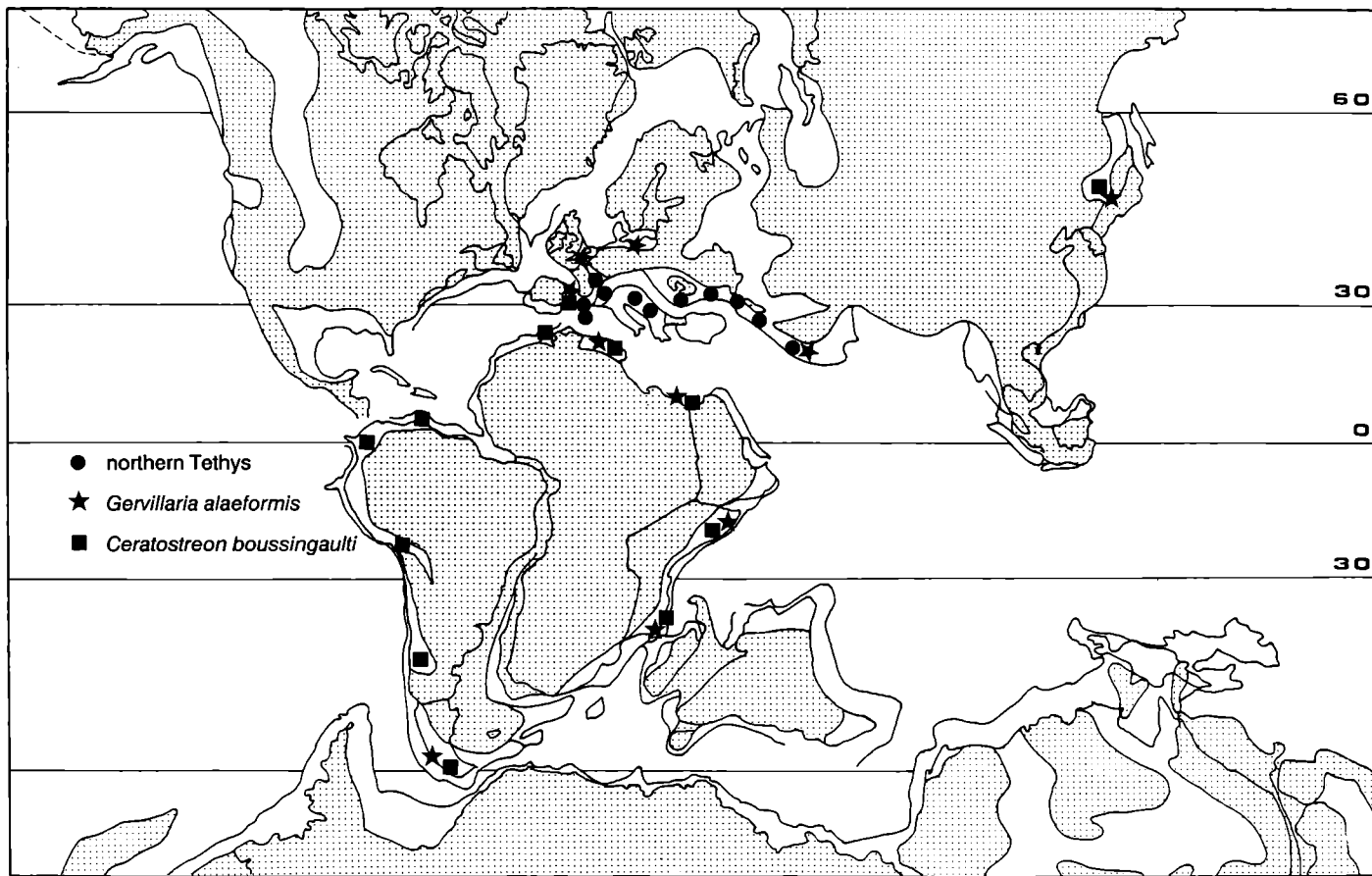


Fig. 2: Map at 120 million years (from BARRON et al., 1981) showing the distribution of *Gervillaria alaeformis* (SOWERBY) and *Ceratostreon boussingaulti* (D'ORBIGNY), and indicating the Valanginian-Hauterivian localities on the northern Tethys side which have very similar faunas (at least 80% of the bivalve species in common).

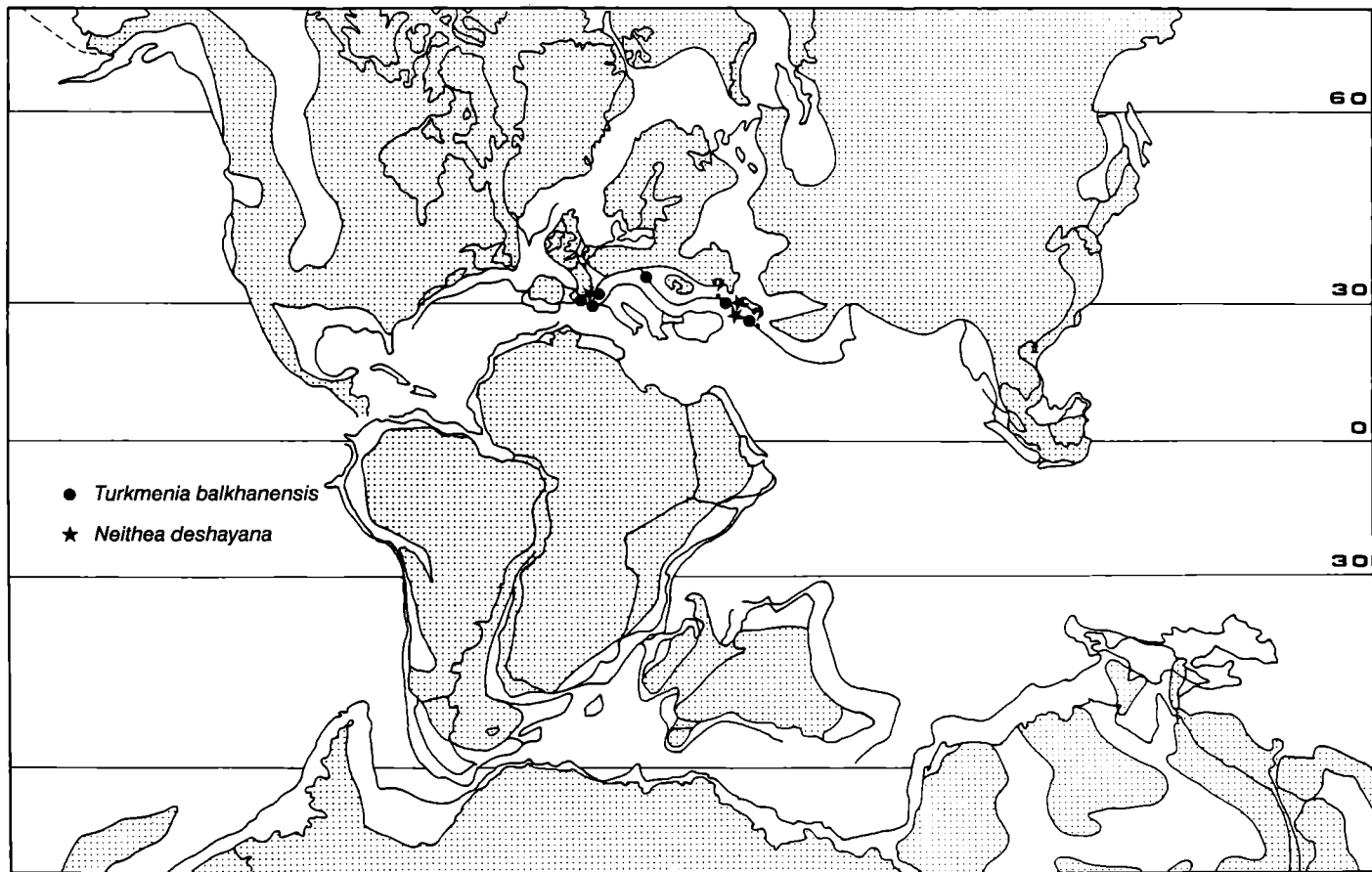


Fig. 3: Map at 120 million years (from BARRON et al., 1981) showing the distribution of *Neithea deshayana* (MATHERON) and *Turkmenia balkhanensis* KRIMHOLZ, species associated with rudist frameworks in Barremian times.

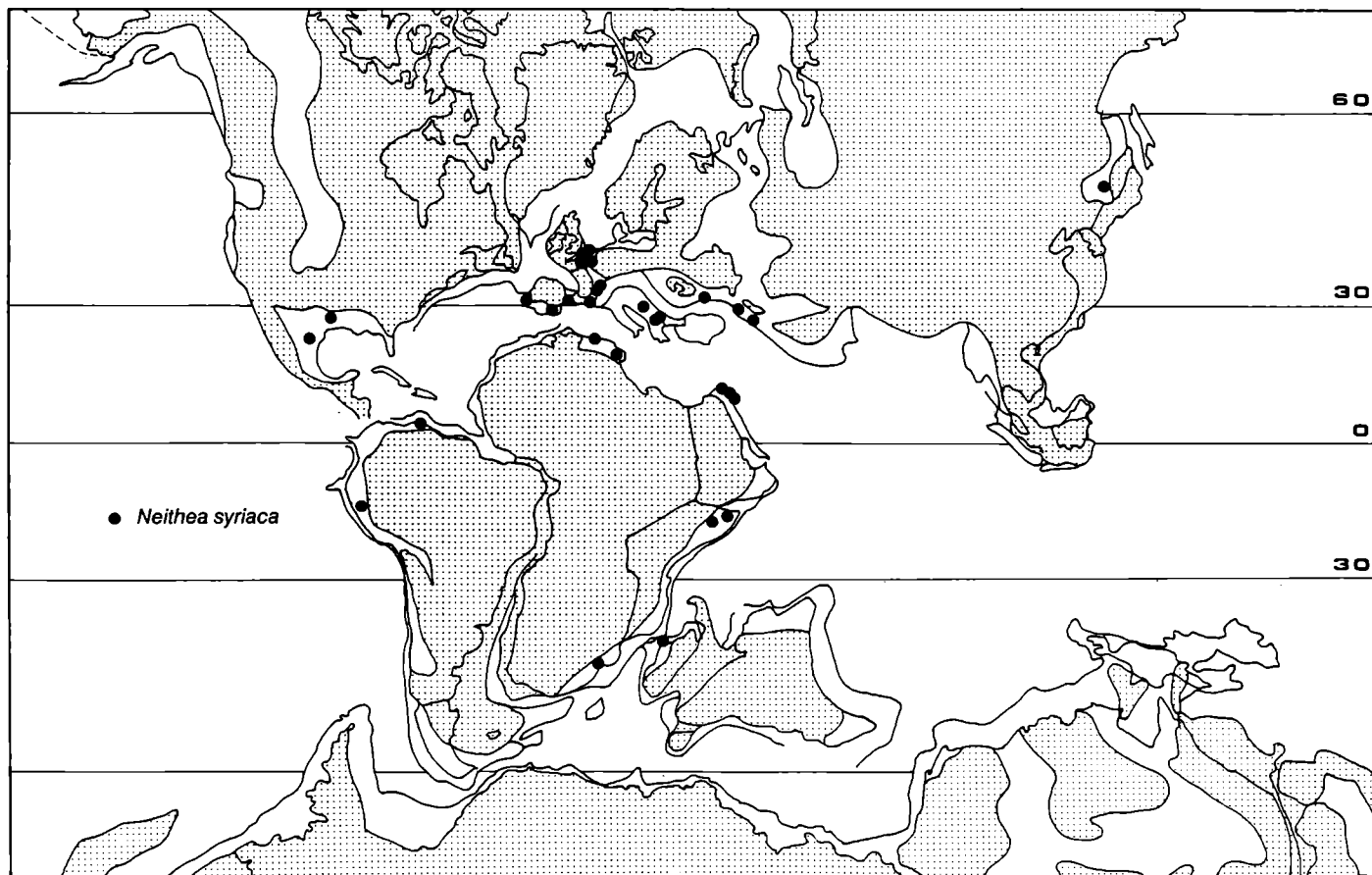


Fig. 4: Map at 120 million years (from BARRON et al., 1981) showing the distribution of *Neithea syriaca* (CONRAD) in the Aptian: from the West-coast of South-America to Japan, reaching the Isle of Wight in England to the North and Zululand in South Africa to the South.

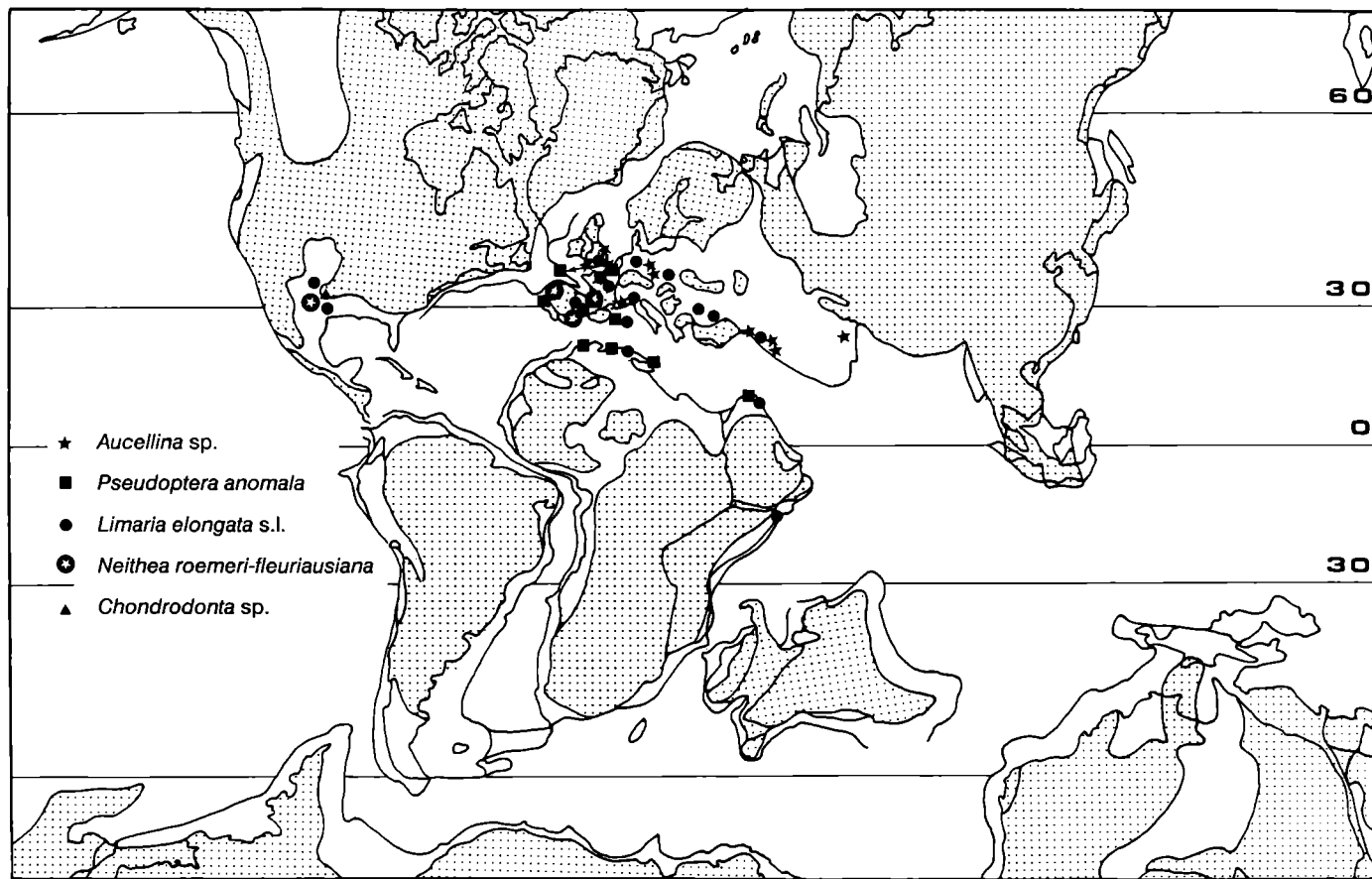


Fig. 5: Map at 100 million years (from BARRON et al., 1981) showing the distribution of the cold water genus *Aucellina* in the Tethys (Upper Albian), of the bakevelliid *Pseudoptera anomala* (SOWERBY), the limid plexus *Limaria elongata* (SOWERBY) s. l. in the Upper Albian - Lower Cenomanian, of the rudist-framework associated species *Neithea roemeri - fleuriausiana*, and *Chondrodonta* spp. in the Upper Albian - Cenomanian.

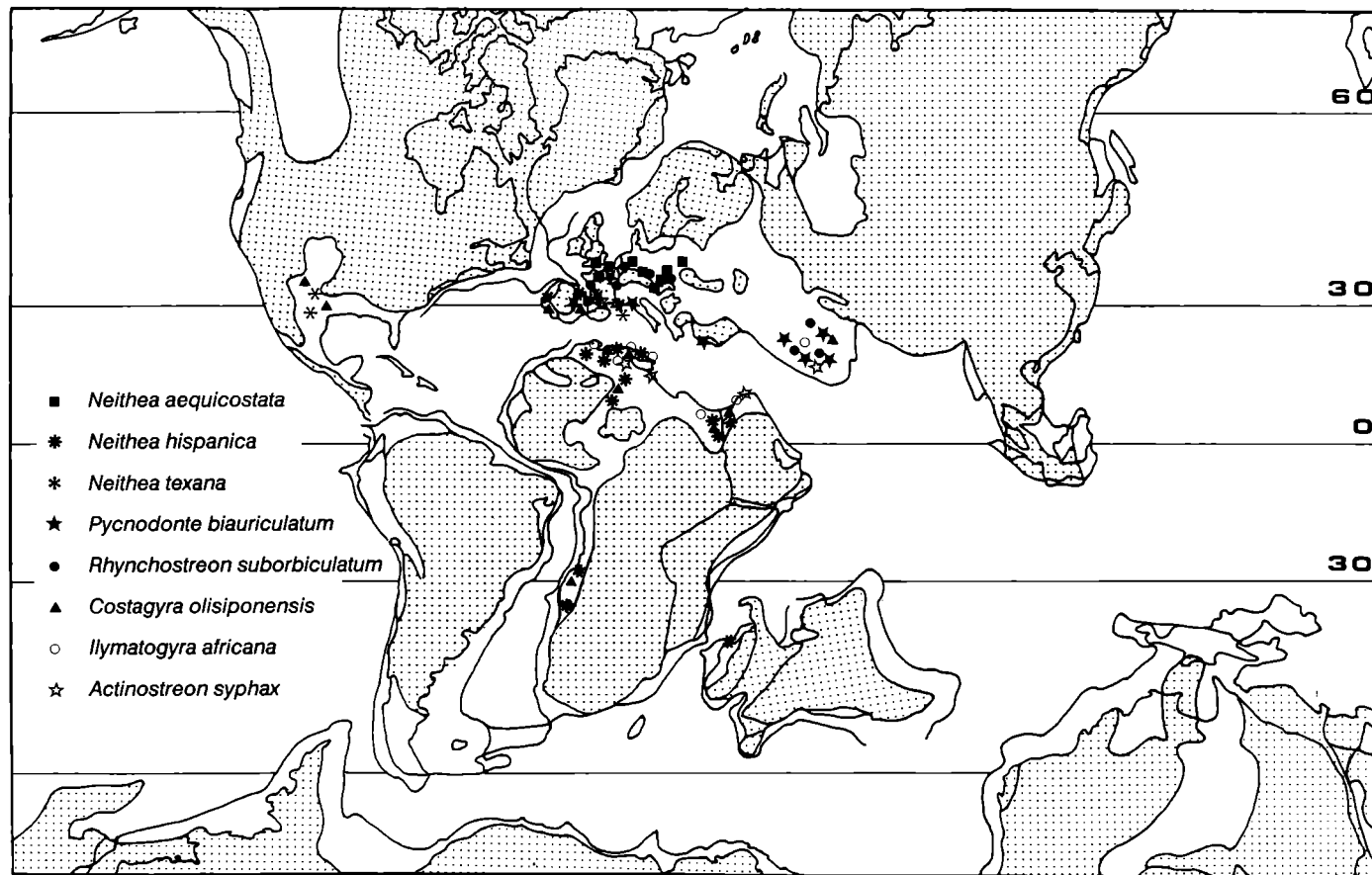


Fig. 6: Map at 100 million years (from BARRON et al., 1981) showing the distribution during the Upper Cenomanian of the Temperate species *Neithea aequicostata* (LAMARCK), Temperate and northern margin Tethys species *Pycnodonte biauriculatum* (LAMARCK), *Rhynchostreon suborbiculatum* (LAMARCK), and of Tethyan species *Neithea hispanica* (D'ORBIGNY), *N. texana* (ROEMER), *Costagyra olisiponensis* (SHARPE), *Ilymatogyra africana* (LAMARCK), *Actinostreon syphax* (COQUAND).

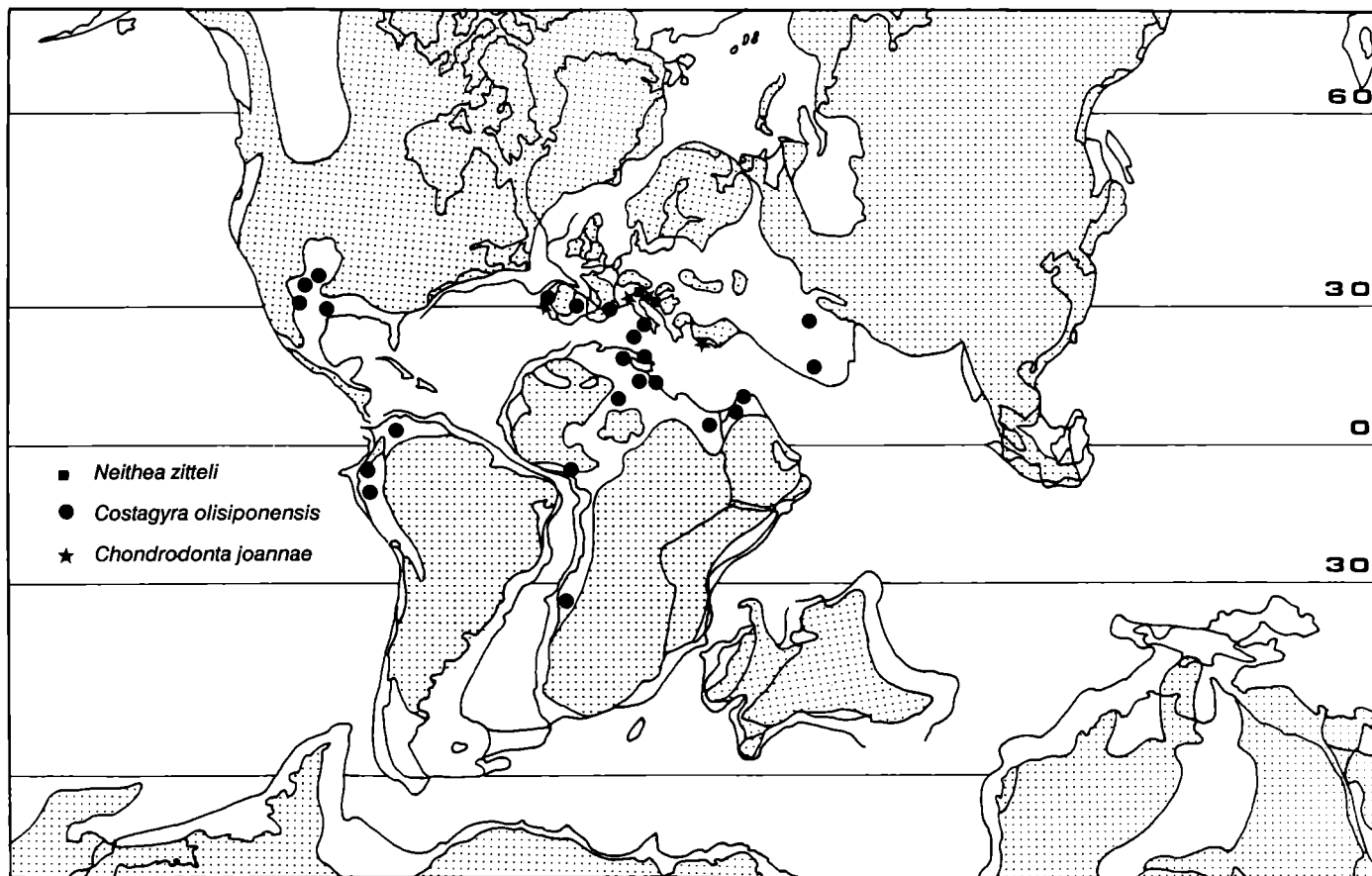


Fig. 7: Map at 100 million years (from BARRON et al., 1981) showing the distribution during the Upper Cenomanian and Turonian of the oyster *Costagyra olisiponensis* (SHARPE) (data partly out of REESIDE, 1929), and of the rudist-associated framework species *Neithea zitteli* (PIRONA) and *Chondrodonta joannae* (CHOFFAT).

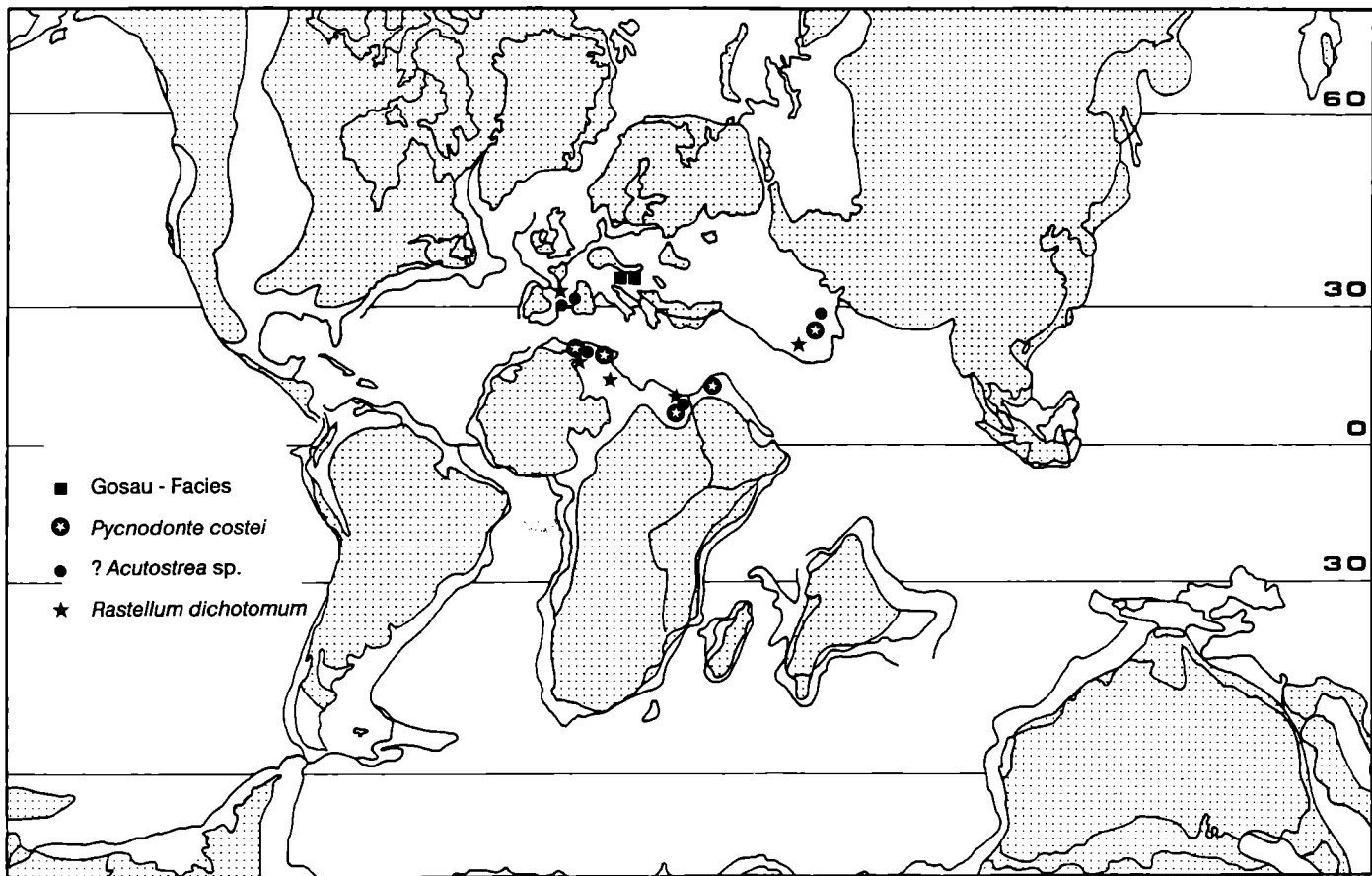


Fig. 8: Map at 80 million years (from BARRON et al., 1981) showing the distribution during the Coniacian-Santonian of oyster taxa typical for the north African oyster association: *Pycnodonte (Costeina) costei* (COQUAND), *Acutostrea acutirostris* (sensu COQUAND non NILSSON), *Rastellum dichotomum* (BAYLE); also indicated is the northern Tethyan Gosau region.

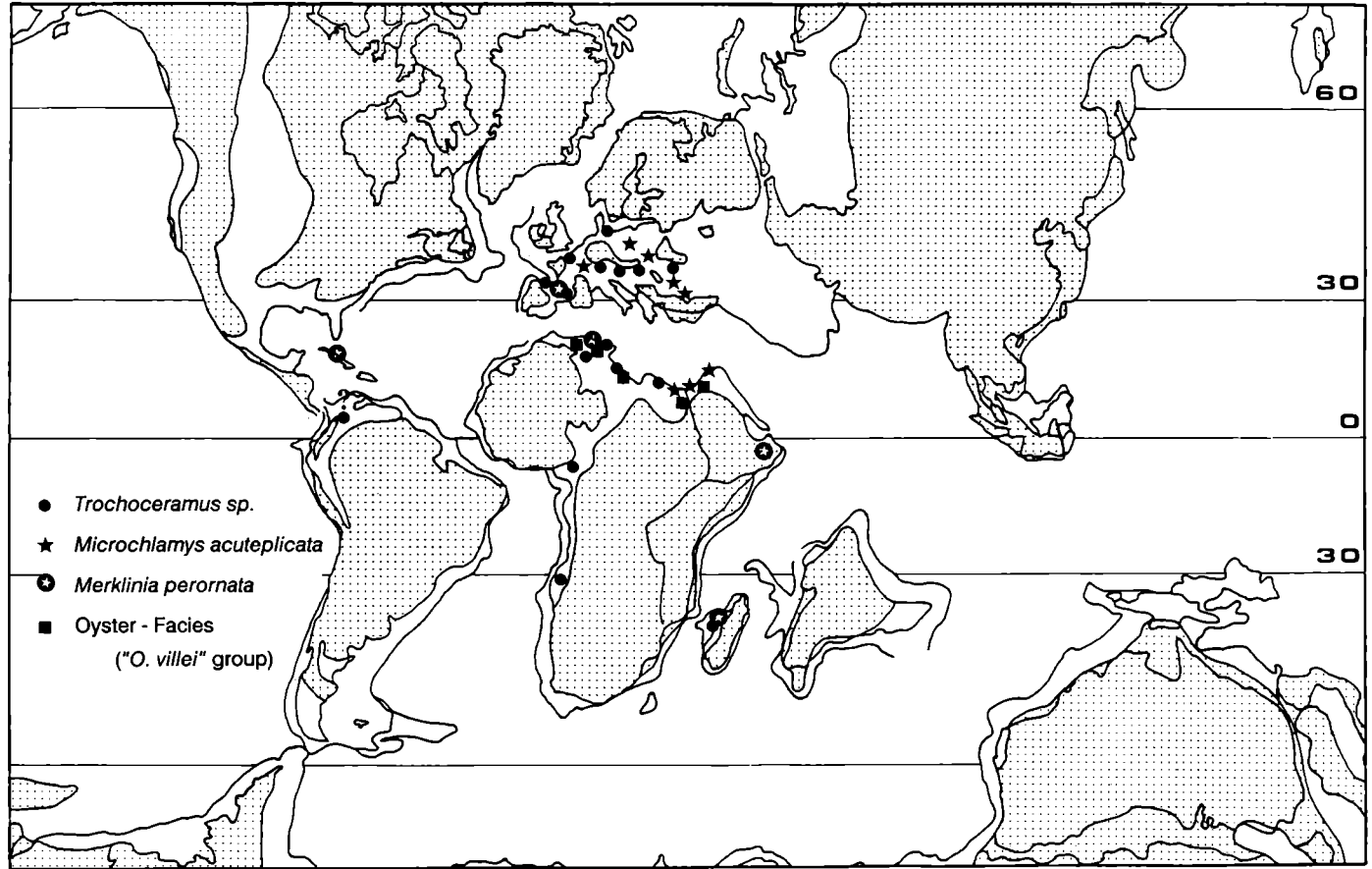


Fig. 9: Map at 80 million years (from BARRON et al., 1981) showing the distribution during the Upper Campanian-Maastrichtian of oyster taxa typical for the northern Africa oyster association: *Exogyra overwegi* (VON BUCH), *Actinostreon villei* (COQUAND), *Nicaisilopha nicaisi* (COQUAND); also indicated is distribution of the Tethyan pectinid species *Merklinia perornata* (COTTREAU), of the Temperate pectinid *Microchlamys acuteplicata* (ALTH) and of the inoceramid genus *Trochoceramus*.