

THE 'DANIAN' AND THE PROBLEM OF THE CRETACEOUS-TERTIARY BOUNDARY

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After giving a review of the present position regarding the controversial problem of the Cretaceous-Tertiary boundary, the paper focusses attention on the identity of the 'Danian' which forms the crux of this boundary dispute. It is pointed out that there are two aspects of the Danian problem : (i) to evaluate the position of the 'Danian' in any particular regional succession vis-a-vis the Cretaceous on one side, and the Tertiary on the other, and (ii) to define and delimit the Danian in absolute terms and fix its place, as such, in the global "Standard Stratigraphical Scale." It is emphasised that the two aspects, though appear similar in objective, are still quite distinct and must be treated differently.

A reorientation in our approach on this basis may help remove the present deadlock in the problem of the 'Danian' vis-a-vis the Cretaceous-Tertiary boundary.

INTRODUCTION

The problem of the Cretaceous-Tertiary boundary is still highly controversial though it has been receiving attention for more than a hundred years. In his other papers (1956, 1960, 1964 and 1968), the author has reviewed the whole problem in general terms with special reference to India and adjacent countries; and inter alia emphasised the need for revising some of the traditional stratigraphical concepts involved in tackling such boundary problems in general. The present paper aims at giving a re-appraisal of the position in this matter and indicate a new line of approach which may help the possible solution of this problem.

At the very outset, it should be noted that there are two distinct aspects of this question : (i) to evaluate the position of the Danian as between the Cretaceous on one side and the Tertiary on the other, in any particular regional succession in the context of the local stratigraphical and palaeontological setting, and (ii) to 'define' the Danian in absolute terms and fix its position as such in the Cretaceous-Tertiary succession in the "Standard Stratigraphical Scale". These two aspects, though appear similar in objective, are still distinct and must be treated differently. In the present paper, the author proposes to confine his attention mainly to the latter aspect which is more fundamental in reconstructing the past history of the earth in terms of world stratigraphy.

In any marine fossiliferous Upper Cretaceous-Lower Tertiary succession, the transition from one to the other is normally covered by the Maestrichtian-Danian-Paleocene succession. It is necessary that in determining the position of the Danian

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with reference to the Cretaceous-Tertiary boundary in such a column, we must be sure of what exactly we mean, in concrete terms of stratigraphy and palaeontology, by the terms Maestrichtian, Danian and Paleocene, but unfortunately we are not in a position to say that we are sure of this, especially in regard to the Danian vis-a-vis the Maestrichtian below and Paleocene above, which forms the crux of our boundary problem. Different workers have used these stage names with different implications and varying connotations. This is particularly true of the Danian.

REGIONAL STUDIES

In our attempt to standardise the Danian and define it as a stratigraphical unit, it will naturally appear that the best way of doing this is to study in detail the Danian of Denmark (where it was first recognised as an independent stratigraphical unit more than 100 years ago) and use it as the 'type section' for comparison and correlation of the Danian of all other areas. Accordingly, strata of Danian age which have been noticed in several other regions all over the world have been correlated both among themselves from one area to the other, backwards and forwards, and also with the 'type Danian' of Denmark on varying stratigraphical and palaeontological considerations. Any attempt to evolve a concept of the Danian based on such studies in any particular area and plead for its international acceptance in the Standard Stratigraphical Scale will obviously be unsatisfactory.

Before proceeding to establish the equivalence of the 'Danian' in widely separated areas, it is most necessary to postulate and agree upon certain basic guidelines which may be accepted as useful in promoting such "global, inter-continental and inter-regional geological correlations". In this connection, the author would like to refer to the valuable report (Hedberg 1964) of the International Subcommittee on Stratigraphic Terminology, under the chairmanship of Hollis D. Hedberg. In this short but very important document, various views have been expounded which have a particular relevance to the problem we are considering. The arguments and conclusions embodied in the Hedberg report are certainly the most acceptable in formulating the guidelines for the age determination, classification and correlation of beds on a global basis for the kind of comparative and coordinated stratigraphy involved in the construction of a universal Standard Stratigraphical Scale.

THE DANIAN

When Desor (1846) recognised the Danian for the first time in Denmark, he considered it as undoubtedly belonging to the Cretaceous forming its youngest sub-division; and this view continued to be generally accepted in other areas also for quite a long time afterwards. In recent years, however, as against this view a large volume of opinion is growing that the Danian is certainly not a part of the Cretaceous, but belongs to the Tertiary, and that this conclusion is convincingly supported by the detailed biostratigraphical studies based on planktonic foraminifers in several areas.

In regard to the so-called break in the planktonic foraminiferal succession on which we so heavily rely upon for fixing the Cretaceous-Tertiary boundary, several

questions have been raised from the point of view of world stratigraphy. One thing is, however, clear : In all places where such a break in any palaeontological succession is noticeable, we must naturally presume that there is a latent corresponding gap in the sedimentary succession; or in other words, an unconformity of varying time span exists there. We can, of course, take advantage of this 'break' to demarcate the boundary between two adjacent formations in any given area; but this can hold good only in regard to the local setting in the particular area concerned, and the conclusion is not bodily transferable to other regions where the situation must be judged on its own merits after giving regard to the regional palaeogeographical and palaeo-ecological variations.

An important point to which attention may be drawn at this stage is in regard to the meaning of such regional breaks in the construction of a "Standard Stratigraphical Scale" from the point of view of world stratigraphy. An unconformity or break is, no doubt, useful in drawing the boundary between two adjacent beds in any given region; but we must remember that such a 'break' is a clear indication of a corresponding 'gap' in our knowledge of Earth's history as a whole; and our main intention should, therefore, obviously be to be on the look out for areas where this discontinuity is bridged over by a succession of 'passage beds' which will help eliminating the 'time-gap' indicated by the unconformity noticed in any local succession, and thus fill in the corresponding 'gap' in our knowledge of Earth's history.

THE DANIAN CONTROVERSY

In regard to the Danian controversy, the following are the divergent views expressed by different workers on the basis of their regional studies regarding its equivalence :

1. The Danian type formation is of the same age as the Maestrichtian type formation;
2. The Danian is undoubtedly part of the Cretaceous and constitutes its youngest subdivision above the Maestrichtian;
3. The Danian does not belong to the Cretaceous; it is part of the Tertiary, forming its lowest subdivision;
4. The Danian is not part of the Cretaceous; it is also not part of the Paleocene; It is a distinct unit, but undoubtedly part of the Tertiary;
5. There is no faunal evidence to support the incursion of the Danian in either the Cretaceous or the Tertiary. To range the Danian with the Cretaceous or Tertiary is only a question of convention;
6. There is no stratigraphical unit like the Danian, and this term should be abandoned as useless and superfluous;
7. Danian and Montian are of identical age being merely different, lithologic and faunal facies. The Danian includes the Montian and is a stage name within the Paleocene.

Now the question is, which of these is correct ? Probably they are all correct so long as we confine any particular conclusion to the observations and interpretations made by the authors in their particular areas; but this does not mean that because it is true in that particular area, it must automatically be equally true elsewhere and everywhere, and as such should be universally accepted.

CRETACEOUS-TERTIARY BOUNDARY

There is also another important aspect of this boundary problem to be considered. To start with a postulate that everywhere there must be a definite 'boundary line' between the Cretaceous and Tertiary, and that the object of all our studies is only to find out where it exists, is not the most helpful or correct approach to this problem. The possibility must also be definitely recognised that where we have a really complete and continuous record of past changes, the beds of the older system may merge so insensibly and gradually, both stratigraphically and palaeontologically, into those of the newer ones that it is impossible to draw a hard and fast divisional line between the two which will hold good from all points of view. There is no doubt that as our studies become more extensive and detailed, we are sure to come across at least some such areas on the earth's surface. Such areas may be few and far apart; but the main thing is to recognise the possibility of such areas actually existing and look for them with an open mind.

As a matter of fact, in regard to the Cretaceous-Tertiary transition with which we are now concerned, a few successions have indeed been noticed from time to time in recent years where we have probably the nearest approach to 'no boundary' areas; and these require a careful consideration on the basis of their intrinsic merits.

According to Pozaryski and Pozaryska (1960), overlying the uppermost Maestrichtian in Poland, there is a sandy calcareous sediment of 0.3 m. in thickness with rich glauconite and phosphatic concretions. Inside this sediment are numerous and well preserved upper Maestrichtian fossils; in the same strata appear pelagic foraminifers occurring in the Danian stage generally, such as *Globigerina daubjergensis*, *G. triloculinoides* and some benthonic species unknown in the Maestrichtian. This bed is a typical passage layer in which Danian microfaunae is associated with the index Upper Maestrichtian faunae.

In Egypt again, for instance, Nakkady's elaborate studies (1952, 1955 and 1957) led him to conclude that there exists a Mesozoic-Cenozoic conformity in those areas where the Esna shales intervene between the Upper Cretaceous and Lower Eocene; and his recognition of the following three zones in a continuous Cretaceous-Tertiary sequence is particularly noteworthy :

Globorotalia zone

Buffer zone

Globotruncana zone

So also in Libya, according to Lehman (1964), in the Sirte basin, rocks occur which contain excellent planktonic foraminifera which are typical of the type Danian and Maestrichtian, and are definitely correlative with the Lower Paleocene and Upper Cretaceous of the Gulf Coast and Caribbean sea. Elements of typical Tertiary planktonic foraminifera are found in the uppermost Maestrichtian series in sections where there was virtually continuous sedimentation from the Cretaceous into the Tertiary.

Yoshida's recent studies (1961) in parts of Japan have also revealed the presence of certain beds occupying a significant position in regard to the Cretaceous-Tertiary passage in that region. The centre of interest in his study is the Nemuro group about which he makes the following striking observations : "The foraminifers

from the constituent beds of the Nemuro group have now been examined in detail, and these studies indicate that while some of these beds are no doubt Maestrichtian, others are clearly Danian and /or Paleocene." According to Yoshida, "the Nemuro group is distributed in the Hanasa ki peninsula partly includes the beds obviously assignable to the Paleocene in view of planktonic foraminifers, but these are hardly distinguishable from Upper Cretaceous on the basis of the megafossil evidence." He draws pointed attention to the Choboshi formation of the Nemuro group whose fossil assemblage indicates two different ages—some indicating Upper Cretaceous and others Paleocene; according to him, the Choboshi "is a transitional formation between Upper Cretaceous and Lower Tertiary; hence intermixture of fossils of two different ages can happen." Yoshida has discussed the various possible alternative explanations to account for this intermixture; and in this connection, refers to similar formations outside Japan like the Maestrichtian Tuff Chalk which contains planktonic foraminifers which are identical to those of the type locality of the Danian and is at the same time characterized by ammonites and other fauna of purely Mesozoic types.

Olsson's observations on "Latest Cretaceous and earliest Tertiary stratigraphy of New Jersey Coastal plain" (1963) are also very interesting. According to him, the New Egypt formation of this region ranges in age from early Maestrichtian to early Eocene. The part equivalent to the Tinton formation is clearly of Upper Maestrichtian age while the lower sections of the immediately overlying Hornerstone formation is probably Paleocene. "There is no convincing evidence of the Cretaceous-Tertiary unconformity, but in contrast most of the evidence suggests continuous deposition from Cretaceous into Tertiary time."

Recent studies have shown that in the Carnarvon basin sequence, between the top most ammonite-bearing bed and the lowest Nummulite-bearing bed, is a sequence upto 120 ft. thick; it contains calcareous, glauconitic and sandy beds. Its macrofaunal assemblage is Cretaceous, although without ammonites; but its microfauna is Tertiary,—a Globorotalia-Globigerina assemblage. In fact, in Madagascar (Collignon 1960 and 1968) the so-called typically Paleocene Globorotalia-Globigerina microfauna is known to occur in the same formation as sphenodiscid ammonites.

In New Zealand, we have according to Hornibrook (1958) another interesting area from the point of view of the Cretaceous-Tertiary transition in the Haumarian-Teurian-Waipawan succession. While the Haumarian is clearly upper Maestrichtian in age, the microfossil assemblage in the Teurian reveals a strong Cretaceous element persisting from the Haumarian side by side with some of the early Paleocene genera, suggesting that the Teurian forms a sort of a passage bed in the local Cretaceous-Tertiary transition. The succeeding Waipawan stage is clearly Paleocene. Hornibrook's concept of the relation between the Maestrichtian, Danian and Paleocene is indicated in his Table I, and is very interesting from the point of view of the Cretaceous-Tertiary boundary.

Coming to the Indian region, we have an interesting and significant observation recorded by Nagappa (1959) in connection with the Cretaceous-Tertiary succession in parts of Baluchistan. He says: "In the Pab range, southern Las Bela, there is a thick group of shales overlying the Pab sandstone. Within this shale group, a full faunal evolution from the Maestrichtian through the Danian into the Paleocene

can be studied. The lithofacies appears to have been constant throughout. Here the typical Maestrichtian forms such as *Globotruncana stuarti* and *Guembelina striata* (Ehrenberg) which occur in the lower part are replaced by *Globigerina triloculinoides* and *G. pseudobulloides* (indicating the Danian) in the higher horizons. In this range *Globotruncana* is absent and *Globorotalia* has been found in only a single sample (compare the *Cardita beaumonti* beds of Sind). Still higher, the fauna is supplemented by typical Paleocene forms belonging to the genera *Bulimina*, *Cibicides*, *Globigerina*, *Haplophragmoides*, *Trifarina*, *Uvigerina*, etc."

Another example of a continuous Cretaceous-Tertiary transition is the succession in the Trichinopoly-Vriddachalam-Pondicherry area of South India. From recent studies (Rama Rao 1960, 1964 and 1968) it is now clear that in this comparatively small area we have an excellent marine fossiliferous series including the Maestrichtian, Danian and Paleocene in quick succession. From the present available evidences based on the study of surface and subsurface rock samples, it is evident that we have in this region a most promising example of an uninterrupted Upper Cretaceous-Lower Tertiary succession without any recognisable boundary line between the two.

In drawing attention to the above mentioned areas with a probably continuous succession in the Upper Cretaceous-Lower Tertiary stratigraphy of the areas concerned, it is not my intention to straightaway claim that they are true 'no boundary' areas; in fact, the author is aware that the position in these is, according to some later workers, still rather controversial and not convincingly clear. The main point is that there are clear indications of the possibility of true 'no boundary' areas actually existing, and to emphasise the supreme importance of such areas from the point of view of world stratigraphy.

THE BOUNDARY IN THE STANDARD STRATIGRAPHICAL SCALE

Since Stratigraphy had its beginnings in Europe, the earlier geologists more than 150 years ago constructed a stratigraphic column including beds of all the then known ages from different parts of Europe which could be used as a 'standard scale' in terms of which the relative age of any bed in that continent could be expressed; and since this scale was generally accepted for adoption all over Europe, it came to be known as the 'European Stratigraphical Scale' providing a sort of a common language for stratigraphical geologists from different parts of Europe to communicate with and understand each other in regard to the mutual age relationships of the strata they were considering in their different regions. As knowledge of Stratigraphy of other parts of the Earth gradually progressed, the workers outside Europe also adopted the well known European scale for reference; and thus it came to be considered as the 'Standard Stratigraphical Scale' for geologists all over the world.

The main point to note is that, from the global point of view, this 'Standard Scale' is by no means complete in the sense that it includes beds of all possible ages constituting a continuous and unbroken record of the entire Earth's history. We have all along been aware that there are several breaks at different time levels in this 'European Scale' of varying magnitude; as a matter of fact, the earlier geologists took advantage of these 'breaks' to draw their boundary lines between their groups, systems and stages in subdividing their scale. While this is perfectly alright so far

as it goes, it is most important to realise that all these breaks, big or small are merely provincial interruptions in an evolutionary continuum. It is most essential that in all our future stratigraphical studies, our endeavour should be directed to the discovery of beds in any part of the world bridging these breaks. It is the finding of such 'missing links' in the stratigraphic succession that will ultimately enable us to synthesise a 'Standard Scale' for world-wide application and thus make our knowledge of Earth's history full and complete, which is the ultimate aim and object of all Stratigraphy and Paleontology.

THE TRUE 'DANIAN'

Confining our attention to the Cretaceous-Tertiary boundary in such a Standard Stratigraphical Scale, the Danian is the crux of the problem. It is now being increasingly realised from detailed studies in many parts of the world that the post-Maestrichtian-pre-Paleocene was a period of general regression and, therefore, beds of that particular age are absent all over there. Thus arises the 'break' representing this period; the time span of the resulting gap depends upon whether the whole or any particular part of the Danian is missing. If these breaks are due to the absence of the Danian, wholly or partly, there is no point in the controversy as to whether the Cretaceous-Tertiary boundary line in such areas should be placed above or below the Danian. The one and only way to resolve this controversy is to define and delimit the Danian in such a manner as to remove it from all terminological inexactitudes. If the term is to be retained in regional studies, although its time-stratigraphic equivalence is not the same in all places, we have to drop the idea of using the same term in the 'Standard Stratigraphical Scale'. On the other hand, if the term 'Danian' is to be retained in the 'Standard Stratigraphical Scale', it should be strictly confined to only such beds in any succession as it form a true passage from the Cretaceous to the Tertiary without its being assignable to either. Such cases are admittedly rare; but it is these rare cases that are really important. If the 'Danian' is thus defined and fixed in the 'Standard Scale' for world-wide adoption, it follows that we must no longer use the same name in regional studies to designate the so called 'Danian' which is either undoubtedly part of the Cretaceous or equally undoubtedly part of the Tertiary. These sets of beds should be given different names in terms of the regional stratigraphy so that their distinction in age as among themselves is clearly brought out, and none of them being equivalent to the 'true Danian', in the Standard Stratigraphical Scale, as defined above. Such a reorientation in our approach will greatly help removing the deadlock in the problem of the Danian vis-a-vis the Cretaceous-Tertiary boundary.

REFERENCES

- Collignon, M. (1960). Le Danian a Madagascar. XXI Session, Int. geol. Congr., Copenhagen, Pt. 5, 117-119.
- (1968). Le Cretace superieur de Madagascar. *Mem. geol. Soc. India*, 320-334.
- Desor, E. (1846). Sur le terrain Danian, nouvel 'etage de la Craie. *Bull. Soc. geol. Fr.*, 2, 179-181.
- Hedberg, Hollis D. (1964). Definition of Geological Systems. Report of the International Sub-commission on Stratigraphic Terminology. *Proc. Int. geol. Congr. New Delhi*, pp. 5-21.

- Hornibrook N. de B (1958). New Zealand Upper Cretaceous and Tertiary Foraminiferal zones and some overseas correlations *Micropalaeontology*, 4.
- Lehman E. P. (1964). *Report Int. geol. Congr.*, New Delhi, Abstracts, 31.
- Nagappa, Y. (1959). Foraminiferal Biostratigraphy of the Cretaceous-Eocene succession in the Indo-Pakistan-Burma Region. *Micropalaeontology*, 5, 151.
- Nakkady S. E. (1952). The Foraminiferal Fauna of the Esna Shales of Egypt. *Bull. Inst. Egypt*, 33.
- (1955). The Stratigraphical implication of the accelerated tempo of evolution in the Mesozoic-Cenozoic transition of Egypt. *J. Paleont.*, 29,
- (1957). Biostratigraphy and Inter-regional correlation of the Upper Senonian and Lower Paleocene of Egypt. *J. Paleont.*, 31.
- Olsson R. K. (1963). Latest Cretaceous and Earliest Tertiary Stratigraphy of New Jersey Coastal Plain. *Bull. Am. Ass. Petrol. Geol.*, 47 No. 4.
- Pozaryski W. and Pozaryska, K. (1960). On the Danian and Lower Paleocene Sediments in Poland, *Rep. Int. geol. Congr.*, Pt. 5, 170.
- Rama Rao, L. (1956). Recent contributions to our knowledge of the Cretaceous rocks of South India. *Proc. Indian Acad. Sci. Sec. B*, 44, 185-245.
- (1960). The problem of the Cretaceous-Tertiary Boundary. *Proc. natn. Inst. Sci. India Sec. A*, 26.
- (1964). The problem of the Cretaceous-Tertiary Boundary, with special reference to India and adjacent countries. *Mysore geol. Assn. Special Publication*, 1—66.
- Rama Rao, L. (1968). The problem of the Cretaceous-Tertiary Boundary. Seminar Volume on Cretaceous Tertiary Formations of South India. *Mem. geol. Soc. India*, 1-9.
- Yoshida, S. (1961). The Cretaceous-Tertiary Boundary in Eastern Hokkaido, Japan. *J. Hokkaido Gakugei Univ.*, 12, 1.