FAUNAL REALMS IN JURASSIC AND CRETACEOUS BELEMNITES

SIR,—In a recent paper, Stevens (1963) has presented arguments maintaining that Boreal, Tethyan and Indo-Pacific faunal realms may be recognized in belemnite faunas of Callovian and most of later Mesozoic time and that, accepting climatic control of the Boreal and Tethyan realms, Jurassic and Cretaceous belemnites can be regarded as stenothermal. He criticizes views that the writer and others have advanced in the past, namely, that very widespread or world-wide temperature maxima and minima occurred throughout the Mesozoic and that the belemnites were eurythermal prior to the Cenomanian and thereafter stenothermal. He also gives a series of text-figures illustrating the development and migration of some of the Mesozoic belemnite faunas. The paper contains a number of internal contradictions and mis-statements. In the early part of the paper, we are told that " from the Aptian onwards the Indo-Pacific realm contracted to include only Australia, Indonesia, and Southern India and became entirely separate from the Tethyan realm." Later, Stevens states that " *Neohibolites* and *Parahibolites* were apparently able to achieve a wider distribution in the Aptian-Albian, but to judge from the paucity of records outside Europe were otherwise not very abundant and perhaps only had limited access to the Indo-Pacific realm." How could they have had *any* access if the two realms were entirely separated ? Then too Stevens states that the Boreal and Tethyan realms were characterized by faunas with different temperature tolerances and " their separation is attributed to climatic zoning ". Elsewhere, however, he remarks that for the Jurassic the paleotemperature results available do not support the hypothesis that these realms " were primarily a result of climatic differentiation ". Which is it to be ? Again, we are informed that the Lias " may have been almost uniform in climate " because Stevens is unable to distinguish between Boreal and Tethyan belemnites before the Middle Jurassic. Unfortunarely for this idea, the physico-chemical evidence given by Bowen (1963) and Bowen and Fritz (1963) shows that the Lias, at least in Germany, is very diverse temperaturewise. In addition, Stevens states that he has failed to find an equivalent of his Boreal fauna in the southern hemisphere Jurassic and attributes this to scarcity or absence of belemnites in critical regions like South America. This appears strange to the writer who has published a paper entitled " O^{18}/O^{16} paleotemperature measurements on Mesozoic Belemnoidea from Neuquen and Santa Cruz provinces, Argentina " which pre-dates Stevens' paper by more than half a year (v. bibliography, Bowen 1963b). Regarding the question of temperature maxima, Stevens observes that " there is no support for (these) in the Coniacian-Santonian and Albian ". This is a very surprising statement in view of the fact that these two maxima have been studied extensively over a period of a decade beginning with the work of Lowenstam and Epstein (1945). These authors wrote of the Coniacian-Santonian climatic optimum that " this is shown not only by the temperature records of the belemnites "—fully supplied, of course, in their paper—" but also by those of the associated fossils analyzed. The fact that this climatic trend is based on determinations from widely separated areas, such as England, the Paris Basin, and Scandinavia, strengthens the climatic inference. More weighty support for the argument that we are dealing with a true climatic optimum and not local climatic conditions is shown by the distant belemnite records from the Colorado group near Fort Benton, Montana (where) temperatures are quite similar to those . . . of northwestern Europe ". The writer's data are in close agreement with these conclusions. Apropos the Albian, even more widespread, indeed truly world-wide data may be used to illustrate the climatic maximum and also the parallelism of temperature trends in two of Stevens' realms, namely, the Tethyan and the Indo-Pacific. Bowen and Fontes (1963) collected material from the Lower and Middle Cretaceous of the Devoluy area of the Hautes-Alpes, France which was in the Tethyan realm through this time interval. Analyses of belemnites and associated aptychi showed a decline of temperature from the Berriasian to the Barremian followed by a rise to the Albian maximum. From additional (unpublished) evidence supplied to the writer by Dr. J. C. Fontes, it appears probable that the increase in temperature from Aptian into Albian was about 7°C., i.e. a change in delta value of about 1·5 per cent. Clearly, a climatic minimum in the Barremian is succeeded by a progressive rise of temperature until the Albian maximum is reached. Bowen (1961a) has plotted a similar course of events in Australia which lay at this time in Stevens' Indo-Pacific realm. The average Albian temperature obtained from a set of specimens from South Australia was 21·9°C., whereas the Aptian temperature average recorded by Dorman and Gill (1959) was about 6°C. lower. Data of Lowenstam and Epstein (1954) on the Australian Albian are not in good agreement with the writer's (the reasons for this are discussed in Bowen 1961a and need not be repeated here), but they still record a higher temperature range than the Aptian one of Dorman and Gill, specifically 15·2°C. to 16·6°C. as compared with 12·2°C. to 16·5°C. (six specimens of which five give temperature readings of less than 15·1°C.). It is apparent that, despite the differences between the writer's data and those of Lowenstam and Epstein, the general picture of a *rise* in temperature from the Aptian into the Albian holds good in Australia as elsewhere. The difference between the Albian high in France and that of the writer in Australia is due to latitudinal factors, i.e. France was much nearer the equator at this time than was Australia. An overall world-wide shallow water oceanic temperature range of only about 24°C. existed during the Jurassic (v. Bowen 1961b); this was somewhat greater in the Cretaceous and is ample to account for this difference. However, we can still observe the maxima and minima even though these may vary quantitatively. The evidence obtained by oxygen isotope analysis demonstrates dramatically the Albian high in almost diametrically opposed areas of the earth and shows the similarity of the climatic trends leading up to this event despite the great geographic separation. Further work by Lowenstam and Epstein (1959) show these world-wide trends in the Maestrichtian and, at least for North America and the U.S.S.R., the data can be readily integrated into the previous data from Western Europe. Lowenstam (1961) states that " the close correlation of climatic trends in widely distant areas of the northern hemisphere indicated that the temperature distribution recorded by the post-Aptian pre-Danian belemnites in Western Europe were a reflection of world-wide climatic conditions during this Cretaceous time interval ". Differences exist between temperature records from Santonian belemnites in the U.S.S.R. and the rest of the world, but Lowenstam suggests several possible explanations for these, e.g. the Russian standard has a different O^{18}/O^{16} ratio from PDB–1, the deposits assigned to the Santonian inside and outside the U.S.S.R. are not timestratigraphically equivalent, Santonian belemnites in the U.S.S.R. may have passed their lives in deep and died in shallow waters therefore recording cooler temperatures, etc. Russian scientific work in this field is also suspect because the writer has discovered that at least some geochemical workers there are using an inorganic calcite scale for paleotemperature determinations on fossil organisms. Hence this point is not of crucial importance. Elsewhere the generally accepted maxima and minima are quite clear. From the evidence cited above—and it must be added that a great deal more could be produced were space not a limiting factor—it will be obvious that Stevens' faunal realms, if they really exist, cannot have been climatically determined (as he himself admits, v. p. 2) for most of their existence and therefore the belemnites must have been eurythermal for most of theirs.[1] In the later

[1] Stevens' restriction of belemnite migration by deep-water barriers and confinement of these organisms to shelf areas where they found their prey is dependent on, as he states, " clearly defined " faunal realms. He has yet to demonstrate the existence of the realms and if we grant their existence we may note that he refers to long-term (specifically Callovian to Tithonian) interconnection by means of which species evolved in Central and Southern Europe and gradually spread " presumably along the Tethyan seaway into the Indo-Pacific realm ". Certainly, therefore, we cannot consider these two to be clearly defined in any meaningful sense of these words and this intercommunication of species is one more argument in favour of an eurythermal mode of life.

Cretaceous the situation becomes more complex because of the increase in temperature range over the planet and the emergence of a meaningful " boreal " area. Earlier than this, the writer believes this word to have practically no significance except in a strictly geographic sense (v. Bowen 1962). As Lowenstam and Epstein (1954) pointed out, " it appears that the belemnites, which during the Albian were summarily considered eurythermal became subsequently stenothermal with tolerance threshold limits ranging from temperate to marginal subtropical. This would satisfactorily explain their northward shift at and about the Coniacian-Santonian climatic optimum and their temporary occupation of arctic waters ". Stevens frequently refers to the faunal realms as " clearly-defined " and mentions that the " Boreal-Tethyan boundary remained remarkably stable except during the Upper Cretaceous "; elsewhere he states that the Tethyan-Indo-Pacific boundary " varied in distinctness throughout Upper Jurassic and Lower Cretaceous time ". It is a pity that he did not insert these boundaries on his text-figures so that we might judge these matters for ourselves.

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