strong winds and heavier seas, and the result is an asymmetric truncation. Whether the attack is vigorous on both sides (Text-fig. 2) or on one only (as illustrated by headlands of Banks Peninsula, where headlands projecting both north and south are attacked by waves from an easterly direction), the distal portion of the headland is reduced in the course of time to a narrow cliff-walled strip (Text-fig. 2, stage 2, and Text-fig. 3, *a*). Later it must dwindle to a row of stacks (Text-fig. 2, stage 3), and when these are destroyed the cycle is completed with resection of the headland and restoration of the terminal straight cliff line (not at this stage plunging, however).

The western end of the Isle of Wight has apparently been subjected to a similar flank attack on its terminal cliff. It would seem that the cliff behind the Needles (Text-fig. 3, *b*), themselves relics of the distal part of a residual strip thus isolated, had been attacked by erosion from each side in some marine cycle, though perhaps not the last. This suggests that owing to some local combination of circumstances the cliff has been of the plunging kind in the episode in which the flank attack began.

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EXPLANATION OF PLATE VIII

Banks Peninsula, New Zealand. View eastward from a point above Akaroa Heads, showing plunging basalt cliffs from which the ocean swell is reflected. (Photograph by V. C. Browne.)

CORRESPONDENCE

FORAMINIFERAL ZONES IN THE TERTIARY OF AUSTRALIA

SIR,—Dr. M. F. Glaessner recently published a paper in this Journal (lxxxviii, 1951, 273–284) in which he describes foraminiferal zones in the Tertiary of Australia and in which he summarizes known and unpublished information on the Australian Tertiary sequence. A great deal of precise stratigraphic work has been done on the Australian Tertiary rocks in the past five years. Dr. Glaessner cannot have been unaware of this and it is regretted that he did not wait until the results of it were available. Recent discoveries since Glaessner's paper was prepared have made necessary a drastic revision

of the age correlations of the Victorian Stages and have emphasized the undesirability of prematurely publishing material based on investigations which are still in progress.

He lists what he calls "three distinctive foraminiferal zones", (1) *Hantkenina alabamensis* Zone, (2) *Victoriella plecte* Zone, and (3) *Austrotrillina howchini* Zone. In his correlation table on p. 274, he indicates a fourth, "? *Sherbornina* Zone," which may be of zonal value. Recent investigations by Raggatt and Crespin (1952) in the Bird Rock section, Torquay, Victoria, which has been regarded as the type area for the "Janjukian Stage", and westward as far as Brown's Creek and Johanna River, have shown that the proposal of *Hantkenina*, *Victoriella*, and *Sherbornina* as distinct zones is incorrect. In the basal portion of the Bird Rock Cliff section, these three forms occur together in the one sample, whilst *Victoriella plecte* has been found in the Upper Eocene beds at Johanna River and Brown's Creek. *Sherbornina atkinsoni* is common in many rock samples containing *Victoriella* in the vicinity of Bird Rock and Point Addis and its occurrence in beds higher in the stratigraphic sequence is extremely rare. "The possibility of establishing a zone based on the occurrence of *Sherbornina* between *Victoriella* and *Austrotrillina* Zones" (p. 278) seems quite untenable. The presence of *Hantkenina alabamensis* in the basal beds at Bird Rock definitely gives an Upper Eocene age for at least the lower part of the so-called "Janjukian Stage", which Glaessner has put down as Upper Oligocene.

According to Glaessner (p. 281) "*Victoriella* does not give any direct age indications". The writer believes that, in the absence of *Hantkenina alabamensis*, *Victoriella plecte* will prove an important age determinant for the Upper Eocene because of its ability to thrive under calcareous or argillaceous conditions. Also, on account of its comparative abundance, it is found in many places where the search for *Hantkenina* is unsuccessful.

On p. 277 Glaessner states that "the *Hantkenina* Zone of Brown's Creek is developed as a glauconitic clay with *Notostrea* forming the lowest fossiliferous bed of a sequence of Tertiary strata which rests, with unfossiliferous ironstones at its base, unconformably upon Jurassic sandstones". Raggatt and Crespin (1952) found that 35 feet of clays containing abundant foraminifera and mollusca are exposed in a continuous section below the bed with *Hantkenina* and *Notostrea*, and that Jurassic rocks are not exposed at this place. Field measurements show that beneath these very fossiliferous beds there is a thickness of 166 feet of Tertiary strata. Also beds with *Hantkenina* are not at the top of the Eocene in Brown's Creek–Johanna River section as shown in the correlation table on p. 274; there are at least 145 feet of beds containing Upper Eocene foraminifera above them. The species recognized include *Anomalina perthensis* Parr, *Angulogerina subangularis* Parr, *Alabamina obtusa* (B. & H.) var. *westraliensis* (Parr), *Bolivinopsis crespinae*, *Asterigerina adelaidensis* (Howchin), *Cibicides pseudoconvexus* Parr, and *Pseudobulimina glaessneri* Howe and Roberts.

On p. 278 Glaessner refers to "carbonaceous, pyritic sands and sandy clays with *Cyclammina*" as occurring above the *Hantkenina* zone. Instead, the *Cyclammina* beds of the "Anglesean Stage" stratigraphically underlie the beds containing *Victoriella* and *Sherbornina* in the Point Addis section. This sequence is common in many of the bores in Gippsland, in the Mallee and in south-western Victoria and the age of the *Cyclammina* beds is very probably Middle Eocene. The writer has examined a considerable amount of material from the section at Anglesea (Singleton, 1941). *Cyclammina* is exceedingly abundant there and many tests are beautifully preserved. Species are readily determinable rather than "not being identifiable owing to distortion" as stated by Glaessner.

Many of Glaessner's comments regarding *Austrotrillina howchini* (pp. 276, 279, 281) are taken from published and unpublished work of the writer, who adheres to her views on the distribution in Australia of this important Miocene Indo-Pacific species (Crespin, 1948, 1950). Similarly, the stratigraphic position of *Flosculinella bontangensis* has been determined by the study of

measured sections in North-West Australia. More recent research, however, shows that both of these forms must be considered as zonal species, in North-West Australia, for " f1 " stage of the Indo-Pacific " letter classification " (Van der Vlerk, 1948) rather than of " f2 ". The upper limit of *A. howchini* has not been definitely proved in South-Eastern Australia. It is also admitted that " f1 " stage is most probably Lower Miocene.

It is difficult to understand why Glaessner in the correlation table on p. 274, should correlate his foraminiferal zones in Australia with definite European Stages of the Tertiary, for example, the *Sherbornina* Zone with the Aquitanian and the *Victoriella plecte* Zone with the Chattian. Surely a long distance correlation of zones in the Australian Tertiaries with European Stages would require the presence of similar zonal species in the foraminiferal assemblages in both parts of the world. It was the absence of similar species in the deposits of these two widely separated regions that caused the early Dutch paleontologists to institute the " letter classification " for the East Indian Tertiaries. In spite of the very considerable detailed work that has been done there, agreement has still not been reached about the correlation of European Stages with Indo-Pacific Stages of Zones.

The correlation of Eocene and Lower Oligocene deposits throughout the world by means of the foraminifera and especially the larger foraminifera is relatively easy. Forms such as *Discocyclina*, *Assilina*, and *Pellatispira* are unknown in rocks younger than Eocene. Amongst the smaller zonal genera, *Hantkenina* is characteristically Middle to Upper Eocene and some of the smaller foraminiferal Eocene species are also widely distributed. It has been generally recognized that the association of reticulate *Nummulites* with *Eulepidina* represents stage " d " in the East Indies which by some authors is correlated with the Rupelian or Middle Oligocene. Beds of Oligocene age are poorly developed in the Indo-Pacific region and in some places are absent.

Tan (1939) regarded the Aquitanian as Lower Miocene or Lower Neogene and suggested that certain beds in the Indo-Pacific region which contained European species of *Eulepidina* such as *E. dilatata*, *E. elephantina*, and *E marginata* could be correlated with the Aquitanian. He urged " that at the present state of knowledge the differentiation of Oligocene from Aquitanian by means of larger foraminifera is only possible if reticulate or other genuine Camerines are present ". Recent research seems to indicate that the Aquitanian is Oligocene-Miocene.

Tan (1939) said it was very difficult to differentiate the Burdigalian Stage and higher European Stages in the Indo-Pacific because of " fundamentally different " marine faunas in Southern Europe and in the Indo-Pacific. It is a well recognized fact that distinct faunal provinces existed throughout the world during Miocene times. Genera such as *Katacycloclypeus*, *Trybliolepidina*, and *Alveolinella* and several species of *Miogypsina* and *Nephrolepidina* which are widely distributed in Miocene deposits in the Indo-Pacific region are unknown in the European beds. Furthermore, *Miogypsina* and *Lepidocyclina* disappear in the Burdigalian in Europe whereas they continue to live during later Miocene times in the Indo-Pacific region. Rayed forms of *Lepidocyclina* with nephrolepidine-trybliolepidine and trybliolepidine embryonic apparatus dominate the " f " stage (Miocene) assemblages in the Indo-Pacific region and are unknown in European assemblages.

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SIR,—(1) For the clearly stated purpose of the paper criticized by Miss Crespin, observations made by the late Mr. Parr were combined with data published by Miss Crespin during the last decade. These were supplemented by a report on foraminifera from bores in the Adelaide Basin which was made available to the writer by the Mines Department of South Australia while it was in the hands of the printer as an Appendix to *Bulletin* No. 27 of the Geological Survey. This is the only " unpublished information " by Miss Crespin used in the paper where it is acknowledged as such. The salient points of her observations, i.e. the occurrence of *Austrotrillina* and *Sherbornina* in bores in South Australia, were published previously by Miss Crespin (1946, p. 300 ; 1948, pp. 138, 139, and Table I).

(2) I was well aware of stratigraphic work being done in the Australian Tertiary by Miss Crespin and others. I welcomed and acknowledged at the time the opportunity given by some other colleagues and organizations to visit and discuss with them critical areas in 1946. A similar field conference with Miss Crespin and her co-author was suggested by the writer in 1950 but this was not accepted. The results of their work are still unpublished at the time of writing, the bibliographic reference to Raggatt and Crespin, 1952, notwithstanding.

(3) Miss Crespin (1950, pp. 70–1) stated : " A detailed stratigraphic and micropaleontologic investigation of the cliff section along the southern coastline of Victoria . . . has been completed by H. G. Raggatt and the writer and the results will be published shortly. The study of the microfaunas in the sediments has yielded considerable information about the stratigraphic range of the foraminiferal species and it has been possible to determine the restricted vertical range of certain species. . . The Anglesean Stage is considered to be Oligocene and the Janjukian, Lower Miocene." In the light of this statement and of what follows, Miss Crespin's remark about " the undesirability of prematurely publishing material based on investigations which are still in progress " may seem rather harsh self-criticism. Investigation of Tertiary strata hundreds to thousands of feet thick and extending over 700 miles of coastline and 150 miles or more inland will continue for many years during which, it is hoped, a vigorous policy of publishing and discussing observations and making tentative compilations will be maintained.

(4) It seems now that after the publication of her 1950 paper and of my contribution Miss Crespin has found *Hantkenina* in one sample of typical

Janjukian with *Victoriella*. If confirmed, this is a new fact not foreseen by anyone. From this Miss Crespin draws the conclusion that all beds with *Victoriella*, previously placed by her in the Middle and then in the Lower Miocene and by the writer in the Upper Oligocene, represent the *Hantkenina* zone and must be Upper Eocene. One would have expected an attempt to solve the problems created by this new correlation but they are not even stated. For example, the sequence is continuous from Janjukian to Balcombian (Batesfordian) at least in Western Victoria (Parr in Baker, 1944) and Gippsland. If the lower beds of the Janjukian are Upper Eocene and the beds conformably overlying this " stage " are Lower Miocene then the upper Janjukian must represent the Oligocene. In the Table Cape beds, at Spring Creek and Waurn Ponds (Janjukian) the squalodontid *Prosqualodon davidi* Flynn occurs which cannot be older than Late Oligocene (Romer, 1945, p. 490).

(5) As the beds with *Sherbornina* apparently follow conformably below the undisputed Batesfordian (Balcombian) equivalents in Gippsland and in the Adelaide area, they cannot be considered as " *Hantkenina* zone ", i.e. Eocene. Notwithstanding the longer range of the genus *Sherbornina* in the Torquay area and possibly Tasmania, of which I was well aware, its locally restricted range still offers the possibility of establishing a zone based on its stratigraphically restricted occurrence in these areas.

(6) It is noted with satisfaction that Miss Crespin has not changed her views on the distribution of *Austrotrillina* with the exception of the one point which I have criticized. It is now admitted to be " most probably " Lower Miocene.

(7) It is not difficult to understand why European Stage terms are placed against Australian zones when it is realized that these stages are " time-rock " divisions of the international standard stratigraphic scale and serve to place these zones in the world-wide continuum of geological time. The question of time stratigraphy and the " letter classification " will be more fully discussed elsewhere, as announced in my paper.

(8) The stratigraphic value of larger foraminifera is well known to me and to other students of the principles of micropalaeontology. The relation of Tan's opinions on this matter to the present discussion is, however, remote.

(9) In conclusion, I am gratified to see, firstly, new evidence coming to light and being promptly published ; secondly, agreement on the wide stratigraphic range and high antiquity of the south-east Australian Tertiary sequence which was denied by Miss Crespin as recently as 1945 and (Aldinga Bay) 1946 ; thirdly, agreement on the Lower Miocene age of the " Batesfordian " and apparently the stratigraphic relations of the younger strata. I am sure that the question of the extent of Eocene and Oligocene in Australia will be solved by further friendly co-operation and competition of many workers in the field.

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