CORRESPONDENCE

THE AGES OF TERTIARY ROCKS AT ULOA AND UMKWELANE, ZULULAND, AND THEIR GEOMORPHOLOGICAL SIGNIFICANCE

SIR,–I think it may be useful to give a simple record of the stratigraphic, palaeontological, structural and geomorphological interrelationships of the sedimentary rock series at Uloa and Umkwelane, Zululand.

The Tertiary sedimentary series at Uloa and Umkwelane

The first dating of Tertiary rocks at Uloa was by King (1953) who, on a basis of more than one hundred species of megafossils (mostly mollusca), specified a *Lower Miocene* age for the richly fossiliferous bed in which *Aequipecten uloa* is extraordinarily abundant. This dating for the bed was later confirmed by Biesiot (1957), who identified fifty-three species of foraminifera.

The Miocene beds are overlain by bedded calcarenites to which a "presumed Pliocene" age was assigned (King & King, 1959) on the basis of a few molluscan species, none of which differed from modern forms sufficiently to be regarded as distinct species. This Pliocene dating was confirmed by foraminiferal identifications from Mr. P. Hardwick of B.P. (Mombasa and Britain), and Dr. F. Wijkhuisen of Royal Dutch Shell (at the Hague). These lists are published in King (1966).

Frankel (1960 and 1966) disregarded this distinction, and upon a mixed collection of ten species of foraminifera (whose ages ranged from Cretaceous to Recent, according to identifications made for him by Dr. J. St. Jean of the U.S.A.) collected at Umkwelane nine miles from Uloa (1960 p.259) declared *all* the Tertiary rocks at the two localities to be of Miocene age. But there are two series of sedimentary rocks, with two distinct faunas.

The physical unconformity between the two lithologically and palaeontologically distinct series at Uloa was then erroneously described by Frankel as an "intraformational disconformity", though he had in 1960 described the dip of the calcarenites from Umkwelane to Uloa as 9 feet per mile, and in 1962 the "*Pecten* bed" east of Uloa as 25 feet per mile (Frankel & Ward, 1962).

There are two unconformities: one below the Miocene at Uloa where it rests upon late Cretaceous marls, and another below the Pliocene at both Umkwelane (where it cuts across Cretaceous) and Uloa (where it transects the Miocene) (Fig.1).

So there are, in the Zululand Tertiary, two lithologically distinct series with two distinct faunas, Miocene and Pliocene respectively, and two dips, indicating that in the time interval between the two depositions (ten million years or more) tectonic movement in the form of gentle seaward tilting had taken place. (Actually, towards the western exposure at Uloa, dip on the Miocene increases to nearly one degree (80–90 feet per mile), and is locally 3° at the section showing contact with the Cretaceous alongside the railway line.)

Finally, in the coastal hinterland of Natal and Zululand are two late Tertiary cyclic erosional surfaces with which I consider the two Tertiary sedimentary series must corre-

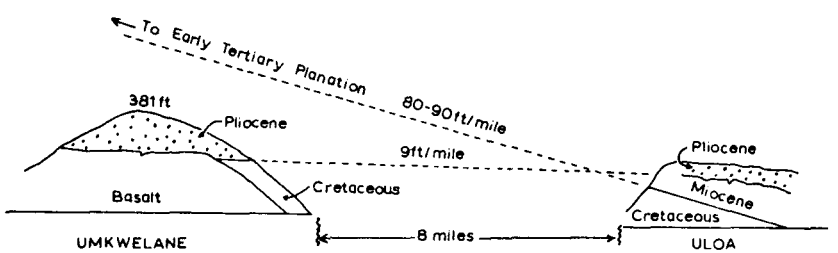

FIG. 1.–Diagrammatic section showing relations between Tertiary sedimentary series at Umkwelane and Uloa, Lower Umfolozi, Zululand.

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late. On the datings by the four palaeontologists mentioned (King, Biesiot, Hardwick and van Wijkhuisen) this is so, and perfect harmony exists between all four classes of data–stratigraphic, palaeontologic, structural, and geomorphological–that have been quoted.

Dr. Frankel's dating of the calcarenites at Umkwelane and Uloa as Miocene led him further to postulate that there could be no natural correlation between the erosional features of the hinterland with the Tertiary series of the coastal plain (1960, p.263); and finally to deny that seaward tilting had occurred during Tertiary time (1966, p.228).

Dr. Frankel's palaeontological statements in his 1966 paper

Dr. Frankel's statements: "No sediments of Post Cretaceous to Mid-Miocene age are preserved at Uloa", and "On general relationships the mollusca suggest a dating best stated as Mio-Pliocene" contrast with my own palaeontological identifications of over a hundred species of megafossils and Biesiot's identification of fifty-three foraminiferal species, both of which researches led us independently to assign a *lower Miocene* or Burdigalian age to the "*Pecten* bed". Dr. Frankel, however, made statements based upon few, or even solitary, species, with sometimes inadequate comparative and background data.

Example 1: Orbulina universa. Frankel wrote: "The first appearance of *O. universa,* however, in Europe and Victoria, Australia, is in the Middle Miocene." Biesiot's paper (1957) clearly gave a late Oligocene date for this foraminifer in Venezuela, Ecuador, Trinidad and British West Indies.

Example 2: Aequipecten uloa comes from a lower Miocene assemblage. The shells from Upper Miocene and Pliocene in Persia were distinguished by Eames & Cox (1956, p.20) as a separate species *A. pseuduloa.* So no case arises to suggest that the Uloa beds are not lower Miocene.

Example 3: Pecten vasseli. Dr. Frankel is referred to my original record from Uloa (1953) which noted the differences reported by Cox between Miocene and Pliocene forms of this species and referred the Zululand specimens firmly to the Miocene.

Example 4: Frankel wrote: "Davies (1964) determined the age of sharks teeth in the 'Pecten bed' at Uloa and Sapolwana as Middle Miocene".

The entire shark fauna included six species. No statement was made as to why the deposit should be regarded as of middle rather than lower Miocene age, other than a footnote: "According to the shark fauna this could be Middle Miocene rather than Lower Miocene." Enquiry has revealed that this note was inserted at the instance of Dr. Applegate of Los Angeles County Museum, who based the suggestion solely upon the presence of *Carcharodon sulcidens,* the other species present being known as both lower and middle Miocene.

A molluscan population is often more conservative in evolution than are free swimming life forms, and it is not unusual to find a stranger indicative of things to come among a sedentary fauna of older aspect. Not far away in Zululand Aptian type ammonites appear among decidedly Neocomian pelecypods. It was to cover such instances that, many years ago, Dr. Gertrude Elles framed the dictum that new stages should be defined by the incoming of new fossil forms *in abundance.* This is why it is so necessary to look at faunas as wholes, and not confine attention to a few arbitrarily chosen forms.

There is nothing in the quoted examples nor in the other similar instances that Dr. Frankel adduced. that would require anyone to depart from the original diagnosis of a lower Miocene age for the Pecten Bed at Uloa which was arrived at independently in their respective spheres by King (1953) and by Biesiot (1957). Certainly there is no justification for the statement: "from the palaeontological evidence available the age of the '*Pecten* Bed' is now considered to be younger Miocene rather than middle Miocene".

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22nd October, 1968.

SIR,–The study of the basal part of the Tertiary at Uloa was made so that a review of the systematic palaeontology of some of the rocks already described (King, 1953; Biesiot, 1957), together with detailed lithology and stratigraphy (Frankel, 1966) would provide a basis for correlation of the many scattered outliers of Tertiary sediments in Zululand. This seemed essential because there was already a disagreement on age determinations from micropalaeontology and consequently of stratigraphical correlation of outliers in the confines of the Lower Umfolosi River valley.

But equally important, geological observations were needed to test the validity of geomorphological theories bearing on the character of the post-Cretaceous erosion surface on which the Tertiary deposits rest and the correlation of this surface and disconformity planes within the Tertiary sequence with inland erosion surfaces at considerably higher altitudes. These theories were:-

(1) that a rising coupled pair of Tertiary landsurfaces from the coast of Natal and Zululand to the interior where it is said to flatten out at near 6,000 feet (King & King, 1959, p.21, 24; King, 1967, p.246) represents the continuations of unconformities within sediments at the coast, and

(2) a contrasting concept also put forward by King (1960, p.254) and again in his present letter, that two Tertiary surfaces rise westward at 80 to 90 feet and at 9 feet to the mile. This must result in an ever-increasing vertical interval between them–at least for some considerable distance to the west.

Because of the very slight slope of the planed basalt surface and the gentle dip of the overlying Cretaceous and younger sediments in the Lower Umfolosi River valley, I could not see how the unconformities that Professor King recognized could be projected westward to join up with specific erosion surfaces inland (Frankel, 1960, p.249). I could not support his thesis of a steep rise of the erosional surface below the Miocene in a score or so of miles to a hinterland plateau at 1,500 to 2,000 feet (King, 1953, p.66) nor that "mighty upwarping with strong seaward tilting" was responsible for this attitude of the early Tertiary landscape (King & King, 1959, p.29).

At Uloa there is a clear unconformity between the marine Cretaceous and the overlying Tertiary sediments, but there is an intraformational disconformity between the "*Pecten* Bed" and the overlying calcarenite succession that rivals the excellent example of Dunbar & Rodgers (1957, p.120). About one mile to the east at Sapolwana Hill this disconformity is even more clearly visible. Here there is no (angular) unconformity between

these units in the Tertiary sequence. From a stratigraphical point of view this suggests no very great time interval between the deposition of the "*Pecten* Bed" and the overlying sediments. The micropalaeontology of these overlying calcarenites suggests Late Miocene to early Pliocene age (Frankel, in press).

The slight variations in dip of the surface cut across the Cretaceous seen in the railway cutting, that are referred to by Professor King, are local undulations–and can even be observed in the short width of outcrop displayed in Plate VIII of my paper.

The lithological character of the "*Pecten* Bed" (Frankel, 1966) and the altitudes at which it, and outcrops of the underlying Cretaceous sediments, lie on the Zululand Coastal Plain suggest that it could never have had any great thickness. In the only places on the coast where bores have revealed the depth of the top of the planed Cretaceous, it is only a few tens of feet below sea level. These bores are located to the north of St. Lucia, but the depth of the top of the planed Cretaceous at St. Lucia cannot be expected to be different. On the basis of the above evidence a previously estimated fall of about 25 feet to the mile for this planed surface eastwards of Uloa on which the "*Pecten* Bed" rests, has been revised. The slope is probably of the same order as that of the surface cut across the Cretaceous from Umkwelane Hill to Uloa that continues as a *disconformity within the Tertiary sequence above the "Pecten Bed" eastward–i.e.9 feet* to the mile (Frankel, in press).

When a cross section from the inland plateau near Hlabisa eastward to the ocean is drawn to scale using the most reliable topographic data available and the geological relationships included thereon (Fig.1), a projected upward slope of 80 to 90 feet per mile inland from Uloa just does not afford the link that Professor King illustrates in his figure 1. Moreover, 6 miles east of Uloa where the "*Pecten* Bed" crops out at the newest locality known, it would have a vertical thickness of about 480 feet if it rests on the 80 to 90 feet per mile slope of Professor King's diagram. The proximity of Cretaceous rocks near sea level along strike to the north, and borehole data from coastal Northern Zululand, also suggest that the thickness of the Tertiary at this point is considerably less.

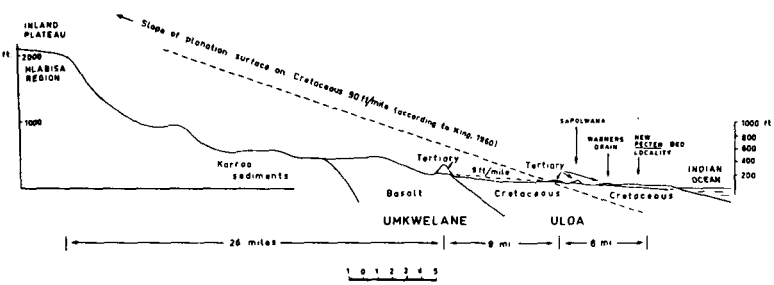

FIG.1.–Cross section from the inland plateau to the Zululand coast in the east showing stratigraphical relationships between the Tertiary and older formations. (5 miles = 8 km).

While Professor King's correlation of unconformities in the marine Tertiary with erosion surfaces inland in his present letter is in accordance with the general views which he has stated elsewhere (King, 1953; King & King, 1959), the palaeontological evidence he has given up to the present time does not support the degree of precision in dating which his correlations imply. Kent (1967) has cast doubt on the validity of this sort of correlation based entirely on physiographical grounds, by suggesting that the ages of the land surfaces in east Central Africa should be reassessed.

Turning to palaeontological matters. Professor St. Jean accepted both King's and Biesiot's age of Lower Miocene for the Uloa "*Pecten* Bed" at the time that he examined many assemblages from the sediments of Umkwelane Hill to the West (identifying many species more than the ten claimed by King), and because of similarity in species and conspecific forms, suggested an age correlation with the basal Tertiary sediments at Uloa then regarded as Burdigalian.

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The amount of detailed systematic palaeontological description by King and Biesiot is recognized, but there can be disagreement over their identifications and interpretation. This became apparent when a number of specialist palaeontologists whose assistance so kindly given, and who are acknowledged in my paper, reviewed the palaeontology as published by King and Biesiot and believe that their datings require some revision.

In the selection of species taken for comment, the palaeontologists concerned most certainly examined "comparative and background data". I reply to Professor King's points:-

(1) *Orbulina universa.* Research carried out since Biesiot's work was done suggests that the presence of *Orbulina universa* in the Uloa sediments is post-Burdigalian (*e.g.* Glaessner, 1959, p.57). The observations by Carter particularly for Eastern Australia, and those by Glaessner of the Indo-Pacific region seem better to fit the Uloa occurrence which also lies within the Indo-Pacific region. The appearance of *O. universa* in the Burdigalian rocks of the tropical and Tethyan provinces has been recorded by many authors, but its appearance generally in temperate regions seems to have been a little later (see also Closs, 1966). The character of the Uloa megafauna, the total absence of hermatypic corals and of larger foraminifera from the limestone suggest that it was formed in a temperate region.

Professor King has not referred to the *Amusium*-bearing blocks in the nodule bed which underlies the "*Pecten* Bed". *Orbulina universa* has not been found in these older *Amusium*-bearing blocks but *O. suturalis* is present, and is regarded as lowermost Middle Miocene in age.

(2) The abundant presence of *Aequipecten uloa* indicates only that it occurs in an assemblage that contains *A. uloa.* In the opinion of Dr. C. A. Fleming (written communication 14th June 1965) any time restriction (as an index fossil) has yet to be demonstrated, and the upper Miocene and Pliocene *A. pseuduloa* is distinguished from *A. uloa* on minor differences only.

King (1953) did not record *A. uloa* from any locality other than the Uloa area and the south side of Hell's Gate about 30 miles to the NNE (King, 1966, p.208), and therefore it is of no value in inter-regional correlation and dating.

(3) The valves that Professor King has referred to an ancestral form of *Pecten vasseli* are worn and have lost the byssal notch which is diagnostic of the genus *Minnivola.* Better preserved specimens have been described as a new species *Minnivola sapolwanaensis* (Carter, 1966).

(4) In the late Dr. Davies' paper (1964) on the sharks' teeth, he was in fact studying a fauna whose age had already been commented upon by King. In a footnote to the first sentence of his paper he immediately wished his readers to understand that he regarded a Middle Miocene age for the fauna at least as probable as a Lower Miocene. Again on page 15 Davies referred the deposit to the Middle Miocene.

Professor G. M. Philip of the University of New England who is studying some of the echinoids from the "*Pecten* Bed" at Uloa and Sapolwana, has supplied some preliminary information (written communication 4th November, 1968): "Three species of echinoid are represented in the collection, *viz. Brissus* sp., *Clypeaster* sp. and *Echinolampas* cf. *woodae* Currie. Although the genera concerned range through most of the Cainozoic, the species suggest a late Miocene or Pliocene age. *Echinolampas woodae* was described for the Pliocene of Kenya and the species of *Clypeaster* and *Brissus* resemble most closely late Miocene forms from the Persian Gulf."

I would refer Professor King once more to his own statement (King, 1953, p.62), "there are few parts of the world where so high a proportion of species is common to Lower Miocene deposits and to modern seas", and later (*ibid*, p.64) "In the mollusca . . . the relative abundance of living species . . . seems rather high for an early Miocene deposit". Palaeontologists normally accept such a circumstance as indicating a younger age.

Contrary to Professor King's belief that a revision of his original diagnosis of a Lower Miocene age for the "*Pecten* Bed" is not required or justified, the palaeontological examples that I gave and the additional data now available underline the need for the revision. It is this revision that brings better accord between palaeontological

datings, lithology, structure and geomorphological aspects in the correlation of Tertiary strata in the Lower Umfolosi Valley (Frankel, in press).

Professor King prefers to read "no severe warping" as a denial by me of seaward tilting during Tertiary times; however, I still maintain that the nearly flat-lying nature of the sediments suggests no marked upwarping. Finally, it may be of interest to record that McCarthy (1967, p.161) and Maud (1968), on the basis of detailed studies of the Tertiary and younger rocks along part of the Natal coast have also concluded that no significant transverse coastal warping has occurred in that region since late Tertiary times.

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