LATE CRETACEOUS-EARLY PALEOGENE STRATIGRAPHIC SEQUENCE IN MARLBOROUGH AND POSSIBLE OFFSHORE SEISMIC EQUIVALENTS

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Stratigraphic and biostratigraphic investigations of Amuri Limestone Group and associated rocks constituting the Late Cretaceous-Early Paleogene succession of the Clarence River valley, Marlborough, New Zealand, have demonstrated a major, intra-Amuri, low-angle unconformity beneath the Teredo Limestone. Regional truncation of older portions of the Amuri, as recognised by fauna and lithology, is the primary evidence for this break.

The unconformity provides a key for clarifying regional stratigraphic relationships. It can be traced southwards at least into the Haumurian Stage stratotype area, with the implication of a comparatively incomplete Haumurian stratotype. It is possibly recognisable at Waipara River, in North Canterbury. Offshore, it is correlated with a major seismic reflector within the fine-grained clastic sections in Canterbury Basin wells, and associated with predominantly chalk sections in the southeast Great South Basin.

Paleontological evidence suggests that the unconformity and associated sediments probably reflect the major late mid Paleocene eustatic sea-level fall and rise of the Haq, *et al.* 2.1 cycle of their TA2 sequence.

INTRODUCTION

This report is based mainly on stratigraphic and biostratigraphic studies of the Amuri Limestone and related rocks in the Clarence River valley of Marlborough. Observations of correlative rocks elsewhere in Marlborough, in North Canterbury, and in offshore seismic profiles indicate that a major intra-Amuri unconformity observed in the Clarence valley extends regionally, and forms a fundamental part of the stratigraphic pattern throughout much of the east coast of the South Island. Stratigraphic investigations often tend to focus on the preserved depositional record, but failure to consider effects of non-deposition and differential erosion on this record can tend to obscure important relationships and lead to misinterpretations.

Within the Clarence valley, Late Cretaceous and Paleogene strata crop out along strike for more than 50 km (Lensen, 1962). In the northern valley, they form a long strike ridge west of the Clarence River. To the south, the sequence is also exposed on the limbs of three tight synclines east of the main strike ridge. Transverse streams, draining into the Clarence at intervals of five to ten kilometres, provide well exposed sections for study, although waterfalls hinder access to some sections. Because of the excellent exposures available, the Clarence valley has become a classic area for stratigraphic studies (e.g. Webb, 1971; Morris, 1987).

Sections exposed along Mead, Branch, Dart, Muzzle, Bluff, and Seymour Streams, (Fig. 1) are especially important in displaying critical stratigraphic relationships, and are discussed later in this paper.

BIOSTRATIGRAPHY

In the Amuri Limestone, biostratigraphic control is vital for recognising stratigraphic relationships due to homogeneous, repetitive, and often non-distinctive lithologies. Foraminifera, which are generally common to abundant, provide age control throughout the succession. Calcareous nannofossils (determined by A. R. Edwards) proved very useful in refining the age of strata overlying the unconformity.

Taxonomic description of the fauna in the Amuri Limestone and related rocks is beyond the scope of this paper. In essence, four main faunal assemblages are critical for identifying physical stratigraphic relationships. These are:

1. Haumurian (Maastrichtian) assemblage: Contains abundant, diverse faunas of numerous planktic and benthic taxa. Common benthics include *Bolivinoides draco dorreeni*, *Gaudryina healyi*, *Notoplanulina rakauroana*, *Dorothia elongata*, and *Gyroidinoides globosus*. *Rugoglobigerina rugosa*, *Globigerinelloides volutus*, *Heterohelix globulosa* and *Globotruncana circumnodifer* are the main planktic taxa; stratigraphically high assemblages also contain the Late Maastrichtian index planktic, *Abathomphalus mayaroensis*. Representative samples: O30/f76, f160, f165, f172.

2. Early Teurian (Early Paleocene) assemblage: Relatively sparse faunas appearing just above the Cretaceous-Tertiary boundary. *Gaudryina whangaia*, *Conotrochammina whangaia*, *Bolivinopsis compta*, *Dorothia biformis* and *Anomalinoides piripaua* are typical benthics, while planktics

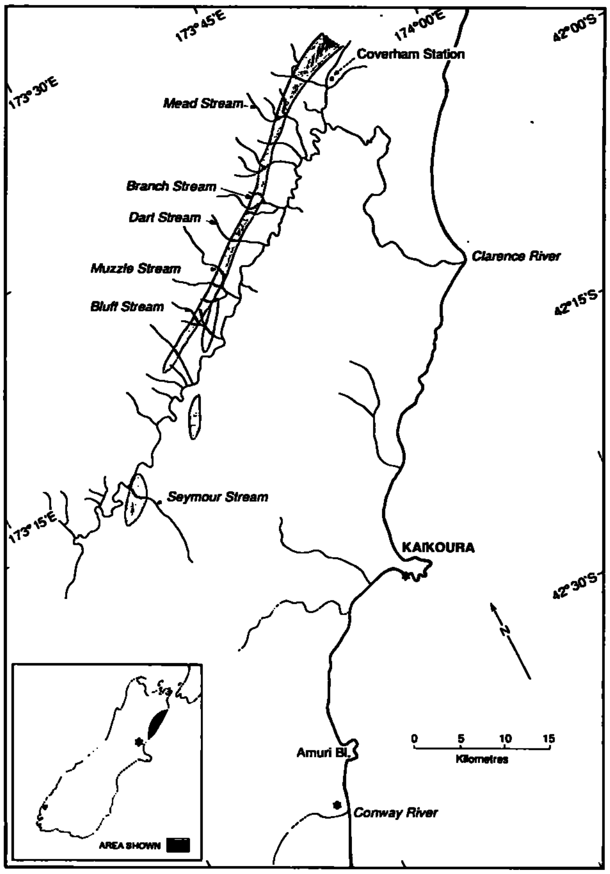

Fig. 1: Locality map. Stipple pattern shows distribution of Amuri Limestone and related units in Clarence River valley. Stars indicate localities cited outside of Clarence valley; Waipara River locality shown on inset.

include the early Paleocene forms *Globoconusa daubjergensis* and *Globigerina triloculinoides*, with *Chiloguembelina* spp. Rocks containing this fauna are overlain by many tens of metres of additional lower to middle Teurian rocks. Representative samples: O30/f171, P30/f331, f332.

3. Late Teurian (Late Paleocene) assemblage: Contains moderately abundant foraminifera, dominated by planktic taxa. Benthic taxa include *Gavelinella beccariiformis*, and apparent *Conotrochammina whangaia* -*C. depressa* transitional forms. Planktics include *Pseudogloboquadrina primitiva* and *Acarinina* spp. Associated calcareous nannoplankton, which provide greater resolution in this part of the column, indicate a late Middle Paleocene age for this assemblage (A.R. Edwards, pers. com.). Typically the assemblage is succeeded stratigraphically within a few metres by Waipawan forms of the next assemblage. Representative sample: O30/f218.

4. Waipawan (Early Eocene) assemblage: Contains abundant faunas dominated by planktic species, mainly *Acarinina soldadoensis* and *A. mckannai*, with minor *Planorotalites australiformis*, and *Chiloguembelina* spp. Benthics include *Anomalinoides orbiculus* and the mid-bathyal indicator *Tritaxilina zealandica*. Representative sample: O30/f219.

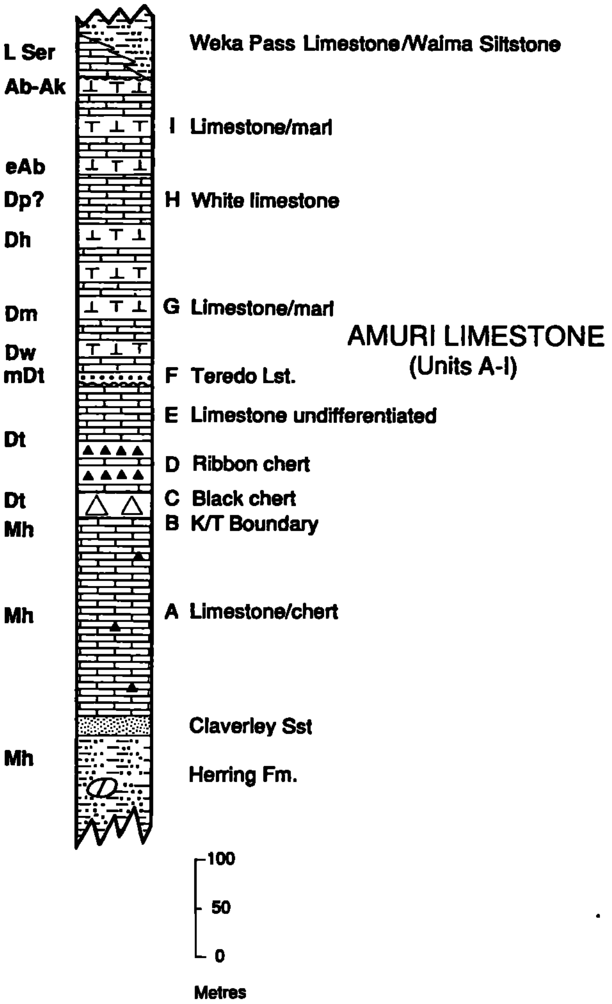

Fig. 2: Composite stratigraphic column, Clarence River valley. Maximum thicknesses shown.

LITHOSTRATIGRAPHY

The Late Cretaceous-Paleogene succession in the Clarence valley (Fig 2 and Table 1) comprises, from its base, Herring Formation (with basal Paton Sandstone), Claverley Sandstone and Amuri Limestone. The succession rests unconformably on older Cretaceous rocks, and is overlain unconformably by the Weka Pass Limestone/Waima Siltstone of Landon (Oligocene) age.

The Amuri Limestone is subdivided here into informal units on the basis of both faunal content and lithology. Although formal subdivision is unnecessary in this report, Morris (1987) in a recent major study of Amuri Limestone in Marlborough, assigned limestones and other intercalated lithologies of Haumurian through Arnold Series (Maastrichtian-Late Eocene) age to six formations and five members within the Amuri Limestone Group.

It is important to note that Fig. 2 and Table 1 represent the *composite* sequence for the valley, and that units shown may or may not be present within a specific section. Tracing their distribution is important for establishing stratigraphic relationships in the Clarence valley.

The Chalk Range Fault, a major high-angle fault east of and sub-parallel to the Amuri strike ridge, progressively deletes Herring Formation, Claverley Sandstone, and lower units of

Weka Pass Limestone/Waima Siltstone (Landon Series; Oligocene)

Unconformity

Amuri Group (Mh-Ab-?Ak*; Maastrichtian-Late Eocene): Limestone, flint, and marl, maximum thickness 600+ m. Combined lithological and foraminiferal data allow delineation within the Amuri of Units A-I below:

I. Limestone/marl (Ab-?Ak; M. to L. Eocene): metre-scale alternating grey-green limestone and marl, ca. 100 m.

H. White limestone (Dp; M. Eocene): Distinctive unit of brilliant white, evenly centimetre-bedded limestone, ca. 50 m.

G. Limestone/marl (Dw-Dh; E. to M. Eocene): Grey-green, trace-fossil rich hard limestone and soft grey-green marl, ca. 150 m.

F. Teredo Limestone (late-mid Dt; L. Paleocene). Glauconitic calcareous sandstone, 3-5 m thick.

E. Non-distinctive grey limestone (Dt; E. Paleocene): ca. 60 m.

D. Ribbon chert (Dt; E. Paleocene): Ca. 50% grey limestone and 50% black chert, alternating on decimetre scale. Ca. 50 m thick.

C. Black chert (Dt; E. Paleocene): Rusty weathering, with ca. 75% black chert and minor siltstone/mudstone partings, ca. 25 m thick.

B. Cretaceous-Tertiary boundary.

A. Limestone with nodular flint beds (Mh; Maastrichtian): Grey limestone with flint and dolomite, 20-200 m thick, containing some locally traceable lithologic units.

Claverley Sandstone (Mh; Maastrichtian): Glauconitic sandstone, typically 2-10 m thick.

Herring Fm. (Mh; Maastrichtian): Grey concretionary siltstone, with jarositic weathering and common clastic dykes. 150+ m thick.

*N.Z. Series/Stage Summary. Mata Series: Haumurian Stage (Mh), Maastrichtian. Dannevirke Series: Teurian Stage (Dt), Paleocene; Waipawan (Dw), Mangaorapan (Dm) stages, Early Eocene; Heretaungan (Dh), Porangan (Dp) stages, Middle Eocene. Arnold Series: Bortonian Stage (Ab), Middle Eocene; Kaitan (Ak), Runangan (Ar) stages, Late Eocene.

Table 1: Summary of Clarence River valley Late Cretaceous-Early Paleogene lithostratigraphy.

the Amuri Limestone north of Branch Stream, so that at Swale Stream, the first major stream north of Mead Stream, Ngaterian (Cenomanian) siltstone is in fault contact with (approximately) the Cretaceous-Tertiary boundary.

The Teredo Limestone, with its associated pattern of sometimes subtle differential truncation, is the key unit of the succession. It lies unconformably on older beds, whose geographic distribution is determined by pre-Teredo degradation. The Teredo is not recorded north of Dart Stream, and the sub-Teredo unconformity is either obscure or absent in sections at Branch and Mead Streams. A possible Teredo equivalent has, however, been recognised at Mead Stream.

The overall succession thins southward, in part due to the increasing intra-Amuri hiatus, and in part due to lower nett deposition. Essentially, there are two types of Amuri successions, their boundary falling between Branch and Dart Streams. To the north of the boundary, the Amuri contains comparatively thick and complete sequences, and to the south, thinner, less complete sequences.

DISCUSSION OF STREAM SECTIONS

Mead Stream

The sequence along Mead Stream is easily accessible and well exposed. It offers the thickest and overall the most complete Amuri Limestone sequence, although the Chalk Range Fault cuts out the Herring Formation and Claverley Sandstone, plus an unknown amount of basal Amuri. At Mead Stream, the Amuri is in fault contact with Clarence Series (Mid-Cretaceous) interbedded sandstones and siltstones.

The Cretaceous-Tertiary boundary, the first distinctive marker unit, occurs about 175 m above the base of the section, and it is followed by a thick Paleocene succession (Plate 1). Teredo Limestone is not recognised here, but its stratigraphic position is probably occupied by a distinctive, 2 m thick, petroliferous, black siltstone with a basal grit of residual chert, a conclusion reached independently by J. Morris (1987). Approximately 100 m of strata, represented by units C,D, and E (cf. Fig. 2), lie between the black siltstone and the Cretaceous-Tertiary boundary.

Branch Stream

Two closely-spaced sections are well exposed along the main and middle forks of Branch Stream, but access is difficult due to waterfalls.

The sections are important because they are the northernmost containing the Herring and Claverley Formations between the Amuri and the Chalk Range Fault, and the southernmost containing the Cretaceous-Tertiary boundary and overlying lower Teurian beds (with the exception of poor exposures along Whisky Stream, 1 km south). Neither Teredo Limestone, nor its possible equivalent, a black siltstone were observed, and the position of the stratigraphic break is obscure. Units C and D (Fig. 2) are present, but it is likely that unit E is either very thin or absent.

The late Maastrichtian index foraminifer, *Abathomphalus mayaroensis*, occurs in a sample 3 m below the Cretaceous-Tertiary boundary.

Dart and Muzzle Streams

These streams, separated by about 5 km, display a similar stratigraphy. The marked difference in thickness and stratigraphic continuity between these sections and the one at Branch Stream and others farther north suggests presence of a fundamental and persistent geological feature, perhaps a hinge line or a fault, in this area.

Teredo Limestone, dated as late Teurian by foraminifera and late middle Teurian by calcareous nannofossils, (A. R. Edwards, pers. com.) has its northernmost occurrence at Dart Stream (Morris, 1987), where it rests unconformably on Haumurian limestone of Unit A. This relationship is better shown by exposures at Muzzle Stream (Plate 2). Pre-Teredo degradation has cut below the Cretaceous-Tertiary boundary, removing units B-E.

Haumurian limestone, Unit A, is only about one third as thick (ca. 40 m) as at Branch Stream. Biostratigraphic evidence (apparent absence of *Abathomphalus mayaroensis*) and location of Teredo Limestone relative to marker horizons within Unit A indicates that approximately 20 m of unit A was removed by pre-Teredo erosion; the remainder of the thinning is considered to be a primary sedimentary feature.

Amuri Limestone overlying the Teredo (Units G-I) is approximately half as thick as at Branch Stream, but a complete sequence of post-Teredo units is recognised, both paleontologically and lithologically (Morris, 1987).

Bluff Stream

This section (Plate 3) demonstrates continued thinning of Unit A from 45 m down to 12 m, with marker horizons indicating that approximately half represents truncation, and the remainder primary thinning. Apparent truncation rate between Muzzle and Bluff streams is about 1.6 m/km. Overall thickness of the post-Teredo sequence is little changed from the Dart/Muzzle sections.

Seymour Stream

The trend for southward-increasing truncation continues (Fig. 3), and Teredo Limestone rests directly on Herring Fm. Overall thickness of the upper Amuri has decreased to about 90 m (Morris, 1986), with paleontological evidence indicating that this is due to lower nett depostion rates, as ages range from Teurian-Waipawan at the base of the sequence up to Bortonian-Kaiatan at the top.

SOUTHERN MARLBOROUGH AND CANTERBURY

Observations based on limited field work and, in some cases, examination of critical samples, indicate that patterns displayed in Clarence River valley can be traced at least into southern Marlborough, and probably beyond.

On the south side of Kaikoura Peninsula, a section exposed near the boat-launching ramp contains Herring and Claverley Formations, overlain by ca. 15 m of Haumurian (Unit A) limestone, which is overlain in turn by Teredo Limestone. The clearly unconformable contact is marked by borings penetrating several cm into the Haumurian, and a basal lag conglomerate with chert, phosphatic pebbles and sharks' teeth.

Near the mouth of the Conway River, 25 km farther south and only about 5km from the Haumurian stratotype at Haumuri Bluff, exposures in a railway cutting span from Herring equivalent into lower Amuri Limestone. Claverley Sandstone, and the overlying Haumurian limestone (as seen at Kaikoura), are missing, and a relatively thick (8 m), Teredo Limestone sequence, containing late Teurian-Waipawan calcareous nannofossils (Waghorn, 1978), directly overlies Herring Formation. The nannofossil localities were later observed by one of us (CPS) to extend for about 6 m below the 2 m bed traditionally called *Teredo Limestone*. Relationships observed here suggest that the Haumurian stratotype just to the north may be *topless*. Present results shed light on problems which Warren and Speden (1977) noted in the upper part of the stratotype section and support their general conclusion that the Haumuri Bluff section leaves much to be desired as a stratotype.

At the classic Waipara River section of North Canterbury (Wilson, 1963; Jenkins, 1971), about 100 km farther south, preservation of late Cretaceous-Paleogene strata increases. The terrigenous succession there has a clearly defined Cretaceous-Tertiary boundary (Strong, 1984), which is overlain by ca. 100 m of Paleocene rocks comprising Birch Siltstone and Waipara Greensand. Based on limited observations, it seems possible that the equivalent of the pre-Teredo unconformity may be represented by a sudden, sharp lithologic change within the Waipara Greensand, from drab greensands in the lower part of the unit, to more strongly coloured, cross-bedded greensand in the upper.

OFFSHORE SEISMIC SEQUENCES

Unconformable stratal relationships within the Paleocene section have been recognised seismicly, both in offshore Canterbury, immediately southeast of the study area (Field *et al.*, 1989) and some 700 km to the south in the eastern Great South Basin (Anderton *et al.*, 1982). In offshore Canterbury wells (all south of Banks Peninsula), the latest Cretaceous and Paleocene section is predominantly clastic sediments, with some glauconite component, not dissimilar to the Waipara River section. The prominent seismic reflector (orange horizon of BP Shell Todd, 1984) is dated as late Teurian in Resolution-1 and Clipper-1, and correlates with volcanic activity in some parts of offshore Canterbury.

The gross lithostratigraphy of the southeastern Great South Basin resembles more closely the Clarence River sections, with chalk predominant in the early Cenozoic of Hoiho-1C and Pukaki-1 (Cook and Beggs, 1989). Anderton *et al.*, (1982) seismicly mapped a wide area of late Paleocene truncation within carbonate-dominated section, extending to about 170° East at 48° 30' South.

CORRELATION WITH HAQ et al., SEA LEVEL CURVES

Eustatic sea level curves of Haq *et al.* (1987), and the concepts of sequence stratigraphy on which they are based, were developed through study of dominantly terrigenous stratal successions. Their lithological expression in the largely endogenous, deep-water limestone sequences of Marlborough is as yet poorly understood. Present work suggests the likelihood that only major sea-level fluctuations will be

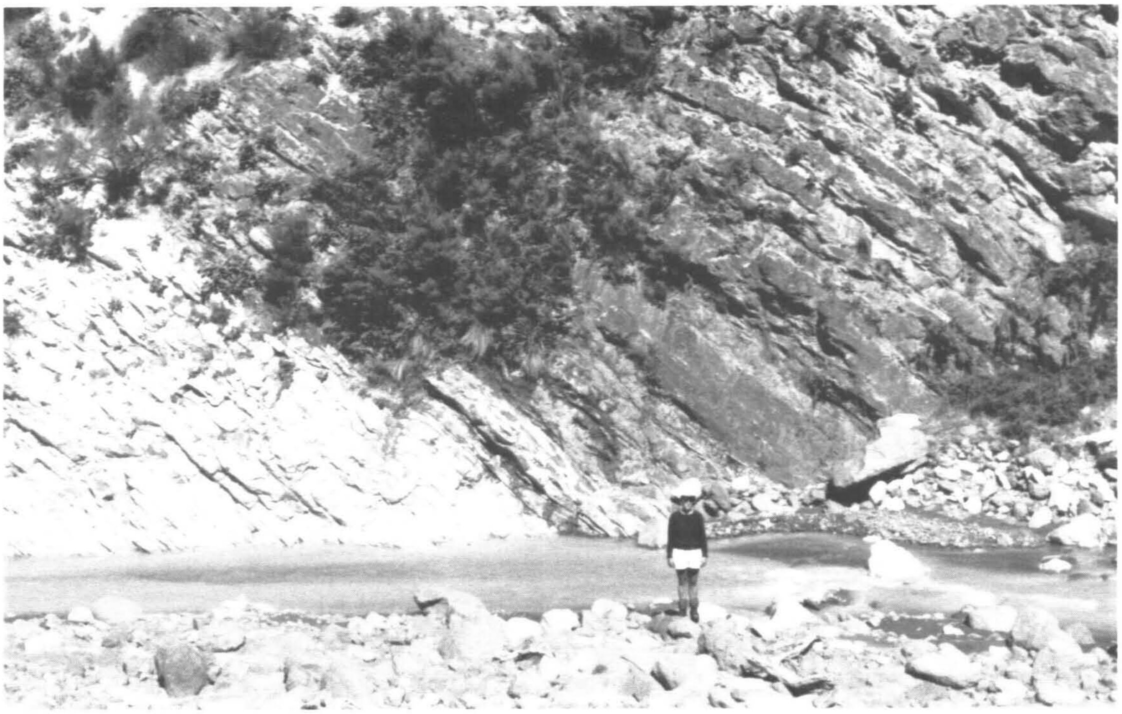

Plate 1: Haumurian Limestone, Cretaceous-Tertiary boundary, and black chert (Units A-C), Mead Stream section. Cretaceous-Tertiary boundary at change in bedding thickness, just to left of figure.

Plate 2: Haumurian Limestone and Teredo Limestone (Units A and F), Muzzle Stream. Teredo Limestone forms slight ridge, extreme right. Arrows indicate two clefts, formed by soft marl marker beds, just left of centre.

Plate 3: Haumurian Limestone and Teredo Limestone (Units A and F), Bluff Stream. Compare with Plate 2. Only lower marl marker bed (shown by arrow) is present, indicating amount of pre-Teredo truncation between Bluff and Muzzle Streams (7.5 km).

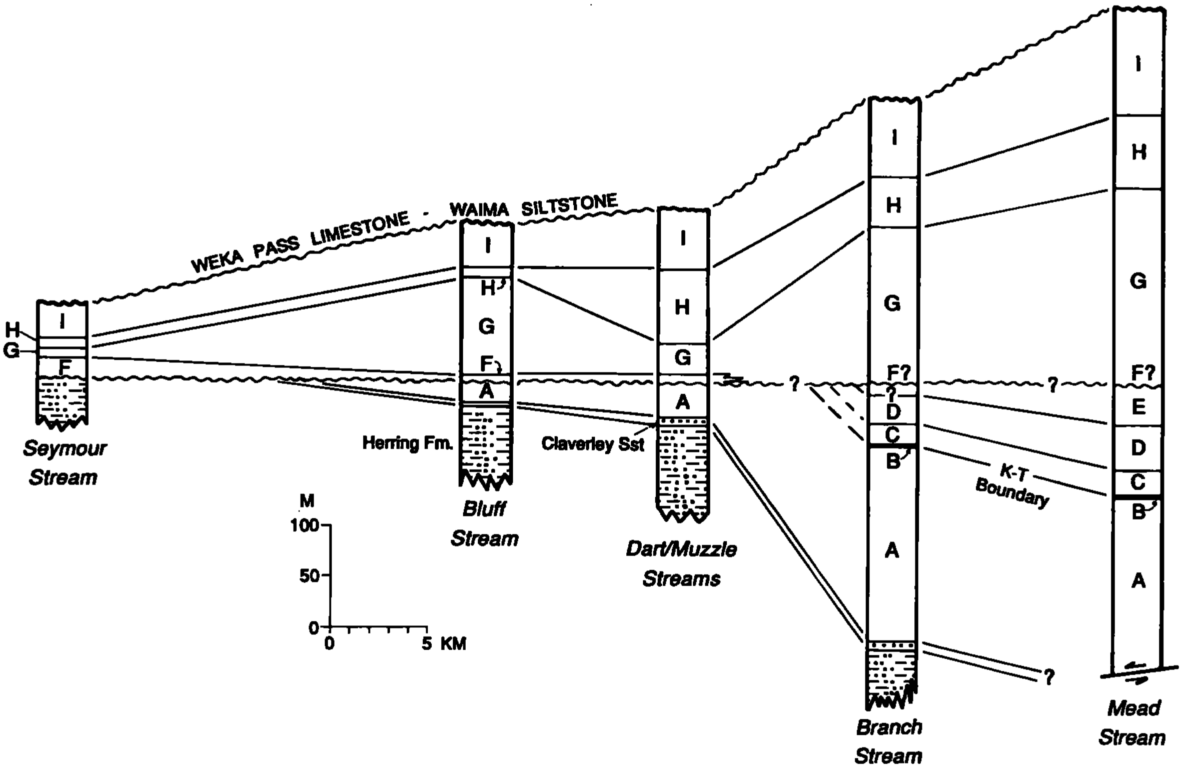

Fig. 3: Summary of Amuri Limestone stratigraphic relationships, Clarence River valley. See Table 1 and Fig. 2 for description of units.

decipherably recorded lithologically, with suitable conditions of shelf setting, low subsidence rates and clastic sediment starvation. Detailed faunal studies may also allow detection of some minor shifts.

Lower Amuri Limestone stratigraphic relationships in the Clarence River valley, as evidenced by major regional truncation beneath Teredo Limestone, and the paleontological ages and paleoenvironments determined for this event correlate well with the major eustatic sea level fall, followed by a major rise, of cycle 2.1 of the Haq *et al.* (1987) TA2 sequence. This is the largest Paleocene sea-level excursion, and the one most likely to be observable in the Clarence River succession. Associated faunas, from the Teredo Limestone and overlying beds, indicate a rapid environmental change from outer shelf to oceanic-bathyal depths, with no direct evidence of subaerial exposure in onshore sections.

There is some indication that the late Maastrichtian sea level rise and subsequent basal Paleocene fall may also be recognisable. The former is seen in the increasingly pelagic character of the upper ca. 10 m of the Haumurian Limestone; the latter in the shelf aspect displayed by lowermost Teurian assemblages.

ACKNOWLEDGEMENTS

We thank H.E.G. Morgans and G.H. Scott for their constructive review of this paper, and Gael Cuttress for draughting the figures.

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