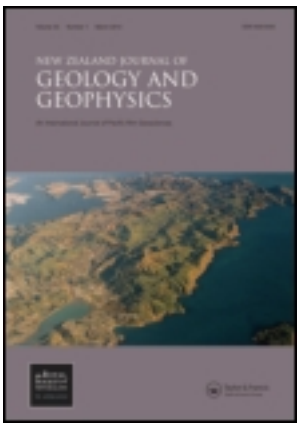

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A proposal for the subdivision of tertiary time in New Zealand

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A PROPOSAL FOR THE SUBDIVISION OF TERTIARY TIME IN NEW ZEALAND

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The leading idea which is present in all our researches, and which accompanies every fresh observation, the sound to which the ear of the student of Nature seems continually echoed in every part of her works, is—
Time! — Time! — Time!
George Poulett Scrope

ABSTRACT

It is suggested that homotaxial biostratigraphic units are an unsuitable basis for the definition of a New Zealand Tertiary geological time scale. Three other possible ways of setting up a time scale are discussed, and it is concluded that stratigraphic marker pegs offer the best basis for a rigorously defined time scale. In order to avoid the disadvantages of a hierarchical system of naming it is further suggested that the primary names in a time scale be attached to the pegs, and not to the intervals between them. Possible objections to the use of named marker pegs as the basis for a time scale are discussed in some detail. An appendix contains points for further discussion, and some specific recommendations on the implementation of a stratigraphic marker peg scheme for New Zealand Tertiary events.

INTRODUCTION

It is seldom that the isolated position of New Zealand in the south-west Pacific brings with it academic advantage, yet from the point of view of discussions on stratigraphic classification our isolation is indeed advantageous. As occupants of a small island country, we are able to discuss the adoption of this or that stratigraphic philosophy without concerning ourselves as to the activities of our immediate neighbours.

It is the purpose of this paper to develop a particular line of thought, not in itself original, in the hope that the technique recommended will aid in the practical solution of problems presently facing New Zealand Tertiary stratigraphers. I personally believe, as do Hughes *et al.* (1967), that the approach recommended here is valid for the division of the whole of geological time on a global scale. Yet such an opinion would carry immensely more weight if the approach could be shown to work in a specific example; in the well documented stratigraphic column of the New Zealand Tertiary we have an ideal testing ground.

HISTORY

New Zealand stratigraphers are fortunate in their possession of a fossiliferous Tertiary rock column subdivided into a satisfactory set of working stratigraphic units termed stages*. This set of stages was introduced by Thomson in 1916, thoughtfully discussed by Allan (1933), and expanded and placed on a sound (if pragmatic) formal basis by Finlay and Marwick (1940, 1947). Historical details of this "evolution" of New Zealand Tertiary stage concepts can be found in a paper by Hornibrook (1965). However, the thought provoking papers by Scott (1960, 1965a) and Gage (1966) reflect an increasing concern among New Zealand Tertiary stratigraphers and palaeontologists about the philosophical basis of their current stratigraphic practices.

The problem confronting us appears to be this: although we have inherited a series of units *termed* stages (and hence ideally meant to be true time-stratigraphic units), these units are in fact recognised solely on fossil criteria (and are hence actually biostratigraphic units). Therefore we do not have an objective, fully operational *time* scale against which Tertiary events may be placed. Although Scott (1965a) has discussed the relationship between time- and biostratigraphy and concluded that, further to their biological content, New Zealand Tertiary stages possess the attribute of homotaxial stratigraphic position, it is clear that such an attribute does little to make the system more satisfactory for use as a time scale.

Lack of a precisely defined time-scale leads to practical difficulty when one is dealing with new observations concerning animals other than those that were originally used to define the "stages". This aspect of the problem has been stated with admirable clarity by Hornibrook, both in his 1965 paper and in his contribution to the Stage Symposium held in Christchurch (December 1968). Any fossil organism may be used to define a zone, and from a biological point of view we are critically interested in the zonal distributions of all fossil animals. But our present "stage" system is based primarily on Foraminiferida, and secondarily on Mollusca; how are we to fit into this the recent work of, for example, Mr A. R. Edwards on nannoplankton? The answer, of course, is that so long as we lack *a conceptually independent time scale* to which any and every zonal scheme may be related, so long will we continually encounter the problems that go with "forcing" new biostratigraphic data into a set of arbitrary but preconceived pigeonholes. Past time was a continuum—not a set of pigeonholes, and adoption of the approach recommended in this paper would both emphasise this fact, and help to solve many of our present problems.

*Wherever the unqualified term "stage" is used in this paper, the term refers to stages as generally *used* for classifying New Zealand Tertiary rocks. When the term "stage (international usage)" appears, a stage as defined in the International Code of Stratigraphic Nomenclature is meant (i.e., a true time-stratigraphic unit).

POSSIBLE WAYS OF SETTING UP A TERTIARY TIME SCALE

The facile assumption is all too often made that the subdivision of geologic time is the province of the stratigrapher alone. In fact the subdivision of geologic time is a matter of major concern to any scientist concerned with the time distribution of "events" of any kind and perhaps especially to those (biologists rather than geologists) who are attempting to reconstruct *in toto* the course of changes in the earth's biosphere through time. It must therefore be clearly appreciated that we are no longer involved in attempting to set up a time-rock stratigraphic framework for the palaeontological servicing of field geologists' samples. Such a framework has already been attained and has served an extremely valuable role over the last 30 years, but its deficiencies are daily becoming more obvious. What we are, or should be, involved in is the setting up of a conceptual time framework to which all students of the earth's history (including stratigraphers, structural geologists, systematists and biologists) will be able to unambiguously relate their various data. To date, three possible ways of achieving such a time scale have been suggested:

1. A time scale based on circumscribed rock units in type sections

This solution commends itself most readily to those who would wish to retain as much as possible of the conceptual framework of time-rock (i.e., stage) stratigraphy; for that reason it is the most open to criticism.

Proponents of this view would suggest that for each stage currently recognised in the New Zealand Tertiary we define a type or standard locality. At this locality would be further defined a basal stratum and an upper stratum; then by definition, the new Age would be that period of time represented by the rock between these two stratal levels, including any unconformities or diastems within the interval.

This type of basis for a *time* scale is so open to criticism that it is difficult to know where to begin. However, it is doubtful if many people today subscribe to the view, so rather than attack a paper tiger we will note only the most obvious objection. That objection is that it is manifestly impossible to catalogue a succession of so defined stratotypes (even though they may be demonstrably homotaxial) and be *sure* that between them they cover *all of past time without either gaps or overlaps.*

2. A time scale based on type formations

The attractive analogy between principles of classification in biology and stratigraphy was first argued by Fleming (1953). Fleming not only gave a concise statement of the philosophical concept involved, but also provided a practical demonstration of its actual application in his mapping, collecting of fossils, and interpreting of sedimentary formations in the Wanganui area. It is thus a little disconcerting to find Sylvester-Bradley (1967) espousing similar principles without reference to Fleming's previous example.

Briefly stated, the argument runs thus: for each stage as presently construed let us designate a fossiliferous type horizon that falls within the boundaries of the stage as exposed at the type or standard section. This then becomes the type formation of the new Age, and the name-bearer; the

type formation is central to the concept of the Age in the same way that the holotype is related to the concept of the biological species. Hence, it provides an objective reference to the fauna of the Age, but in no way defines the boundaries of the Age in time.

There is no doubt that this approach has a very great deal to commend it, particularly in view of the successful use of the principles involved in the ordering of zoological nomenclature. It is, however, an open admission that the boundaries between stages (as presently conceived and used in New Zealand) are not precisely definable, and hence it is similar in conception to Hornibrook's plea (1965, p. 1199) for the recognition of "buffer zones" between stages. Moreover, such a system of classification as applied to the setting up of a time scale will involve many operational difficulties, among them:

(1) How thick is the type formation to be? It obviously cannot be thicker than the total stage thickness at the type locality, but can it be literally any lesser figure, or ought it to be of an order of magnitude less? (To quote an example of Fleming's from the Wanganui district, the Nukumaruan stage was adjudged to be 1,015 ft thick in the coast section, but was based on the Nukumaru Brown Sand, a formation only 95 ft thick.)

(2) Having decided on a type formation let us insert a conceptual peg at its top and bottom. How now is the Age to be defined? Are we to take only the actual rock crossed by a string between our two conceptual pegs as defining the stratotype of the Age; if so, a microfauna might conceivably be collectable at any horizon within the stratotype, but a macrofauna will certainly not? Alternatively, are we to have a column of rock 6 in., 6 ft or 600 ft wide (assuming the type section to be that wide); if an arbitrary figure such as one of these be selected, what conceivable logical justification can there be for it, and what practical use will such a two- (or three-, even that would have to be decided) dimensional body of rock be *as a definer of points in past time.*

(3) Because we are dealing with a finite thickness of rock, it is only too likely that some future date will see us finding disconformities within the type formation. How are these to be dealt with?

(4) Assuming that we centre our concept of a certain Age (say the Nukumaruan) on a type stratum of a certain thickness (in this case 95 ft), what happens when we wish to split our Age into Subages in the future? Without actually spelling out all the other complications involved, let us note that at the very least we will have to decide whether to retain the original Age name for one of the new Subages, with consequent change of information content of that name.

One could go on: there are many other practical difficulties raised by such a system. I have no doubt that most, if not all, could be met by the phrasing of suitably complicated operational guides, but how much simpler not to engender the difficulties in the first place. All of the above objections stem from the fact that simple definition of objective unambiguous points in the continuum that is past time is not attainable when *thicknesses of strata* are involved in the *definition.* The approach recommended in the next section raises none of the above procedural difficulties.

3. A time scale based on stratigraphic reference points

It has been obvious for some years that a body of opinion is growing that believes a useful geologic time scale can only be set up by the use of objective reference points of one sort or another. Within England this opinion recently crystallised in the publication of the Geological Society Report of Stratigraphic Nomenclature (George *et al.*, 1967). Unfortunately, as with most documents of this nature, the report represents a compromise between the views of many, and hence its clarity of statement is much impaired. Particularly unfortunate is the perpetuation in this report of the classical distinction between time-rock and time terms under the guise of the unnecessary new terms stratomeric and chronomeric. However, the report is valuable in that it strongly makes the point (pp. 81–2) that "divisions of the standard (time) scale should be arbitrarily defined by marker-points alone in standard sections".

For the purposes of discussion in the rest of this paper, it is necessary to comment briefly on what constitutes a marker-point. Variously termed marker-points, reference points, or conceptual golden pegs, Hughes *et al.* (1967) have provided an admirable statement of their nature: "Reference-points in themselves have no characters except location in rock. They serve to divide rock sequences precisely (if arbitrarily) and so give a framework for reporting observations on rock or for any attempted time-correlation between different sequences. This time-correlation is necessarily done by the interpretation of rock-characters from above and below the reference points."

There are obviously a variety of totally objective ways in which such reference points could be defined. For instance, a point could be defined as the first known appearance (on a given date) of a certain fossil taxon (as interpreted on that same date) in a type or standard section. Alternatively, and in my view preferably, a marker point would actually be inserted in a suitable section and, in much the same way that a trig-point serves to define a geographic position relative to a triangulated grid, the reference point so created would serve to define a point in past time with respect to the whole time scale. For ease of transition, such a reference point could be located at the base of a present stage in its type section (in so far as that ideal horizon is known); and tradition would suggest that the point be used to define the beginning of a named period in time, an Age.

It is here that the value and originality of the suggestion of Hughes *et al.* (1967) becomes apparent. These writers suggest that many of the complicated procedural recommendations of past stratigraphic codes stem from the simple fact that arbitrary *periods* of time carry the primary names (i.e., Age names). Their recommendation is that the *reference points themselves* be named, and that the intervals of time between any two reference points be referred to by combination names involving both of the two reference point names. Thus, assuming for the moment that we retain our present naming system (a procedure probably not to be recommended in any real implementation of this scheme) and insert the two relevant reference points, what is presently termed the Bortonian stage would become Bortonian-Kaiatan time. Strata thought to have been laid down during Bortonian-Kaiatan time could be simply termed Bortonian-Kaiatan rocks.

THE ADVANTAGES OF SUCH A NAMED-POINT SCHEME

Before any New Zealand stratigrapher would accept a term as clumsy as Bortonian-Kaiatan time (though, be it noted, we are in advance of many countries in that we already have an ideal type of shorthand expression for this, i.e., Ab(d)-Ak(d) *d* for datum), he would need to be convinced of the advantages that accrue therefrom. The major advantages of such a named-point scheme are:

1. In practical terms, it is bound to be necessary to add new reference points to the scheme. If a hierarchical nomenclature with named intervals is used, complicated sets of rules will be necessary for the introduction of new terms, and there will be an inevitable change in meaning of the nomenclature. For instance, the recent informal suggestions of Mr G. H. Scott (at Tertiary Stages Symposium, Christchurch, 1968) to merge the Awamoan and Hutchinsonian with the Altonian, and to place the base of the Southland series above (instead of below) the new Altonian would result in changing the information content of at least three names: the Altonian Stage, and the Pareora and Southland Series. It will in future be necessary to know the date at which one of these terms was used before its meaning can be known.

On the other hand, under a named-point scheme, we can add or subtract (merely by neglecting) reference points without in any way upsetting the established nomeclature or changing the information content of currently used names. For instance, should it be deemed necessary to subdivide Ld-Lw time (supposing for the sake of this argument that there are reference pegs in Landon Creek and at Trig Z), the introduction of a new marker peg (Ln (d)) at a stratigraphic-level known to fall between the Ld (d) peg and the Lw (d) peg would result in the following available time subdivision: Ld (d)–Ln (d) : Ln (d)–Lw (d) ; and the original Ld (d)–Lw (d). In other words, there has been a gain in precision of subdivision *without any change in the meaning of the existing terms.* Anyone who has attempted to follow the rapidly changing status and meanings of the Wanganui Series stages (i.e., Waipipian, Mangapanian, Waitotaran, Hautawan, Marahauan, and Nukumaruan) over the last few years, will well appreciate the advantages of a system that does not result in changes in the information content of names.

2. Provided one chooses to mark actual physical reference points in known sections, and not to define conceptual markers on first appearance of a given taxon on a given date, it is a major advantage of a named-point system that faunal events are not involved in its definition. Hence no future taxonomic changes or fossil range extensions threaten the stability of the system; and theories, facts, and problems of evolution, taxonomy, and stratigraphy are not involved in the *definition* of the marker points on the time scale, and so may be kept logically separate.

3. Such a system will be able to be calibrated in the future in any way we see fit (e.g., age in years, however determined) without changes in the basic framework.

4. It was suggested earlier in this paper that a major problem presently facing New Zealand Tertiary stratigraphers is the integration of many different zonal schemes into a single time scale. Because a named-point system "defines" a continuum of past time, it is a suitable framework for any number of different biostratigraphic zonal schemes.

5. If N pegs are named then there are N(N–1)/2 possible time intervals defined by them. Therefore the naming of a peg at the base of each of our present 26 Tertiary stages would give us a terminology capable of referring to 325 rigorously defined time intervals.

6. By the use of a named-point system, an exclusive hierarchy of stratigraphic terms is avoided (*see* Sylvester-Bradley, 1968, and Hughes *et al.*, 1968, for a discussion of this point).

7. There is no *a priori* reason for assuming that any particular time span is more important than any other; but the present practice of naming intervals of time and arranging the intervals in hierarchies seems to be based on the assumption that certain time intervals are more important, and certainly leads to particular time boundaries being given undue emphasis (for instance, the seemingly endless semantic struggle over the Pre-Cambrian/Cambrian boundary). Logically one might expect it to be necessary to refer to the interval Ak (d)–Lwh (d) just as frequently as to the interval Ab (d)–Ld (d), and such reference would be both possible and encouraged by a named-point scheme. However much people accept in principle that the boundary between two Ages is no less important than one between two Eras, a hierarchical nomenclature will always tend to emphasise the boundary between Eras. And undoubtedly one tends to unconsciously emphasise differences near a major nomenclature boundary and ignore similar differences away from it.

8. We may be confident in New Zealand that our level of Tertiary correlation is sufficiently accurate to ensure that we never get our initial set of pegs in the wrong order. However, this is certainly not true for all pegs in all places; for example, could we be so sure that the New Zealand Permian is in correct stage order? It is a very great theoretical and practical advantage of a named-point system that it does not matter if the inserted pegs are later shown to be in the wrong relative order. This, incidentally, suggests the system may have applications in Precambrian and metamorphic stratigraphy.

9. Recent overseas writings would suggest that a named-point system will ultimately be adopted for the definition of marker points on a unique geological time scale for the whole world. (The trend this way can be detected in the correlation by the use of Datum planes—e.g., the Menardii Reduction Datum (Bandy and Wade, 1967)—now popular amongst workers on planktonic foraminifera; and it is surely highly significant that the authors of the recent "Fossil Record Symposium" (Harland *et al.*, 1967) have assembled a stratigraphic scale (for the purposes of that volume alone) in which all divisions are defined solely by a nominated datum horizon at their base). A world-wide named-point scale would be agreed upon by International Commission selection of suitable world marker points from pre-existing local sets of marker points. It would be advantageous to be in advance of, rather than behind, this development.

POSSIBLE OBJECTIONS TO A NAMED-POINT SYSTEM

1. A common line of argument heard from palaeontologists runs thus: supposing you define your reference point intending it to mark the first appearance of a certain taxon in a given section, and someone later finds that taxon 20 ft lower; surely we must then be able to move our boundary (in present usage; "point" in future usage) down by 20 ft?

This line of thought clearly illustrates that logical impasse that one is led into under the present system of defining *intervals* of time. It is apparently based on the *petitio principii* that the first occurrence of a fossil in a stratigraphic section is due to one of two things:

(1) Either the defining organism migrated into the area from extra-New Zealand seas (i.e., it is a true immigrant, not merely appearing because of local facies change, and its presumed ancestors are therefore not known in immediately earlier rocks in New Zealand); or

(2) That the defining organism has evolved instantaneously from its previously known ancestors, or at least that the lineage it represents is so well known that we can define an arbitrary but objective point along it.

In either case, the occurrence of the animal 20 ft lower in the type section is presumed to be closer than the originally defined level (or peg) to some ideal moment in time.

I would disassociate myself from such a view for the following reasons:

(1) The viewpoint entirely misinterprets the whole point of defined and named stratigraphic reference pegs. Whilst for reasons of pragmatism we may at this moment wish to insert the pegs at levels in the column that seem to us significant (i.e., at stage bases as presently conceived), once inserted *they represent no ideal stratigraphic level*, but rather mark an arbitrary point in time whose relative position to other points is usefully ascertainable.

(2) My own experience of New Zealand Tertiary stratigraphy, based entirely on the collecting of molluscan fossils, convinces me that the vast majority of fossil species appear and disappear in any section because of local facies control, and not because of either immigration or evolution.

(3) Neo-Darwinian theory does not envisage instantaneous evolution of new species, but rather lays stress upon a relatively slow process of genetic divergence based principally on an allopatric speciation model.

(4) The literature of palaeontology contains a mere handful of examples of fossil invertebrate lineages that have been well enough documented to enable an arbitrary point along them to be designated as a time marker. Lineages possibly suitable in this respect include *Haeuslerella* and *Globigerina* (Scott, 1965b and 1966; Foraminifera), *Athleta* (Fisher *et al.*, 1964; Gastropoda), and perhaps *Micraster* (Kermack, 1954; Echinodermata). It has taken over 100 years of palaeontological research to produce these rare examples of quantitatively documented lineages, and in view of the prerequisites of the preservation of a thick series of sediments of relatively unchanging facies—it seems unlikely that the near future will see any major increase in this rate of documentation. It is therefore being unrealistic to expect to subdivide the whole of geological time using such lineages, at least in the foreseeable future.

However, let us for the sake of the argument admit of a lineage that is sufficiently well known to enable a series of points along it to be selected as stratigraphic reference points. Then, and this point is worth labouring, we are tacitly accepting the truth of the *a priori* assumptions that underly all lineage studies, based as they inevitably must be on samples from different populations of animals living at many different geographical localities and geological horizons. These assumptions include the hypothesis of complete panmixis of genes, and the hypothesis that morphological change takes place synchronously over large areas and always reflects genetic change. Both of these assumptions are known to be false in particular instances concerning Recent animals, and Scott (1965a, p. 861) has thus been led to conclude that " 'time stratigraphic' units based on evolutionary lineages may seem to have theoretical advantages, but practically they are as weakly testable as units based on species presumed to be unrelated".

By far the greatest advantage gained from using physical markers (and not fossils) for reference points is that the placing of a marker entails no such *a priori* assumptions.

2. It is frequently claimed that nothing about a reference peg aids correlation of any type, which (even after reference pegs have been selected) must still be dependent upon fauna or lithology.

The proponents of reference pegs would be the first to agree with such an observation (cf. the definition of reference pegs quoted from Hughes *et al.*, p. 354 of this paper), but would add the rider that this is the unique advantage of such reference pegs. It is precisely because their definition does not involve theories of evolution, correlation or stratigraphy that they are so suitable for defining points on a *time* scale.

3. Related to the last objection is the claim that "an Age and a Stage are equally unrecognisable away from their type locality, so why not stick to the stages?" This is a point on which one might digress at length, but I shall confine myself to a brief answer. The reason that ages, and not stages, should be considered the basic unit is that many of us wish to make statements about events which happened in past time without necessary reference to the idealised concept of "all rocks" that were laid down during that period of time. Further, to involve the concept of "all rocks laid down during a particular period of time" in the definition of points on a time scale is as indefensible as involving biological events in similar definitions; we have already dealt with this point elsewhere in the paper. (Incidentally, there is surely something a little awry with the reasoning of those who define a stage as "*all* rocks laid down during a particular period of time", and then accept, not only many different local stage systems for marine sediments in different areas, but also different stage systems for marine and non-marine beds in the same area.)

The question that immediately arises is whether the retention of time-rock units (such as stages) would be desirable in the event of the introduction of a marker peg system. Gage (1966, p. 406) has already posed the rhetorical question "should we declare the time-stratigraphic category, with all its complexities, redundant as soon as possible". Others too have found the preoccupation of the American and International codes with time-

rock stratigraphy both distressing and confusing (e.g., Miller, 1965, Allan, 1966), and the confusion reigning over the status of chronostratigraphy and its relation to time-rock stratigraphy is well illustrated by the following quotation from Sylvester-Bradley (1967):

> It is suggested, then, that the International Code should be restricted to chronostratigraphy. Even in chronostratigraphy there are two sets of terms, two hierarchies. One deals with units of time, the other with thickness of rock, bounded by isochronous surfaces. Both hierarchies have in the past attracted a terminology and a nomenclature. However, those applied to the classification of time have been little used except in theoretical discussions, whereas the rock terms are in almost all systems in universal use. If the time terms (chronomeric) are exactly parallel to the rock terms (stratomeric), there is no need for a separate nomenclature. We can talk of the Bathonian Stage (rocks) or the Bathonian Age (time). It is, therefore, suggested that, at least in the first instance, the code should be restricted to chronostratigraphic rock terms or "stratomeres".

As a statement summarising the pointlessness of having both time and time-rock categories, this has its merits; but in its suggestion that time-rock, and not time, be considered conceptually basic, it shows with clarity how pervasive and long-lasting has been the influence of Schenk and Muller (1941).

My own viewpoint is that there is no need for the time-rock concept currently termed stage (International usage). The majority of information I wish to communicate has to do with animals that lived at a certain period of past time. Though, in common with many other people, I have been in the careless habit of referring to the fauna of, e.g., the Bortonian Stage, I have in fact generally meant the fauna of the Bortonian Age. In addition, is is extremely difficult to be sure that any particular rocks fall in a given stage (International usage), using the accepted definition of stage (rocks deposited during a given period of time), though placement in a New Zealand Tertiary "stage" may be easy using the standard New Zealand practice of homotaxial biostratigraphy. For this reason I am in agreement with Scott (1965a) who has put the point of view that in fact a stage (International usage) *as presently defined* (*see* American Commission on Stratigraphic Nomenclature 1961, International Subcommission on Stratigraphic Terminology 1961, and Geological Society of New Zealand 1967) is practically unknowable, since fossils generally demonstrate homotaxy and not age equivalence.

However, all this notwithstanding, there are still some stratigraphers who apparently feel that the concept of homotaxy is "so obvious that only a fool ensloughed in pedantry . . . would bother with it" (Waterhouse, 1966). For such people, who can apparently both recognise and use the concept of stage (International usage) as presently defined, it may be necessary to retain the category, perhaps slightly redefining it as the rocks laid down during a period of past geologic time, bounded by two suitable stratigraphic marker points.

4. There is a necessity to communicate at several levels of precision in stratigraphy. For instance, an event that took place in the Mangapanian may usefully be referred to as Tertiary, late Tertiary, Pliocene, late Pliocene, mid-Wanganui Series, or whatever, as well as Mangapanian, according to the precision of one's data and the precision one wishes to express. Such usage is simple, and useful, under the present hierarchical system, but would be impossible using only a named point terminology.

This appears a valid criticism, but it assumes that under a named-point system we retain none of our present hierarchical units. In fact, the introduction of a named-point system by no means implies that we are going to drop such obviously useful terms as Mesozoic and Tertiary; it does mean that we will define such terms rather more closely than we have in the past. For example the Mesozoic era might be defined as the period in time between the two reference pegs "base-Induan-stage" (= present base of the Triassic) and "base-Danian-stage" (= present base of the Tertiary). (The fact that this will enable stress to continue to be laid on such era boundaries may be philosophically deplorable, but it is undoubtedly pragmatically necessary if we are ever to achieve universal acceptance of a named-point system.) Hence, terms such as Mesozoic will still be readily available.

CONCLUSIONS

Gage (1966) has suggested that much of the controversy and confusion over stratigraphic classification in the last 20 years has stemmed from the unfortunate reintroduction of the stratigraphic categories termed time-rock (Schenck and Muller, 1941), a view with which I find myself in complete agreement. Whilst perhaps necessary at the time of its introduction, the time-rock concept has far outlived its usefulness, and it is unfortunate that it has received a prominent position in the American and International codes, and in the Geological Society of London's report (George *et al.*, 1967).

In order to communicate intelligibly, all students of the earth's history are in dire need of some precisely defined conceptual time framework that is entirely free from all theories of evolution, taxonomy, homotaxy, and stratigraphy. If the use of named marker points, recently suggested by Hughes *et al.* (1967) and strongly endorsed in this paper, had only that one advantage, it would merit most serious consideration. In fact, of course, such an approach would carry many other concomitant advantages, thus making it imperative that it be considered a serious candidate in any revision of New Zealand Tertiary stratigraphic concepts.

By the simple procedure of establishing a set of stratigraphic marker pegs, and by *naming those pegs* (*not* the intervals between them), we can achieve a completely objective stable set of *marker points* in *absolute* past time. With present techniques we will normally only actually know the *relative* time position of any reference point, but future hopes of knowing the absolute time position become vastly more exciting and probable if we can establish a rigorous conceptual framework on which to build.

ACKNOWLEDGMENTS

My thoughts on the concepts discussed in this paper have been greatly influenced by my fortune in being at the Sedgwick Museum, Cambridge, during the period in 1967 when a series of informal "geologic logic" seminars was held amongst research workers in the building. The result of these discussions was a paper by Hughes *et al.* (1967), and this present paper is an attempt to apply similar principles to the problem of the subdivision of Tertiary time in New Zealand. I must here acknowledge the stimulus I received from my associates at Cambridge, particularly from Drs D. B. Williams and J. L. Cutbill; I have drawn heavily on the notes that they presented to the Cambridge seminar group, particularly in the framing of the "suggestions" in the appendix.

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APPENDIX

The following points are suggested as a possible basis for further discussion:

(1) Is it agreed that "the reference scale of ages/stages in current use in stratigraphy is no longer well enough defined to satisfy modern requirements including those of data storage and retrieval"? (Hughes *et al.*, 1967.)

(2) Is it agreed that the ultimate objective is the establishment of a unique geological *time* scale by international agreement?

(3) Is it agreed that past time was a continuous and uniform phenomenon and therefore that a hierarchical nomenclature is basically not suitable for the subdivision of such time?

(4) Is it agreed that a nomenclature for a stratigraphic scale should ideally have at least the following properties:

(a) any point or interval of time can be referred to easily and unambiguously,
(b) the meaning of names should never alter,
(c) refinement of the scale should result in minimal additions to the nomenclature,
(d) the nomenclature should not be biased towards any hypothesis concerning the continuity or otherwise of the geological rock record?

(5) Can one accept the contention (contained in the Report of the London Geological Society, and in Hughes *et al.* (1967)) that a geological *time* scale must be defined by reference to marker points in rock sequences?

(6) Is it agreed that the positions of these markers is logically quite arbitrary?

(7) Is it agreed that the procedures for placing markers should ensure that they define a point in time, and not a period of time?

(8) Is it agreed that a reference point is only useful if it is possible to correlate with it? It is therefore essential that a chosen point is closely related to events that are useful for correlation. In terms of New Zealand Tertiary stratigraphy this means that points should be chosen in sections in which the occurrences of fossil assemblages (or other characters useful in correlation) have been worked out.

Practical Implementation in New Zealand

It is quite clear that the vast amount of carefully collected, and valuable data contained within our present Tertiary biostratigraphic system must be retained in any new classification. Hence by far the most important feature of a named-point system is that it is a permissive development that can take place without upsetting the presently established system. Whilst it is a theoretical strength of the reference point principle that pegs could be inserted totally at random in random sections, such a proposal would clearly be irresponsible. In order to retain the information content of our present system, we would need to place our initial marker points as nearly at the base of presently conceived stages as is possible. The sort of procedure one might envisage is:

(1) The formation of a working committee containing micro- and macro-palaeontologists and stratigraphers to attempt to define as closely as possible the present faunal basis for the base of each present New Zealand stage.

(2) For any given stage the committee would ascertain, in order of apparent usefulness, several faunal elements that appear to presently be used in defining its base.

(3) Pairs of workers drawn from throughout New Zealand could then document in detail the most suitable standard locality to see if the appearance of one of these fossils can be objectively recognised in that section.

(4) When both a suitable section and a suitable defining organism have been ascertained for any stage, the relevant reference peg may be inserted.

During the transition phase, the original type locality of any stage would remain essential as the name-bearer of the stage to enable the selection of suitable standard localities. Once the marker points have been established, the old stage type locality becomes irrelevant.

Retention of Present Names

Both from a nostalgic point of view, and from the view of practicality, it would probably be deemed desirable to name our initial set of pegs with the same (or similar, perhaps Bortons peg instead of Bortonian) basic terminology as is in use at the moment. There is no doubt that logically the best plan would be to introduce a completely new set of terms, but it is doubtful if this would find ready acceptance.

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