STRATIGRAPHIC TIME-CORRELATION IN THE LATE TRIASSIC OF SVALBARD: A DISCUSSION OF N. F. HUGHES'S WORKING METHODS

by D. G. SMITH

ABSTRACT. N. F. Hughes has shown how the processes of stratigraphic correlation (using miospores) can be broken down into discrete components—biorecords, comparison records, events, and correlation brackets. Critical attention has been directed almost exclusively at the first of these. This paper concentrates on the latter three in the context of a miospore-based correlation study of Late Triassic strata in Svalbard. No biorecords are described, but traditional identification is avoided in favour of graded comparisons with published records. 'Events' can be qualitatively correlated or, preferably, seriated to give a composite sequence to taxon range limits. Bracket correlations become unwieldy for inter-regional correlation, and comparison with a probabilistically-derived global composite is more easily depicted by the graphic correlation method. It is believed that Hughes's challenging standards of scientific integrity can be maintained through selective use of existing published data if nomenclatural considerations are set aside, at least for the purpose of correlation.

NORMAN HUGHES has developed a methodology aimed at improved standards of palynologic data recording, especially though not exclusively with improved stratigraphic time-correlation in mind (Hughes and Moody-Stuart 1967, 1969; Hughes and Croxton 1973; Hughes 1975 and in press). Commentators have focused attention on the perceived threat of Hughes's proposals to traditional (Linnean) nomenclature as widely applied in non-industrial palaeontology (e.g. Traverse 1975; Jansonius 1980), but there has been little commentary on their implications for time-correlation. Hughes's arguments for reforms in palaeontologic data-handling present a challenge which should not be ignored by any palaeontologist, but I also propose in this paper to explore further the direction in which he has attempted to lead the geoscientifically central discipline of time-correlation. The work reported here was largely supervised by Hughes and I am indebted to him for many of the ideas from which this work developed.

Stratigraphic time-correlation is the establishing of time relationships among geological phenomena at different localities. Hughes's philosophy hinges on the observation that *equation* of stratigraphic events in different sections is logically unsound, and prevents any further refinement. His solution is to express stratigraphic relationships as 'older than/younger than' brackets with respect to a scale of 'events' in a standard reference section.

Hughes's 'events' are quantified collections of observations of selected taxa; each 'event' is derived from a single, carefully circumscribed sample. The taxa are semi-quantitatively *compared* (not identified) with previously described biorecords (taxa based on specimens from a single sample). Hughes recognizes the appropriateness of his approach for computer handling, but has not found it necessary while dealing with taxa of only one general type (*Cicatricosisporites*).

In what follows, I have attempted to apply Hughes's principles to the correlation of several Late Triassic to earliest Jurassic sections on islands in eastern Svalbard (Norwegian Arctic). The chronostratigraphic implications of this study have already been outlined in several papers which newly described the stratigraphy of these islands (Lock *et al.* 1978; Smith *et al.* 1975; Smith 1975; Smith *et al.* 1976), but the data and methods have not been presented previously.

The strata selected for this study form part of a formerly poorly dated succession, which in places can be seen to lie above ammonoid-controlled Scythian to Carnian (Early to early Late Triassic) strata, and elsewhere to underlie strata in which the oldest ammonites are Toarcian (late Early
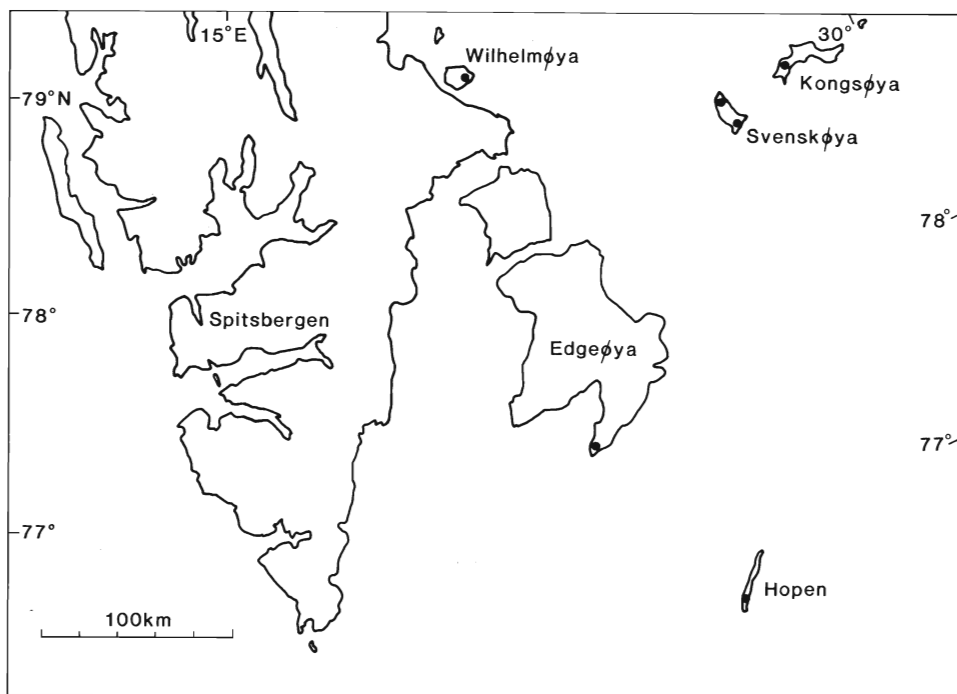
TEXT-FIG. 1. Location map of Svalbard, showing position of sampled sections.

Jurassic) or younger. The strata in question belong to the Kapp Toscana Group, within which deltaic, marginal marine and shallow marine facies are variously developed in a basin whose principal shoreline lay to the west, in western Spitsbergen (Mørk *et al.* 1982; Steel and Worsley 1984). I describe first the data-handling method adopted; secondly, the application of the data to local correlation of sections within Svalbard; and thirdly, the separate problem of correlation with the chronostratigraphic scale, drawing attention to similarities and differences between my approach and that of Hughes.

DATA-HANDLING AND PRESENTATION

As Hughes has repeatedly observed, it is vitally important to collect and present the primary observational data as independently as possible of any interpretation (taxonomic or stratigraphic). Ideally, the only subjective element is the observer's partitioning of the specimens in a preparation into taxa. Once that is done, description (with or without illustration) can proceed at whatever level of detail is appropriate to the objective. I know of no satisfactory study demonstrating the number of specimens or the level of descriptive detail required to accomplish specific objectives; the potential for wasting valuable observer-hours is considerable.

Samples were selected from measured sections considered to be representative of the Kapp Toscana Group in Hopen, Kong Karls Land (Svenskøya and Kongsøya), Wilhelmøya, and Edgeøya (text-fig. 1). Standard palynological preparations were made and the more productive ones were singled out for detailed analysis. Palynomorph types for recording were selected on the basis of distinctiveness, good preservation, reasonable abundance, and likelihood of stratigraphic value based on known ranges of published taxa of similar appearance. Specimens, numbering twenty or more per taxon if possible in each of the selected preparations, were described using a limited number of simple and easily repeatable measurements (e.g. overall dimensions, size and distribution of sculptural elements, exine thickness). These results were tabulated so that each record of each palynomorph could be compared and checked for reasonable similarity with others of the same type. The

complete data set has been deposited with the British Library, Boston Spa, Wetherby, Yorkshire LS23 7BQ as Supplementary Publication no. SUP 14028.

These records provide the data for the two separate operations of: 1, correlation within Svalbard, to establish the relative ages of sections within the archipelago; and 2, correlation elsewhere in order to establish the chronostratigraphic age of the Svalbard successions. The first of these aims can be achieved with the data as they stand (i.e. with the taxa described but essentially unidentified). The second objective requires comparison (traditionally 'identification') with previously published records.

Although Hughes (1975) points to compatibility with existing methods as an essential requirement for any new method, he did not provide examples of the use of existing data, preferring to make comparisons only with his own biorecords. In illustrating his method only in its 'pure' form he has thus drawn attention to the differences, and away from the essential similarities, of more conventional methods. My approach here is to join Hughes in rejecting 'identification' as a blunt instrument inappropriate to stratigraphic refinement, but to recognize that many palynological publications do in fact present data of high quality to which Hughes's method can be applied. The only slightly unconventional step is to single out the individual record of one taxon in one sample as the unit for comparison, rather than an entire palaeontological 'species' with its ever increasing number of attributed specimens. Selective reference to published records is of course normal palaeontological practice, but tends to be overshadowed by concern over synonymy and priority.
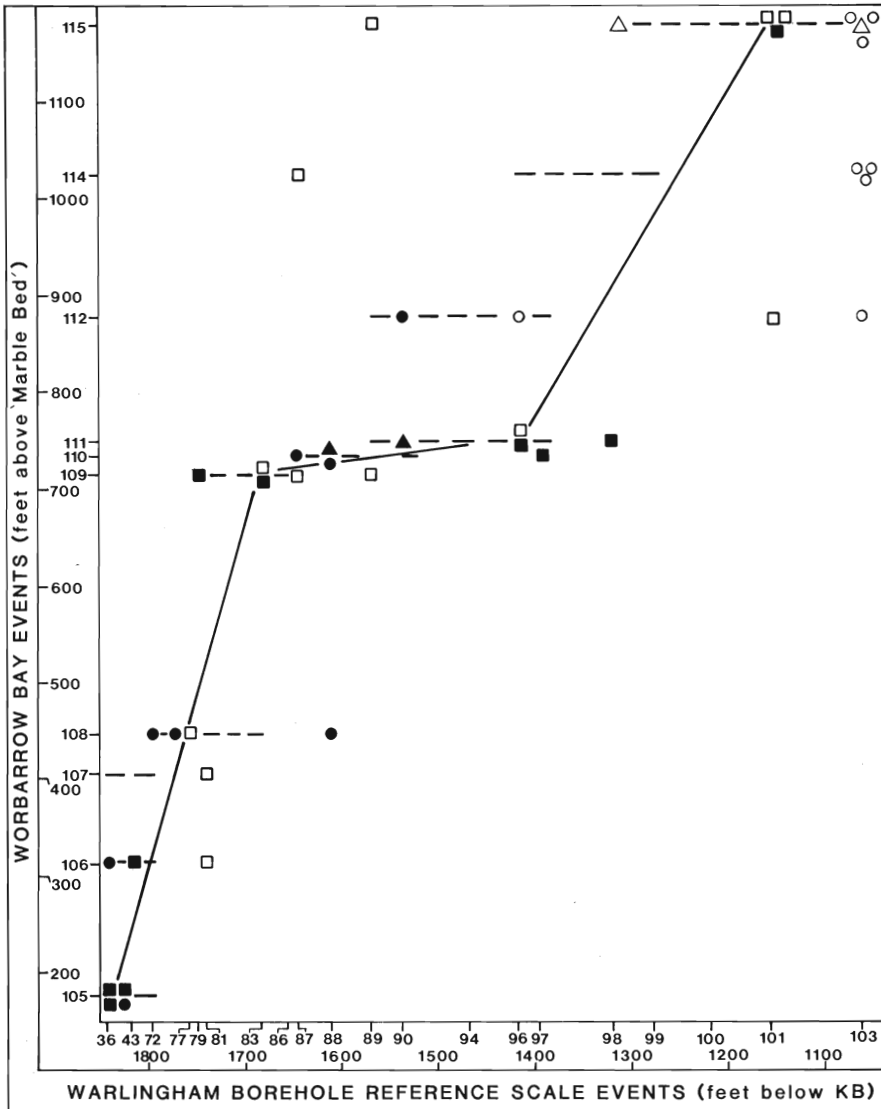
For each type of palynomorph described from Svalbard, I have selected a published reference record, using the criteria of: *a*, morphologic similarity to the Svalbard material; *b*, clear description, preferably based on a stated number of specimens; and *c*, clearly identifiable stratigraphic position. I have then used graded comparisons to compare each Svalbard record with the appropriate reference record: cf.A, the equivalent of conventional identification, implies no significant difference from the reference record; cf.B implies minor differences; cf. means that insufficient data are available for comparison at cf.A or cf.B level. For convenience in referring to palynomorphs from Svalbard, I use the name of the reference record regardless of its nomenclatural correctness. I found no need to erect new biorecords, although a few of the reference records would not pass more rigorous vetting.

Table 1 sets out the occurrence, in all the samples to be considered, of the numbers of specimens of each palynomorph type and its grade of comparison with the selected reference record. Each collection of observations from a single sample corresponds to an 'event' in Hughes's terminology.

EXPRESSION OF LOCAL CORRELATION

Central to Hughes's method is 'bracket correlation', the bracketing between the closest possible pair of points ('events') in a reference scale of an 'event' in the section being studied. Correlation of two sections may consist of any number of such brackets. Illustrated examples, in which the sections to be correlated are drawn parallel to each other, are in Hughes and Moody-Stuart (1969, text-fig. 2), and Hughes and Croxton (1973, text-fig. 2). The method of drawing conclusions from the resulting tangle of brackets is obscure in this form of presentation, and a graphical method is preferred here. By way of introduction I have first replotted Hughes and Croxton's (1973) correlation of Wealden sections in Dorset (Worbarrow Bay) and Surrey (Warlingham Borehole) in text-fig. 2.

Of the many possible methodologies for retrieving a stratigraphically significant signal from the primary data of Table 1, I present two here. The first is more closely similar to that used by Hughes. Qualitative inspection of the data is combined with the stratigraphic information already implicit from superposition, leading to statements of correlation between samples ('events') in different sections. Whereas Hughes uses pairs of such statements to form correlation brackets with reference to the regional standard section (Warlingham Borehole), lack of a single suitable section in Svalbard requires a more general approach, illustrated in text-fig. 3. I depict each correlation statement ('A is older than B') as an unquantified vector, building up what I have elsewhere called a network diagram (Smith and Fewtrell 1979). It should be noted that correlation statements are not possible between all pairs of samples, as significant facies differences may be present, preventing the necessary compositional comparisons. The correlations shown in text-fig. 3 are all those which can be made with reasonable (but unquantified) probability, between samples of sufficiently similar character. The arguments in support of each correlation statement can of course be set out in words (cf. Hughes and Moody-Stuart 1969, p. 103), but they remain subjective and unquantifiable.

TABLE 1. Summary tabulation of comparison records from Kapp Toscana Group, Svalbard. Stratigraphic positions of numbered samples (DS154 etc.) are shown in text-fig. 3. A, B, cf. indicate grade of comparison (see text); numbers indicate numbers of specimens. Taxonomic names are those of the reference records with which comparison is made, and are not necessarily nomenclaturally correct.

Reference taxa	Kongsøya			Svenskøya				Wilhelmøya			Hopen			
	DS154	DS147	DS155	DS86	W004	DS20	DS3A	DS247	DS217	DS133	DS281	DS299	W054	W011
Neoraistrickia taylorii						A23	cf4							
Perinopollenites elatoides	A9	A20		A10			A9							
Planisporites ovalis	A20			A20		A108								
Tigrisporites halleinsis	A9			cf3		A100								
Rogalskaisporites cicatricosus	A14			A18	A10	A100								
Quadraeculina anellaeformis	A8	A20			cf3									
Polycingulatisporites triangularis			cf3											
Aratrisporites palettae			A7					A17						
Aratrisporites minimus														
Zebrasporites laevigatus			A5											
Granulatisporites subgranulosus														
Chasmatosporites hians											A43			
Limbosporites lundbladii			A30								A4			
Polycingulatisporites circulus											A10			
Classopollis torosus	A19	A15	A10	A12							A7	cf2		
Heliosporites reissingeri					cf4	A25	A32				cf4	cf1		
Rhaetogonyaulax rhaetica												B33		
Camarozonosporites laevigatus					cf3							A9		
Aratrisporites laevigatus		A6	A4		A3				A3			A4		
Chasmatosporites apertus	A20	A24	A6								cf3		A6	
Cerebropollenites thiergartii	A20			A19			A13				cf5	cf3	cf8	
Kyrtomisporis speciosus					A17							A20	A39	
Aratrisporites fischeri													A6	
Ricciisporites tuberculatus			A40								B5		B7	
Lycopodiacidites kuepperi	A15	A13		A9		A70			A5		A6			
Chasmatosporites major			A27		A11				A16	A6			A30	
Annulispora folliculosa					A23			A8				A29		
Zebrasporites interscriptus			A13		A13							A13	A17	
Uvaesporites reissingeri									A30	A10				
Kraeuselisporites cooksonae									A11	cf3				
Euconmiidites troedssonii	A9	A100		cf2				cf4	A29	A8	cf4	cf5	A18	
Duplexisporites scanicus		A8	A21		A20					A12	A14	A10	A11	
Camarozonosporites rudis								A10	A35	B13				
Granuloperculatipollis rudis									A11					
Polypodiisporites lativerrucosus									B13				B14	B20
Ovalipollis ovalis													B10	B12
Equisetosporites chinleana														B32
Conbaculatisporites hungaricus														A25
Protosacculina macrosacca								B10						A8
Apiculatisporites spiniger									A9					A7

TEXT-FIG. 2. Correlation of 'Wealden' (Early Cretaceous) of outcrop section of Worbarrow Bay, Dorset, with Warlingham Borehole, Surrey (both southern England) after the graphical correlation method of Shaw (1964). Data from Hughes and Croxton (1973, tables 3–4). Symbols represent the highest and lowest common occurrences of taxa comparable at the same grade: filled symbols are bases, open symbols are tops; squares represent range of cf.A comparison grade, triangles are cf.B, circles are cf. Diagonal line is Line of Correlation, and leaves similar numbers of correlative points to either side of line. Note suggestion of missing section at Worbarrow Bay (700–750 ft) relative to Warlingham (1700–1400 ft). Horizontal dashed lines represent Hughes and Croxton's correlation brackets by which they compared Worbarrow with Warlingham. KB = Kelly Bushing.
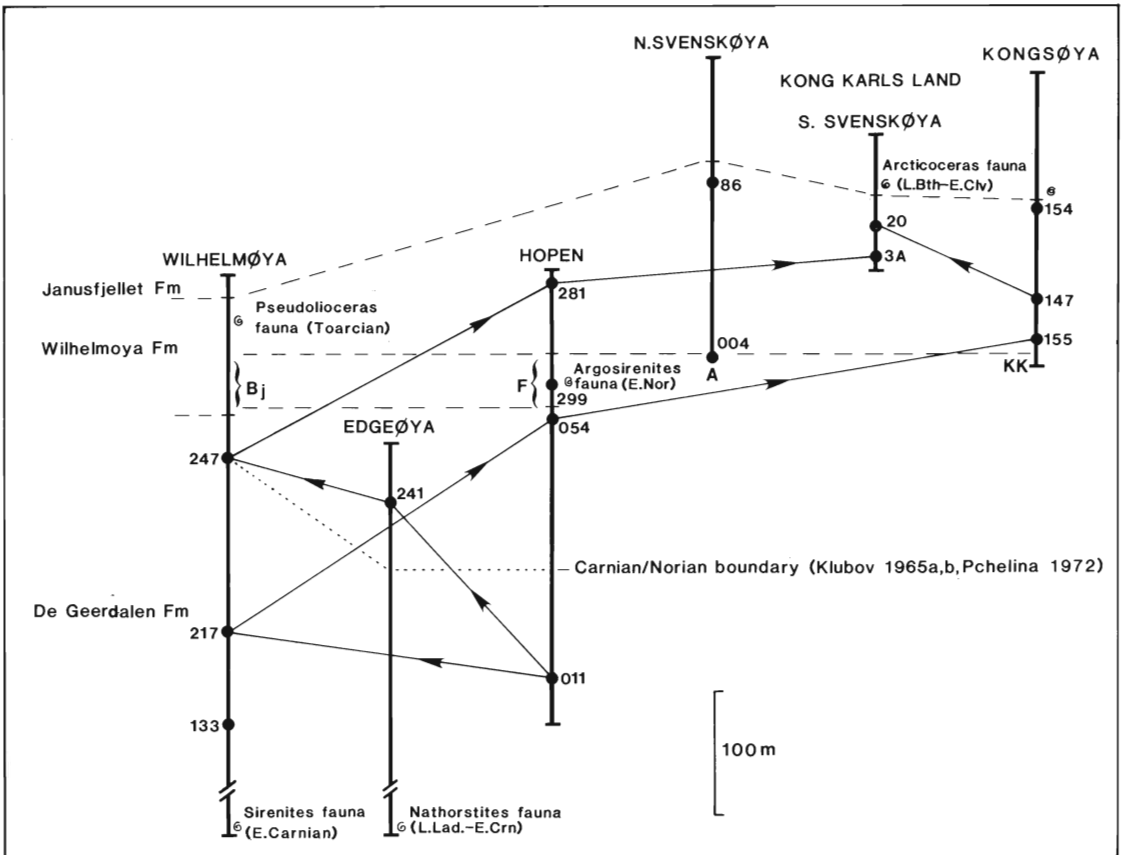
TEXT-FIG. 3. Correlation of sections in Svalbard using palynological data from the samples whose numbers are shown against the sections. Lithostratigraphic correlation is indicated by dashed lines. The horizontal datum is the top of the marine shale unit of the Wilhelmøya Formation; Bjørnbogen Member (Bj) in Wilhelmøya, Flatsalen Member (F) in Hopen, Arnesenodden Bed (A) in northern Svenskøya, Kapp Koburg Member (KK) in Kongsøya. Ammonoid data points are shown, as is the Carnian–Norian 'stage' boundary picked by Soviet workers on the basis of bivalve faunas (see Lock *et al.* 1978; Smith *et al.* 1975; Smith *et al.* 1976). Palynological correlation is expressed as arrowed lines indicating confident earlier/later relationships (see text, and Smith and Fewtrell 1979).

A less subjective approach is to use the technique of seriation. The taxon occurrence table (Table 1) is simply rearranged, row by row, column by column, until the occurrences all cluster as closely as possible along the leading diagonal (Table 2). The technique makes use of the progressive change in taxonomic composition which is normally observed in stratigraphy and it does not in this respect differ from the 'eyeball' approach described above. The assumption that such change represents a succession in time is normal practice and is encouraged by, though not strictly dependent upon, the acceptance of conventional evolutionary theory.

The advantage of the second of these techniques of analysis over the first lies in the application of the results. Presentation of correlation statements in the form of text-fig. 3 is a useful summary of the implied time relationships among the geological sections studied. It does not immediately lend itself to solution of the next problem, which is that of correlation outside the area of study and with the standard chronostratigraphic scale. Seriation on the other hand yields a composite ordering of all of the samples; application of this is dealt with in the next section.

TABLE 2. Seriation of fifteen samples from Svalbard on the basis of their palynomorph content (compare Table 1). Samples (rows) and taxa (columns have been rearranged until the taxon ranges all lie as close as possible to the leading diagonal of the table. Sample numbers correspond to those in Table 1 except for the addition of 241 from Edgeøya (see text-fig. 3) for which complete comparison record data were not recorded.

Samples	Co. hungaricus	Pr. macrosacca	Ana. spiniger	Kr. cooksonae	G. rudis	U. reissingeri	Eq. chinleana	Ar. minimus	Pp. lativerrucosus	O. ovalis	Ar. fischeri	Cam. rudis	Ann. folliculosa	Ky. speciosus	Cam. laevigatus	Ch. major	Z. interscriptus	Ar. laevigatus	Ri. tuberculatus	Du. scanicus	Ch. apertus	Rh. rhaetica	Eu. troedssonnii	Cer. thiergartii	Ly. kueppeti	Cl. torosus	Ro. cicatricosus	H. reissingeri	Q. anellaeformis	Pc. triangularis	Z. laevigatus	Ar. palettae	Lim. lundbladii	Pc. circulus	Ch. hians	Pe. elatoides	Pl. ovalis	T. halleinsis	N. taylorii
20																								+		+	+										+	+	+
154																						+	+	+		+	+	+									+	+	+
86																						+	+	+		+	+										+	+	+
3A																								+		+											+	+	
147																				+		+	+	+	+	+			+							+			
281																	+	+		+	+	+	+			+		+			+	+	+						
155															+	+	+	+	+		+					+			+			+	+	+					
004													+	+	+	+	+	+	+							+	+	+											
299												+	+	+	+		+	+		+			+			+	+	+											
054									+	+	+	+	+	+		+		+	+		+																		
247		+	+								+	+				+																							
241			+	+	+	+	+	+			+	+											+	+															
217	+		+	+		+		+			+					+		+	+					+															
133				+			+				+	+	+						+																				
011	+	+	+				+				+	+																											

EXPRESSION OF INTER-REGIONAL AND CHRONOSTRATIGRAPHIC CORRELATION

Hughes's Wealden reference scale, the Warlingham borehole, serves as a local standard but does not provide evidence of chronostratigraphic age. This requires correlation with a marine succession, and an example, with some theoretical discussion of this application of the bracket-correlation method, was given by Hughes (1973). An intermediate step (via sections in Lincolnshire and Norfolk) was required to reach the marine Speeton Clay succession, from which macrofossil evidence implicitly supplies bracket correlations with the (as yet undefined) Age boundary stratotypes in Europe. However, the cumulative uncertainty of such stepwise correlations is difficult to reconcile with the apparently greater certainty with which correlations are traditionally expressed. Hughes and Moody-Stuart (1969) recognized that their method may be less appropriate for long-distance than for local correlation. I suggest here that it is more appropriate to employ a composite of the local data when attempting inter-regional correlation, rather than attempt to preserve the primary data throughout. There are many ways of doing this without resorting to traditional methods of zonation. This principle is illustrated using the Svalbard data set which (*a*) requires correlation elsewhere to refine its chronostratigraphic age, and (*b*) has information of chronostratigraphic significance to contribute to global understanding of Late Triassic time.

Chronostratigraphic control on the age of the Kapp Toscana Group is limited; the key ammonoid occurrences are summarized in text-fig. 3. An important feature to note is the Early Norian *Argosirenites* fauna from the Flatsalen Member of Hopen, described recently by Korchinskaya (1980; see also Smith 1982). This provides a potentially important link between ammonoid and palynomorph biostratigraphy in this poorly understood interval of Late Triassic time.

Considering now the question of compositing the palynostratigraphic data from Svalbard, Table 2 yields not only a seriation of the samples studied, but also an ordering of the taxa, which, by the same assumptions, must have time-significance. However, the taxon series is not very useful as it stands, and the ranges vary greatly in relative duration. More useful for comparison elsewhere is the sequence

of taxon range *limits* (first and last appearances), which is readily extracted from the same table. This adequately summarizes the information contained in Table 1 without forcing it into preconceived zones.

Abundant data are available on Late Triassic palynostratigraphy outside Svalbard, mainly from Europe and the Arctic. Most of the sections described are poorly dated chronostratigraphically. The difficulties in making use of these data are familiar in biostratigraphy generally: 1, many locally valuable zonation schemes have been devised but none has been successfully applied to all available successions; 2, the sequence of biostratigraphic events (appearances, acmes, disappearances) is highly variable between sections; and 3, there are inconsistencies of taxonomic usage. These drawbacks make reliance on a single standard section inappropriate, and lead me to reject the kind of deterministic approach (relying on actual occurrences of taxa, or on cf.A comparison records) as applied qualitatively by Hughes and quantitatively by Davaud (e.g. 1982). Instead, a probabilistic approach is more appropriate (Hay 1972).

Using the computer program RASC (Heller *et al.* 1983), I have derived an optimum sequence of palynostratigraphic events (tops and bottoms of ranges) from twenty-five sections in Europe and the Arctic (see References for data sources). A full description of the process of deriving this optimum sequence is beyond the scope of the present paper; the methods are described in papers by Agterberg and Nel (1982*a, b*). Suffice it to say here that events were chosen for inclusion largely on the basis of their being widely recognized in the literature as having good time-correlation potential; events having too wide a spread of possible positions in the optimum sequence were eliminated. Taxonomic names are applied exactly as in the earlier part of this work; i.e. taxa whose ranges were being used were referred to by the names adopted for comparable taxa recorded by me in Svalbard, and not necessarily by the names given to them in the literature cited.

The RASC program allows the additional inclusion of marker horizons of relatively certain

TABLE 3. Optimum sequence of palynostratigraphic events, generated by the computer program RASC from twenty-five Late Triassic/Early Jurassic palynostratigraphic successions, from sources identified in references.

TOP					
51	Top	*Heliosporites reissingeri*	54	Base	*Kyrtomisporis speciosus*
84	Top	*Ricciisporites tuberculatus*	107	Base	*Zebrasporites laevigatus*
57	Top	*Limbosporites lundbladii*	23	Base	*Chasmatosporites major*
106	Top	*Zebrasporites interscriptus*	56	Base	*Limbosporites lundbladii*
112	Base	*Psiloceras planorbis* zone	92	Top	*Sverdrupiella* spp.
68	Top	*Ovalipollis ovalis* s.l.	105	Base	*Zebrasporites interscriptus*
8	Top	*Aratrisporites minimus*	45	Base	*Eucommiidites troedssonii*
94	Top	*Taeniaesporites rhaeticus*	50	Base	*Heliosporites reissingeri*
81	Top	*Rhaetipollis germanicus*	100	Base	*Triancoraesporites* spp.
108	Top	*Zebrasporites laevigatus*	42	Top	*Enzonalasporites* spp.
21	Base	*Cerebropollenites thiergartii*	76	Base	*Quadraeculina anellaeformis*
101	Top	*Triancoraesporites* spp.	102	Base	*Uvaesporites reissingeri*
109	Top	*Rhaetogonyaulax rhaetica*	91	Base	*Sverdrupiella* spp.
33	Top	*Cornutisporites seebergensis*	121	Carnian–Norian boundary (see text)
10	Top	*Aratrisporites palettae*	80	Base	*Rhaetipollis germanicus*
7	Base	*Aratrisporites minimus*	48	Base	*Granuloperculatipollis rudis*
78	Base	*Retitriletes austroclavatidites*	29	Base	*Classopollis torosus*
19	Base	*Cerebropollenites mesozoicus*	83	Base	*Ricciisporites tuberculatus*
49	Top	*Granuloperculatipollis rudis*	16	Top	*Camerosporites secatus*
60	Base	*Lycopodiacidites rhaeticus*	34	Base	*Corollina meyeriana*
117	Top	*Choristoceras marshi* (see text)	40	Top	*Duplicisporites granulatus*
116	Base	*Choristoceras marshi* (see text)	67	Base	*Ovalipollis ovalis* s.l.
115	*Argosirenites* fauna (see text)	BASE		

stratigraphic position; marker horizons included for this study were as follows: Base of *Psiloceras planorbis* ammonite zone (earliest Jurassic, available in thirteen of the twenty-five sections); top and base of the range of *Choristoceras marshi* (Rhaetian zonal ammonoid) in the Kendelbachgraben section, Austria (from Morbey 1975); occurrence of the *Argosirenites* fauna (indicating *Mojsisovicsites kerri* ammonoid zone, earliest Norian) in Svalbard. The sequence of events resulting from running the RASC program is presented in Table 3.

A convenient way of checking the Svalbard composite event sequence for consistency with the probabilistically determined optimum sequence is through a modified version of Shaw's (1964) graphic correlation method (cf. text-fig. 2), as described by Edwards (1978). Whereas Shaw used stratal thickness as the dimension for his graph axes, Edwards's 'no-space graph' has no scale and thus preserves only order and not distance. This is appropriate to the present case, where neither the Svalbard composite sequence nor the optimum sequence generated by RASC is scaled to any one stratigraphic section. Text-fig. 4 shows the resulting diagram, in which bases (B) and tops (T) of ranges identifiable in both sequences are plotted. If the two sequences are compatible, it should be possible to connect the plotted points by a line which always rises diagonally in the same direction; bases, however, may lie above the line and tops below it, representing incompleteness of ranges in the Svalbard sequence relative to the optimum sequence. Such a line is plotted on the diagram, and it shows that only two Svalbard events are out of place with respect to the line selected; they are the bases of the ranges of *Aratrisporites minimus* and *Cerebropollenites thiergartii* (both occurring lower in Svalbard relative to the optimum sequence). This confirms that, in a strictly non-quantitative way, the Svalbard composite sequence shows the same general changes through time as the optimum sequence, confirming in turn the Late Triassic (Carnian–Norian) to earliest Jurassic age of the Svalbard succession.

The diagram may be used to suggest a position in Svalbard for the base Lias datum (event no. 112), which is not otherwise recognizable; it probably is represented no lower than the Top *Limbosporites*/ Top *Ricciisporites* level, i.e. between samples 281 and 147 in the composite Svalbard sequence. This puts it above the top of the Hopen section and within the lower part of the Kong Karls Land section.

The correlation diagram of text-fig. 4 may also be used in reverse. For instance, the base *Choristoceras marshi* horizon of the optimum sequence is seen to fall only slightly above the horizon of the *Argosirenites* fauna of the Svalbard sequence. This either indicates that very little change took place in palynofloras through the intervening Norian time interval, or that the changes which did take place have not been documented because of lack of suitable sections globally; I prefer the latter interpretation (see also Smith 1982).

CONCLUSIONS

I consider Norman Hughes's contribution to palynology to be scientifically exemplary, in that he has not contributed data without questioning the methods of its collection and recording, nor without analysing the way in which the data are to be applied. Palaeontology (as far as the earth sciences are concerned) is a method, and a means to the goal of stratigraphic analysis; not an end in itself. The evolving needs of stratigraphy require continual review of its methods. In particular the increasing use of numerical methods in basin analysis and an increasingly scientific approach to stratigraphy in general demand continual improvements in handling the basic data. Hughes has recognized that there is no particularly good reason for maintaining the tradition of applying nomenclatural rules originally devised in the eighteenth century (for a completely different science) to palaeontological data-recording. He further recognizes that good stratigraphy can only be accomplished using good data; and that the data must be retrievable independently of nomenclatural considerations.

However, although Hughes's analytical logic is sound, critics inevitably resent the revolutionary nature of his proposals, and indeed the science of palaeontology depends on large bodies of data already published in more traditional guise. Hughes's principles can, however, be honoured without abandoning all previously published data; indeed, most palaeontologists probably, though less explicitly, make the kind of selective use of existing data which I advocate here. Recording of the
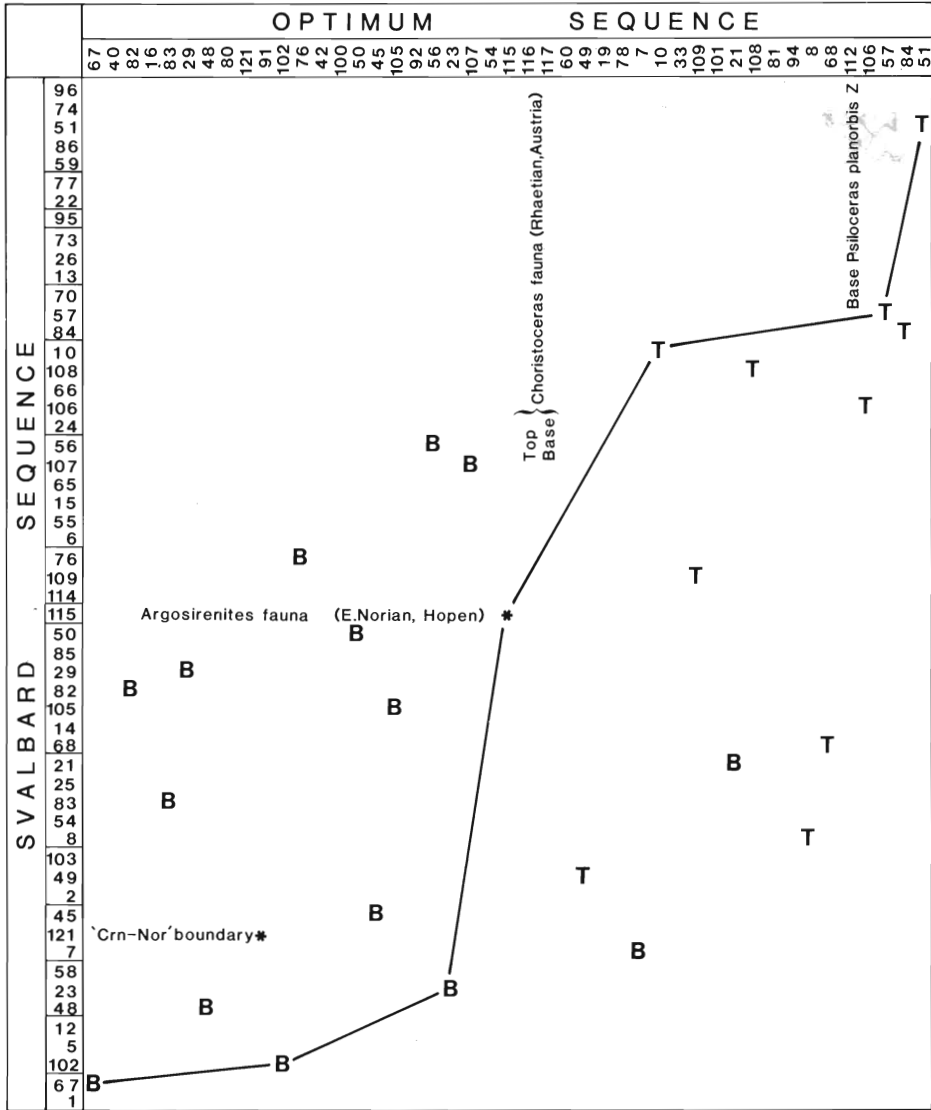
TEXT-FIG. 4. Comparison of Svalbard composite sequence of palynostratigraphic events with optimum sequence of Table 3, using the method of Edwards (1978). Base-of-range events occurring in both sequences are plotted as Bs, tops as Ts. The diagonal line has been drawn so as to separate, as far as possible, bases from tops. Events are identified in Table 3. See text for further explanation.

primary data is paramount; individual records can subsequently be treated as if they were 'bio-records', or identified in the traditional way if the palaeontologist is prepared to spend the necessary time establishing the validity of the name he wishes to use. Stratigraphic application of the data does not require such identification (in the strict nomenclatural sense); carefully stated comparison is sufficient. Avoidance of nomenclatural priority allows selection of the most appropriate record or records for comparison.

While agreeing with Hughes that the 'biorecord' (by whatever name) is primary, I am less persuaded that the 'event' (or collection of records from a single sample) is the most appropriate basic unit with which to express stratigraphic correlation. It is not readily treated by quantitative means, and I see no abandonment of principle in making appropriate abstractions from the base data such as taking tops and bases of ranges. My comparison with Hughes's bracket-correlation method in text-fig. 2 suggests that rather little loss of information may be involved, while the gain in terms of applicability of a more quantitative method of analysis is considerable. (I am aware that the 'Unitary Associations' method of Eric Davaud and Jean Guex (e.g. Davaud 1982) extracts assemblage zones by quantitative means from data sets resembling Hughes's 'events', but Hughes envisaged the use of all of the available data including relative abundance, preservation, and palynofacies, and not just presence/absence as used by Davaud and Guex.) In any case I suspect that bracket correlations would become substantially more difficult to handle as more than one genus-level group of palynomorphs was taken into account.

Hughes's description of the process of stratigraphic correlation in terms of bracketing a new 'event' between 'events' in a reference section is logically correct and usefully borne in mind; indeed, one may envisage all the correlations ever made as forming a huge three-dimensional web of such 'older than/ younger than' statements, linking every section ever described eventually to the appropriate chronostratigraphic stratotypes. However, in the same way that 'events' may not make the best base units of correlation, it may be too much to expect that bracket correlations make the most practical elements in expressing correlation of a new section with a standard. I therefore used seriation to make a composite of the local data, and a probabilistic method of abstracting the essential information from the many available reference sections outside the area of my study; alternative methods are numerous. An advantage of thus compositing a large and complex data-set is that graphical representation of correlation becomes much simpler. As a way of comparing sequences of biostratigraphic events, as in my need to compare the Svalbard composite sequence with the probabilistically derived one from the many sections described from other regions, the graphical correlation method is both simple and elegant, allowing easier extraction of the required answers than did the type of correlation network shown in text-fig. 3. Its more widespread use is to be encouraged.

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