

ROCKS, LIFE AND TIME
-AN INTERNATIONAL GUIDE THROUGH THE STRATIGRAPHIC LABYRINTH-^{1,2}

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“Geology is Earth-History”. Thus begins the first chapter of what was, and in some respects still is, one of the finest introductions to geology ever written (READ, 1949). There is no history without the concept of time, and consequently time holds a central place in nearly every branch of geology. The other natural sciences have historical aspects –physics being the only exception, unless one accepts a changing gravitational constant g as advocated by Dirac and by Jordan– but when the notion of time beyond man’s individual experience is removed from them, large parts remain completely unaffected. This holds true even for biology, notwithstanding Dobzhansky’s emphasis on evolution, essentially a historical process, as a central theme: ‘Nothing in biology makes sense except in the light of evolution’ (DOBZHANSKY, 1973).

Not so with geology. Without the concept of time geology is reduced to a mere description of our planet’s present state, and of the processes in operation at or near its surface. Not surprisingly the borderfields between geology and other natural sciences are usually situated where time becomes an essential element. This is most obviously the case where geology and biology meet in the field of palaeontology. Indeed, geology is earth history, or geological historiography, i.e. the Earth’s natural history. The notion of time is evident from Leonardo da Vinci’s observation that the shells in the rocks of the high mountains bear witness to the former extension of seas, rather than being lost from pilgrims’ wornout pockets. Observations of this kind, however, were only of an incidental nature. As pointed out by TOULMIN(1963), the discovery of time is a late event in the history of the natural sciences. It took place in the last quarter of the eighteenth century, and particularly in the ten years between 1778 and

1788, marked by the publication of Buffon’s *Les époques de la nature*, a supplement to his *Histoire naturelle générale et particulière* and Hutton’s first paper in the *Transactions of the Royal Society of Edinburgh*, an expanded version of his paper orally presented in 1885. The recognition of a historical dimension in nature was of course a prerequisite for the development of geology as a science in the modern sense of the word.

At about the same time William Smith was the first to use fossils as guides through the stratigraphic succession. It was, however, only much later that geologists freed themselves from Werner’s concept of ‘universelle Formationen’, and this was largely due to the work of Alcide d’Orbigny in France, and Albert Opper in Germany. Two quotations may serve to illustrate this breakthrough, that laid the foundation of biostratigraphy, and paved the way for what is now called chronostratigraphy. D’ORBIGNY (1842, p. 9) who may well be considered as the founder of the concept of stage, wrote:

‘La division des formations, celle des nombreuses couches qui les composent, me trouvent toujours d’accord avec les géologues spéciaux; et si je m’écarte parfois de leur opinion, quant au groupement des couches partielles de ces formations par étages distincts, c’est que nous partons de deux principes différens. Les géologues, dans leur classement, peuvent se laisser influencer par la composition minéralogique des couches, tandis que je prends pour point de départ, avec les limites des formes zoologiques, l’anéantissement d’une série d’êtres remplacée par une autre. Je procède seulement d’après l’identité de composition des faunes, ou l’extinction des genres ou des familles.’

Fourteen years later OPPEL (1856, p. 3), to whom we owe the concept of biozone, wrote:

‘Wir besitzen keine Eintheilung der Juraformation nach ihren kleinsten Gliedern, gestützt auf die Nachweise derselben in den verschiedenen Ländern. Es wurden immer bloss ganze Schichten gruppen mit einander parallelisiert, nicht aber gezeigt, dass ein jeglicher Horizont, der an dem einen Orte durch eine Anzahl für ihn constanter Species markirt wird, auch in der entferntesten Gegend mit derselben Sicherheit wieder zu finden sei. Diese Aufgabe ist zwar eine schwierige, aber nur durch ihre Erfüllung kann eine genaue Vergleichung ganzer Systeme gesichert werden. Es wird dabei nöthig gemacht, mit Hintansetzung der mineralogischen Beschaffenheit der Schichten, die verticale Verbreitung jeder einzelnen Species an den verschiedensten Orten zu erforschen,

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hernach diejenigen Zonen hervorzuheben, welche durch stätes und alleiniges Auftreten gewisser Arten sich von den angrenzenden als bestimmte Horizonte absondern. Man erhält dadurch ein ideales Profil, dessen Glieder gleichen Alters in den verschiedenen Gegenden immer wieder durch dieselben Arten charakterisirt werden. Eine solche Theilung habe ich versucht und sie bei den meisten Etagen ausführbar gefunden; bei andern halte ich sie noch für unvollendet. Die Schwierigkeit dabei hängt hauptsächlich an der ungenügenden Zahl gut beschriebener Arten. Je schärfer die Species getrennt ist, desto genauer können auch die Schichten eingetheilt werden.'

From the middle of the last century onward geochronology has been inseparably associated with stratigraphy. The discovery of radioactivity and its application in geology (geochronometry) has broadened the possibilities and deepened the insight, but not essentially changed the old truth that the record of time is nowhere better preserved than in the Earth's stratigraphic succession. It is for this reason that the way stratigraphers deal with the subdivisions of the succession and the recognition of time intervals achieves a significance far beyond the field of stratigraphy proper.

The earlier sessions of the International Geological Congress, from the first in Paris (1878) were concerned with the establishment of stratigraphic subdivisions and of corresponding time units. Most of our present stratigraphic (and geochronologic) scale is the result of discussions and decisions during the sessions in the eighties of the last century. Later, interest shifted to other matters but after the second world war the enormously increased geological knowledge on a global scale, and the need for more precise correlations, led to a renewed interest in old problems.

A quarter of a century has elapsed since the International Subcommittee on Stratigraphic Terminology was created by the 19th International Geological Congress in Algiers (1952). In the sixties the Subcommittee's scope was broadened when the word 'terminology' in its name was replaced by 'classification'. The first circular was distributed as early as 1955, followed by nearly fifty others until the final preparations for the *Guide* were started. Part xxv of the Report of the 1960 Copenhagen congress was the Subcommittee's first report, and it clearly showed the direction in which thoughts and opinions among its members were developing. Prior to the Montreal congress (1972) drafts of most chapters to be included in the definite *Guide* were made available. Nobody can reproach the Subcommittee that it completed its first task in secrecy.

From the start it has been evident that the Subcommittee opted for a scheme similar to the one adopted by the AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE (1961), viz. a threefold division of stratigraphic successions, according to lithological, palaeontological and chronological criteria. This

seems a sound basis, although particularly in Europe some geologists were not too happy, perhaps because they had forgotten that the widely used stratigraphic scale was largely an early European 'lithostratigraphy', repainted with the brush of chronostratigraphy.⁴⁾

After such a long time in preparation, and the publication of reports and drafted chapters the first edition of the definite *Guide* does not contain any surprises for the reader who has followed the Subcommittee's proceedings over the years. Still there is ample occasion to admire the concise style and the excellent way in which the subject matter has been arranged.

There are two introductory chapters (1 and 2), dealing with the history and the status of the *Guide*, and with the underlying principles respectively. The latter chapter is too short to be a defence of the principles adopted by the Subcommittee against those who hold fundamentally different opinions. Indeed, the *Guide* is not the place to start the discussion again. Two general chapters follow (3 and 4) dealing with definitions and procedures, and with stratotypes. Most of what is said here, applies equally to the three types of classification distinguished. The arrangement of these matters in two separate chapters avoids repetition in the next three chapters (5, 6 and 7) on lithostratigraphic, biostratigraphic and chronostratigraphic units. The final chapter (8) deals with the relation between the several kinds of stratigraphic units. The text proper of the *Guide* comprises less than a hundred pages. Four appendices give details about membership of the Subcommittee, its published reports, a list of depository libraries where a complete set of the subcommittees' 46 circulars is available, a list of national and regional stratigraphic codes, and the vote of the Subcommittee's members on publication of the *Guide*. A 74-page bibliography completes the book. It contains about 1500 references to papers on stratigraphic principles and practice, terminology and procedures, from Arduino's, and Gressley's classic papers to Schindewolf's dissentient views, or the papers by Seneš and co-workers on neostratotypes in the Central Paratethys region of the sixties and seventies. This extensive, but still not exhaustive bibliography is a most valuable addition. An excellent index and a detailed table of contents (eight pages) allow easy and fast tracing of any specific point. The text is written in a clear and unambiguous style, and this by itself would be sufficient reason to make the *Guide* compulsory reading for students.

Nobody can deny that the *Guide* in its present form constitutes a valuable and indispensable piece of work, although some readers may feel disappointed by the lack of modern techniques and concepts of increasing importance. Apart from the conventional lithostratigraphy several physical techniques have been introduced to approach the stratigraphic succession, particularly those developed by oil companies in well-logging. Whether or not one adheres to Jeletzky's disapproving label of 'technologically glorified' stratigraphy (JELETZKY, 1956, p. 683), it does exist and we have to

⁴⁾ How much this confusion between lithostratigraphy and chronostratigraphy still continues in Europe, may be seen from the inclusion in the Rotliegend of marine lower Permian deposits occurring in the North Sea area below the typical Zechstein evaporite cycles, a practice followed by many authors.

deal with it. Neither is there any discussion of the problems raised by the introduction of subsurface units, and this is the more deplorable as with increasing activity on the continental shelves many new formations or other units are being separated which are unknown from the surrounding land⁵). Even more important from a general stratigraphic point of view are the results from ocean drilling projects. There can be no doubt that the knowledge thus obtained will be of ever increasing importance for the later part of Phanerozoic stratigraphy. Owing to the nature of the oceanic record new stratigraphic concepts have been introduced, and one may hope that the Subcommittee will consider this matter when preparing future editions of the *Guide*. Associated with –though not restricted to– the ocean bottom stratigraphy, is the use of the so-called magnetic polarity time-scale. Of course this is an unfortunate and misleading term, as a succession of normal and reversed polarity intervals does not constitute a time-scale any more than physically separated intervals of a stratigraphic succession. In this respect the polarity scale is rather a poor one, as it is a simple and irregular a/b rhythm. However, coupled with radiometric dates it yields a new tool of the highest importance, because the magnetically separated intervals are based on world-wide isochronous events. Again, the Subcommittee should incorporate this development in the *Guide* in future.

One can hardly expect general agreement to prevail from now on in such controversial matters as stratigraphic nomenclature and classification. The Subcommittee is the first to recognize that continued discussion is desirable, and will lead to improvements in future editions. The following suggestions may be offered towards this end.

The Subcommittee recommends that the printing of names of fossils when used to designate stratigraphic units should follow the rules of zoological or botanical nomenclature (p. 23), e.g. *Exus albus* Assemblage-zone. It is deplorable that the Subcommittee did not follow Arkell's sound reasoning that the name of a fossil once included in the name of a stratigraphic unit, should follow the rules of stratigraphic nomenclature, in other words: no italics and an initial capital, even if the genus name is dropped, in case no confusion arises: *Arietites bucklandi* Zone, or *Bucklandi* Zone (ARKELL, 1956-a, p. 464-465). As a general rule the spelling of words follows their actual meaning, not their derivation. When J. Sowerby named an ammonite species after Dean William Buckland, the specific name became 'bucklandi', according to the rules of zoological nomenclature. Similarly no initial capitals are used in words as diesel engine, roentgenography, etc. (SYKES, 1976). Notwithstanding Arkell's strong words the confusion of zoological nomenclature with stratigraphical nomenclature still continues.

⁵) This neglect seems reciprocal. In a recently published lithostratigraphic standard for parts of the North Sea (Deegan & Scull, 1977) a number of members are introduced named after famous historical figures as Eirik Raude, Fridtjof Nansen, and others.

Regarding boundaries between chronostratigraphic units the *Guide* emphasizes the importance of boundary-stratotypes, rather than of unit-stratotypes: a unit (i.e. a stage)' is best defined simply by its boundary-stratotypes' (p. 71). The use of unit-stratotypes immediately leads to difficulties except in the very rare cases where two stages are defined in one continuous succession. Usually successive stages are based on different sections, more often than not in different sedimentary basins (cf. the classic stages of the Jurassic), and then there is the conflicting evidence of the upper boundary of one stage and the lower boundary of the next one. Therefore the only unambiguous way to define units, and particularly stages, is by defining the boundary between two successive stages in a boundary-stratotype. However, in order to avoid a profusion of type-localities, boundary-stratotypes should as far as possible be connected with the lower boundary of what has traditionally been considered the unit-stratotype. At that particular locality the upper boundary depends on correlation with the lower boundary of the stratotype of the next succeeding unit, in other words it is subject to changes when more, or more reliable, data become available.

The Subcommittee is well aware of the importance of stage boundaries 'because they serve to define not only stages but also chronostratigraphic units of higher rank . . .' (p. 71). It is surprising to see that this important point is just mentioned as an incidental remark. Theoretically it would be possible to start at either end of the hierarchy of chronostratigraphic units, or even anywhere in between, but it should be borne in mind that once a boundary is defined at a certain hierarchical level, it is fixed in the corresponding hierarchical categories as well. As soon as e.g. the boundary between the uppermost stage of the Permian and the lowermost stage of the Triassic is defined, all corresponding boundaries of the units of higher ranks, up to and including the boundary between Palaeozoic and Mesozoic, are established, and vice versa. From a theoretical as well as from a practical point of view it seems desirable to start from the boundary between stages, generally considered as the standard units of chronostratigraphy. Ironically one of the first successful attempts at reaching agreement on a much disputed boundary, viz. between Silurian and Devonian, proceeded precisely the other way round (MARTINSSON, 1977). I am afraid that not everybody is fully aware of the consequences regarding the definition and nomenclature of units of lower rank in this interval. Taking into account the particular climatic conditions prevailing towards the end of the Cainozoic, one must admit that it was unavoidable to define the Pliocene-Pleistocene boundary –as was done at the London congress in 1948– long before there was any consensus on Pliocene, let alone Pleistocene stages.

As a general rule geochronologic units bear the same name as the chronostratigraphic units with which they correspond and from which they are derived. The time interval corresponding to the Devonian System is the Devonian Period. Similarly Frasnian Time corresponds to the Frasnian Stage.

This is a simple and unambiguous procedure. There is no reason for a dual nomenclature as long as we are aware that each of the unit names has a double meaning: e.g. the Devonian succession (stratigraphic meaning) is largely made up of carbonate rocks, or: in the Devonian (chronologic meaning) seas corals flourished. I fail to see what makes the Subcommittee bow to the growing number of stratigraphers who neglect this old and sound rule when it comes to series and epochs. Here the adjectives 'Lower' and 'Upper' are replaced by 'Early' and 'Late' when applied to epochs. The time interval corresponding to the Upper Devonian series is then referred to as Late Devonian. The Subcommittee recognizes 'early' and 'late' (without initial capitals) as useful but informal terms when reference is made to something that occurred at the beginning or towards the end of a certain interval of time (and then not necessarily an epoch). There can be no objection to this informal use of 'early' and 'late', although in several languages other than English it is difficult to apply the subtle difference. It is a matter of regret that the Subcommittee has not taken a stronger point of view, and tried to eliminate the bad usage of 'Early' and 'Late' as adjectives in formal geochronological terminology. It is a symptom of unhealthy thinking; when we accept that geologic time is signified by the recognizable stratigraphic succession, and agree that the same set of names is to be used for the subdivision of both, then the only appropriate term for the time interval corresponding with the Upper Devonian Series is the Upper Devonian Epoch. Any other procedure leads only too easily to confusion. Let me illustrate the point by quoting a sentence not from a student's written report, but from an acknowledged scientific journal: 'The age of deformation of the rise-complex in the northern area is post-Early-Late Devonian, pre-Late Late Devonian (i.e. post-Frasnian, pre-Famenian)' (sic!) (SCHENK, 1971, p. 1223).

On nearly every page of the *Guide* the Subcommittee provides evidence of its straightforward and clear way of thinking, as of course it had to do when writing a code to lead us through the labyrinth of stratigraphic nomenclature. Of zones the Subcommittee says: 'The loose use of the unqualified word 'zone' . . . has been the source of much confusion' (p. 67). And of series: 'The term series has been frequently used incorrectly as a lithostratigraphic term more or less equivalent to a group and consisting of an alternation of lithologic types. This usage should be discontinued' (p. 73). This is only too true. When we accept a term in a formal sense, as is the case with 'series', we should avoid using it in an other meaning.

Unfortunately the Subcommittee has suffered a single moment –if I am allowed to use this term here in an informal sense– of weakness when it introduced the term chronozone with two distinctly different meanings. On p. 67 the term is defined as 'a zonal unit embracing all rocks formed anywhere during the time range of some geologic feature or some specified interval of rock strata'. The time range of any stratigraphic feature –occurrence of fossils, lithology or any other

feature, 'provided it has features allowing time-correlation with stratal sequences elsewhere' – may be the basis for the time span of a chronozone. On p. 69 the chronozone is introduced as 'a formal term for the lowest ranking division in the hierarchy of chronostratigraphic terms', i.e. below a stage. It is not easy to follow the Subcommittee in sanctioning, or even recommending, a term with two different meanings. Admittedly the difference is perhaps not as fundamental as it might appear at first sight. This, however, makes the matter only worse, because 'The time span of a chronozone [in its formal sense as a subdivision of a stage] is usually defined in terms of the time span of a previously designated stratigraphic unit such as a formation or a member or a biozone'. This is a straightforward invitation to confusion.

Apart from a practical objection against the procedure, a much more fundamental one must be made. Here the whole system seems to be turned upside down. Our concept of geologic time, as contrasted to radiometric time, is based on the recognition of events that took time to proceed. As such the stratigraphic succession is the most generally used. In other words a part of this succession defined in one way or another, is accepted as a chronostratigraphic unit, and then, and only then, the corresponding time interval is recognized as a geochronological unit. But in this case the Subcommittee starts by defining a time span, on dubious grounds, and from this a chronostratigraphic unit is derived. If there is any need to dispose of units of lower rank than a stage, the only sound procedure seems to divide an established stage into two or more subdivisions, preferably but not necessarily at the stage type-section. However, in the Subcommittee's opinion the time span of chronozones is usually defined in terms of the time span of stratigraphic units (formations, members, biozones) which more often than not are bounded by diachronous surfaces, and hence are unsuitable in the delimitation of time-stratigraphic units. The introduction of the term chronozone in an informal and in a formal sense seems an unfortunate step. In its informal meaning the use of the term presupposes established time correlations, but as soon as these are available there is no longer any need for an informal term, as biostratigraphic or even chronostratigraphic terms satisfy the needs. For the chronozone as a formal term the situation is not better. Theoretically stages are world-wide chronostratigraphic units, and eventually one set of stage names would suffice the world over. We are still far away from this situation. ARKELL's *Jurassic geology of the world* (1956-b) is an attempt to show the applicability of a single set of stages on a global scale. At the same time, however, it clearly demonstrates with how many difficulties such an attempt is beset, even in a system where ammonites are nearly perfect stratigraphic fossils.

Therefore in the present state of affairs the creation of formal, world-wide units below stage rank does not seem to be an urgent matter, but where the need occurs substages would perfectly suit the requirements. Units smaller than stages are in many cases available in the form of biostrati-

graphic units. Such units, however, are not formal subdivisions of a stage. Two or more zonal schemes may exist side by side, and their respective boundaries need not, and usually do not, coincide. The Subcommittee must have been aware of at least some of the trouble ahead, as the reader, much to his surprise, is told on p. 70: 'Chronostratigraphic units, such as stages, cannot very satisfactorily be subdivided hierarchically into chronozones of this type (i.e. biostratigraphic units) because, while the time span of a stage is fixed by its boundary-stratotypes, the time span of such a chronozone may vary, not only from place to place, but also at any place with increasing information about the diagnostic characters of the stratigraphic unit on which it is based. Chronozones of this sort may not only develop overlaps and gaps among themselves, but also their boundaries may not continue to be at the stage boundaries with which they were originally supposed to coincide.' Here I completely agree with the Subcommittee. One can easily see that *mutatis mutandis* similar objections exist against chronozones based on lithostratigraphic units. The introduction of chronozones as formal chronostratigraphic units of lower rank than stages, remains an unfortunate step, and should be abandoned as soon as possible.

The Subcommittee has missed the opportunity of suggesting that in titles of papers lithostratigraphic, or other not generally known names, should be followed by a chronostratigraphic name, preferably of system or series rank, in order to give an indication of the whereabouts in the stratigraphic column to the reader. Bibliographers as well as more serious readers would have been grateful for an additional 'Holocene' (between parentheses) in a title as 'Metasedimentary 'Graben' and associated structures in the lagoonal Almere Member (Groningen Formation, The Netherlands)' (VAN LOON & WIGGERS, 1976). The Ordovician age of the fauna described in COOPER'S (1956) monograph 'Chazyan and related brachiopods' (well over a thousand pages) is only casually mentioned in the introductory stratigraphic section.

One of the main specific objectives of a chronostratigraphic classification is the establishment of a 'standard global chronostratigraphic scale'. By definition this leads immediately to a 'standard global geochronologic scale', i.e. a single set of names in different categories denoting precisely defined intervals of geologic time. There can be no doubt that such a hierarchical set of names is urgently needed. The present state of geology demands more than ever the availability of an unambiguous frame to put events of all kinds into their proper place in time. It is most confusing to see that different names are still being used for more or less similar intervals, or that the same names are used for only vaguely or even differently defined intervals. The Subcommittee recognizes that a uniform set of names in the lower rank units, although desirable, is still a distant goal. However, in the higher categories, systems and periods, and perhaps series and epochs as well, the prospects seem fairly bright since the International Commission on Stratigraphy has established a

number of subcommissions to deal with systems, and mixed working groups have been formed to study the joint boundaries. In view of all this work now in progress, it is understandable that the Subcommittee did not feel the need to introduce changes into the commonly used terminology on its own authority. Nevertheless the Subcommittee might well have suggested the abolition of the more obsolete or clumsy terms, such as Quaternary, Tertiary or Precambrian.

As a whole, the *Guide* is a beautiful and most welcome piece of work, on which the Subcommittee and its chairman are to be congratulated. The publication of the *Guide* represents a milestone in the history of stratigraphy. After a century of discussion this is the first coherent attempt to create some order in the wilderness of stratigraphic terminology. Even those of our colleagues who differ fundamentally from the *Guide*'s point of view, cannot fail to recognize its historical importance.

Finally all those who hold deviating opinions, whether on fundamental or on minor points, must feel consoled that the *Guide* is not more than a recommendation. For students of crystalline rocks there is no reason to worry when they read in the opening sentence of chapter two, that 'The whole Earth is stratified, in a broad sense, so that all rocks and all classes of rocks – sedimentary, igneous, and metamorphic – fall within the scope of stratigraphy and of stratigraphic classification.'

Taking into account the international status of the Subcommittee and the nature of the *Guide* as a recommendation, one is probably justified in saying that according to recognized international legal procedure no lower authority, such as a society's council or a journal's editorial committee, is entitled to impose the *Guide* as a set of rules on its membership, or its authors.

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