Remarks on stratigraphical classification.

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Contents.

Abstract.

One may distinguish between chronostratic (or chronostratigraphical) classification (units with time boundaries) and protostratic classification (with quality boundaries). Protostratic classification embraces biostratic and lithostratic classification. Bio- and lithochronostratic units are chronostratic units originally based on biotratic and lithostratic data, respectively. It is suggested to retain the term zone (chronozone) for small chronostratic units based on palaeontological data and to use the term substage for small chronostratic units based on other data. Zonite is suggested instead of zone for small (proto-)biostratic units. The prefixes holo-, topo-, and mero- may be added to stratic terms when it is desirable to stress that they are based on a total, local, or partial range, respectively. Mixed topostratic units are local units with one boundary based on palaeontological data and the other boundary on lithological data. Different types of time-correlation is discussed and it is distinguished between time-correlation of the same unit in different places (auto-correlation) and of different stratigraphical units (allo-correlation). Type sections are believed to be necessary for the boundaries of chronostratic units.

Introduction.

Much and important work has been done by the International Subcommission on Stratigraphical Terminology to clarify stratigraphical concepts and towards reaching an internationally acceptable terminology, but there are still controversies on stratigraphical terminology and classification. Since responsible stratigraphers all over the world work more or less along the same lines, it should be possible to reach an agreement on these questions. The following lines are written as a contribution to the discussion of the problems and in the hope of diminishing some of the controversies.

To avoid misunderstanding, some important concepts are defined or discussed below.

Stratic unit. Since it has been doubted whether a so-called lithostratigraphic unit *(e.g.* formation) really should be regarded as a stratigraphical unit, I shall refer to is as a *lithostratic unit* in the following, and by analogy also make use of the terms *biostratic unit* and *chronostratic unit.* These terms are non-committal, and in any case shorter and at least as precice as the terms lithostratigraphic unit, etc. They may all be referred to as stratic units.

Boundary. When nothing else is stated, the (stratigraphically) upper or lower boundary of a stratic unit is meant.

Time-level. A level corresponding to the subaerial and subaquatic surface of the Earth at a given moment.

Range. The distribution normal to time-levels. It is here opposed to geo-

graphical (or horizontal) distribution. The expressions horizontal and vertical distribution allure to the idea that sediments are deposited in horizontal layers. As we know, this is in most cases only approximately true, and in some cases far from true. Furthermore, later tilting and folding of strata may render it unfortunate to apply the adjectives horizontal and vertical in this connection. The expressions stratigraphical distribution (or range) and geographical distribution seem better. A range corresponds to a certain span of time.

Correlation. According to Webster's Dictionary (1946), correlate is defined as "to put in relation with each other: *v.i.* to be reciprocally related", and correlation is defined as "reciprocal relation". Correlation thus does not necessarily include the time concept.

Apparently the word "correlation" has been used for different reciprocal relations in stratigraphy (cf. also Rodgers, 1959). Thus the correlation of a unit S in one locality with a unit T in another locality may mean that unit T is the lateral extension of the unit S, but not necessarily deposited during the same span of time. On the other hand, it may mean that it is believed that units S and T were deposited during the same span of time. To avoid misunderstanding, one may use the term *time-correlation* in the second case.

Remarks on time-correlation.

One may distinguish between correlation of time-levels *(time-level correlation)* and time-correlation of beds or sequences of beds *(stratum correlation)*.

Any point on the time-scale and any point in a section corresponds to a time-level. Some time-levels distinguish themselves from the others in a particular section, namely as boundaries; lithological, palaeontological or others (not boundaries representing a hiathus, since such boundaries correspond to time-intervals). Time-levels, even if they distinguish themselves in a particular section, are only useful for correlation if they can be recognized elsewhere, at least approximately. In trying to trace time-levels from one locality to another, we make use of various kinds of evidence, but, as we all know, accurate time-level correlation can rarely be undertaken. Usually it happens that a certain time-level in one locality cannot be accurately recognized in another locality, but can be ascertained to lie within a restricted sequence of beds. This may be called an approximate time-level correlation and has a certain mar-

gin of correlational error. The actual sequence representing this margin may be referred to as the "interval of correlational error", or, for short, as the "interval of error". The time-level in one locality thus is correlated with an interval in another, or two such intervals may be correlated.

In trying to time-correlate sequences of beds, one way of doing this would be to demonstrate that two time-levels in one locality are the same as two time-levels in another locality. Provided there are no breaks, the intervening beds in the two localities would then represent the same span of time. This is a kind of stratum correlation which may be called *inter-level correlation*. As just mentioned, time-levels can rarely be traced accurately from one locality to another. If one or both of the levels can only be pin-pointed to a certain interval of error, we have an approximate inter-level correlation. The interval of correlational error of the *sequence* of beds ranges from the lower limit of the interval of error of the lower boundary to the upper limit of the interval of error of the upper boundary.

Instead of inter-level correlation, stratigraphers often undertake another kind of stratum correlation, which may be called *unit correlation*. If a sequence of stratic units (A1 to A4) in one locality (A) is compared with a sequence of units (B1 to B4) in another locality (B), and even provided that the two sequences represent the same span of time, it would only be by chance (and the chance is small) that any intervening boundary (time-level) in A is synchronous with any boundary in B. A time-correlation of A1 with B1, A2 with B2, etc. would then only be an approximate time-correlation. However, such unit correlation is often the best we can achieve, and so may still be most usefull. Unit correlation of two lithostratic units is often based on the occurrence of the same fossil in them, even if the fossil occurs only in a part of one or both of the units. This is not the same as true biostratic correlation as discussed below.

There is no sharp distinction between approximate time-level correlation and approximate stratum correlation. When correlating sequences of the order of size of systems, the lower or upper boundary interval of correlational error may well happen to be greater than the interval of error of the whole sequence when dealing with units of a small order of size, like fossil zones.

One may distinguish between time-correlation of the same unit (*e.g.* zone, formation) in different localities and between different units in

different localities. The first type, which may be called *auto-correlation* (from Greek *autos*, self) generally is less inexact and less complicated than the other type, which may be termed *allo-correlation* (from Greek *allos*, other).

On stratic units and boundaries.

There seem to be two main types of stratic units, those with time-boundaries *(chronostratic units)* and those whose boundaries delimit and embrace beds with a common physical property, such as a particular lithology or a particular fossil content. The latter units, with such quality boundaries, might perhaps be called physio-stratic units. However, since chronostratic units may also be measured in metres and are physical units, this term may lead to confusion, and I propose to call them *protostratic units* (from Greek *protos*, first) because they may be regarded as primary stratic units. They are often the first stratic units to be recognized in an area, and they form the basis for chronostratic units.

We may then distinguish between time-stratic or chronostratic units and primary stratic or protostratic units, and similarly between chronostratic boundaries (or time boundaries) and protostratic boundaries (or quality boundaries). Ideally chronostratic units have time-levels as boundaries. In practice they are usually recognized between two intervals (of correlational error or uncertainty) since time-levels can rarely be traced accurately, and the chronostratic boundaries are then not time-levels but time-intervals ("time-belts").

As discussed below, chronostratic boundaries are primarily based on protostratic boundaries in particular sections. Chronostratic units are generally based on a protostratic unit in a particular section, and one may distinguish between a biochronostratic unit (based on a biostratic unit) and a lithochronostratic unit (based on a lithostratic unit). Where there is danger of misunderstanding, I shall add the prefix "proto-" to make it quite clear that the protostratic unit is meant.

Another difference between stratic units is that some may be arranged in time-continuous sets ("time-sets"), representing a continuous span of time, whereas other kinds of stratic units generally can not, because their ranges either overlap or do not meet each other. These two kinds may be referred to as *time-set-units* and *independent units.*

Furthermore, when possible, and when necessary to anvoid confusion, one may separate between the entire body of a stratic unit, the "whole

unit" or *holostratic unit* (from Greek *holos*, whole) and a local part of the unit, a "local unit" or *topostratic unit* (from Greek *topos*, place). The maximum range of a holostratic unit (the total range) may or may not be represented in any one locality. The range of the topostratic unit, the local range, generally is shorter than, but may equal the total range. A holostratic unit may well be regarded as one large topostratic unit. A unit based on a partial range may be called a *merostratic* unit (from Greek *meros*, part). Holo-, topo, or mero- may be used as prefix for any stratic term when desirable to stress whetcher it is based on a total, local, or partial range (cf. fig. 1).

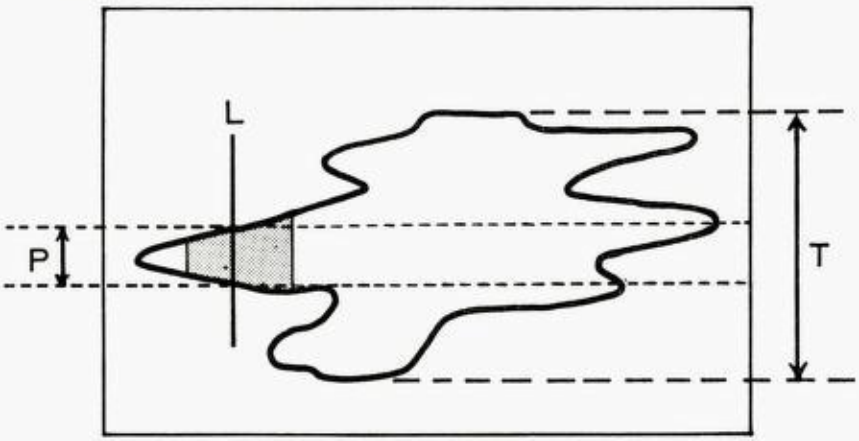

Fig. 1. Schematic cross-section of a protostratic unit, *e.g.* a formation (lithostratic unit) or a zonite (biostratic unit). Horizontal lines represent time-levels. The heavy line delimits the whole unit (the holostratic unit, *e.g.* holo-formation, holozonite). The grey area represents a local part (a topostratic unit, *e.g.* topo-formation, topo-zonite). 'T' denotes the total range of the unit. If the boundaries of the total range delimit a biozone (ontozone), this is then a holozone. 'P' denotes the range in a particular locality ('L'). If the boundaries of this range delimit a biozone, this is then a topozone, and in this case also a merozone because the local range is only a partial range.

Skjematisk tverrsnitt av en protostratisk enhet, f. eks. en formasjon (lithostratisk enhet) eller en sonitt (biostratisk enhet). Vannrette linjer angir tids-plan. Den tykke linjen begrenser hele enheten (den holostratiske enhet, f. eks. holo-formasjon, holo-sonitt). Det grå felt representerer en lokal del (en topostratisk enhet, f. eks. topo-formasjon, toposonitt). «T» angir den totale stratigrafiske utbredelse av enheten. Hvis grensene for utbredelsen avgrenser en biosone, er denne en holosone. «P» angir den stratigrafiske utbredelse i en bestemt lokalitet («L»). Hvis grensene for utbredelsen avgrenser en biosone, er denne en toposone, som i dette tilfelle også er en merosone, da den lokale stratigrafiske utbredsele bare er en del av den totale.

Biostratic versus biochronostratic units.

Biostratic units are based on palaeontological data. In analogy with lithostratic units, biostratic units are understood here to be protostratic units. Just like the fossil forms themselves, biostratic units may have a world-wide to rather local geographical distribution and are generally restricted to a certain facies or group of facies. They are usually named after one or more fossils (index fossils).

The biostratic units are the bodies of strata containing the index fossil(s). The upper or lower boundary of a biostratic unit may be of different age in different localities. A biostratic unit of the zone category has been called a *range-zone*. According to Hedberg (1958, p. 1888), "The vertical and horizontal limits of a range-zone are the vertical and horizontal limits of the particular fossil form concerned." As an international term for a range-zone I propose the term *zonite*. One may distinguish between the entire range-zone (or *holozonite*), a local range-zone (or *topozonite*), and a partial range-zone (or *merozonite*) (cf. fig. 1). The term *acrozone* has been proposed by Moore (1957) as an international term for range-zone. Since Greek *akron* means top, summit, or peak, acrozone might be understood as an epibole (peak-zone) and is then perhaps not so good as an equivalent of range-zone. An assemblage-zone as defined by Hedberg (1958, p. 1887) consists of the body of strata characterized by a certain assemblage or association of fossil forms. It is thus a (proto-)biostratic unit based on an assemblage rather than on the range of a single taxonomic unit. As an internationally more acceptable term, Moore (1957) has proposed the tern *cenozone* (from Greek *koinos*, common, "in common"). In analogy with zonite, it might perhaps rather be termed *cenozonite*.

Biochronostratic units differ from the above in having time-boundaries, not quality boundaries. They are thus true chronostratic units, and the term only implies that the units are *based* on *bio*stratic units. Both (proto-)biostratic and biochronostratic units have often been referred to as biostratic units. Apparently some of the controversies and misunderstandings in stratigraphical classification is due to this inclusion of two kinds of stratic units in one concept.

When a biochronostratic unit is based on the range of a fossil form, it may be called a *life-zone* (alluring to the evolutionary duration of the form in question), and has been referred to as a *biozone*. The latter term has been given various meanings (cf. Teichert, 1958, p. 114; Hed-

berg, 1958, p. 1888, footnote 1; Hupé, 1960, p. 7) and for this reason another term may be desirable, and I propose the term ontozone (from Greek *ontos*, being, thing, — cf. palae-onto-logy). I would personally prefer to retain the term biozone for this chronostratic concept, although it was originally (Buckman, 1902) proposed to "signify the range of organisms in time as indicated by their entombment in the strata" and so may be understood as a time term. According to whether the unit is based on a total, local, or partial range, one may, when possible and necessary, distinguish between entire, local, and partial life-zone, or between holobiozone (holontozone), topobiozone (topontozone), and merobiozone (merontozone), or, for short, between *holozone*, *topozone*, and *merozone*. The term *teilzone* has been used for merozone, but it was originally defined as a time term (Pompeckj, 1914) and is a poor name etymologically. The term *topozone* was introduced by Moore (1957) to replace teilzone in its spatial sense. Although a local life-zone very often is a partial life-zone, it may represent the entire life-zone, and it seems convenient to retain the term topozone for a local range-zone.

More on biostratic and biochronostratic units. The terms *faunizone* (Buckman, 1902) and *florizone* have been given somewhat different meanings (cf. Hupé, 1960, p. 6), but will here be understood to be units based on the range of a certain fauna or flora. This seems to be the best definition from a biological point of view. Buckman's definition (1902, p. 557), "belts of strata, each of which is characterized by an assemblage of organic remains", seems to fit for the (proto-)biostratic term, which might be referred to as *faunizonite (florizonite)*, whereas faunizone (florizone) is retained for the chronostratic term. An epibole (Trueman, 1923) is a unit which has been defined as all beds deposited during the maximum abundance (acme) of a taxonomic unit (Hupé, 1960, p. 8) and as rocks deposited during a hemera (time of the acme of development) (Teichert, 1958, p. 115) and may thus be interpreted as a chronostratic unit. The corresponding (proto-)biostratic unit (all beds containing the acme of a fossil form) hardly needs any special term, but might be referred to as the acme beds.

A section through a shale (fig. 2, colum I) has yielded the fossil forms A to E, their range and frequency being shown in column II. As shown in colum III, the shale embraces 5 biozones (ontozones), whether merozones (if the ranges are partial) or holozones (if the ranges are total ranges). The 5 possible epiboles are shown in colum IV.

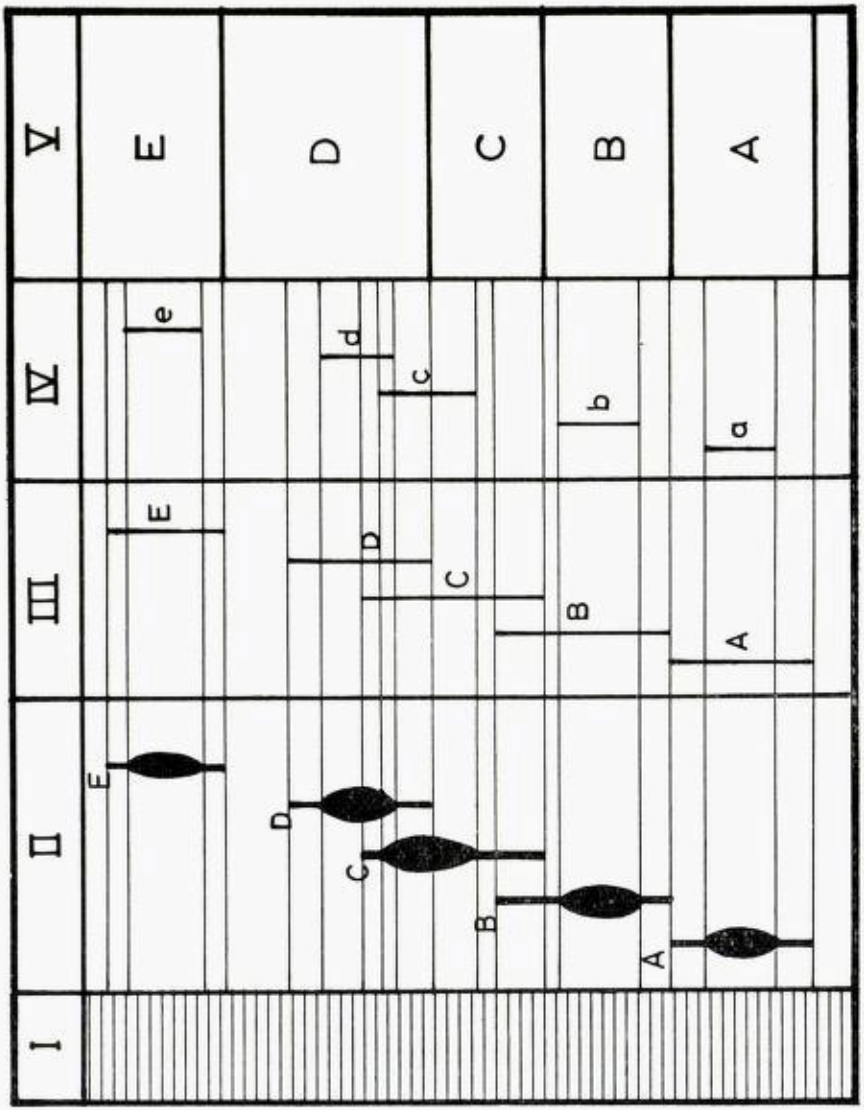

Fig. 2. Column I: Section through a succession of beds. Column II: Range and frequency of the fossil forms A to E. Column III: Biozones (ontozones) A to E (holozones or merozones). Column IV: Epiboles a to e. Column V: Chronozones A to E.

Rad I: Lagrekke. Rad II: Utbredelse og hyppighet av fossil-formene A til E. Rad III: Biosonene (ontosonene) A til E (holosoner eller merosoner). Rad IV: Epibolene a til e. Rad V: Kronosonene A til E.

Neither the biozones nor the epiboles contitute a continuous set of units since the ranges generally overlap or do not meet each other. Exceptions in this example are the ranges of A and B, which just meet. Such exceptions are rare (where there are no breaks), except when B developed from A. Even in the latter case there may be an overlap. Faunizones and florizones, as defined above, would agree with biozones and epiboles in having ranges which generally overlap or do not meet, *i.e.* they are independent units as defined above.

Biozones (ontozones), faunizones, florizones, and epiboles are all units which are based on a range (total or partial) from its beginning to its end, whether of a taxonomic unit, a fauna or flora, or of the greatest frequency of a fossil form. They may be called simple biochronostratic units. To the same group may be referred those units which are based on two or more ranges, from the beginning of the range of the earliest form to the end of the range of the latest form.

Somewhat different are chronostratic units representing the interval from the beginning of the range of one form to the beginning of the range of another form (or the interval between the ends of two ranges). Such units may be referred to as special biochronostratic units. They may be said to be based on both the presence and absence of certain fossils, and their lower boundary is always controlled by another fossil than their upper boundary. In contradiction to the case with simple biochronostratic units, the special biochronostratic units (A to E in colum V, fig. 2) may be chosen so as to form a time-continuous set of units (they are time-set units), although they are based on the same palaeontological data as the independent, simple biochronostratic units. They will be discussed further under chronozones.

Several other types of biostratic and biochronostratic units have been given names (cf. *i.a.* Teichert, 1958, and Hupé, 1960). For names of terms, see also below under "Chronostratic units" and "Zone versus substage".

Time-correlation of biostratic units. When we try to time-correlate two sequences by the help of fossils, it is often the fossil ranges which we compare, or, in other words, we make use of the biochronostratic units.

Both time-level correlation and stratum correlation may be based on fossil evidence. Time-levels recognizable outside the type section are especially those through the beginning or end of total ranges. Since we usually deal with partial ranges, the time-level correlation is usually

only approximate, and so is inter-level correlation. The margin of correlational error cannot, however, be greater than the corresponding holozone. This is why fossils with short ranges should be preferred in connection with time-correlation. Total ranges of fossil species may be assumed to correspond to time spans from about 5 million years to at least as little as 300.000 years (cf. Teichert, 1958, pr. 107). Total ranges of subspecies and short-lived species probably correspond to about 1 million years or less.

What is written above pertains to auto-correlation. Allo-correlation of biostratic units is more complicated and uncertain. If the fossils in two regions are different but related, it is still possible to undertake an approximate correlation, which, however, may be rather rough. The same is true if the fossils are on the whole different, but there are stray elements of forms from one region (or facies) into the other region (or facies). When the fossils are entirely different, time-correlation has to rely on such evidence as interfingering and position in relation to known levels.

Lithostratic versus lithochronostratic units.

Lithostratic units are protostratic units based on lithological data. They generally have a rather restricted geographical distribution and at least are not world-wide units.

A succession of geological strata may be divided into lithostratic units with more or less uniform lithology *(e.g.* formations, members). It is well known that such lithostratic units may be of different age in different localities. An extreme example of this is a transgressive conglomerate. Thus the lower and upper boundary of a lithostratic unit need not, and generally do not represent the same time-levels in different localities (but are quality boundaries). The range of the various time-levels of the upper boundary may even overlap the corresponding range of the lower boundary. The locally present part of *e.g.* a formation is a topostratic unit (topolithostratic unit). Its range, the local range, generally is shorter than but may equal the total range of the whole formation (a hololithostratic unit). One may, when necessary, distinguish between *e.g.* a holo-formation, topo-formation, and mero-formation (cf. fig. 1).

One of the longer total ranges known to me, its that of the Alum Shale formation in Scandinavia, which ranges from and including the

lower Middle Cambrian to and including the Lower Tremadocian. One may assume that total ranges of formations may correspond to a time span of the order of size of 100 million years, although most formations no doubt have a considerably shorter range. One might argue that formations might represent even considerably more than 100 million years. Thus *e.g.* sand most probably has been deposited all through geological time. However, this has hardly taken place continuously in any one area, and even if it had, it would no doubt be possible to distinguish between various types of sandstone, permitting a division into several formations.

Lithochronostratic units have time-levels (or time-belts) as boundaries and are based on the interval between two lithological boundaries (often the range of a certain lithology) in a type section. As with biochronostratic units, they may be based on total or partial ranges, or on ranges of topostratic or holostratic units. Chronostratic units based on succeeding topolithostratic units in a certain section represent a continuous span of time (where there are no breaks) and are thus time-set units. The ranges of the corresponding hololithostratic units generally overlap, and the chronostratic units based on them thus do not constitute a time-continuous set of units but are independent units. As terms for lithochronostratic units may be used: system, series, stage, substage (cf. p. 80), and format (p. 74).

Time-correlation of lithostratic units. When fossils are present, both auto- and allo-correlation of lithostratic units may be carried out by their help. Only time-correlation without the help of fossils is considered in the following.

When we try to time-correlate lithostratic units in two or more localities, it is really their local ranges or the corresponding lithochronostratis units which we compare. Such chronostratic units are generally poor with respect to time-correlation, since time-levels (or smaller time-belts) can rarely be recognized on lithologic data alone. Thus lithologic boundaries usually cannot be used for tracing time-levels, because they may be of rather different ages in different localities. An exeption is the tracing of time-levels by the help of beds which may be assumed to have been deposited during a short span of time such as lava beds, bentonite beds, and varves. Such marker beds are, in fact, the best means we have to trace time-levels rather accurately. The problem in this case is to recognize the same *e.g.* bentonite bed in different localities. Where there are more than one bentonite bed, a certain bed

may be recognized by its thickness or position in relation to other betonite beds, thus using the same methods as in dendrochonology. Where we have more than one such marker bed, inter-level correlation can be rather accurate. A drawback is that marker beds generally have a rather restricted geographical distribution. The body of strata between two such marker beds have been called a *format* (cf Hedberg, 1959, p. 679, footnote 2). A synonymous term is *arbet,* proposed by K. Kanehara in 1955 cf. Ida, 1958). Formats are unusual units as they may be regarded both as lithostratic and chronostratic units, since their boundaries are both quality boundaries and time boundaries.

The above cases are expetions and generally time-correlation of beds based on similar lithology is rather hazardous. Thus even if the beds belong to the same formation, the total range may be considerably longer than the local range, and the interval of correlational error becomes unreasonably large. As just mentioned, total ranges of formations may be assumed to correspond to a time span up to the order of size of 100 million years. No doubt most formations have much shorter ranges, but the difficulty is to be sure of this. If one has a rather thick sequence with many non-littoral lithostratic units, and they appear in the same order in another locality, the chances are fairly good that the two sequences are of approximately the same age, especially if the various units have more or less the same thickness in the two localities and these are not too far from each other. Neither this is quite certain, however.

Allo-correlation of lithostratic units (without the help of fossils) has to rely on such evidence as interfingering, transitions, and position in relation to known horizons.

Mixed topostratic units.

Lithostratic and biostratic divisions are two common types of stratic division of a geological sequence. It has, however, often been the practice of stratigraphers to divide a sequence into units of which some are lithostratic ones, others biostratic, whereas some units are of an intermediate type, *i.e.* units with the lower boundary based on lithologic data and the upper boundary on palaeontologic data, or *vice versa.* This type of unit may be referred to as mixed topostratic units. They may locally be very useful, and Jaanusson, recognizing this, has recently (1960, p. 218) proposed the term topo-stratigraphic units for them.

According to him "The term topostratigraphic classification can also be used when referring to a regional classification of rocks which includes topo-stratigraphic as well as conventional lithostratigrapical subdivisions".

Topostratic classification is here taken in a somewhat wider sense to include topo-lithostratic and topo-biostratic, as well as mixed topostratic units. Mixed topostratic units occur where either a lithostratic unit is divided further on palaeontological grounds, or a biostratic unit is divided further on lithological evidence.

Some differences between litho- and biostratic units.

Apart from being based on different properties, there are other differences between litho- and biostratic units, some of which are of special interest in connection with time-correlation.

As already stated, lithostratic units have a more or less restricted geographical distribution, whereas biostratic ones may be up to world-wide. Furthermore, the interval of correlational error is generally greater when concerned with lithostratic than with biostratic units. A very important difference is connected with the fact that fossils, besides allowing the local succession to be worked out, in most cases also give a more or less definite indication of the relative age of the succession, that is whereabout in the stratigraphical scheme the succession is located, *e.g.* in the Lower Silurian ("evolutionary clock"). Local successions of lithostratic units may generally also be worked out, but there is usually no way of telling the age of the succession in relation to others without the help of fossils. One might illustrate the situation by comparing it with the case of being able to work out the succession of historic events which took place during 17 days, without being able to tell in which year. It should be added that radioactive age determination may help somewhat, but at least at present only in a rough way (in the above parable to be able to refer the events to a certain century).

Chronostratic units and boundaries.

Chronostratic units are stratic units with time-boundaries. Ideally they have time-levels as boundaries, in practice often time-belts. As chronostratic terms have been used (in decreasing rank): system, series, stage, and substage or zone (cf. further under "Zone versus substage").

A unit like "system" is neither a lithostratic nor (proto-)biostratic unit. All Permian strata of the world cannot be ascribed to a single lithostratic unit, and neither to a single (proto-)biostratic unit since the fossil content varies from region to region and even more so from facies to fasies. A system may be regarded as a typical chronostratic unit; the various systems constitute a time-continuous set of units, and their boundaries are time-levels.

Assuming that it was possible to trace accurately the time-levels of the lower and upper Permian boundary all over the world, it would no doubt appear that the Permian outside the region where originally defined would not correspond to a whole number of fossil zones, but that its boundaries would cut right through zones, except by chance. It is irrelevant in this connection that we usually have no means of tracing time-levels accurately enough to demonstrate this, since we know that zonal boundaries in one region or facies only by chance would coincide with boundaries of other zones in other regions or facies.

I admit that a system might be regarded as a large (proto-)biostratic unit but would then have to be accepted as a local unit (as also suggested on other grounds by Wheeler e.a. 1950), which is against practice and would no doubt result in the establishment of some chronostratic unit in its stead. The Cambrian and later systems may be regarded as biochronostratic units because their boundaries are usually defined on palaeontological data.

Much the same as is argued above for "system", may also be argued for "series" and "stage", when applied outside the region where originally defined. As put by Arkell (1957, p. 9), stages "transcend zones both vertically and horizontally". Where originally defined, a stage comprises so and so many zones, and a series so and so many stages, and there is little difference between zones and higher categories except in their order of size. Whereas zones are usually not recognized outside the region and facies of the index fossil(s), this is often the case with stages and series, and, of course, generally the case with system. When used outside where originally defined the units can only be recognized where their lower and upper boundaries may be traced by correlation. Because of the margin of correlational error, this is hardly possible on a world-wide scale with as small units as zones (and rarely even with stages). If it was possible, there would be no significant difference between zones and higher categories except in their rank.

Chronostratic boundaries are primarily based on *e.g.* biostratic or lithostratic boundaries in particular sections, and where erected, the chronostratic unit may correspond in time to a biostratic or lithostratic unit in a particular section (the chronostratic unit is then "based" on a protostratic unit). However, when chronostratic units are recognized elsewhere, its boundaries may be recognized on other evidence (in contradiction to protostratic units). Thus chronostratic boundaries originally based on palaeontological evidence may well happen to be recognized on lithological data elsewhere, or *vice versa*. The terms biochronostratic and lithochronostratic unit only indicate that the boundaries of the unit *originally* were based on biostratic and lithostratic boundaries, respectively. Some (mixed) chronostratic units may have one boundary based on a lithostratic boundary and the other on a biostratic boundary.

Several authors have regarded chronostratigraphy and biostratigraphy as synonyms. It is no doubt true that biochronostratic units are chronostratic units, but (proto-)biostratic units are not, and chronostratigraphy embraces more than biochronostratigraphy. Thus it is the lithochronostratic concept which we make use of when we try to correlate lithostratic units without the help of fossils. Furthermore, one should recall that stratigraphers make use of such names as Eocambrian, Riphean, Beltian, Sinian and others. They are not lithostratic units since they include too variegated lithologies. Concerning these examples, one might argue that the upper boundary is palaeontologically controlled, since they are all succeeded by fossiliferous Cambrian strata, but also units like Gotho-Carelidian, Huronian, and many other Precambrian units may be regarded as chronostratic units. They are not based on palaeontological data and include too different lithologies to be accepted as large lithostratic units. Such Precambrian units are only of regional importance, since correlation from region to region is hardly possible on lithologic data alone. However, radioactive age determination has already enabled us to correlate different Precambrian "supersystems" in different regions. This may be regarded as an approximate unit correlation. Even if the margin of correlational error corresponds to say 100 million years, this is no worse for units of the order of size of 500 million years than 0.5 million years when concerned with units of the order of size of 2.5 million years (as some fossil zones). Radioactive age determination may lead to the erection of very large but world-wide Precambrian units between intervals (rather than time-levels) which

are large, but not unreasonably large in relation to the unit. Some correlation of Precambrian sequences may be looked upon as a rough and approximate inter-level correlation. Thus sequences between the same two orogenies may be correlated with each other. The margin of error then equals the duration of the orogenies. We all know that time-correlation on lithological data is generally far more uncertain than on palaeontological data, and only possible locally, but it is often the best we can do and there is no difference in principle between chronostratigraphy based on lithological and on palaeontological data.

One should not forget that even rather small chronostratic units may be based on lithological data, since rather accurate inter-level correlation may be based on such evidence in exceptional cases (lava beds, bentonite beds, varves, and perhaps sedimentary cycles). This type of chronostratic units are also of rather local importance, but very useful as such. They generally have a smaller margin of correlational error than do chronostratic units based on fossil evidence, which likewise may have rather restricted geographical distribution. There is thus no fundamental difference between these two types of chronostratic units.

If one accepts that a unit like "system" is neither a lithostratic nor biostratic unit, or if one accepts that chronostratic units need not necessarily be based on palaeontological evidence, it seems logical to regard chronostratic classification as an independent kind of stratic classification, different from biostratic and lithostratic classification.

The most useful chronostratic units are those which may be arranged in time-sets. Geochronologic schemes are based on such chronostratic time-set units, and geochronologic and chronostratic units have in common that their boundaries are time boundaries. It may be added here that chronostratic units and geochronologic units based on them hardly will be abolished even if absolute age determination becomes accurate. Thus historians use the term "Viking age" rather than "800 to 1050 after Christ", in spite of "Viking age" not being of world-wide applicability and thus is used only locally.

Time-correlation of chronostratic units. Chronostratic units should be chosen so as to be as easily recognizable as possible. In other words, as their boundaries should be chosen time-levels (or small intervals) which can be recognized as accurately and as far away as possible. Since, on the whole, time-levels (or time-belts) can be recognized safer on palaeontological than on lithological data, chronostratic units should preferably be based on palaeontological data. Biochronostratic units gene-

rally are to be preferred over lithochronostratic units where there is a choice. Since time-levels through the ends of total ranges can more safely be recognized than time-levels through the ends of partial ranges, chronostratic units should preferably be based on total ranges. One should avoid basing them on mixed topostratic units.

One may distinguish between world-wide and local chronostratic units, and as with other stratic unit, one may make use of both interlevel correlation and the generally more inexact unit correlation. One may likewise differentiate between auto- and allo-correlation of chronostratic units. Allo-correlation of chronostratic units relies on such evidence which is used in allo-correlation of biostratic and lithostratic units.

Chronostratic versus protostratic boundaries.

It seems important to distinguish between chronostratic and protostratic boundaries, since confusion has arisen when protostratic boundaries (quality boundaries) have been mistaken for chronostratic boundaries (time boundaries).

There is one interesting difference between these two types of boundaries. Chronostratic boundaries should not, if possible, be erected at a break, since a chronostratic unit can be properly defined only where at least the adjoning parts of the over- and under-lying units are present. On the other hand, breaks are natural boundaries for (proto-)biostratic and (proto-)lithostratic units, and protostratic boundaries should be drawn at any larger break. As biostratic breaks may be regarded breaks in fossil content due to *e.g.* 1) non-deposition, 2) unfossiliferous beds (barren zones), 3) change in facies, 4) change in fauna or flora due to invasion, and of course secondary breaks, due to erosion, faulting, thrusting, etc.

According to Teichert (1958, pp. 115—116) the "type Permian", "type Triassic", etc. do not exist, thus *e.g.* all and any rocks deposited during the Ordovician period are typical for the Ordovician system. This is logical; nevertheless, we do need a kind of type section for systems (and other chronostratic units), namely for the boundaries. Thus in the case of the Ordovician system, we need a type section for the Cambrian/Ordovician boundary and another for the Ordovician/Silurian boundary. The two type sections need not necessarily be located in the same area.

Since time is universal, such type boundaries would not be necessary if one could determine the absolute age of any horizon accurately. In that case, we had only to agree upon a certain year to represent the boundary between *e.g.* the Cambrian and Ordovician periods. However, as it is, we make use of relative ages and dating by correlation. It is therefore practical to select a type boundary. In other localities, one has to determine the corresponding time-level as accurately as possible (trying to obtain as small an intervall of correlational error as possible). For this reason, the type boundary should be chosen so as to allow the corresponding time-level to be recognized in other localities as accurately as possible, thus preferably be based on data on fossils with great geographical small stratigraphical distribution.

Zone versus substage as unit term.

The reasons for retaining the term "zone" for the subdivisions of stages (étages) have recently been well discussed by Hupé (1960). Hedberg *(e.g.* 1958, p. 1892) advocates the use of the term "substage", apparently to avoid confusion with other "zones", such as "range-zone", teilzone, etc. Hedberg (1959, p. 631) further suggests the use of the term "zone" for a "general basic unit in all kinds of stratigraphical classification, particularly in those kinds which do not already have more specialized unit terms".

The term "chonozone" was suggested by the present writer as an alternative to "substage" (in reply to questions in Circular no. 7, 1959, of the Subcommission on Stratigraphical Nomenclature). It was accepted as an informal chronostratic unit in the Report of the International Subcommission on Stratigraphical Nomenclature submitted to the 21st. International Geological Congress, 1960.

I would, however, prefer to regard chronozone as a formal term, and as a synonym of the classical zone, to be used whenever there was danger of confusion. In stratigraphical schemes it would seem unnecessary to write *e.g.* "chronozone of *Parabolina spinulosa*" instead of "zone of *Parabolina spinulosa*". However, the term chronozone may be useful when discussing chronostratic units of the 5th. order and in certain cases to distinguish it from *e.g.* biozone. One might argue that the term "chronozone" is not so good, since the time concept is included in all chronostratic units. However, the word "zone" (Greek for belt, girdle) does not suggest any time element.

Against the term "substage" one might argue: If "substage" were to replace "zone", by which term should "subzone" be replaced? Surely not "subsubstage".

If world-wide chronostratic units of the order of size of chronozones could be recognized (in all types of facies), the term "substage" might be retained for these units. They should then not be named after fossils, since no fossil occurs in all types of facies. Just as "chronozone" is a biochronostratic unit, the term "substage" may be retained for small chronostratic units based on non-palaeontological evidence. Generally, so small *e.g.* lithochronostratic units are of limited use.

Since time is universal one might advocate that chronozones could be used as world-wide units. However, even if the correlation was certain, it would seem no better to refer *e.g.* at certain sequence with land plants to the ammonite zone of *Euhoplites lautus* than to refer the find of South American pottery to an Egyptian dynasty.

On different types of chronozones.

The classical zone (chronozone) may be of varius types, as recently shown by Hupé (1960). Thus the fossil after which the zone is named may be 1) restricted to the zone and occurring all through the zone, 2) restricted to a part of it, and 3) also occurring stratigraphically below, above, or both below and above the zone.

As chronozones may be used various kinds of biochronostratic units, both simple ones like biozones (= ontozones, whether holozones or merozones), epiboles and faunizones, and special ones as defined above (p. 71). In other words, they may be based either directly on ranges (partial or total) or on intervals representing the range from the beginning (or end) of one range to the beginning (or end) of another range. Which would be the better chronozones?

Since the boundaries of chronozones ideally are time-levels (in practice often time-belts), one should, of course, select such time-levels (time-belts) as boundaries which may be recognized outside the type sections. The time-level through the ends of *partial* ranges do not seem to be good choices, since they can hardly be recognized elsewhere. The same is true of maximum frequency ranges, since the maximum frequency of a fossil need not occur in the same horizon in different localities. The best (most useful) chronozones seem to be those with boundaries based on time-levels through the beginning or end of total ran-

ges, whether holozones or special biochronostratic units. This would reduce the interval of correlational error to a minimum. It has been advocated that ranges of fossils may correspond to different spans of time in different localities also because of the time involved before *e.g.* a species reached its maximum geographical distribution. This is strictly true, but this time factor is negligible when geological times are concerned (cf. Schindewolf, 1950; Teichert, 1960, pp. 107—108; Hupé, 1960, p. 14). There may be exceptions, but they are then only exceptions.

The main difficulty is, of course, to know when we deal with a partial range and when with a total range. In some cases it seems rather certain that we deal with total ranges, namely when we have succeeding ranges of species which developed from each other. Another case where it at least seems possible, is where we have the same type of lithology and succeeding species of the same group of fossils. On the other hand, where change in fossil content is accompanied by a change in lithology, and where there are breaks, the chances are good that we deal with partial ranges. We can thus to a certain degree choose the most promising ranges and keep the intervals of correlational error reasonably small.

If we accept that chronozonal boundaries should preferably be drawn through the ends of total ranges, which would be the better chronozones; those based on a single range (like holozones) or those based on the interval between the beginning (or ends) of different ranges (like special biochronostratic units)? It seems that the one kind may be as good as the other. However, except when we deal with ranges of *e.g.* succeeding species which developed from one another, such total ranges do not correspond to a continuous span time, and thus do not generally lend themselves to the erection of chronostratic time-set units, whereas this is always possible with special biochronostratic units. Furthermore, this kind of units may often correspond to a shorter time span than holozones, and thus allow the recognition of smaller chronostratic units. I do not know whether the lower or upper end of a range is the safer for establishing boundaries, but it is possible that the lower ends (first occurrence) will prove to be the better.

There seem to be some inconstancies in the use of the terms zone and subzone (chronozone and subchronozone). It seems advisable to use the term zone (chronozone) for rather small units (reserving subzones for more exceptional splitting of such units) and preferably use the

term stage instead of zone where the index fossil is restricted to only a part. However, it depends also somewhat on the history of the term, and, as maintained by Hupé (1960, p. 6), series may occasionally be divided directly into zones and not first into stages.

Discussing different types of chronozones, it is well known that a certain sequence may be divided into various sets of chronostratic units, depending on which group of fossils they are based upon. So-called standard or reference schemes should have units based on fossil groups with great geographical and short stratigraphical distribution. However, it is useful to have alternative schemes for fossils in other facies and for fossils of special use in certain circumstances (*e.g.* microfossils).

A chronozone may be defined as a small chronostratic unit based on palaeontological data, generally either on an interval corresponding to the range (total or partial) of a taxonomic unit or complex of taxonomic units or on the interval between the beginnings (or ends) of two such ranges. Apparently the best chronozones are those with boundaries through the beginning or ends of total ranges, since such time-levels have the possibility of being recognized rather accurately outside the type section.

Interzones.

Fig. 3 shows the ranges (partial or total) of the species A to E in a section (I) with uniform lithology.

On this evidence one would tend to establish a zonation as shown in column II, *i.e.* one would include the non-fossiliferous beds in the zones, either by drawing the boundaries at the base of the range of each species (as shown here) or at the top, or arbitrarily somewhere inbetween.

Since the boundaries of the zones are rather uncertain, they should be regarded only as potential chronozones. It is quite possible that zones A to H will prove to be useful units in correlation. Even if it was found that a fossil X had a range between that of D and E in another locality, one might keep the already established zonation by referring the beds with the fossil X to the zone of D or zone of E, possibly as a special subzone.

However, instead of publishing a zonal scheme as shown in column III, one could, in some way or other, indicate that there are barren beds between the fossiliferous ones. These barren intervals may be called *interzones* (from Latin *inter*, between). Their presence could be indicated for example as shown below on the next page.

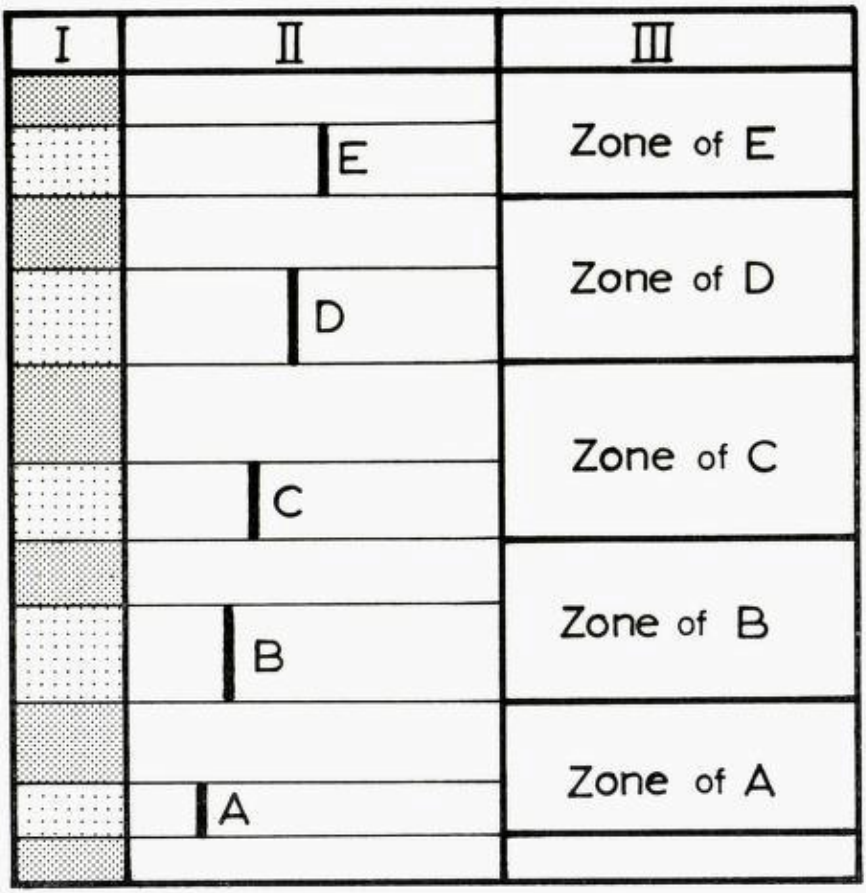

Fig. 3. Column I: Section (unfossiliferous beds heavily stippled). Column II: Ranges of fossils A to E. Column III: Zones A to E.

Rad I: Lagrekke (fossiltomme lag mørke). Rad II: Utbredelse av fossilene A til E. Rad III: Sonene A til E.

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or

Zone of D	Zone of D
	Interzone
Zone of C	Zone of C
	Interzone
Zone of B	Zone of B
	Interzone

The recognition of interzones is not a great point, but is nevertheless of some importance in the refinement of stratigraphical procedure. Thus in the example above, if it was later shown that the ranges were not total but only partial ranges, it is possible that a part or the whole of an interzone should have been included in the overlying, rather than in the underlying zone as done here.

As to non-fossiliferous beds *within* a zone, they need not be paid any attention in this connection. Their importance falls within the dicipline of ecology etc.

The concept of stratigraphy.

The recognition of different kinds of stratigraphical classification, such as chrono-, bio-, and lithostratigraphical classification has recently been emphasized especially by Hedberg *(e.g.* 1959).

Various authors have criticized this, thus Schindewolf (1957) regards lithostratigraphy as a "tentative step towards final chronological determination of the rocks, which alone deserves the title of stratigraphy" and refers to lithostratigraphy as "prostratigraphy", "no proper stratigraphy", and as "stratigraphic propaedeutics". According to him, chronostratigraphy and biostratigraphy are mere synonyms of stratigraphy in its proper sense. Seitz (1958) maintains that in some cases chronostratigraphy equals biostratigraphy, whereas in other cases it equals lithostratigraphy. Hupé (1960, p. 15) states that biostratigraphy appears like a specialized branch of stratigraphy *(i.e.* chronostratigraphy).

Evidently much of the controversy depends on the definition of the term stratigraphy. Two somewhat different definitions are quoted below:

Schindewolf (1960, p. 8) defines stratigraphy in the following way: "Stratigraphie ist derjenige Zweig der Historischen Geologie der die Gesteine nach ihrer zeitlichen Bildungsfolge zu ordnen und eine Zeitskala zur Datierung der geologischen Vorgänge und Ereignisse aufzustellen hat.", adding that: "Der letztere Auftrag überschreitet zwar den Bereich der Stratigraphie im eigentlichen Wortsinne; es handelt sich da um eine von den Gesteinen abstrahierende Chronologie (Geochronologie)".

According to Hedberg (1958, p. 1881) stratigraphy "is essentially that branch of geology which deals with the arrangement, the distribu-

tion, and the chronological succession of rock strata (and other associated rock bodies), with respect to any or all of the various characters, properties, and attributes which rocks may possess."

One may distinguish between a wider and a narrower definition of the term stratigraphy, the latter corresponding more or less to the definition of chronostratigraphy, and one main difference being whether lithostratigraphy is included or not.

The narrower meaning of the term stratigraphy may be said to be favoured by the nomenclature adopted by the Bologne (1881) and Paris (1900) geological congresses, since only one set of stratigraphical terms were recognized.

On the other hand, the wider meaning of the term stratigraphy may be indicated by the term stratigraphy itself which literally means "description of strata" and may be understood as the "descriptive science of strata" or "science of strata".

In areas with succeeding lava beds it is often possible to work out the succession and show which bed was formed after another, or in other words, it is often possible to work out a stratigrapical scheme, albeit of very local use, but still of interest and possibly of practical importance within that area. It seems that at least this type of lithostratigraphy may be regarded as true stratigraphy. But where, then, should we draw the border between "stratigraphical lithostratic units" and "non-stratigraphical lithostratic units"? Perhaps where it is possible to demonstrate what is up and down in a sequence of lithostratic units? This is, however, always one of the aims of lithostratigraphy. Remembering this, one might go as far as to accept a lithologic division into strata as stratigraphy, even if one does not know what is up or down in the sequence. This, no doubt, may be discussed, but it is a description of strata and stratic units, and when the true chronologic succession later is demonstrated, we may make use of results already arrived at, *e.g.* make use of any already established names for units.

If stratigraphy is taken not to include lithostratigraphy, we have no Precambrian stratigraphy. This seems hardly right. Even if it is not possible to correlate lithostratic units from continent to continent or from region to region,[1]) it is possible to arrive at a stratigraphical scheme of Precambrian rocks within a region or at least a smaller area. Besides the often great economic importance of being able to work out even

[1]) Disregarding the possibility of correlation by the help of radioactive age determination.

rather local stratigraphical schemes, they make is possible to arrange events in a chronological order in that restricted area. Should this not be called stratigraphy? And if we have a sequence of unfossiliferous Phanerozoic sedimentites should we not be able to talk about the local stratigraphy even if we do not know whether the sequence is of Silurian or Triassic age? If we do, it seems that the definition of the term stratigraphy rests upon whether very local stratigraphy should be regarded as true stratigraphy or not.

In discussing "local" versus "translocal" stratigraphy, it is of interest to note that the Commission on Stratigraphy of the U.S.S.R. separates between a unique (standard) stratigraphical subdivision and auxiliary regional stratigraphical subdivisions, in fact to that extent that auxiliary regional stratigraphical units (local units) are known by different terms than those in the standard scheme (cf. Report of the International Subcommission on Stratigraphical Terminology, submitted to the 21st. International Geological Congress, 1960). As long as the local units can be correlated with those of the standard scheme, the terms of the latter are used. If *e.g.* the divisions of the Ordovician system in a certain area cannot be correlated with those of the standard scheme, it is divided (in decreasing rank) into seri'a, svita, podsvita, pačka, and gorizont, rather than into the standard units otdel (division, section), jarus (stage), and zona. This is an explicit way of stressing that a unit is only of local importance. It would help ut to arrive at a universal terminology if the term "seri'a" was transferred from the auxiliary set of terms to the standard set, as "series" is elsewhere the commonly used term rather than "section", although the latter was accepted as a synonym at the Bologne (1881) geological congress.

In the connection with the definition of the term stratigraphy, it is of interest to note that the Commission on Stratigraphy of he U.S.S.R. apparently regards both local and standard classification as true stratigraphical classification. There is only a gradational difference between "local" and "translocal" stratigraphy and hardly possible to draw a distinct border between them, so it seems that true stratigraphy should also include stratigraphy of very local applicability.

Conclusionary remarks.

From the above it seems that one may distinguish between chronostratic units (with time boundaries) and protostratic units (with quality boundaries). The protostratic units embrace both lithostratic units, biostratic units, and mixed topostratic units. The boundaries of chronostratic units are time-levels (time-belts) and are based on palaeontological or lithological boundaries in particular sections. When the lower and upper boundary of a chronostratic unit are based on the lower and upper boundary of a single protostratic unit in a particular section, the chronostratic unit may be said to be based on this unit. One may distingunish between litho- and biochronostratic units, whose lower and upper boundaries originally are based on lithological or palaeontological data, respectively. Mixed chronostratic units have the one boundary based on palaeontological data and the other on lithological data.

Several stratic terms have been discussed in the present paper. Generally only a few are needed (those tabulated below), whereas many others *(e.g.* biozone, epibole, format, and the "holo-", "topo-", and "mero-units") are needed only in special cases and may be used rather as descriptive terms where it is possible and desirable to define some of the more generally used terms more precisely. They are furthemore of theoretical interest and should in any case be properly defined.

By using the term lithostratic instead of lithostratigraphic, etc., it seems that the above terminology may be used both by those favouring the narrow concept of the term stratigraphy and by those favouring the wider concept. As advocated above, I would personally prefer to regard protostratic units as stratigraphical units and thus regard both protostratigraphy and chronostratigraphy as stratigraphy. However, apart from the definition of the word stratigraphy, it would make little difference if others prefer to exclude protostratic units from stratigraphy and even refer to them as prostratigraphical units. Thus protostratigraphy is essentially the same as prostratigraphy as defined by Schindewolf (1954). Furthermore, I believe that both local and translocal stratigraphy may be regarded as true stratigraphy.

The connection between the different stratic classifications and between them and geochronology may be tabulated as follows:

GEOCHRONOLOGY	GEOCHRONOLOGIC UNITS	Absolute age determination
CHRONO-STRATIGRAPHY (time boundaries)	CHRONOSTRATIC UNITS (System, series, stage, zone or substage, subzone)	
	Bio-chronostratic units	Mixed chronostratic units	Litho-chronostratic units
PROTO-STRATIGRAPHY (quality boundaries)	Biostratic units (zonite)	Mixed topostratic units	Lithostratic units (group, formation, member)
	PROTOSTRATIC UNITS		

Sammendrag.

Bemerkninger om stratigrafisk klassifikasjon.

Stratigrafisk (eller «stratisk») klassifikasjon og terminologi blir diskutert. Det skilles mellom kronostratigrafisk og protostratigrafisk klassifikasjon. Kronostratiske (tidsstratiske) enheter er slike som har tidsgrenser. Protostratiske (primær-stratiske) enheter er slike som har grenser bestemt av utbredelsen av en viss lithologi (lithostratiske enheter), et visst fossil (biostratiske enheter) e.l. Man kan skille mellom biokronostratiske og lithokronostratiske enheter, som er kronostratiske enheter basert på henholdsvis paleontologiske og lithologiske data. Videre kan man skille mellom tids-sett-enheter (som i en fortløpende rekke tilsvarer et kontinuerlig tidsrom) og uavhengige enheter (som ikke gjøre det, men ofte overlapper hverandre). Kronostratiske grenser (ideelt tids-plan, i praksis ofte tids-belter) bør helst ikke trekkes ved brudd i lagrekken. Brudd er derimot naturlige protostratiske grenser. For kronostratiske enheter er det ikke nødvendig med type-profil for hele enheten, men det er nødvendig med type-profil for undre og øvre grense (type-grenser). For eksempel for det ordoviciske system for kambrium/ordovicium-grensen og for ordovicium/silur-grensen.

Det skilles mellom forskjellige sorter tids-korrelering. Tidsplan-korrelering er korrelering av tidsplan (nivåer som svarer til den

subaeriske og subakvatiske landoverflate i et bestemt øyeblikk i jordens historie). «Inter-level» (inter-plan) korrelering er korrelering av lagrekker mellom de samme to tidsplan på forskjellige steder. «Unit»-korrelering er en som regel mer omtrentlig tids-korrelering av en stratigrafisk enhet med en annen. Auto-korrelering er tids-korrelering av samme stratigrafiske enhet på forskjellige steder. Allo-korrelering er tids-korrelering av forskjellige stratigrafiske enheter.

Flere forskjellige stratigrafiske termer blir dikutert. Det foreslås å beholde termen «sone» (eller «kronosone») for små kronostratiske enheter basert på fossil-data, og benytte termen «substadie» («substage») for slike enheter basert på andre data. «Sonitt» («zonite») foreslås som betegnelse på (proto-)biostratiske enheter av sone-kategorien. Forstavensene «holo-», («hel-»), «topo-» («lokal-») og «mero-» («del-») kan settes til stratigrafiske termer når det er nødvendig å understreke om enheten er basert på henholdsvis den totale, lokale eller delvise utbredelse av et kriterium (f. eks. ledefossil).

Index to some terms and expressions.

Postcript.

According to Dr. H. D. Hedberg (personal communication) "range" means extent in any direction — horizontal (geographic) or vertical (stratigraphic).

Throughout this paper "range" should therefore be understood as "stratigraphic range".

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