International Geological Correlation Program (IUGS-UNESCO)

Project 343: Stratigraphic analysis of the foreland epicratonic Tethyan Basin

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This is the first contribution of a "cellule de réflexion" of the IGCP 343 Project and related EPTB Project with the task :

"contribution to evaluation of rate, or speed, or location of geological phenomena" considered within the above two projects. For this purpose, and in addition to the ages to be quoted, the "cellule" intends to help in suggesting realistic margins of uncertainties able to give the actual time dimension of the quoted phenomena.

ABSTRACT

A realistic Time scale for a multidisciplinary project

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Any mulidisciplinary research project needs a realistic time scale for estimates of rates, speed and actual location of geological processes or events.

There are diverseified proposals dealing with the subdivision of the stratigraphical sequence in the litterature and, although disconnected from acquisition of actually new data, a constant flux of production of time scales makes the situation probably more complex than it is.

A better understanding must consider that a time scale is a combination of both
- a conventional factor and
- a scientific knowledge.

The conventions comprise: the names of the subdivisions into Stages (the fundamental units of global significance) and the location of the inter-Stages boundaries.

The scientific knowledge comprises the estimates of the age in Ma (mega anni) of the boundaries between the conventional units. The latter estimates are primarily based on the geochronological study of dateable materials correlated versus the conventional stratigraphical subdivisions. The geochronological study, in turn, is a combination of i- analytical measurements and ii- interpretation of those measurements in terms of ages in Ma.

Therefore, fundamentally, age estimates for the time scale rest on acquisition of geochronological data and their correct interpretation. In this context, the geochronologist should be the motor of any positive action or program dealing with time scale calibration; the present sometimes unclear situation with Numerical Time scales results directly from the fact that most recent (within last 10 years) proposals for time scales were not prepared with sufficient care to the available geochronological information.

During past years,
+ IGCP Project 133: "**Radiometric dating of Mesozoic & Cenozoic sediments**" (Project

leaders: P. Pasteels-1975- then G. S. Odin 1976-1979) allowed proposal for the first revision of the historical 1964 Time Scale of the Geological Societies of London and Glasgow. The work (Numerical Dating in Stratigraphy, 1982 : NDS1982) comprised 2 volumes; vol. 2 was devoted to gathering and revision of published and original data (1964-1981) under the form of 251 key points, probably more than 90 % of the knowledge at that time. These data are still valid for the majority of them. Vol 1 was devoted to new knowledge in the significance of radiometric data obtained from geochronometers and time scale syntheses.

Peculiar points in the proposed time scale syntheses of NDS 1982 are

i- that estimates were given as intervals of times within which the concerned boundaries must lie according to the data available and not as unique ages and

ii- no estimates were derived when too few data were available.

For these cautions were taken, the resulting estimates are still valid for most of them. The following progress consisted to

i- reduce the duration of the deduced intervals of time;

ii- give estimates for age boundaries previously not known and, exceptionnally,

iii- modify a few estimates previously based on data shown later to be misinterpreted.

+ In order to encourage progress in the way shown by our 1st 1981 synthesis, a new IGCP Project with the title: "**Phanerozoic time scale**" was led by G.S. Odin and N.H. Gale 1983-1986, then by G.S. Odin and A.J. Hurford, 1986-1989. The same subject was developed under the aegis of the International Commission on Stratigraphy, Subcommission on Geochronology (SOG) led by N. J. Snelling durig years 1981-1988. The author was member of that subcommission; coordination was established during years 1981-1988, and in 1989, the leadership of the Subcommission became his task. A new Time scale synthesis was undertaken in 1989 with numbers proposed for most (but not all yet) of the 110 unit boundaries of the Earth's history. This was published in 1990 with the title Ehelle numérique des temps géologiques" (Géochronique, 35: 12-21). (O & O, 1990)

Numbers there are based on the 1964 calibration points + the 251 calibration points of the NDS volumes (NDS, 1982) , + 95 newly computed studies (1982-1989) -a number of them being established by members of the IGC Project or the SOG- + 30 previous NDS calibration points revised with modern analyses.

In addition, the subdivision of the column was undertaken with a new aim: to present a single simple stratigraphical column, using subdivisions supposed to have global significance in contrast to previous more complex, commonly regional parallel subdivisions.

The subdivisions of the column (O & O, 1990)

In order to reach the above quoted objective (a unique column), an enquiry was undertaken near all ICS Subcommissions by System and a synthesis established. The IGCP 343 Project is concerned with the Stages from the Late Carboniferous (Silesian) Moscovian Stage up to the Late Pliocene Piacenzian Stage. Independantly from the recommandations by the ICS Subcommissions for Systems, our personnal choice was based on the following practical rule: a recommended Stage must have an order of magnitude for its duration longer than the lower rank regional or super-regional unit: the biozone (commonly 0.5 to 2 Ma long) - this is connected to the necessity that a Stage being a priori of global application must be easily recognized on a global scale which is not the case for biozones- and shorter than the higher rank subdivision: the Series (about 10-30 Ma). Therefore, a global Stage must be 3 to 10 Ma long to be valid as far as the duration factor is concerned; this is practically achieved for the vast majority of the Stages widely used; we calculated mean Stages durations between 3 and 8 Ma for all Systems of the Phanerozoic Era (O & O, 1990).

Application of this prerequisite to the Late Carboniferous Series (about 30 Ma long) lead to select a subdivision into 5 to 6 Stages (see O & O, 1990, NB 29) in contrast to some proposals (i.e. Harland et al. 1989, p.44 or 176) quoting up to 18 "Stages" (equal or shorter tha biozones) and 5 "Series" for the same interval of time. Similarly, application to the Late Permian about 10-15 Ma long (but this is poorly known), suggests that subdivsion into no more than 2 Stages (and not 4 Stages) is reasonable. The question of the subdivision of the Lower Triassic subdivision (5 to 10 Ma long according to recent data) into 1, 2, 3, or 4 Stages has been considered recently by the Subcommission on Triassic Stratigraphy with final vote in favour of 2 Stages; this can be considered reasonable if the base of the P°/Tr boundary is actually as old as 250 Ma. The subdivision of the Jurassic and Cretaceous Stages is not debated. Within the Palaeocene, it has been proposed by the appropriate subcommission to add a third Stage between the well accepted Danian and Thanetian Stages. This does not appear to be a necessity in terms of duration for a rather well known interval of time of 12 Ma. Our last comment concerns the commonly used subdivision of the 18 Ma long Miocene Series into 6 Stages. All published time scale consider the Messinian Stage shorter than the Langhian one both being less than 2 Ma short. Recent direct radiometric datings would suggest, in contrast that the Messinian is longer than the Langhian, the former being about 2 Ma long, the latter being only about 1 Ma long. This suggests that deletion of the Langhian as a global Stage would be reasonable.

The actual knowledge of the ages of the Stage boundaries

Actual knowledge of the numerical ages of the Stage boundaries must be considered in the light of the following 2 preliminary remarks.

1- ***A radiometric date*** is the result of a physical measurement which comprises an error bar (analytical uncertainty) expressed as a proportion of the age. This practically means that a good date is known with an indetermination of the order of 1% of the measured age or:

± 0.3 Ma for a Lower Oligocene 30 Ma old sediment or

± 3 Ma for an Upper Carboniferous rock 30 Ma old.

The later interval of time of ± 3 Ma, is precisely equivalent to the duration of a mean Carboniferous Stage which would make "difficult" to estimate the durations of those Stages in terms of radiometric measurements.

2- ***For the above reason*** and in various other younger portions of the scale, boundaries between Stages cannot be dated directly due to the lack of known suitable dateable material. In this situation, age estimates must consider an additional reasonable hypothesis for extrapolation between known ages. The resulting error bars for the extrapolated estimates must combine uncertainties on the anchors and the uncertainty calculated from the extrapolation procedure.

Commonly, the later uncertainty cannot be easily estimated and is forgotten; furthermore, many proposed extrapolated numbers do not consider the analytical uncertainties and are even quoted 10 or more times more precise than the calibration points from where they are derived. This results in apparently nice scales but their real usefulness is doubtful.

Today, January 1993, there are 140 new (post 1982) dates or groups of dates available for calibration of the PTS in our constantly up to date files prepared from the literature, a number of works in progress or presented during recent meetings. Actual knowledge for interstage boundary ages is diversified along the scale with 3 different situations i- complete absence of data; ii- poor knowledge or disagreement between dates; and iii- good knowledge.

+ ***Late Carboniferous Stages***: we have not a single date for calibration of the marine global Stages; however, there is a good control with modern dates for the continental Stages boundaries (± 3 Ma) which is the reason why those continental Stages are shown in O & O, 1990 parallel to the global subdivision.

+ ***Permian Stages***: Our knowledge of the Permian marine Stage boundaries (and the related Stage durations) is very poor; the proposed numbers (O & O, 1990) must be understood with a ±7 to 8 Ma. The Carboniferous-Permian boundary is reasonably well dated between 290 and 300 Ma; the Permian-Triassic boundary is certainly between 240 and 250 Ma with more probability (more precise dates) for the older portion of this interval of time.

+ ***The Triassic Anisian and Ladinian Stage*** boundaries are well known with a ± 3 to 4 Ma; no radiometric dating is available for the Carnian, Norian, and Rhaetian Stages the former 2 ones are agreed to be long to very long (with a limit shown with a ±8 Ma), the latter is very short (according sediment thickness and number of ammonoid zones). The Rhaetian-Hettangian boundary is well dated between 200 and 208 Ma.

+ ***The interval comprising Early Jurassic (Hettangian) to the Early Cretaceous*** (Aptian) Stages is documented with very few dates in the literature. When available, the data are either imprecise, or poorly known or very indirectly correlated to the Stage sequence established in Europe. The numbers quoted in O & O are based on an extrapolation using equal Ammonite subzone durations, an extrapolation procedure which has been shown to be surprisingly realistic in several occasions. The resulting estimates are 8 to 10 Ma younger than the ones proposed by Palmer (1981, DNAG) with which the authors disagreed.

◦ During years 1988-1992 the mid Jurassic portion was dated in Géorgia (Caucasus), Argentina, and the US. The resulting situation is a long Bajocian followed by a short Bathonian as follows:

- the base of the Bajocian (Early Bajocian volcanics in Caucasus; Odin et al. 1992a in press) would not be much older than 174 (±2) Ma (compare Palmer: 1983; Harland et al. 1989: 173.5 ±11!; O & O: 176 ±4 Ma);
- the Bajocian-Bathonian boundary would be at 163-164 Ma (± 1 Ma; K-Ar on plagioclase and hornblende from volcanics in Caucasus - Odin et al. 1992a in press- and minerals from bentonites in the US- Kowallis et al. 1992, in press); compare Palmer: 176; Harland et al. 1989: 166.1±7! Ma; O & O: 167 ±4 Ma);
- the Bathonian-Callovian boundary would be at 160-161 Ma (±1 Ma; U-Pb on Argentina zircons; Odin et al. 1992b in press); compare Palmer: 169 Ma; Harland et al.1989: 161,3 ±7! Ma; O & O: 160 ±4 Ma.

◦ For the 6 Stages bracketting the Jurassic-Cretaceous boundary, recent radiometric datings are scarce. The situation is summarized now. Recent datings on Early Cretaceous volcanics from China (Ye Bodan, 1988; Bull IGCP Proj. 196) would suggest ages as low as 130±2 Ma for the J/C boundary, but the continental biostratigraphic control is difficult to evaluate. Berriasian zircons from the US gave ages at 135.2 (±1.5) improved later to 137.1 +1.6-0.6 Ma (Bralower et al., 1990, EPSL). No recent dates are available for the Kimmeridgian and Tithonian Stages. In summary: on the young side, there is no geochronological result consistent with a J/C boundary younger than 130 Ma (glaucony dates in W Europe concern Portlandian sediments which are now regarded as partly Cretaceous in age); on the old side, there is no radiometric dating which would document ages older than about 140 Ma. This is the reason why O & O propose the interval 135 Ma ±5 Ma; the final age will parly depend on the future precise definition of that boundary and data still to be obtained. Estimates at 144 or 145.6 (Harland et al. 1989: 145.6±10! Ma) have low probability and/or are too imprecise compared to the data available.

+ ***Late Cretaceous and Palaeogene Stages*** : in contrast to the former interval of time, we have a good knowledge of the Late Cretaceous and Palaeogene Stages since 10 years. Some disagreement for numbers in the literature is mostly based on the application of extrapolations procedures (sea-floor anomaly lineations) which used incorrect anchors and showed poor knowledge of the meaning of the available geochronological data. In particular, the 15 years long debated question of the age of the Eocene-Oligocene constantly located near 34 Ma by us (Odin, thesis, 1975; Odin, NDS, 1982; O & O, 1990) has been shown diversely near 37-38 Ma (Palmer, 1981) or 35.4 (Harland et al. 1989: 35.4 Ma) which represents differences up to more than 10 % of the age when the latest radiometric results lead to a precise estimate between 33 and 34 Ma (see appropriate comment in O & O, 1990).

+ The Miocene time scale has long been a quiet question; this was not because of many data available but because of few age data connected to diverse regional subdivisions making a scale difficult to recommend in absence of global conventions. The recent (1988-1992) discover of the usefulness of a large number of dateable volcano-sedimentary layers in the Mediterranean area, as well as in Japan, lead us to create an international working group within the Subcommission on Geochronology. This WG is studying this material in the aim at defining a well documented global integrated stratigraphy for the interval 24 Ma - 5 Ma. As previously said, our main preliminary results suggest that the Messinian Stage would be about 2 Ma long and the Langhian one about 1 Ma long and the precise age estimates now attainable will allow soon to propose a detailed knbowledge of the Miocene Series.

Conclusions

The numerical Phanerozoic time scale is first based on radiomeric data. The way to improve the still unsuficient knowledge of which we must be aware, is not to reestimate past results as commonly (too often) undertaken in the past 10 years but to encourage research for new data where needed. this is the job the author is concerned with; this effort results periodically in time scale synthese where distinction must be shown between what is known and what is to be improved. This is done by relevant comments in the published time scales; the discussion of the validity of the radiometric data is not always easy but this does not justify underestimate or forgetting of the geochronological information which has been

- either replaced by long term extrapolation estimates without known error bars (which means no physical validity);
- or replaced by arithmetic means of numbers of different geochronological funding and with different uncertainty intervals.

The time scale in O & O was the state of the art in 1990. Its scientific significance (and use) must be considered in the light of the comments published in the original version. The present talk added a few more comments which will be added to the new version which was submitted in 1991 and, hopefully, to be published in English as it was required by the past and new chairmen of the Commission on Stratigraphy.

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