A COMPARATIVE TABLE OF RECENTLY PUBLISHED GEOLOGICAL TIME-SCALES FOR THE PHANEROZOIC TIME — EXPLANATORY NOTICE

By

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES; COMMISSION ON GEOCHRONOLOGY FOR COORDINATION OF RADIOMETRIC AND STRATIGRAPHIC DATA IN THE DEVELOPMENT OF A WORLD TIME-SCALE

One of the fundamental aims of geochronological studies is the drawing up of a time-scale which embraces the totality of geological events, and which is capable of providing as precise data as possible on the absolute age of the formations. The paleontological and lithological methods frequently allow stratigraphers to establish, for the sedimentary series they are studying, a very finely calibrated scale on which the numerous degrees are generally marked by characteristic fossils. Obviously such scales can provide no indication of the absolute ages: they remain relative scales.

At our present stage of knowledge, only by radiometric methods can we determine these absolute ages with any certainty. A very great number of measurements have been taken, and the results obtained by separate laboratories using a number of different methods on a variety of materials very often appear concordant.

Without question enormous progress has been made during the last few years. We should not, however, be led to over-estimate the present possibilities of absolute geochronology, and this applies as much to the accuracy of the subdivision as to the precision of the values put forward.

The principal difficulties no longer seem to be due to analytical errors. The accuracy of modern mass spectrometers, and particularly the reproducibility of their measurements, is extremely satisfying and achieves a margin of $\pm$ 2–5 %, including the errors due to the usual wet chemical processing. The main cause of divergence among the proposed values — a cause which stems from the very use of spectrometers — comes from a slight difference between the values of the decay constants used in the calculations; constants which have to be known if we want to compare the measurements carried out in two different laboratories.

On the other hand, the interpretation of the numerical values obtained is generally a very delicate task, and the elements necessary to the solution of the problem are not always known in their totality.

A first point concerns the history of the substance being analysed. A dating will be exact if the rock or mineral studied has, as far as the isotopes being considered are concerned, evolved constantly as a 'closed system', thus excluding the possibility of differential gains or losses. Experience shows that, even for a sample that is reputed to be completely valid, differences, greatly superior to those that can be admitted as analytical error, can appear in the results. If, thanks to the improvement of techniques, the geochronologist can rightly feel that he is progressively reducing a part of the analytical error, he must also admit to the remaining leakage, the origin of which is closely linked to geological factors, either known or unknown.

A second point has to do with the choice of the samples, or more precisely with their representativity as markers on a relative geological time-scale that we want to date. This is perhaps the most difficult problem to solve. The sample has got to be taken from layers that are perfectly defined from the stratigraphic point of view. Of course, they must also satisfy the other previously mentioned conditions (evolution in a closed system).

No single country can on its own provide the necessary samples for a geological time-scale covering all the geological time. For this objective to be reached in the best conditions, international collaboration is essential.

When we take these errors of measurement and interpretation together, it becomes clear that *absolute geochronology cannot at present date too short episodes in geological time*. To be honest, and once again we come across the problem of the choice of layers, *it is not certain that the limits considered as isochrones in stratigraphy are always really so*; the degree of inaccuracy of these limits risks being on the same scale as, or even greater than that of the geochronological measurements, and hinders or limits the setting up of a too detailed time-scale.

On the accompanying Table different geological time-scales have been juxtaposed in order to indicate the progress made since 1937, and to bring out the similarities as well as the differences among the results obtained during the past years. This is only a provisional table, and should, of course, be revised in view of the latest results obtained.

The name of A. Holmes is unquestionably linked with the development of geochronology. He was the first, in 1913, to give an Archean to Carboniferous geological time-scale, which was in fact not very accurate, for it was simply based on 4 or 5 radiometric measurements. Later, having access to more numerous and more exact data, he published other scales. Those of 1937 and 1959 can be seen in the first two columns of the table.

Holmes' 1937 scale was based on 18 U-He analyses and 12 U-Pb analyses. It was used for a long time, but its only interest today is historic.

In fact, the increasing number of measurements and the discovery of new methods (K-Ar, Rb-Sr) allowed him to present a corrected scale in 1959. The Table shows that other scales proposed more recently are in their broad outlines almost in agreement with Holmes' scale of 1959.

One year later, J. L. Kulp, at the international Geological Congress in Copenhagen, presented a new geological time-scale for the Phanerozoic time (third column), which was based on 18 samples very carefully selected from the stratigraphic point of view and for the most part dated by the methods K-Ar ($K^{40}\,\lambda_e = 0{,}584.10^{-10}y^{-1}$) and Rb-Sr ($Rb^{87}\lambda_\beta = 1{,}47.10^{-11}y^{-1}$).

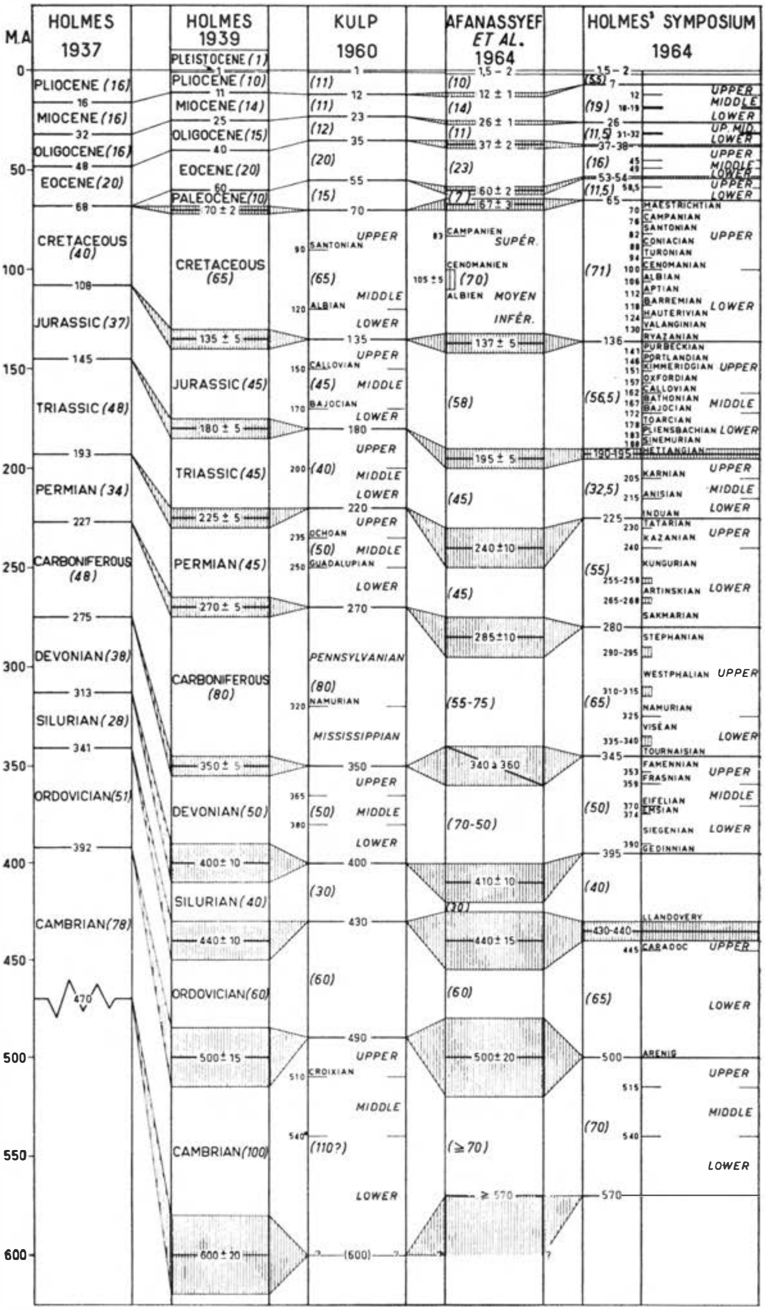
Even when limited to the post-Cambrian time, the making of such scales is far beyond the scope of one single man and one single laboratory. Two groups of geochronologists, working independently, undertook the task of making new scales, with much more numerous and very strictly controlled data.

The first of these was published by the U.S.S.R. Academy of Science in 1964, after research by G. D. Afanassyev et al. (4th column). It is accompanied by detailed information on the 222 samples dated: 14 by Rb-Sr ($Rb^{87}\lambda_\beta = 0{,}147.10^{+10}y^{-1}$), 37 by the different methods U-Th-Pb, and the rest by K-Ar ($K^{40}\lambda_e = 0{,}557.10^{-10}y^{-1}$). The authors rightly avoided seeking an illusory precision and gave for each limit measured a margin of uncertainty often much superior to that brought about only by the analytical errors.

Shortly afterwards there appeared the results of the Glasgow Symposium of 1964 in honour of A. Holmes. The editors gathered together the datings presented in the stratigraphical articles in a '*Geological Society Phanerozoic time-scale*', reproduced in the 5th column. It is the most detailed scale ever published, and is based on 337 datings particularly chosen because of the origin of the samples and the quality of the analyses ($Rb^{87}\lambda_\beta = 0.147.10^{-11}y^{-1}$; $K^{40}\lambda_e = 0,584.10^{-10}y^{-1}$).

In contradistinction with the other scales which are practically all only concerned with the limits between systems, this one gives the limits of the ages for the majority of stages from the Devonian to the Cretaceous. Such values are certainly interesting to retain for the region in which they were defined; it would, on the other hand, be unwise to take them as being representative of a world scale. In fact, without going into a detailed discussion at this point on these datings of the limits between stages, it is above all a tentative solution, the importance of which cannot be compared with that which we can here and now attribute to the ages proposed for the limits between systems or eras. In support of this reservation, we have only to consider the highly improbable theory that the different Jurassic and Cretaceous stages are of equal duration, which is no more than a simple working hypothesis ('The theoretical time-scale for the Cretaceous period is based ... on the proposition that the 12 stages recognized on paleontological criteria were of approximately equal duration, i.e., 6 m. y. This is set up purely as a basis for discussion in the absence of a more positive scale of calibration'. (The Phanerozoic Time-Scale, pp. 198–199).

Finally, the principal orogenic phases, as they are defined by Stille and Brinkmann, can be dated approximately with the most recent geological time-scales, in the following manner. The time is given in millions of years.


M.A
HOLMES 1937
HOLMES 1939
KULP 1960
AFANASSYEF ET AL. 1964
HOLMES' SYMPOSIUM 1964
PLIOCENE (16)
MIOCENE (16)
OLIGOCENE (16)
EOCENE (20)
CRETACEOUS (40)
JURASSIC (37)
TRIASSIC (48)
PERMIAN (34)
CARBONIFEROUS (48)
DEVONIAN (38)
SILURIAN (28)
ORDOVICIAN (51)
CAMBRIAN (78)
PLEISTOCENE (1)
PLIOCENE (10)
MIOCENE (14)
OLIGOCENE (15)
EOCENE (20)
PALEOCENE (10)
CRETACEOUS (65)
JURASSIC (45)
TRIASSIC (45)
PERMIAN (45)
CARBONIFEROUS (80)
DEVONIAN (50)
SILURIAN (40)
ORDOVICIAN (60)
CAMBRIAN (100)
PENNSYLVANIAN
MISSISSIPPIAN
SANTONIAN
ALBIAN
CALLOVIAN
BAJOCIAN
OCHOAN
GUADALUPIAN
NAMURIAN
CROIXIAN
CAMPANIEN SUPÉR.
CENOMANIEN
ALBIEN MOYEN INFÉR.
MAESTRICHTIAN
CAMPANIAN
SANTONIAN
CONIACIAN
TURONIAN
CENOMANIAN
ALBIAN
APTIAN
BARREMIAN
HAUTERIVIAN
VALANGINIAN
RYAZANIAN
PURBECKIAN
PORTLANDIAN
KIMMERIDGIAN
OXFORDIAN
CALLOVIAN
BATHONIAN
BAJOCIAN
TOARCIAN
PLIENSBACHIAN
SINEMURIAN
HETTANGIAN
KARNIAN
ANISIAN
INDUAN
TATARIAN
KAZANIAN
KUNGURIAN
ARTINSKIAN
SAKMARIAN
STEPHANIAN
WESTPHALIAN
NAMURIAN
VISÉAN
TOURNAISIAN
FAMENNIAN
FRASNIAN
EIFELIAN
EMSIAN
SIEGENIAN
GEDINNIAN
LLANDOVERY
CARADOC
ARENIG
UPPER
MIDDLE
LOWER

ALPINE OROGENY

∼ 2: Walachian phase
∼ 7: Attic phase
∼ 37: Pyreneic phase

LARAMIDE OROGENY

∼ 65: Laramide phase
∼ 80: Subhercynian phase
∼ 100: Austrian phase
∼ 140: Neocimmerian phase
∼ 195: Cimmerian phase

HERCYNIAN OROGENY

∼ 225: Palatine phase
∼ 260: Saalian phase
∼ 295: Asturian phase
∼ 320: Erzgebirge phase
∼ 325: Sudetic phase
∼ 345: Bretonic phase

CALEDONIAN OROGENY

∼ 395: Ardennes phase
∼ 435: Taconic phase
∼ 500: Sardinian phase

ASSYNTIC OROGENY

∼ 570: Cadomian phase

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