SCALE OF ABSOLUTE GEOLOGIC TIME

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RELATIVE AND ABSOLUTE SCALES

GEOLOGY, as an historical science, has to deal with the chronology of geological events, which are important for the history of the earth and for the development of life upon its face. Up to the twentieth century it used for this purpose the scale of relative time, which determines only the sequence of events. As a basis for this scale principles of stratigraphy and palaeontology were used. Phenomena of a radioactive decay of a number of elements, with the formation of stable isotopes, which proceed in nature with an unchanging rate, permit the scientists to create an approximate scale of absolute geologic time. Minerals containing radioactive elements served as keepers of the geologic time.

Until recent years the main difficulty in creating a scale of absolute geologic time consisted in the necessity to compare the biostratigraphic scale of relative age with the data obtained for the age of magmatic rocks or minerals of magmatic origin. Yet it is always difficult to establish the exact stratigraphic position of the latter. Usually it is possible to speak only approximately about the position which an intrusion occupied in a stratigraphic section. The number of geologic sections with magmatic rocks, which would satisfy conditions necessary for the compilation of a scale, is comparatively limited. All these facts resulted in a rather poor correlation of the figures obtained with the biostratigraphic scale.

One of the ways out of the situation was the application of the method of maximum thicknesses of sedimentary rocks, according to which time intervals in the absolute scale were calculated, or, to be more exact, the relative value of this time between index points of the scale.

GLAUCONITE DETERMINATION

In 1955 one of the researchers of Soviet Geochronological Laboratories, namely M. Rubinstein, in Tbilisi, had the idea of using glauconite as a sedimentary rock, which contained a sufficient amount of potassium and yet could be regarded as essentially a mineral of the same age with the country rock.

Still some doubts were arising. As is known, glauconite is a mica-like mineral of a changing composition, capable of absorbing various bases and changing the quantity of water. How does it behave in a rock during a period of millions of years ? These doubts have not been fully settled even now. However, the practice of using glauconite rocks seems to refute the mistrust felt for the mineral inasmuch as in the majority of cases figures have been obtained which fitted very nicely into the time intervals dictated by the modern scale of absolute age.

At the present time we possess already hundreds of exact analyses, done both for the rock as a whole and for a carefully segregated glauconite. Valuable data have been received, which to a great extent filled the gaps in the absolute scale (Ar^{40}/K^{40} Ratio).

For this reason we started in the USSR to introduce these data into our scale, especially for such geologic periods which, for the time being, cannot be dated by magmatic rocks.

I would like to quote data confirming a good use of glauconite determinations. They relate to deposits of Upper Pre-Cambrian, which are called Riphean in the USSR and Sinian in the Chinese People's Republic. Data for Riphean rocks, obtained in the eastern part of the European platform, can be nicely correlated with data for magmatic rocks in a more western region, for instance, for deposits in Sweden and Norway cut by magmatic rocks.

Comparison of a number of figures obtained by our laboratories for magmatic rocks of Sweden with figures obtained by the same laboratories for glauconitic rocks of the European platform and partly of Bashkiria indicates a great convergence of these figures and permits to concentrate them, just as for Sweden, into three groups of formations within the age limits from 700 million years to 1 milliard 300 million years.

These new data provided a good fill-out for the gap in our observations, which was due to the fact that we did not succeed in obtaining figures for a great time interval between the Cambrian and the Archean of at least 600 million years, neither within the Baltic shield on the territory of the USSR nor within the South Ukrainian shield.

Now we can confidently state that both in the north and south of the European part of the USSR, there was, apparently, a lengthy period of continental development, during which these areas were not covered by sea-water, but being subjected to vertical uplifts, have been continuously eroded. On the other hand, on the margins of the shield, where small islets of sedimentary and metamorphic rocks have been preserved, different conditions were predominating. For instance, rocks of Kildin cape and Rybachi Peninsula (Kola Peninsula) provide the same figures, which have been obtained for Southern Sweden and Bashkiria.

It is interesting to stress that these figures refer, on the one hand, to obviously platform formations, and, on the other, to formations which are a transition to geosynclinal. They are well correlated among themselves and indicate that while uplifts were predominant in the north and south, in the west of Southern Sweden and the Baltic sea, as well as in the east of present-day Bashkiria, geosynclinal or related conditions were prevailing.

For the time being, the method using glauconitic rocks is the only one in the USSR which permits figures to be obtained for the Cambrian period also. It is true that in this case the convergence of figures for rocks of different parts of the Soviet Union is still insufficient, and we cannot reliably accept exact age data characterizing various subdivisions of the Cambrian. However, we accept the figures of the order of 600-625 million years, obtained for glauconites of Cambrian blue clays occurring near Leningrad and in its neighbourhood. It is possible that later this figure will become more precise.

For the nearest future an important task should be to work out criteria which would help to establish the exactness of the figures obtained for glauconite. Such criteria exist for magmatic rocks, and our radiologists can at the present time select from a number of figures the most reliable. In this work they use these criteria, on the one hand, and the convergence of the results, obtained for different minerals in the same magmatic or postmagmatic rock, on the other.

The table given on the following page is compiled according to data

$$\left(\frac{Ar^{40}}{K^{40}}, \frac{Pb^{206}}{U^{238}}, \frac{Pb^{208}}{Th^{232}}, \frac{Pb^{207}}{Pb^{206}} \text{ Ratio}\right)$$

obtained by our laboratories on absolute age for numerous rocks and minerals from different areas of the Soviet Union. For comparison a separate column gives figures used as a basis for the scale of absolute geologic time by Arthur Holmes. Our data permit to extend the previously suggested scale and consider the Permian, Carboniferous and Devonian periods older.

They also permit raising the question of a complete revision of the existing subdivisions of Pre-Cambrian. The oldest is plagiogranite found as a rolled boulder in old conglomerates of Kola peninsula. Its age by Ar-method proved to be 3500 million years.

The age of the earth has been determined by means of a curve plotted on the basis of a shift in the isotopic composition of lead. It is accepted to be 5500 million years.

PROBLEMS OF ABSOLUTE AGE

What problems face researchers of our laboratories on absolute age?

First of all, this is the problem of a further specification of the scale of absolute age of geologic formations. This introduction of greater precision should be effected by a detailed study of local deposits which correspond to stratigraphic subdivisions. A correlation of such local scales will result in the compilation of one general scale.

The second problem is of importance for a detalization of some questions of general geology. Thus, for instance, methods of

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Era	Period	Division	Holmes scale	New scale
Cenozoic	Quaternary (Anthropogene)	Holocene	1	0·01
		Pleistocene		0·70
	Neogene	Pliocene	12	10
		Miocene	26	25
	Palaeogene	Oligocene	38	45
		Eocene		
		Palaeocene	58	55
Mesozoic	Cretaceous	Upper		80
		Lower	127	120
	Jurassic	Upper		135
		Middle		170
		Lower	152	
	Triassic	Upper		
		Middle		195
		Lower	182	
Palaeozoic	Permian	Upper		240
		Lower	203	275
	Carboniferous	Upper		300
		Middle		
		Lower	255	360
	Devonian	Upper		370
		Middle		
		Lower	313	
	Silurian	Upper		420
		Middle		
		Lower	350	
	Ordovician	Upper		
		Middle		
		Lower	430	465
	Cambrian	Upper	450	485
		Middle		
		Lower	520	620
Riphean				750
				925-1000
				1265
Proterozoic				1380
				1640
Archean				1900
				2800
		Katarchean		3500
Age of the earth				5500

absolute age determinations of magmatic rocks help to solve the problem of so-called 'tecto-magmatic cycles' which, for the time being, have no exact absolute dating. In this case, methods based on a study of minerals in magmatic rocks help, comparatively easily, to establish an age sequence in the formation of magmatic rocks and to compare by time the stages of their formation in various areas of the Soviet Union and the entire world.

The third important task is in the solution of the question of the absolute age of different ore deposits and an establishment of the age of various metallogenic epochs. In this respect work has hardly started and, for the time being, we possess only certain disjointed results which show that ores of different deposits, and, particularly, nonmetal minerals accompanying them, undoubtedly open up a possibility of determining the absolute age of these deposits. However, we did not work out yet criteria for an appraisal of the material which is being used for age determination and for an evaluation of the figures obtained. Extensive work has been started in this respect which will certainly be of great assistance to practical investigations.

Fourthly, it is very important to establish the absolute time of the formation of different Quaternary deposits. It should be admitted that great difficulties exist in this respect, connected with a correlation of mostly barren rock masses of the Quaternary period. For this reason, in Quaternary geology relative age determinations provide results of a lesser clarity than those which are available for older periods in the life of the planet. Unfortunately, we do not possess here sufficiently exact methods which would embrace the entire length of the Quaternary period. As is known, events not older than 25,000 years can be dated by the so-called radiocarbon method. This method, suggested by an American, William Libby, is well elaborated now and provides quite reliable data. It is widely used abroad not only for archaeological studies, but also for dating Late Quaternary deposits. Very promising is the use of this method for cores obtained during studies of bottom sediments in seas and oceans.

All these problems are, naturally, connected with a further improvement in the methods of age determination themselves and a progress in the use of new material for the establishment of reliable figures. In this respect, attention should first be paid to rocks containing glauconite. They are widely developed in all deposits, beginning with Tertiary and up to Proterozoic. Thus, a knowledge of how to manage glauconitic rocks will, undoubtedly, result in a more detailed and exact scale of absolute geologic time.

There is no doubt that within a few years we will witness a substantial introduction of absolute age determination methods, by minerals and rocks, into the practice of geological prospecting work. These methods will yield far-reaching and vital results in the work of field geologists and will also provide extremely valuable material for a settlement of a number of cardinal problems in general geology. Even now, we see how these methods resulted in an exact dating of individual rocks and certain deposits and permitted reaching at a judgement about the time of regional metamorphism processes which were superimposed upon previously formed rocks and brought about substantial changes in their mineralogical composition. Figures of absolute age are important now as natural constants, permitting us to estimate changes in the composition of various natural formations in time. As coefficients they should become part of computation formulae which permit, according to data of present composition and isotopic relations of individual elements, to resurrect the picture of the composition of separate shells of the earth — the air, water, etc. That is why the tendency to create and expand laboratories engaged in absolute age determinations, which we observe now in the Soviet Union, is understandable. As a result, such laboratories are being formed in various regions of the Soviet Union and within different Soviet organizations.