From Proc. Imp. Acad. Tokyo Vol. XX.

101. Concept of Time in Geology 1.

On the Major Classification of the Geological Age.

By Teiichi KOBAYASHI*.

(Comm. by H. YABE, M.I.A., July 12, 1944.)

Time, for purposes at hand, may be classed into two major kinds, one with and the other without historical contents. Time of the latter kind is abstract, absolute, objective and physical; that of the former kind, concrete, relative, subjective, and historical. *Geological age* belongs to the former while *chronology* is of the latter kind, archaeism in both kinds of time being measurable as a rule with reference to certain irreversible phenomena.

As usual in the cognition of time, geologists have cognized historical time before the physical one. Nikolaus Steno (1638-86) was the first to call our attention to the superposition of a formation above another. Later in 1777 Girand Soulavie suggested the use of fossils in distinguishing different strata[1]. Since William Smith (1769-1839) established two laws of stratigraphy on superposition and the correlation of strata by fossils, geologists have succeeded in classifying the various strata into systems, except as regards the Carboniferous which is divided into the Mississippian and the Pennsylvanian system in North America.

This classification is made possible by the fact that transformation of animals and plants is irreversible, though not constant in speed. Alternations of slow and rapid transformations, i. e. evolutions and revolutions on major and minor scales, enable the geologists to distinguish the labile from the mobile parts of history.

At the Eighth International Geologic Congress at Paris in 1900 it was resolved to call different units of strata thus classified, as group, system, series, stage and zone in diminishing order, and the respective time-durations as era, period, epoch, age, and phase[2]. A *period* for instance is the duration in which a *system* of strata deposited, and a system is in turn defined by the biota contained.

It is desirable to find the absolute length of these durations. At-

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* This series of prpers is an outcome of research which I have conducted under a financial grant from the Department of Education. In the course of this study Prof. Mikinosuke Ishida of the Taisho University, Tokyo, Profs. Yoshindo Shinoto and Akiyoshi Suda of the Imperial University of Tokyo, and Mr. Ichiro Yawata of the Ethnological Institute gave me valuable suggestions from the various viewpoints of history, heredity, anthropology and archaeology respectively. Prof. Yabe of the Tohoku Imperial University read this paper at the Academy. For these courtesies I wish to express here my sincere gratitude.

1) Leonardo da Vinci is generally thought to be the first to decipher the so-called *Lucas Naturae*, but in fact Chu Hsi (朱熹) correctly understood the origin of fossils some 300 years before him (Analectr. of Chu Hsi, collected and classified by Li Chung-te in 1270. 朱子語類).

2) The term "*phase*" has since been seldom used in Geology in this sense, being more commonly employed in the sense of a phase of development in Geotectonics.

tempts to estimate the duration were made by Phillips (1860) and several others with reference to the rate of sedimentation. The idea at the back of this method is very old; it was indeed suggested by Herodotus (at about 450 B. C.), but taken by itself it is not dependable. Among chronological studies estimates based on radioactive minerals and glacial varved clay are more important. Because the disintegration of radioactive minerals is known to take place very slowly, its rate being constant regardless of all circumstances, they can be used in chronological measurement. Varved clay can also be used for glacial ages, varves corresponding to year rings in a plant.

Because time as given by the mineralogical method comes in units of ten million years or more, varved clay yields results incomparably more accurate. But this method by de Geer can be used merely for glacial ages and in glaciated areas. It is an advantage of the method of the radioactive mineral that it is applicable throughout the geological ages. The oldest rock yielded by this method so far is in Carelia in Russia; it is 1.850 million years old. The margin of error in the estimation of the mineral-time by the three different ways of this method covers a space of 30 million years at the maximum[1]. Its scale is thus not accurate enough to show the length of a period. For relative length of different periods or of still shorter units of time, one must have recourse to strata-time.

There is, furthermore, a great difficulty in correlating *mineral-time* (鑛時) with *fossil-time* (化石時) as well as with *strata-time* (層時). The mineralogical method can give us only the absolute age of a certain phase in an intrusion of magna occurring in the profound depth of the earth-crust[2] whereas the palaeontological and the stratigraphic method yields respectively the relative age and the duration of a sediment accumulated on the surface of the crust. Since between different levels of the globe there is room for conjecture in these correlations, the estimated geological ages are inevitably rough.

Although much still remains to be checked in the correlation between the two kinds of time, the European and American geologists have now come to an agreement of a sort as shown in Table 1. The difference in the estimated length of the era is 5 percent or less. The difference however becomes larger in periods, the greatest being in the Triassic and Cretaceous periods where the former is estimated to be longer and the latter shorter in Europe than in North America. This is probably because the Triassic is a large system in Europe as is the Cretaceous in North America where it was once divided into the Comanchian and the Cretaceous in the narrow sense.

Among the Cambrian and later periods, older ones are not always

1) N. B. Keevil (1938), Radon Condensation Method of Determining Geological Age. *Am. Jour. Sci. 3d. ser. vol. 36.*

2) The attempt at age-estimation with phosphotized bones, phosphatic concretions or with other sedimentary rocks in strata by the mineralogical method has been unsuccessful so far (J. Joly, Radioactivity and Geology, 1909, London), although deep sea deposits, especially red clay and radiolarian ooze, are known to contain radium in relatively large amounts (L. M. Kurbatov, On the Radioactivity of Bottom Sediments. *Am. Jour. Sci. 3d. ser. vol. 33, 1937*).

TABLE I showing the correlation of the fossil time with the mineral time. (mill. years).

Geological Age			After D. White			After H. Stille		Mean
Caino-zoic	Quaternary			1	60.1	0.6	60.6	0.8
	Tertiary	Neogene	25	60		60		60
		Palaeogene	35					
Meso-zoic	Cretaceous	Late	50	80	140	55	140	67.5
		Early	30					
	Jurassic			35		30		32.5
	Triassic			25		55		40
Neo-Palaeo-zoic	Permian			40	150	30	150	35
	Carboniferous	Pennsylvanian	40	70		60		65
		Mississippian	30					
Eo-Palaeo-zoic	Devonian			40		60		50
	Gotlandian	Sibirian		30	190	100	200	100
	Ordovician			70				
	Cambrian			90		100		95
Sum					541	550.6		545.8

TABLE II showing the revised classification of the Geological Age.

Time Length (years)	Geological Age							
$+1.5\times 10^9$	Eons	Cryptozoic			Phanerozoic			
$\pm\ 5\times 10^8$	Eon	Eocryptozoic	Mesocrypto-zoic	Neocrypto-zoic				
$(1.5\text{–}2)\times 10^8$	Era				Eopalaeozoic	Neopalaeozoic	Mesozoic	Cainozoic
$(3\text{–}9)\times 10^7$	No. of Periods				3	3	3	1
Mineral—Time								
Fossil Time: Marine Time								
Fossil Time: Continental T.								

shorter than younger periods. But with the exception of the Quaternary which is not a *period* as discussed later, all of these periods fit the simple formula of $n \times 10^7$ years where n is a number fluctuating between 3 and 9.

Thus estimated lengths are at present more reliable for eras than for periods. Those of the Cainozoic, Mesozoic and Palaeozoic eras are roughly in the ratio of 3 : 7 : 17, where the Cainozoic is an unfinished era. It is advisable on the other hand to divide the Palaeozoic into the Eo- and Neo-Palaeozoic eras. This is because there is a very important difference between the post-Gotlandian eras with continental time (陸時) and the pre-Devonian era without continental time. Continental time defined by limnobios and geobios appears to several places in this transitional interval, while halobios occur abundantly through Cambrian and later periods. Therefore marine time (海時) is taken as the standard.

When the Palaeozoic is divided into two eras with reference to the appearance of continental time, the three complete eras, Eo- and Neo-Palaeozoic and Mesozoic must lie within the length of from 150 to 200 million years. In other words, it can be concluded that revolutions of biota significant enough to make off the boundary of an era have taken place more or less periodically. The boundary between the Cambrian and the pre-Cambrian time is of a still higher order, because fossil time comes on the scene with the arrival of the Cambrian period and lasts through the Phanerozoic eon.

This eon is approximately one-third of the Cryptozoic eons and roughly three times the length of an era. The three past eras as defined here each consists of three periods. Therefore if it is permissible to take their mean value for the length of a period, the relative lengths of these time-units can be expressed in a very simple formula, namely, that *the period, era, eon and eons are respectively in the radio of 1/3, 1, 3, and 9.* (See table 2). This relation of 3^n among the time-units of Geology tempts one to classify the major unit into three minor ones with prefixes, eo, meso and neo. *Complex* and *Complexes* are here proposed to designate the strata accumulated in an eon and eons respectively.