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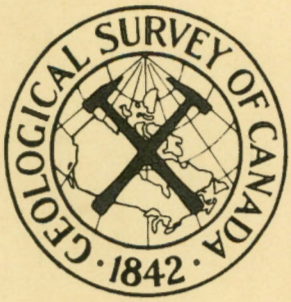

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REVISED PRECAMBRIAN TIME SCALE FOR THE CANADIAN SHIELD

Four previous progress reports summarized available isotopic age determinations for the Canadian Shield and gave an interpretation of the results up to 1964 (Stockwell, 1961, 1963a, 1963b, 1964). Since then a considerable number of new determinations have been made by a greater variety of methods and important changes in interpretation have resulted. Consequently, a revised time scale is needed and is given, very briefly, in the present report.

In the earlier reports, K-Ar ages, mainly on orogenic* micas, were taken as indicating approximate times of crystallization, and the ages of orogenies and time-stratigraphic units were estimated on that basis. Now, however, as ably presented by Moorbath (1967), and by numerous other authors, abundant evidence points strongly to the conclusion that K-Ar and Rb-Sr ages on minerals are younger than the age of primary crystallization and that many of them indicate time of cooling.

In rocks that cooled quickly, such as volcanic rocks and chilled dykes, the differences between age of cooling and age of crystallization is negligible; but for orogenic minerals, having crystallized at depth, the period of uplift, erosion, and cooling is very long and the cooling period is measurable by isotopic methods. The actual measurement, however, is not simple and straightforward because the analytical error for each age is so great that it obscures the differences being sought. To overcome this difficulty, averages are used, and these, for each post-orogenic cooling period, indicate that the ages and the retentivity or closure temperatures for different minerals are, by the K-Ar method, in the order: hornblende>muscovite>biotite and, by the Rb-Sr method, muscovite>biotite. That is to say, in each case the average K-Ar age on hornblende and the average Rb-Sr age on muscovite approach most closely the age of crystallization. Similarly, the average K-Ar age on biotite and the average Rb-Sr age on the same mineral give later stages in the cooling history and each serves as a maximum for the beginning of deposition of unconformably overlying waterlain sediments deposited at surface temperature.

On the other hand, the age of primary crystallization of orogenic materials is, on the whole, better given by U-Pb methods and, with some exceptions, by the Rb-Sr whole-rock isochron method. For this purpose ages on unmetamorphosed orogenic intrusions are preferable because they can generally be interpreted with considerable confidence. Ages determined by these methods are here used to revise the ages assigned to orogenies and to the boundaries between units of eon, era, and sub-era rank. Such boundaries are drawn at the end of the youngest phase of orogeny and consequently at the beginning of the immediately following post-orogenic cooling period. The youngest orogenic phase is represented by late orogenic granitic rocks and often by pegmatite.

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*The term "orogeny" is used here to denote the process of important folding that affected large segments of the crust and was commonly associated with virtually contemporaneous regional metamorphism and the emplacement of granitic bodies. The term "orogenic materials" is used to denote those minerals or rocks that formed in conjunction with this process.

EON	ERA	SUB-ERA	EVENT	AGE OF BOUNDARY (m.y.)		
				U-Pb scale	Rb-Sr scale (constant 1.47)	Rb-Sr scale (constant 1.39)
PROTEROZOIC	HADRYNIAN					
	HELIKIAN	NEOHILIKIAN	Grenvillian Orogeny	Ca 1000	Ca 1010	Ca 1070
		PALEOHELIKIAN	Elsonian Event	? 1400	?	?
	APHEBIAN		Hudsonian Orogeny	Ca 1800	? 1750	? 1850
ARCHEAN			Kenoran Orogeny	Ca 2560	? 2540	? 2690

Table I. Precambrian time classification for the Canadian Shield and estimated age of boundaries in type regions by the U-Pb and Rb-Sr whole rock isochron methods.

The revised ages for the boundaries are somewhat older than previous estimates but the revisions do not alter the nomenclature or definition of the orogenies nor of the time-stratigraphic units because these are not defined by isotopic age but are based on rock and geological relationships in type regions.

The Kenoran Orogeny is defined, geologically, as the last period of important, widespread folding and closely related metamorphism and intrusion in its type region which is the Superior Structural Province. Similarly defined are: The Hudsonian Orogeny of the Churchill Province as the type region; the Elsonian event of the Western Nain Sub-province as the type region; and the Grenvillian Orogeny of the Grenville Province as the type region. It is hoped that, eventually, it may be possible to select much smaller areas for type regions, while still retaining the present geological definitions and still containing rocks and minerals that are suitable for dating by a variety of methods on a variety of materials. For purposes of this report, the word orogeny is used in the above restricted sense as opposed to the expression, orogenic cycle, which includes the deposition of closely related sedimentary and volcanic materials and possibly also epeirogeny and faulting.

Boundaries between time units of eon, era, and sub-era rank are, as already stated, drawn at the end of orogeny. They are natural boundaries that set apart very important events in Precambrian history. Thus, each orogeny was followed by a long period of uplift, deep erosion, and cooling, and by a depositional hiatus, before unconformably overlying sediments were laid down. The boundaries are of practical value for they set apart contrasting events that must be shown on geological and tectonic maps and must be recognized in any study of geological history. Although such boundaries are readily recognized in the type regions, their correlatives may not be similarly expressed world-wide or even throughout a continent and, at some places, may be spanned by continuous deposition of sedimentary or volcanic material, making the boundary difficult to date. The best that can be done is to choose a boundary in a type region that sets apart important events in Precambrian history and that is also most widely recognizable geologically. Orogenies seem to serve this purpose best.

In the type regions the Archean is defined as the time of folding and of crystallization of igneous and metamorphic materials of the Kenoran Orogeny and all older rocks. The Proterozoic spans the time extending from the close of the Kenoran to the beginning of the Cambrian. Subdivisions of the Proterozoic comprise the following eras: The Aphebian, spanning the time from the close of the Kenoran to the close of the Hudsonian; the Helikian, from the close of the Hudsonian to the close of the Grenvillian; and the Hadrynian, from the close of the Grenvillian to the beginning of the Cambrian. The Helikian is divided into two sub-eras, the Paleohelikian and the Neohelikian, separated by a time boundary at the close of the Elsonian (see Table I).

Because of the generally large analytical errors and uncertainty in interpretation, the U-Pb and Rb-Sr whole-rock isochron ages are each averaged for similar orogenic materials in any one province. Omitted from the averages are survival ages from older orogens and also younger dates that appear to result from rejuvenation. In the determination of ages by the U-Pb method, concordant and concordia results are preferred but, as these are few in number, extensive use is made of Pb^{207}/Pb^{206} ages as well. The averages for each method and, preferably for late orogenic phases, are used for estimating the end of orogeny as indicated by the boundaries as shown in

Table 1. Because of the uncertainty in the Rb^{87} decay constant, Rb-Sr ages cannot yet be correlated with ages determined by other methods so that, in Table 1, a U-Pb time scale is shown independently, and two Rb-Sr scales are given, the one based on a decay constant of 1.47×10^{-11} yr^{-1} and the other, using the same data, based on a decay constant of 1.39×10^{-11} yr^{-1}. As can be seen, the ages of boundaries vary appreciably according to the method and decay constant used, but each depicts, within the limits of available information, the same geologically defined unit. The figures given are based on inadequate numbers of U-Pb and Rb-Sr ages which are also far from being fully representative of the very large type regions and, accordingly, are subject to change as more and better information becomes available. Meanwhile, as shown in Table 1, approximate isotopic ages of boundaries are given or, in cases where there is a larger degree of uncertainty, the figures are questioned.

A more detailed and fully documented report will give more data and add further discussion regarding the time classification and will place many volcanic and sedimentary sequences and several non-orogenic intrusions into the framework.

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