GEOLOGY

The Geological Time-Scale

RECENT contributions[1-3] on post-Proterozoic geochronology are timely, for national organizations in the U.S.S.R. and in the United States are now preparing reports on this topic for submission to the International Geological Congress next year. In the recent discussions two questions have been raised: (*a*) the validity of the extended time-scale proposed by investigators at the University of Oxford; and (*b*) the validity of age determinations made on the Upper Cambrian kolm of Sweden. On both these issues there is much more evidence than has been cited.

The time-scale proposed by Dr. K. I. Mayne[1] and his colleagues puts back the date of the uppermost Cambrian strata from 450 to 650 million years. The structure of evidence forming the foundation for this conclusion has, deservedly, been demolished by Prof. J. L. Kulp[3] and his associates, of Columbia University; but the latter go too far in asserting that the scale of the Oxford workers "is not supported by measurements other than their own". While for reasons given below I do not accept this scale, it is very relevant that it is upheld by recent determinations reported from the laboratories of the United States Geological Survey[4]. These record a uraninite from Triassic strata in New Jersey giving concordant lead/uranium and lead/lead determinations of 228, 228 and 230 m.y., and a uraninite from Lower Pennsylvanian strata in Pennsylvania giving various ages ranging from 296 to 337 m.y.

This greatly extended time-scale is however ruled out, in my view, by an immense weight of other evidence. The Oxford team claims to have evaluated earlier researches, with rejection of all save eleven determinations, "because the stratigraphy of the samples or their measured age is not free from unwarranted assumptions"; but of their 11 acceptances, which are mostly transgressive igneous rocks of debatable stratigraphy, no less than ten values are rejected by Prof. Kulp. Lately, in preparing a geochronological table to be published elsewhere[5], I have culled from world-wide literature more than two hundred age determinations on Mesozoic and Palæozoic rocks, mostly executed during the past five years. Of these, more than half were adjudged unacceptable because of inadequacies of sampling, analysis or documentation; and the remainder comprises 91 values, all relating to stratigraphically well-defined samples, which cannot be so rejected. Of these values, 66 are derived from Russian literature. The great variety of techniques represented includes rubidium/strontium determinations on micas and glauconite; potassium/argon assays on micas, glauconite, sylvite, primary feldspar, and authigenic feldspar; potassium/argon assays on lavas, tuffs, minor intrusions, slates, hornfelses, and some granitic rocks; potassium/calcium analyses on sylvite; lead/alpha studies on zircon; and helium studies on magnetite. In ten instances two or more methods have been employed on the same sample, with good agreement.

To establish a geochronology from these data without incurring suspicion of subjective selection, an average age has been calculated for the rocks of each system. Where there are sufficient data this should approximate to the mid-point of the period in question. In Table 1 the values derived from recent experiments are compared with the mid-points on the Holmes, Belousov and Oxford scales.

Table 1. MID-POINTS OF THE GEOLOGICAL PERIODS (MILLIONS OF YEARS)

	Holmes B	Belousov	Oxford	Recent experiments	(Number of records)
Cretaceous	92	90	100	100	(27)
Jurassic ..	140	130	160	153	(9)
Triassic ..	167	169	225	174	(5)
Permian ..	192	205	275	212	(5)
Carboniferous	229	250	350	284	(5)
Devonian ..	284	292	440	329	(11)
Silurian ..	332	328	510	368	(6)
Ordovician ..	390	368	600	410	(8)
Cambrian ..	470	423	700	517	(15)

The records from which these averages were compiled include potassium/argon determinations on feldspars and whole rocks. If there has been loss of argon from feldspar, these ages will be less than the true values. But, notwithstanding Dr. Mayne's conclusions to the contrary[2], the evidence strongly suggests that in unweathered and unmetamorphosed rocks such loss is exceptional. Where sets of analyses are available (in four instances), there is no significant difference between age determinations on biotites, on non-perthitic feldspars, and on whole rocks. It seems that potassium/argon ages on feldspar have quite unjustifiably received a bad name as a result of many demonstrations of loss of argon from pegmatitic microclines. Since Dr. S. S. Sardarov[6] has shown that this loss is directly proportional to the degree of development of perthite or microperthite (thus being dependent on the late thermal history of the rock), we have an acceptable explanation why ages based on pegmatitic feldspars tend to be low, while whole-rock ages on granodiorites, plagiogranites and unmetamorphosed eruptives devoid of perthitic structures agree well with determinations on the biotites which the same rocks contain.

A final word about kolm. Prof. Kulp rejects my contention that although the uranium and lead in the alum shales is syngenetic, these elements are largely epigenetic in the kolm concretions. It would be wise to bear in mind the practical researches of Dr. E. V. Rozhkova and others[7], who have shown that even hydrocarbons as highly anthracitized as the middle Proterozoic shungite of Karelia still retain a marked capacity for adsorbing uranium. Since the groundwaters of the alum shales are, and presumably always have been, highly uraniferous, and since there has been no demonstration that the adsorptive capacity of kolm is out of line with that of similar hydrocarbons, the hypothesis that uranium has been continually introduced into the kolm throughout the ages should not be dismissed so cavalierly. In brief, this material is no more suited to be a geochronological bench-mark than was the uraniferous phosphorite on which Strutt made his pioneer age determinations more than fifty years ago.

C. F. DAVIDSON

Department of Geology,
University of St. Andrews,
Scotland.
Sept. 12.

[1] Mayne, K. I., Lambert, R. St. J., and York, D., *Nature*, **183**, 212 (1959).
[2] Davidson, C. F., *Nature*, **183**, 768 (1959).
[3] Kulp, J. L., Cobb, J. C., Long, L. E., and Miller, D. S., *Nature*, **184**, BA 62 (1959).
[4] Stieff, L. R., U.S. Geol. Surv. Report, TEI–740, 301 (1958).
[5] Davidson, C. F., *Liverpool and Manchester Geol. J.*, Centenary Vol. (in the press).
[6] Sardarov, S. S., *Geokhimiya*, 193 (1957).
[7] Rozhkova, E. V., Rasumnaya, E. G., Serebryakova, M. B., and Shcherbak, O. V., Conf. Peaceful Uses of Atomic Energy, **6**, 420 (Geneva, 1958).