

ON THE USE OF THE TERM "ARCHÆAN" IN PRECAMBRIAN STRATIGRAPHY

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THE term Archæan was introduced by J. D. Dana in 1872 to designate all the formations older than the Cambrian. In the International Geological Congress held in 1885, it was agreed to use Archæan, as a group name to include the various Precambrian systems.

The early workers who investigated the geology of Precambrian shields generally found that those regions were underlain by high-grade metamorphic rocks, intrusive rocks, and areas of less highly metamorphosed sedimentary and volcanic rocks. The high-grade metamorphic rocks were considered to be Archæan on the assumption that they were the oldest known crystalline rocks of that region. In Africa, for example, such Archæan rocks were named the Basement Complex (Somalia, Nigeria, Rhodesia, Uganda), Basement System (Kenya), or Primitive System (Southern Africa).

In Scotland, which is a classical area for Precambrian geology, the Lewisian complex of the Northwest Highlands has been referred to as the 'fundamental complex' or 'fundamental gneiss' because it was considered to be the Archæan basement on which the generally horizontal Torridonian strata lie (Peach *et al.*, 1907, p. 10).

Similarly, in India, it was found that more than half the area of the peninsula was occupied by old crystalline rocks which must have obtained their present characters at great depths. These rocks were covered in many places by younger sediments and lava flows. It is in consequence of its position with regard to the ordinary sedimentary rocks that the old crystalline group was earlier referred to as the 'Fundamental Complex'. The fundamental complex in India was found to be similar in essential respects with that of other countries, for instance, America, where this group, on account of its great age, *i.e.*, greater than that of any known fossiliferous rocks, was first named Archæan. Thus T. H. Holland (1906, p. 47) grouped under Archæan both the Dharwars and the fundamental crystalline rocks, drawing attention to the great 'break' which separates

the gneisses and Dharwars from the much younger Cuddapahs and other unfossiliferous rocks of the peninsula. This unconformity between the Archæan and the Purana groups was named the Great Eparchæan Interval (Holland, 1909, p. 55). L. L. Fermor (1909, p. 236) was also substantially of the same view as Holland.

The earliest departure from the above concept was probably due to R. D. Irving (1888, p. 450) who in Canada suggested that the name Archæan of Dana, which up to that time had included all the Precambrian, be restricted to the Laurentian 'gneissic basic terrane', and that an entirely new name of equal rank with Palæozoic and Archæan be introduced to cover the formations between the gneissic series and the Cambrian. Following this proposal of Irving, the geologists of the United States Geological Survey chose the name 'Algonkian'.

In India, Holland (1913, p. 371) reviewed the group classification and summarised the reasons for defining the Archæan as generally accepted by the Geological Survey of India. Noticing the tendency of some Canadian and American geologists even as late as 1922 to use the term Archæan for all Precambrian rocks, which was a departure from Dana's final meaning of the term Archæan, Holland (1926, p. 38) suggested the adoption in India of the special term 'Vedic' for the basement complex.

Until some decades ago, the Precambrian of Sweden (Geijer, 1963, p. 85) was commonly divided into two parts, *viz.*, Archæan and post-Archæan formations. The Archæan covered 'the granite-interwoven basement', which so far was found to be impossible to divide into a series of formations separated by unconformities. As 'post-Archæan' were classified such supracrustal series that showed a distinct unconformity against the underlying Archæans.

In the United States, C. R. Van Hise (1892, p. 13) applied the term Archæan to 'granitic, gneissic and schistic rocks, among which are never found beds of quartzite, limestone, or

any other indubitable clastics'. It was used in this sense for the first time in India by R. B. Foote (1895, p. 26) who limited the use of the term Archæan to the gneisses and granitoid members of the crystalline complex, thus excluding the rocks of the Dharwar system which he designated 'Lower Transition' and regarded as distinctly younger than the gneisses and gneissic granites. This was also the view of Holland who considered the Archæan Group of India to be composed of the oldest Gneissose and Schistose rocks, followed by some granites, anorthosites, charnockites, etc., and demarcated from the younger Dharwarian rocks by an Eruptive Unconformity. E. Vredenburg (1907, p. 4) also restricted the use of the term Archæan to gneissic rocks 'underlying the oldest undoubted sediments' which represent 'in part, at least, the original crust of the globe'; he excluded the khondalites which are metamorphosed sediments!

Later, Van Hise (1901, pp. 316-317) changed his original view and included in the Archæan certain sedimentary rocks like the iron formations. Till this time the Algonkian was understood to comprise all Precambrian sedimentary rocks, and the Archæan to include all pre-Algonkian formations which were supposed to be composed wholly of igneous rocks.

A Committee of the Royal Society of Canada on Stratigraphical Nomenclature recommended in 1932 that Precambrian time be divided into two eras, and that the names of the eras be Archæan and Proterozoic (Alcock, 1932, p. 119). This was accepted by the Precambrian geologists of the Geological Survey of Canada at a meeting in 1935.

In India, the term Archæan was applied to all rocks which lie stratigraphically below the Eparchæan Interval, the beds which normally succeed being described by Holland as 'Purana' which is the nominal equivalent of the Algonkian. For example, in Mysore State, which is a classic ground for Precambrian geology, B. Rama Rao (1940, p. 83) considered that except for some mafic dykes, all the other formations like the Dharwar, Peninsular Gneiss, Champion Gneiss, charnockites, felsites, and porphyry dykes, belonged to the Archæan. This was essentially what was proposed earlier by W. F. Smeeth (1916, p. 20).

The distinction between Archæan and Purana rocks is in many places so imperceptible that

in Peninsular India, Fermor (1936, p. 14) took the presence of either granitic or pegmatitic intrusives as sufficient reason for referring the rocks into which they are intruded to the Archæans rather than to the Puranas, a procedure which has been sharply criticised by Holmes (1963, p. xix).

A. Holmes (1948), in an address to the International Geological Congress, suggested that Precambrian geology must be liberated from the 'tyranny of a telescoped classification in which the Archæan, be it Laurentian, Lewisian, Swaziland, or Dharwar, is regarded as a single era of world-wide distribution' because five Archæan cycles were already known and there was time enough in the geological past for double that number. According to Holmes (1963, p. xix), 'it is more than surprising that the tyranny of the Archæan—correlation by a word of seemingly magic authority—should have survived so long' especially when it is now known that many of the so-called 'Archæan rocks' are of Palæozoic age. What were once considered to be 'characteristically Archæan orogenic belts' have continued their activity well into the Palæozoic on the east and west coasts of India, as well as to the Cambrian and Ordovician phases of such orogenic activity in Kerala and Ceylon.

Geochronological investigations of the ancient unfossiliferous rocks have yielded surprising results, especially in the realisation of the great span of Precambrian time, and in the recognition of several orogenic cycles. Based on such geochronological data, attempts have recently been made to fix the upper age limit of the Archæan, but here again there is wide divergence in the views of the different workers. A. P. Vinogradov and A. I. Tugarinov (1961, pp. 492-499) put the Archæan-Proterozoic boundary at 1,900 m.y.; C. H. Stockwell and H. Williams (1964, pp. 1-29) suggested 2,500 m.y. A. B. Ronov (1964, p. 715) placed rocks with ages from 3,500 to 2,600 m.y. in the Archæan, and those with ages from 2,600 to 600 m.y. in the Proterozoic. According to L. I. Salop (1968, p. 62) the boundary is at 2,800 m.y.

Reluctance to give up the term Archæan, which has such a great geological age-span, has led to its further subdivision. For eastern Fennoscandia, Polkanov and Gerling (1960, pp. 183-191) have proposed the following cycles

of sedimentation, metamorphism and magmatism :

Katarchæan (3,590-2,770 m.y.)	..	} Katarchæan I—3,500-3,200 m.y. Katarchæan II—3,100-3,060 m.y.
Lower Archæan (2,770-2,150 m.y.)	..	} Lower Archæan I—2,870-2,500 m.y. Lower Archæan II—2,490-2,100 m.y.
Upper Archæan (2,150-1,650 m.y.)	..	} Belomorides—2,100-1,950 m.y. Svecofennides and Karelides—1,870-1,640 m.y.

Salop (1968, pp. 62-65) considers that the Archæan complex of the U.S.S.R. is more than 2,800 m.y. old. According to him, there are no indications of breaks and especially unconformities, and so there is no basis for the attempt of some geologists for distinguishing two groups separated by diastrophism such as a Kata-Archæan group (> 3,500 m.y.) and an Archæan one (2,800-3,500 m.y.); also, that the rocks whose radiometric ages are about 3,500 m.y. have not been delimited geologically from the Archæans that were metamorphosed 2,800 m.y. ago and form the same complexes with them.

In Canada, the name 'Laurentian' was being used to include all the pre-Huronian or Archæan formations (Irving, 1888, p. 450). Later recognition of the effects of more than one episode in the Laurentian 'gneissic basic terrane' rendered the term Laurentian inappropriate for use in correlating rock units and geological events (Peach and Horne, 1930, p. 23). Difficulties have also arisen in attempting to divide the Archæan basement complex characteristic of so much of the Canadian Shield. It is being realised that in the present state of information it will be most satisfactory to use local names for sedimentary belts within the basement succession, and if some correlation becomes possible, to make such parts subsidiary divisions within the Archæan (Wilson, 1965, p. 358).

It is now known that the Lewisian Complex of Scotland which was formerly considered to be Archæan contains remnants of at least two sedimentary groups and shows evidence of poly-phase deformation and polymetamorphism in at least three orogenic episodes—Scourian, Inverian, and Laxfordian—dated at about 2,600 ± to 2,460 m.y. ago, 2,200 to 2,000 m.y. ago, and 1,600 to 1,300 m.y. ago, respectively (Bowes, 1968, p. 577).

Enough has been said to show that the monolithic Archæan has now been fragmented so much that the term has lost whatever stratigraphic significance it might once have had.

During the enormous span of geological time comprised by the Archæan, there have been

several cycles of orogenic activity. As a stratigraphic term, therefore, Archæan has practically no value. Even after the term Proterozoic was coined in 1932, there has been no consensus of opinion as to where Archæan ends and Proterozoic begins.

In India, as elsewhere, the Eparchæan boundary has been bobbing up and down in the stratigraphic scale according to the predilections of the individual worker. On the assumption that all the gneisses, granulitic gneisses such as charnockites, pyroxene granulites, etc., and amphibolites, are older than the Dharwars, S. P. Nautiyal (1966, pp. 5-6) considers them as Archæan, and the Dharwars as Proterozoic. The Dharwars have been divided by him arbitrarily into the high grade metamorphic rocks such as sillimanite, kyanite-garnet schists and gneisses, biotite schists, marbles, and quartzites, together with 'younger migmatites' which he groups under Upper Archæans; and the hornblende and chlorite schists which he considers as Lower Proterozoic. There is no geochronological or field evidence in support of these conjectures (Pichamuthu, 1970, pp. 245-247). In a polymetamorphic assemblage like the Precambrian, it is not possible to assume metamorphic grade as a function of age. In contrast to the suppositional classification of the Dharwars by Nautiyal, there is much to be said in favour of that proposed by B. P. Radhakrishna (1965, p. 105) as it is based on the general structure of the Schist Belts, as well as on the lithological succession from the oldest Bababudan series to the youngest Supa-Dandeli series.

Time is a continuum and can, therefore, be subdivided in any manner but the main object of stratigraphy is the subdivision of rock sequences in terms of time and not the subdivision of time itself. The arbitrary fixation of the upper limit of the Archæan at 2,500 or 2,600 m.y. leads to irreconcilable anomalies in the Mysore Precambrians, since such an age limit cuts across all the three prominent

constituents—the Dharwar Schists, the Peninsular Gneisses, and the Charnockites. These rock sequences contain within themselves the frozen history of many episodes of metamorphism, intrusion, metasomatism, and assimilation which occurred during a long span of geological time, and hence, are not susceptible of being classified in terms of rounded units of time.

Recently, some have avoided the use of the term Archæan in Precambrian stratigraphy. F. F. Grout and his associates (1951, p. 1021) proposed a three-fold time division into Earlier, Medial, and Later eras for the Precambrian of northern Minnesota. H. L. James (1955, p. 1459) classified the Precambrian rocks of northern Michigan into Lower, Middle, and Upper parts. In the third report of the American Commission on Stratigraphic Nomenclature (Harrison, 1955, p. 1859), it was recommended that the major divisions of Precambrian time, approximately equal to eras, be known as Early Precambrian and Late Precambrian.

In view of the various uncertainties in the Precambrian stratigraphy of India, S. N. Sarkar (1968, pp. 23-25) has suggested that the Precambrian be classified into five groups, thus avoiding the controversy regarding the exact position of the Eparchæan Interval which, according to Holmes (1955, p. 97) only connotes 'a mental telescoping of several such intervals'. The three oldest groups in this classification are as follows:

Precambrian I (3,000 to 3,500 m.y.) Older Metamorphics; Basement Complex.

Precambrian II (2,500 to 3,000 m.y.) Iron Ore, Dharwar, B.G. Complex.

Precambrian III (1,600 to 2,500 m.y.) Satpura and Aravalli (in part).

At present, one is not certain how ancient or how characteristic the rock sequences of the 'Archæan' are, and hence, there seems to be no justification for continuing the use of this term in Precambrian stratigraphy.

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