[AMERICAN JOURNAL OF SCIENCE, VOL. 254, JANUARY 1956, P. 19-31]

ABSOLUTE AGES OF THE ARCHAEAN OROGENIC CYCLES OF INDIA

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ABSTRACT. Correlation within the Archaean rocks of India has been difficult and, without the aid of radioactive age data, not very satisfactory. The available age data pertaining to the Archaean obtained by the Pb-U-Th, alpha-helium, and Rb-Sr methods are presented cycle-wise, and the degree of dependability of each determination is given. The Eastern Ghats orogenic cycle (1625 ± 75 M.Y.) is older than the Satpura (955 ± 40 M.Y.) and Delhi cycles (735 ± 5 M.Y.), and younger than the Dharwar cycle (2300 ± 100 M.Y.)—a succession which is fully consistent with the structural evidence. Recent advances in the field of measurement of geologic time have thus facilitated the bringing together of two distinct, but nevertheless mutually related, approaches; namely, the correlation of rock formations and the dating of orogenic cycles.

PREVIOUS NOMENCLATURE AND CORRELATIONS

The term "Archaean" was originally proposed by Dana (1872, p. 253) to designate all the Precambrian formations. Subsequently, in the United States, the Precambrian formations were separated into two systems—an upper Algonkian system, which includes undoubted original sediments lying below the base of the Cambrian, and a lower Archaean system, which consists of granitic, gneissic, and schistose rocks, among which are seldom found beds of quartzite, limestone, or any other indubitable clastics. These two systems are no longer generally recognized as time units in the United States, however.

In India, the formations below the Eparchaean unconformity (the unconformity at the base of the Cuddapah system and its equivalents) were included in the Archaean. It must, however, be admitted that, at present, there is no strict definition for the term Eparchaean unconformity, particularly as the Cuddapah system cannot be correlated with formations in other parts of India "officially" regarded as its equivalents (personal communication from Professor Holmes). The so-called Lower Transition System consisting of certain sedimentary rocks, and mixtures of sedimentary and igneous rocks was included within the Archaean. These rocks, which occur in compressed and partly buried synclinoria in South India, were grouped in the Dharwar system of Bruce Foote (1886). The term Dharwar was later extended to similar formations in other parts of India and has been widely used to designate the schistose Archaean rocks older than the Eparchaean unconformity. Such a wide usage of the term seems unfortunate, firstly because it tends to confuse the Archaean chronological succession and secondly because, like the term "Laurentian" in North America, it is incorrectly used to designate rock formations that are widely separated geographically and chronologically. On these grounds, Holmes (1949) expressed himself strongly against the use of the term "Dharwar" for the rocks of the Satpura and Eastern Ghats belts. It has been very correctly stated that "the term has become so well entrenched in Indian geological nomenclature that it is scarcely possible to discard it" (Krishnan, 1949, p. 94-95). The term "Dharwar" will have to be retained, but in the interests of clarity of stratigraphic nomenclature, it is better to restrict it to the type area in South India.

Archaean rocks occupy about two-thirds of Peninsular India. "They stretch continuously from Cape Comorin to the Central Provinces and Bihar and apparently continue underneath the Ganges alluvium into the Assam plateau; the Mysore area is also presumably connected with that of Gujarat and Rajputana beneath the Deccan Traps" (Krishnan, 1949, p. 96). In Extra-peninsular India, Archaean rocks are found in the Lesser Himalayas.

Correlation of the Archaean formations of Peninsular India is much more difficult and complex than correlation of the higher sedimentary systems. For the latter, stratigraphic correlation is usually a comparatively simple job as, in most cases, at least one of the major criteria for stratigraphic correlation (lithology, stratigraphic superposition, and fossil content) is available. "These criteria are, however, either absent or comparatively of little help in the case of Precambrian formations, and especially of metamorphic complexes, for they are devoid of fossils, their lithology is transformed by metamorphism, and their stratigraphical relationships confused by intricate folding, disturbance, and dislocation" (Krishnan, 1949, p. 140-141). The cumulative effect of regional metamorphism, igneous contact action, magmatic stoping, assimilation, and hybridism has resulted in the production of a bewildering variety of petrological types with complex characters which must necessarily be difficult to unravel.

Fermor (1936) made the first systematic attempt to correlate the ancient schistose formations of the Peninsula. He (1936, p. 42) demarcated two regions in the Archaean rocks of the Peninsula—the non-charnockitic (including iron-ore provinces, manganese-ore marble provinces, and igneous provinces), and the charnockitic (also including iron-ore provinces and manganese-ore marble provinces, of normal type and garnetiferous type). The separation was based on the belief that the charnockitic region of Archaean rocks had witnessed a plutonic invasion of charnockite and at the same time had been subjected to a severer degree of metamorphism (hypo-metamorphism) than the non-charnockitic region. The validity of such a separation was later brought in question by two significant observations: (1) there is no clear evidence for the major fault separating the charnockitic and non-charnockitic regions postulated by Fermor (1936, p. 48-49), and (2) all the types of hypo-grade rocks enumerated as characteristic of the charnockitic region except khondalites and eclogites have been found in the Sausar series of the Central Provinces and therefore outside the charnockitic region (Pascoe, 1950, p. 70). The association of marbles, manganese ores, and iron ores which Fermor took up as a major criterion for purposes of correlation, was based on the assumption that at a certain period of Earth's history these special groups of sediments were formed.

AGE DATA

With the objective of dating the pegmatitic cycles of the Archaean structural provinces (Aravalli, Dharwar, Eastern Ghats, and Satpura), detailed investigations were undertaken on five radioactive minerals drawn from various parts of Peninsular India—namely, samarskite from Nellore (Andhra State), monazite from Mewar (Rajputana), and allanites from Madura

(Madras State), Purulia (Bihar), and Aanakapalle (Andhra State). Their physical and optical characters, autoradiographic pattern, and chemical composition were studied to determine their suitability for purposes of age determination. While samarskite has been found to be highly suitable (Aswathanarayana, 1953a), allanites from Purulia and Anakapalle are fairly so, but allanite from Madura (Aswathanarayana, 1953b), and monazite from Mewar are undependable as age indicators, as they have suffered leaching. The age data on the three suitable radioactive minerals together with some unpublished alpha-helium ages and published Rb-Sr and lead ages pertaining to the Precambrian rocks of India, are presented in the following tables.

The crude lead ages in the tables have been read from the family of curves of Wickman (1944).

The epithets "excellent," "good," "satisfactory," and "doubtful" have been used in the tables to connote specific degrees of dependability.

Excellent: Highly dependable, supported by isotopic analysis of lead.

Good: Dependable.

Satisfactory: Of the right order of magnitude, though not altogether dependable.

Doubtful: Too low, unlikely to be correct.

It is found that among the 36 ages listed, 16 are lead ages (5 excellent, 9 good, and 2 satisfactory), 18 are alpha-helium ages (9 satisfactory and 9 doubtful), and the other 2 are Rb-Sr ages (both satisfactory).

AGES OF THE ARCHAEAN OROGENIC CYCLES

In contradistinction to the approach of Fermor (1936), Holmes (1949, 1950) and Krishnan (1953) tried to arrive at the relative ages of the orogenies which produced the characteristic regional strikes of the Archaean structural provinces (N.E.-S.W. for Aravalli cycle, N.N.W.-S.S.E. for Dharwar cycle, N.E.-S.W. for Eastern Ghats cycle, and E.N.E.-W.S.W. for Satpura cycle). The age data are presented cycle-wise in tables 1 to 4, and all ages except those of doubtful nature are plotted on the structural map of India (fig. 1). Where alpha-helium age data are available from adjacent localities, the highest recorded age for the region has been plotted at a central location.

Aravalli and Delhi Cycles

Holmes (1949) delineated three orogenic cycles in Rajputana belonging to (1) the Gneissic Complex with N. or N.N.W. trend, believed to form a deeply denuded basement on which later formations were deposited, (2) the Aravalli orogenic belt whose N.E.-S.W. trend becomes N.-S. in the proximity of the Champner series and changes to N.N.W.-S.S.E. as the Deccan Traps are approached, and (3) the Delhi orogenic belt which is superimposed on the Aravalli belt and has the same regional trend. All the three orogenic cycles have produced pegmatites, and hence it is commonly difficult to fix up the geologic age of a pegmatite.

The pegmatites belonging to the Gneissic Complex and Aravalli orogenic belts are barren of radioactive minerals and hence cannot be dated by the lead method. But the trend lines of the Aravalli orogenic belt are helpful in correlating it with the other Archaean belts. "In the Gujarat region, it (Aravalli strike) tends to splay out rather widely and a part of it, if continued, is directed towards Mysore in South India where the Dharwarian rocks have a dominant N.N.W.-S.S.E. strike. Though the area intervening between Gujarat and Mysore is covered by the Deccan Trap lavas, there appears to be little doubt about the direct connection between the Archaeans of the two areas" (Krishnan, 1953, p. 5). The breach in the trend of the Aravalli rocks in the Cambay-Gujarat region was surmised to be due to faulting of the Aravallis (Krishnan, 1953, p. 5).

The post-Delhi pegmatites are highly mineralized and have yielded radioactive minerals like uraninite and monazite. Attempts have been made by the author to date the monazite from the post-Delhi pegmatites of Ajmer-Merwara but they proved unsuccessful. The autoradiograph clearly indicates that the mineral had suffered leaching, presumably of lead and uranium, in unknown quantities and hence is undependable as an age indicator. As could be expected, the mineral has given a low age.

Holmes (1949) dated the uraninite from Bisundni, Ajmer-Merwara, which yielded an age of 735 ± 5 M.Y. for the Delhi pegmatitic cycle. The AcD/RaG, RaG/U, AcD/U, ThD/Th have given very closely agreeing ages and hence the above age can be regarded as of "first-class reliability."

Dharwar Cycle

The ages obtained by using the lead, alpha-helium and Rb-Sr ages are given in table 1.

Lead ages.—The monazite from the pegmatites of Yediyoor (Bangalore) gave a crude age of 1850 M.Y. (Holmes, 1951). The lead in the mineral was subsequently analyzed isotopically. From the 204, 206, 207, and 208 lead contents, Holmes (1955) deducted the "inherited lead," which he took from the isotopic analysis of lead from Chitaldrug galena, and calculated the percentage of radiogenic lead in the monazite. The 207/206 age was read from the nomographs of Wickman (1939). Other ages were calculated by the formulae given by Keevil (1939). The spread of the ages is as follows:

207/206	206/U	207/U	208/Th
2300 ± 100	1430	1810	1800 ± 40

It is seen that the four ages given above markedly deviate from the crude age, which is strongly indicative of the altered nature of the mineral. Such a spread of the ages could be brought about by (a) loss of lead, (b) loss of radon, and (c) any combination of (a) and (b). There is, however, direct evidence to show that loss of radon is negligible (Holmes, 1955).

When lead is lost, RaG/UI, AcD/AcU and ThD/Th give low values, RaG/UI giving a lower value than AcD/AcU. The above spread of the ages closely corresponds to this case, as 206/238, 207/235, and 208/232 ages are consistently lower than the crude age and 206/238 gives the lowest value of all. In such a case as this, the correct age is given by 207/206, which is 2300 ± 100 M.Y.

TABLE 1

Dharwar Cycle

Serial no.	Name of the mineral or rock dated	Locality	Method of age determination	Age (in M.Y.)	Degree of dependability	Remarks
1	Monazite	Yediyoor, near Bangalore, Mysore	Pb-U-Th	2300 ± 100	Excellent	Based on the isotopic analysis of lead
2	Galena	Chitaldrug, Mysore	Lead isotopes	2450 ± 130	"	"
3	Magnetite crystals	Holenarsipur, Mysore	Alpha helium	1700	Satisfactory	Moderate helium loss
4	Magnetite-bearing chlorite schist	"	"	1600	Doubtful	Schist material must have lost an appreciable proportion of its helium content
5	Felspathized hornblende schist	"	"	1400	"	Extensive helium loss
6	Chlorite schist	"	"	1250	"	"
7	Hornblende schist	Kolar Gold Fields Mines, Mysore	"	1400	"	"
8	Quartz vein	"	"	600	"	"
9	Phlogopite	Punalur, Travancore	Rb-Sr	1630 ± 200	Satisfactory	"

1, 2—Holmes, Arthur (1955).

3 - 8—Unpublished ages (obtained by Prof. R. S. Krishnan and his associates on materials earlier studied by the author).

9 —Venkatasubramanian, V. S. (1953).

The age of 2300 ± 100 M.Y. is an excellent agreement with the age of the Chitaldrug galena (2450 ± 130 M.Y.—as dated from the isotopic analysis of the lead), since the gold-galena veins are likely to be older than pegmatites.

The age of 492 M.Y. given by Bowie and Horne (1953) for cheralite (a mineral belonging to the monazite family, from Kattakuzhi, Travancore) was first considered anomalous by the author because of its low magnitude, but Professor Holmes, in a personal communication, pointed out that it is of the same order as that of thorianites from Ceylon with an age of 485 M.Y. The marked similarity in the ages of these minerals is strongly suggestive of the existence of a pegmatitic cycle common to both South India and Ceylon. Such a conclusion is in keeping with the geological history of the two regions.

Alpha-helium ages.—The age of the magnetite from Holenarsipur (1700 M.Y.) is the highest among the alpha-helium ages for Dharwar rocks and minerals. Hornblende schist and chlorite schist from Holenarsipur and hornblende schist from the Kolar Gold Fields Mines have given consistently low values, which is not surprising as the well-developed cleavages of the constituent minerals are highly conducive to helium leakage. As the stratigraphic age of the pegmatites and quartz veins examined is not clear, it is difficult to reach a conclusion on the degree of dependability of their alpha-helium ages but there is evidence to suggest that the ages are unlikely to be correct.

Rb-Sr age.—The age of the Travancore phlogopite (1630 ± 200 M.Y.), which occurs in the pyroxenite dikes at Punalur and Neyyoor, is interesting. The occurrence of the mineral where the Dharwar and Eastern Ghats strikes join and the general strike (N.N.W.-S.S.E.) of the associated charnockites and leptynites (Subramanyam, 1941) have rendered it difficult to place the mineral in either the Dharwarian or the Eastern Ghats structural province. As the phlogopite from Visakhapatnam belonging to the undoubted Eastern Ghats province has given an age of 1490 ± 200 M.Y., and as the strike of the formations associated with the Travancore phlogopite is closer to the Dharwarian than to the Eastern Ghats strike, it may be argued that the phlogopite belongs to the Dharwar cycle. Alternately, the phlogopite can be considered to belong to the Eastern Ghats cycle on the ground that phlogopite-pyroxenite is not a characteristic Dharwar rock whereas it is associated with Eastern Ghats, especially in Ceylon (personal communication from Prof. Holmes). The available evidence, however, does not warrant any specific conclusion on this subject.

Eastern Ghats Cycle

The lead, alpha-helium, and Rb-Sr ages are presented in table 2.

Lead ages.—The lead ages given by samarskite from Nellore, allanite from Anakapalle, and detrital monazite from Cuttack (207/206 age) do not differ much. An age of 1625 ± 75 M.Y. can therefore be given to the Eastern Ghats cycle, taking into consideration the range of variations in the age data available.

Alpha-helium ages.—As could be expected, the alpha-helium ages for rocks and minerals of Eastern Ghats cycle vary within wide limits, depending upon the degree of retention of helium in each sample. While magnetites, in

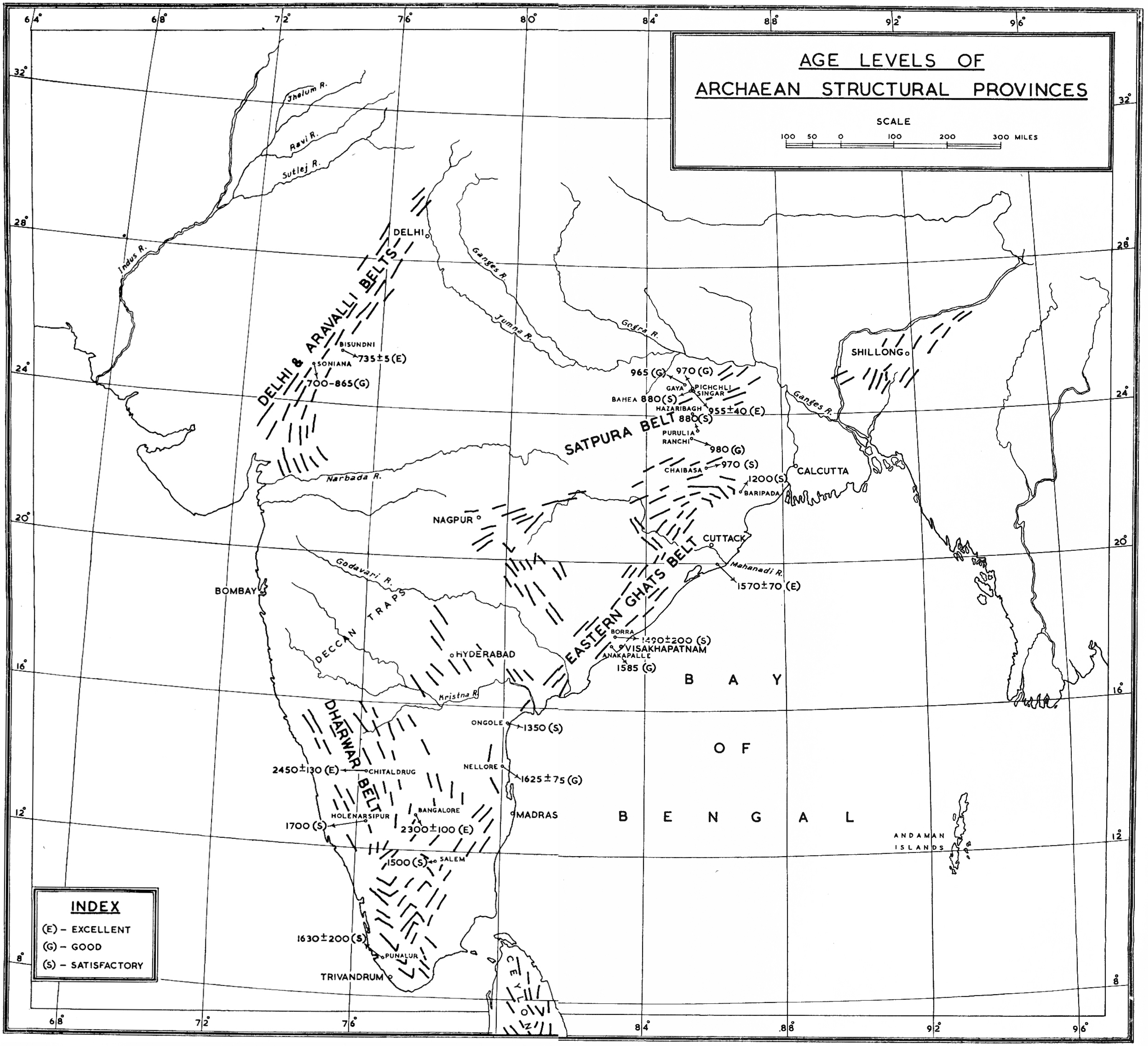
AGE LEVELS OF
ARCHAEAN STRUCTURAL PROVINCES
SCALE
100 50 0 100 200 300 MILES
INDEX
(E) – EXCELLENT
(G) – GOOD
(S) – SATISFACTORY
Jhelum R.
Ravi R.
Sutlej R.
Indus R.
Ganges R.
Jumna R.
Gogra R.
Narbada R.
Godavari R.
Kristna R.
Mahanadi R.
DELHI
DELHI & ARAVALLI BELTS
BISUNDNI
735±5 (E)
SONIANA
700-865 (G)
SATPURA BELT
965 (G)
970 (G)
GAYA
PICHCHLI SINGAR
BAHEA 880 (S)
HAZARIBAGH
955±40 (E)
880 (S)
PURULIA
RANCHI
980 (G)
CHAIBASA
970 (S)
1200 (S)
BARIPADA
CALCUTTA
SHILLONG
NAGPUR
CUTTACK
EASTERN GHATS BELT
1570±70 (E)
BOMBAY
DECCAN TRAPS
HYDERABAD
BORRA
1490±200 (S)
VISAKHAPATNAM
ANAKAPALLE
1585 (G)
B A Y
O F
B E N G A L
DHARWAR BELT
ONGOLE
1350 (S)
NELLORE
1625±75 (G)
2450±130 (E)
CHITALDRUG
MADRAS
HOLENARSIPUR
1700 (S)
BANGALORE
2300±100 (E)
1500 (S)
SALEM
1630±200 (S)
PUNALUR
TRIVANDRUM
CEYLON
ANDAMAN ISLANDS

Fig. 1

general, yield satisfactory ages, rocks like charnockites, biotite schists, amphibolites, and pegmatites and minerals like felspar are found to be undependable age indicators, as they invariably lose helium.

The alpha-helium ages of magnetites from the same locality, as for example Ongole and Kanjamalai, are significantly non-reproducible. This can be explained by bringing in the results of investigations of Professor C. Mahadevan in Professor P. M. Hurley's laboratory at Massachusetts Institute of Technology. He found that there is a change in the age ratio with depth in the magnetite grains because, while the helium content remains fairly constant, the superficial radioactivity of the magnetite grains decreases steadily as the acid dissolves the outer layers. This highly significant observation, besides explaining the absence of good reproducibility in the alpha-helium age data in the table 2, also suggests that the cores of magnetite can be expected to yield dependable ages.

The magnetite quartzites of Ongole and Salem belong respectively to the Madras-Ongole province (no. 12) and Salem-Arcot province (no. 11) of Fermor (1936, p. 42). Both of them belong to the iron ore province of the charnockitic region and both are characterized by the Eastern Ghats trend (Krishnan, 1953, p. 4). The similarity in the magnitude of their alpha-helium ages, though not dependable enough for dating the Eastern Ghats cycle because of the loss of helium which may occur in ancient minerals, suggests that the iron ores of Ongole and Salem were deposited contemporaneously.

The similarity in the ages of the Anakapalle (1585 M.Y.) and Nellore pegmatites (1625 ± 75 M.Y.), which are intrusive into khondalites and mica schists respectively, constitutes additional evidence in favor of the surmise of Mahadevan (1949, p. 78) that the Nellore mica belt is a continuation of the khondalitic zone. The allanite-bearing pegmatites of Aanakapalle and the monazite-bearing pegmatites of Cuttack (which yielded detrital monazite) are both intrusive into khondalites of the Eastern Ghats and, significantly enough, the apparent lead age of the former (1585 M.Y.) is of the same order as the 207/206 age (1570 ± 70 M.Y.) of the detrital monazite. Thus the radioactivity age data, besides indicating the continuation of the Eastern Ghats from parts of Orissa down to Nellore and beyond, also suggests that the pegmatitic display which marks the closing stages of the Eastern Ghats orogeny is contemporaneous in the various parts of the Eastern Ghats.

It is relevant to refer here to the controversy raised by Holmes (1949, p. 299) regarding the age of the Nellore samarskite. He calculated the apparent ages from the U, Th, and Pb contents given by Sarkar and Sen Sarma (1946) and Karunakaran and Neelakantam (1948), which he found were 830 and 1550 M.Y. respectively. He therefore pertinently questioned the accuracy of the chemical analytical data on the ground that the Nellore samarskite cannot give such highly discrepant ages. Krishnan (1953, p. 7) also came to the same conclusion on the strength of the available geological evidence. It was subsequently shown by the author (1953a) that the apparent discrepancy in the ages was due to an unfortunate mistake regarding the locality from which the mineral was collected. Sarkar's analysis of samarskite

TABLE 2
Eastern Ghats Cycle

Serial no.	Name of the mineral or rock dated	Locality	Method of age determination	Age (in M.Y.)	Degree of dependability	Remarks
1	Samarskite	Nellore, Andhra	Pb-U-Th	1550	Good	Crude age
2	”	”	”	1615	”	”
3	”	”	”	1765	”	”
4	Allanite	Anakapalle, Andhra	”	1585	”	”
5	Detrital monazite	Cuttack Dt., Orissa	”	1570 ± 70	Excellent	207/206 age
6	Vanadium-bearing magnetite	Baripada, Mayurbhanj, Orissa	Alpha-helium	1200	Satisfactory	Moderate helium loss
7	Magnetite quartzite	Ongole, Andhra	”	1350 (1160)*	”	The proportion of magnetite in the rock is highly variable and since the helium retentivity index of quartz is low, it can affect the over-all helium retentivity index to an extent depending upon its content.
8	”	Konizedu, near Ongole, Andhra	”	1290 (1050)*	”	
9	”	North Arcot Dt., Madras	”	1150	”	
10	”	Salem, Madras	”	1050	”	
11	”	Kanjamalai, near Salem, Madras	”	1500	”	
12	Charnockite	Ongole, Andhra	”	950	Doubtful	Highly active. Accessory radioactive minerals appear to have raised the specific activity of the rock, thereby lowering the helium age.
13	Pyroxenite	Kanjamalai, near Salem, Madras	”	1315 (1300)*	Satisfactory	The compact nature of the rock appears to be responsible for its moderate helium retentivity.
14	Pegmatite	Nallipalaiyam, Madras	”	880	Doubtful	Extensive helium loss
15	Pink felspar	Iddapadi, Madras	”	570 (500)*	”	”

16	Garnetiferous pegmatite	"	"	400	"	High specific activity coupled with extensive helium loss have lowered the age.
17	Phlogopite	Borra, near Visakhapatnam, Andhra	Rb-Sr	1490 ± 200	Satisfactory	—

* The ages in the brackets indicate the results of independent observations. The higher of the two ages is given first.

1. Aswathanarayana, U. (1953).
2. Karunakaran, C., and Neelakantam, K. (1948).
3. Nandi, S. K., and Sen, D. N. (1950a).
4. Unpublished age (calculated from the analytical data provided by Mr. Ch. Leelanandam).
5. Holmes, Arthur (1955).

6-16. Unpublished ages (obtained by Professor R. S. Krishnan and his associates on materials earlier studied by the author).

17. Venkatasubramanian, V. S. (1953).

TABLE 3

Delhi Cycle

Serial no.	Name of the mineral or rock dated	Locality	Method of age determination	Age (in M.Y.)	Degree of dependability	Remarks
1	Uraninite	Bisundni, Rajputana	Pb-U-Th	735 ± 5	Excellent	Based on isotopic analysis of lead
2	Monazite	Soniana, Rajputana	"	700-865	Good	"

1. Holmes, Arthur (1949, p. 292).
2. Holmes, Arthur (1949, p. 294).

TABLE 4
Satpura Cycle

Serial no.	Name of the mineral or rock dated	Locality	Method of age determination	Age (in M.Y.)	Degree of dependability	Remarks
1	Uraninite	Singar, Bihar	Pb-U-Th	955 ± 40	Excellent	Supported by isotopic analysis of lead
2	Monazite	Gaya, Bihar	"	965	Good	Crude age
3	Allanite	Ranchi, Bihar	"	980	"	"
4	"	"	"	980	"	"
5	"	Bahea, near Singar, Bihar	"	880	Satisfactory	"
6	"	Purulia, Bihar	"	880	"	"
7	Monazite	Pichchli, Bihar	"	970	Good	"
8	Magnetite	Chaibasa, Singhbhum, Bihar	Alpha-helium	970	Satisfactory	Highly active. High alpha index might have lowered the helium age.

1. Holmes, Arthur (1950, p. 21).
2. Sarkar, T. C. (1941).
3, 4. Sarkar, P. B., and Sen Sarma, R. N. (1946).
5. Nandi, S. K., and Sen, D. N. (1950b).
6. Unpublished age (calculated from the data provided by Mr. Ch. Leelanandam).
7. Nandi, S. K., and Sen, D. N. (1950c).
8. Unpublished age (obtained by Professor R. S. Krishnan and his associates).

is now placed under the Satpura cycle as the mineral came from Gaya and not Nellore as was mistakenly thought.

Satpura Cycle

The lead and alpha-helium ages given by minerals belonging to the Satpura cycle are presented in table 4.

Lead ages.—The isotopic analysis of lead from the uraninite of Singar could not give a definite age to the Satpura cycle. It could only suggest the limits of the age (912-995 M.Y.) and, averaging them, the age was given by Holmes (1950, p. 24) as 955 ± 40 M.Y. Monazites from the Gaya district and allanite from the Ranchi district have given ages which fall within these limits. Allanites from Bahea and Purulia and samarskite from Gaya have yielded slightly lower ages than the rest.

Alpha-helium age.—The magnetite from Singhbhum has yielded an alpha-helium age of 970 M.Y. which is less than the alpha-helium age (1350 M.Y.) of the magnetite quartzites of Ongole belonging undoubtedly to the Eastern Ghats province. The age is termed satisfactory because, though it ought to be greater than that of Satpura pegmatites, which are later intrusives, it is only of the same order. The high specific activity of the mineral appears to have given it a low apparent age.

It is known that parts of the Shillong series show a Satpura strike and parts an Eastern Ghats strike; hence, it will not be surprising if further researches show that parts of the Shillong series belong to the Satpura cycle, and parts to the Eastern Ghats cycle.

CONCLUSIONS

A tentative succession of Precambrian diastrophic cycles for India, based on the available radioactive ages, is given below:

Vindhyan

— — —

735 ± 5 M.Y.

Delhi cycle (= ? Cuddapah)

— — — — — — —

955 ± 40 M.Y.

Satpura cycle

— — — —

1625 ± 75 M.Y.

Eastern Ghats cycle

— — — — —

2300 ± 100 M.Y.

Dharwar cycle (= Aravalli cycle)

— — — — — — — —

Older Gneissic Complex

These conclusions, based on the available radioactive age data for the Archaean orogenic cycles, are fully supported by the structural evidence. Krishnan (1953, p. 86) suggests that (1) the Dharwarian trend is a continuation of the Aravalli trend, (2) the Eastern Ghats trend is younger than the

Dharwarian as it is superposed on (and flows around) the latter, and (3) the Satpura trend is younger than that of the Eastern Ghats as is evident from their interrelation in Gangpur State.

The recent advances in the field of measurement of geologic time by radioactivity methods have greatly facilitated the bringing together of the two distinct, but nevertheless mutually related approaches—correlation of the rock formations and dating of the orogenic cycles. The K_{40}/A_{40} and K_{40}/Ca_{40} methods of dating potassium-bearing rocks, the lead method for determining the age of the accessory zircons in acid and intermediate rocks, and the Rb-Sr method for dating accessory biotite in rocks have now made possible the estimation of the ages of the rock formations directly, thus facilitating correlation in the sense of Fermor (1936). All these methods together with the classical lead methods, Pb-210 method, and the method of radiation damage in zircons can be used to date the pegmatitic minerals, and through them the ages of the orogenic cycles, in the sense of Krishnan (1953) and Holmes (1949, 1950). The two sets of data are directly comparable as they have been arrived at by the application of similar methods.

FURTHER WORK

The present investigations have served the useful purpose of dating the four major Archaean structural provinces of Peninsular India and have thereby laid the basis for detailed investigations on the correlation of the highly complex Archaean formations in the various parts of India. Kohman and Saito (1954) have recently given a succinct account of our present state of knowledge on the theory and techniques of measurement of geologic time, which shows that the Archaean rocks are capable of providing several age indicators.

Investigations are in progress on Archaean correlation problems, which, while making full use of correlation criteria like petrology, mineragraphy, grade of metamorphism, petrofabric pattern, etc., permit considerable scope for using the radioactive decay process as a yardstick of measurement of geologic time (by the application of the lead, potassium, and Rb-Sr methods). It is hoped to obtain thereby a correlation table, largely based on geologic criteria and suported in most cases by radioactive ages of absolute nature.

ACKNOWLEDGMENTS

The author is grateful to Professor C. Mahadevan for his kind interest and helpful guidance. It is a pleasure to thank Professor R. S. Krishnan and his associates who kindly determined the alpha-helium ages for some of the samples collected by the author. My thanks are due to Dr. D. N. Wadia who kindly sent the specimens of radioactive minerals. The assistance of my associate, Mr. Ch. Leelanandam, in the analysis of radioactive minerals is thankfully acknowledged. Professor Arthur Holmes and Dr. J. P. Marble have kindly given the author the benefit of their vast and mature experience in giving shape to this work. The investigations were sponsored by the Council of Scientific and Industrial Research (India).

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