EVIDENCE FROM FOSSILS OF THE AGE OF THE VINDHYAN SYSTEM

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ABSTRACT—A comparison of the plant and animal fossils that have been found in the beds of the Vindhyan System with similar Cambrian and older fossils found elsewhere, and the absence of trilobites and undoubted brachiopods from the Vindhyan beds, indicate that some, at least, of the Vindhyan beds are of Proterozoic age, although others of them may be Cambrian.

THE determination of the age of the Vindhyan System has long been a difficult problem. For years the only fossils known from Vindhyan rocks were the little black discs from the Suket Shale which were considered by some authors to be the remains of primitive brachiopods, snails, Hyolithids, or ostracods, and by others to be fossils of one celled algae (Holland, 1909, p. 66 ; Pascoe, 1927, p. 18 ; Pascoe, 1928, p. 21 ; Fermor, 1932, pp. 28, 29 ; Fermor, 1933, pp. 20, 21 ; Chapman, 1935 ; M. R. Sahni, 1936). Recently other fossils have been discovered in these rocks (Rode, 1946 ; Misra, 1948, 1949, 1950, 1951 ; Ghosh and Bose, 1950 ; Rao, 1952 ; Sitholey, Shrivastava, and Varma, 1953). Some of these fossils are the remains of non-calcareous algae, some are said to be spores of fungi and fragments and spores of vascular plants, some may be fossils of coiled worms, and others have been identified as probably the shells of a species of *Hyolithes*. As a result of these discoveries the Vindhyan rocks have been variously referred to the Proterozoic, the Cambrian, and partly to the Proterozoic and partly to the Cambrian.

Excellent work has been done, and is now being done, by Indian palaeontologists on these Vindhyan fossils ; and the writer will not attempt to add anything here to our knowledge of the form and structure of these interesting remains of very ancient organisms. But it will perhaps be useful, and possibly stimulating to future studies of the palaeontology and stratigraphy of the Vindhyan rocks, if he records some of the thoughts concerning the problems presented by these rocks and fossils which have come to him during the twenty years in which he has been especially interested in them.

During the past forty years palaeontologists have come to realize that fossils of calcareous algae and marine worms are abundant in many rocks of Proterozoic age throughout the world. Little attention has been paid to the trails and burrows made by Proterozoic worms ; but many descriptions of Proterozoic calcareous algae have been published. In the hope that a greater knowledge of these ancient plants may enable palaeontologists to use them as index fossils, Professor J. Harlan Johnson, of the Colorado School of Mines, has been studying Proterozoic calcareous algae from many parts of the world. He has recently compiled a list of the papers relating to these fossils which will be published soon.

Other kinds of fossils are rare in Proterozoic rocks. What was known of these fossils twenty years ago was summarized by Raymond (1935). At that time there had been found in Proterozoic sediments objects which had been described as fossils of bacteria, calcareous and non-calcareous algae, foraminifers, radiolarians, sponges, worms, echinoderms, brachiopods, snails (trails only), and arthropods ; and in 1941 a jellyfish was described by Bassler (1941) from the Proterozoic Nankoweap Beds of the Grand Canyon, in Arizona. There is some reason to doubt whether the objects which were described from the Proterozoic rocks of France by L. Cayeux as foraminifers and radiolarians are truly such. Delaflandre (1949) has recently suggested that Cayeux's "radiolarians" are actually fossils of microhystrichospheres (flagellates). But, while there is also some doubt about the evidence of the occurrence of echinoderms and mollusks in Proterozoic seas, there is no doubt about the presence of calcareous and

non-calcareous algae, sponges (Greenly, 1919, pp. 394, 395, text-fig. 193), and worms, and little doubt about the existence of jellyfishes, brachiopods, and arthropods, as is evidenced by Bassler's 1941 paper, by a paper by C. L. Fenton and M. A. Fenton (1936), in which the authors describe a linguloid brachiopod from the Proterozoic Newland Formation of Montana, and by Raymond's 1935 paper, which records an arthropod from the Proterozoic Altyn Formation of Montana.

Thus we find that many different kinds of plant and animal fossils have been found in Proterozoic strata, but that all of them are too rare to be of much use except for the worm trails and burrows, which are seldom satisfactory as index fossils, and the calcareous algae, which have not yet been sufficiently studied to be very useful as age indicators. So stratigraphers still identify strata as being of Proterozoic age because they underlie beds containing Cambrian fossils, or because they yield no fossils except worm trails and burrows and calcareous algae. Cambrian beds, on the other hand, are usually easy to identify because of the remains of trilobites, brachiopods, and other animals which they contain.

However, when we attempt to learn the age of the rocks of the Vindhyan System, we find that we can not use the usual evidence to determine whether they are Proterozoic or Cambrian, or partly Proterozoic and partly Cambrian, for they do not contain the calcareous algae which are so characteristic of the Proterozoic, nor do they contain trilobites, which are found in most Cambrian rocks. The non-calcareous algae in the Vindhyan beds may be of either Proterozoic or Cambrian age, the fossils identified as spores of fungi and fragments of vascular plants would seem to indicate an age not older than Cambrian, the single coiled fossil that may be the remains of a worm might be either Proterozoic or Cambrian, and the single species of *Hyolithes* is more probably Cambrian than Proterozoic. And, since most of these fossils have been found in strata of the Semri Series, which is Lower Vindhyan, or in the Kaimur Series, which is lower Upper Vindhyan, we are led to the conclusion that the entire Vindhyan System is probably of Cambrian age. This is the conclusion reached by Sitholey, Srivastava, and Varma (1953). And yet, one can not refrain from wondering why, if the Vindhyan rocks are of Cambrian age, they do not contain trilobites and undoubted brachiopods of characteristic Cambrian genera.

True, some of the Vindhyan sediments may have been deposited in fresh waters, and would therefore not be expected to contain trilobites and brachiopods. But some of them were almost surely laid down in marine waters. And, if they are really of Cambrian age, why have they not yielded trilobites and brachiopods ? Will a more thorough search disclose that the marine beds do actually contain such fossils ? Surely, such a careful search should be made. It is to be hoped that it will be made soon.

In the mean time one can perhaps add here a little to our understanding of two of the kinds of fossils which have been found in Vindhyan rocks, the *Hyolithes* and the *Fermoria*.

Hyolithes rohitaswei was found by Rode (1946) in a limestone of the Rohtas Stage, at the top of the upper Lower Vindhyan Semri Series of the Rhotas Hills, in Bihar. The shells of this species are small and cone-shaped, being a quarter of an inch, or less, in length and about half as wide at the wide end as they are long.

These very interesting fossils may well be referable to the genus *Hyolithes*, which is common in Cambrian rocks in many parts of the world. But they also resemble in form, and especially in size, little fossils from the Lower Cambrian Kinzers Formation of Pennsylvania, which were described by Resser and Howell (1938, pp. 214, 215, pl. 3 figs. 13–16) as *Salterella acervulosa*. Whether the Indian fossils are referable to *Hyolithes*, or whether they are more nearly related to *Salterella acervulosa* (which may not be properly referred to the genus *Salterella*), they may well indicate that the beds in Bihar in which they occur are of Cambrian age. Yet they may also be of Late Proterozoic age ; for much larger shells of somewhat similar form, such as *Hyolithes americanus* Billings (1871, p. 215, text-figs. 2a, b ; 1872, pp. 353, 354, text-figs. 2a, b ; Walcott, 1886, pp. 132, 133, pl. 13, figs. 6, 6a-f ; 1890, p. 620, text-fig. 64, pl. 75, figs. 2, 2a-f) are common in Lower

Cambrian rocks, and their ancestors may well have lived in Late Proterozoic seas.

The genus *Hyolithes* is usually classified as a genus of pteropods ; but it seems more probable that it should be referred to the worms (Howell and Stubblefield, 1950).

The true nature of *Fermoria* is much more difficult to determine. The writer believes that it is probably a genus of non-calcareous algae ; but he agrees with other investigators who have studied these disk shaped fossils from the Suket Shale that their true affinities are very difficult to determine and are still doubtful, although important evidence re-recently presented by M. R. Sahni and R. N. Shrivastava (1954, pp. 1—4, figs. 1—4) indicates that they are almost certainly referable to the algae. However, there are some Cambrian and Proterozoic fossils in other regions than India which resemble *Fermoria* enough to make a comparasion of it with them of interest.

Chapman (1935), who originally described *Fermoria*, called attention to its resemblance to the Canadian Middle Cambrian alga, *Morania* (Walcott, 1919, pp. 225–233, pls. 43–45, 47–50) ; and Holland (1909, p. 66) has quoted Jones, who first discovered these fossils in the Suket Shale, as considering them to be possibly similar to the fossils from the Proterozoic Chuar Group of the Grand Canyon, in Arizona, which Walcott (1899, pp. 234, 235, pl. 27, figs. 12, 13) named *Chuaria circularis*. They resemble even more an unnamed fossil which Walcott (1899, p. 235, pl. 27, fig. 9) described from a limestone in the Chuar Group at the same locality.

Walcott (1899, p. 235) called attention to the description by Wiman (1894) of small disks resembling *Chuaria* which Wiman had found in the Proterozoid Visingsö Group of Sweden. These Swedish fossils were named *Chuaria wimani* by Brotzen (1941, p. 258). They are smaller than the specimens of *Fermoria* found in the Suket Shale, but much resemble these Indian fossils in form.

There is one other fossil, *Corycium enigmaticum* Sederholm, from the late Archaean Bothnian phyllites of Finland, which is believed to be a non-calcareous alga and which somewhat resembles unnamed fossils that are possibly the remains of non-calcareous algae which have been described by Misra (1949) from Lower Vindhyan beds. This Finnish fossil has been discussed, and its algal nature has been demonstrated, by Rankama (1948), who has included in his paper a full bibliography of the literature relating to it. *Corycium engimaticum* is found in beds that are much older than those of the Vindhyan System ; but it is evident that non-calcareous algae existed even before the Proterozoic Era and must have been abundant and varied in Proterozoic seas. This evidence of the early origin of marine algae and the reports of the discoveries of plant spores in Cambrian rocks of Sweden, Russia, and Kashmir, recorded by Darrah (1937), Naoumova (1949), Reissinger (1939, 1952), Kopelivitch (1951), Ghosh, Sen, and Bose (1951), Ghosh and Bose (1952), and Jacob and Jacob and Shrivastava (1953), make less surprising the reports of the discovery of fossils of vascular plants in rocks of the Vindhyan System by Jacob and Jacob (1953).

Thus the problem of the age of the Vindhyan rocks remains as yet unsolved. Indian palaeontologists seem inclined to assign these rocks to the Cambrian; but it seems to the writer that the apparent absence of trilobites and undoubted brachiopods from them indicates that a part of them at least, are probably of Proterozoic age, although some of them may possibly be Cambrian.

It is to be hoped that during the next few years a very thorough search for additional fossils will be made in the Vindhyan beds. Although some of these beds may have been deposited in fresh waters, others must have been laid down in the sea. If these marine strata are really of Cambrian, rather than of Proterozoic age, they should yield trilobites and characteristic Cambrian brachiopods.

There is one other line of investigation which may, if pursued, yield information which will help us to date the Vindhyan System. Auden (1943) has pointed out the fact that "the Vindhyans are in the main a fluviatile continental formation, with only minor marine intercalations, and these more particularly in the Semri series (Lower Vindhyans)", and has concluded that "the age of the Vindhyans should be regarded as extending from late pre-Cambrian to

Lower Palaeozoic". If this conclusion is correct, it is possible that somewhere in the succession of Vindhyan strata there may be found glacial deposits of the great ice age which occurred near the end of the Proterozoic Era. As the Semri Series may possibly be of late Proterozoic age, and as oscillations of sea level such as those which presumably produced the interfingering of marine and continental deposits of the Semri Series are characteristic of times of waxing and waning glaciation, one is led to wonder whether at least a part of the Semri Series was deposited during the great glacial period which is known to have occurred near the end of the Proterozoic.

Jacob and Jacob (1953) have suggested that this late Proterozoic glacial period may have led to a rapid evolution of the plants of that time and to the appearance of the first vascular plants, just as the Permian ice age caused a rapid evolution of land plants at the end of the Palaeozoic Era. This suggestion has much merit; for there was certainly widespread glaciation in the Late Proterozoic (Howell, 1940 ; Thiesmeyer, 1939 ; Wegmann, 1951), and it may well have influenced the evolution of the plants of those days.

It is greatly to be hoped that Indian stratigraphers will search for evidence of glacial deposits in the Vindhyan rocks. If they find such evidence somewhere in the Vindhyan succession of strata, it may well prove to mark the top of the Proterozoic portion of that succession, the beds above the stratigraphically highest glacial deposits being then probably of Cambrian age. Even if there are no glacial tillites in the Semri Series, some of the "fluviatile continental" sediments of that series may possibly be glacial outwash deposits.

The recent excellent work of the Indian palaeontologists on the fossils that have been found in the Vindhyan rocks and in the Cambrian beds of the Salt Range and Kashmir has aroused great interest throughout the world. The palaeontologists of other lands look forward to hearing of additional discoveries by their Indian friends which will ultimately solve the now very puzzling problem of the age of the Vindhyan Series and the true nature of its remarkable floras and faunas.

REFERENCES

AUDEN, J. B., 1943, The age of the Vindhyans. *Proc. 29th Indian Science Congress, Baroda* (1942), pp. 111, 112.

BASSLER, R. S., 1941, A supposed jellyfish from the pre-Cambrian of the Grand Canyon. *Proc. U. S. National Mus.*, Vol. 89, pp. 519-522, Pl. 1.

BILLINGS, E., 1871, On some new species of Palaeozoic fossils. *Canadian Naturalist*, Vol. 6, pp. 213-222, 4 text-figs.

——, 1872, On some new species of Palaeozoic fossils. *Amer. Jour. Science*, 3rd ser., Vol. 3, pp. 352-360, 4 text-figs.

BROTZEN, F., 1941, Några bidrag till Visingsöformationens stratigrafi och tektonik. *Geologiska Freningensi Stockholm Förhandlingar*, Vol. 63, pp. 245-261.

CHAPMAN, F., 1935, Primitive fossils, possibly Atrematous and Neotrematous Brachiopoda, from the Vindhyans of India. *Records of the Geol. Surv. of India*, Vol. 49, pp. 109-120, Pls. 1, 2.

DARRAH, W. C., 1937, Spores of Cambrian plants. *Science*, Vol. 86, pp. 154, 155.

DELAFLANDRE, G., 1949, Les soi-disant radiolaires du Précambrien de Bretagne et la question de l'existence de radiolaires embryonaires fossiles. *Bull. Soc. Zoologique de France*, Vol. 74, pp. 351, 352.

FENTON, C. L., and FENTON, M. A., 1936, Walcott's "Pre-Cambrian Algonkian algal flora" and associated animals. *Bull. Geol. Soc. America*, Vol. 47, pp. 609-620, Pls. 1-3.

FERMOR, L L., 1932, General Report of the Geological Survey of India for the year 1931. *Records of the Geol. Surv. of India*, Vol. 66, pp. 1-150.

——, 1933, General Report of the Geologica Survey of India for the year 1932. *Records of the Geol. Surv. of India*, Vol. 67, pp. 1-82.

GHOSH, A. K., and BOSE, A., 1950 Microfossils from the Vindhyans. *Science and Culture*, Vol. 15, pp. 330, 331, 4 text-figs.

GHOSH, A. K., SEN, J., and BOSE, A., 1951, Evidence bearing on the age of the Saline Series in the Salt Range of the Punjab. *Geological Magazine*, Vol. 88, pp. 129-132, 6 text-figs.

——, and BOSE, A., 1952, Spores and tracheids from the Cambrian of Kashmir. *Nature*, Vol. 169, p. 1056, 1 text-fig.

GREENLY, E., 1916, The geology of Anglesey. Vol. 2. *Memoirs of the Geol. Surv. of Great Britain.*

HOLLAND, T. H., 1909, General Report of the Geological Survey of India for the year 1908, *Records of the Geol. Survey of India*, Vol. 38, pp. 1-70.

HOWELL, B. F., 1940, Late Proterozoic and Early Cambrian climates. *Report of the 17th Session of the Internat. Geol. Congress, Moscow* (1937), Vol. 6, pp. 7-10.

——, and STUBBLEFIELD, C. J., 1950, A revision of the fauna of the North Wales *Conocoryphe viola* Beds implying a Lower Cambrian age. *Geol. Mag.*, Vol. 87, pp. 11-1, Pls3. 1, 2.

JACOB, K., JACOB, C., and SHRIVASTAVA, R. N., 1953, Evidence for the existence of vascular plants in the Cambrian. *Current Science*, Vol. 22, pp. 34-36, 9 text-figs.

——, and JACOB, C., 1953, New light on the early phylogeny of the vascular plants and on the influence of cycles of past glaciation and mountain-building on plant evolution. *Current Science*, Vol. 22, pp. 133-135, 1 text-fig.

KOPELIOVITCH, A. C., 1951, Some questions concerning the stratigraphy of the Lower Cambrian of the central regions of the Russian Platform. *Papers of the Acad. of Sciences of the U.S.S.R.*, Vol. 78, pp. 975-977.

MISRA, R. C., 1948, Evidences of the existence of life during the Vindhyan Period. *Proc. of the 34th Indian Science Congress, Delhi* (1947), p. 144.

——, 1949, On organic remains from the Vindhyans (Pre-Cambrian). *Current Science*, Vol. 18, pp. 438, 439, 2 text-figs.

——, and BHATNAGAR, G. S., 1950, On carbonaceous discs and 'algal dust' from the Vindhyans (Pre-Cambrian). *Current Science*, Vol. 19, pp. 88, 89, 2 text-figs.

——, 1951, A new collection of fossils from the Suket Shales. (Vindhyans). *Current Science*, Vol. 20, p. 223.

NAOUMOVA, S. N., 1949, Spores du Cambrien inférieur. *Bull. de l'Acad. des Sciences de l' U.S.S.R., Série Géologique* 1949, no. 4, pp. 49-56, Pls. 1-3.

PASCOE, E. H., 1927, General Report of the Geological Survey of India for the year 1926. *Records of the Geol. Surv. of India*, Vol. 60, pp. 1-127.

——, 1928, General Report of the Geological Survey of India for the year 1927. *Records of the Geol. Surv. of India*, Vol. 61, pp. 1-140

RANKAMA, K., 1948, New evidence on the origin of Pre-Cambrian carbon. *Bull. Geol. Soc. America*, Vol. 59, pp. 389-416, Pls. 1-6.

RAO, S. R. N. 1952, *The Micropalaeontologist*, Vol. 6, p. 19.

RAYMOND, P. E., 1935, Pre-Cambrian life. *Bull. Geol. Soc. America*, Vol. 46, pp. 375-392.

RESSER, C. E., and HOWELL, B. F., 1938, Lower Cambrian *Olenellus* Zone of the Appalachians. *Bull Geol Soc. America*, Vol. 49, pp. 195-248, 13 pls., 1 text-fig.

REISSINGER, A., 1939, Die "Pollenanalyse" ausgedehnt auf alle Sedimentegesteine der geologischen Vorgangenheit. *Palaeontographica*, Vol. 84, Abt. B, Lieferung 1-2, pp. 1-20.

——, 1952, *Naturwiss, Gesellschaft Beyreuth*, pp. 1-24.

RODE, K. P., 1949, A new find of fossils in Vindhyan rocks of Rohtas Hills in Bihar. *Current Science*, Vol. 15, pp. 247, 248, 1 text-fig.

SAHNI, M. R., 1936, *Fermoria minima* : a revised classification of the or ganic remains from the Vindhyans of India. *Records of the Geol, Surv. of India*, Vol. 69, pp. 458-468, Vol. 43.

——, and SHRIVASTAVA, R. N., 1954, New organic remains from the Vindhyan System and the probable systematic position of *Fermoria* Chapman. *Current Science*, Feb., 1954.

SITHOLEY, R. V., SRIVASTAVA, P. N., and VARMA, C. P., 1953, Microfossils from the Upper Vindhyans, with a discussion of the age of the Vindhyans in the light of plant-fossil discoveries. *Proc. Nat. Inst. of Science of India*. Vol. 19, pp. 195-202, Pls. 3, 4.

THIESMEYER, L. R., 1939, Varved slates in Fauquier County, Virginia. *Virginia Geol. Surv. Bull.* 51-D, pp. 107-118.

WALCOTT, C. D., 1886, Second contribution to the studies on the Cambrian faunas of North America. *U. S. Geol. Surv. Bull.* 30, 369 pp., 33 Pls.

——, 1890, The fauna of the Lower Cambrian or *Olenellus* Zone, 10*th Ann. Rept, U. S. Geol.* ,. *Surv.* pt. 1, pp. 509-760, Pls. 49-98.

——, 1899, Pre-Cambrian fossiliferous formations, *Bull. Geol. Soc. America*, Vol. 10, pp. 199-244, Pls. 22-28.

——, 1919, Middle Cambrian algae. *Smithsonian Miscellaneous Collections*, Vol. 67, no. 5, pp. 217-260, Pls. 43-59.

WEGMANN, E., 1951, Subkambrische Tillite in der herzynischen Faltungszone. *Geologische Rundschau*, Vol. 39, pp. 221-234.

WIMAN, C., 1894, Ein Präkambrisches Fossil. *Bull. Geol. Inst. Upsala*, Vol. 2, pp. 109-117, Pl. 5, figs. 1-5.