MICROFOSSILS FROM THE UPPER VINDHYANS, WITH A DISCUSSION ON THE AGE OF THE VINDHYANS IN THE LIGHT OF PLANT-FOSSIL DISCOVERIES

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CONTENTS.

INTRODUCTION.

The work embodied in this paper forms a part of the programme of palaeobotanical investigations sponsored by the Committee on the Measurement of Geological Time in India. The formations constituting the Vindhyan system are among the oldest sedimentary rocks of India. The vast strata of sandstones, shales and limestones attain a total thickness of over 14,000 ft. and are almost barren of organic remains. This paucity of the fossil record is significant, for the strata exhibit little evidence of metamorphism and other structural disturbances and are thus well suited to the preservation of life. The name Vindhyan system was proposed in 1856 by T. Oldham. The system has been included by Holland (1926, pp. 12-13) within his *Purana* group. This group was instituted for all the unfossiliferous peninsular formations resting above the Archaen-Dharwar complex and is regarded by Holland as pre-Cambrian in age. Vredenburg believed the Vindhyan system to be Cambrian on the basis of a rough lithological semblance between its rocks and the fossiliferous Cambrian strata of the Salt Range (Holland, *loc. cit.*, pp. 13-14). From the point of view of homotaxis great interest attaches to the question of the occurrence of fossils in the Vindhyans. A few remains have been found which, there is good reason to believe, are really organic. It has been suggested that if that is so, at least a part of Vindhyan system may have to be included in the Cambrian (Wadia, 1939; Reed, 1949). The system is divided into four main series (Holland, *loc. cit.*, pp. 177–179; Krishnan, 1949) as follows:—

Upper Vindhyans ..	Bhander Series.
	Rewa Series.
	Kaimur Series.
Lower Vindhyans ..	Semri Series.

There are two distinct facies. The Semri series is marine and mainly calcareous. The Bhander, Rewa, and the Kaimur series are mainly arenaceous, of fluviatile or estuarine origin.

Previous Records of life in the Vindhyans.

In 1908 H. C. Jones discovered small discoid bodies (1·5 mm.–4·5 mm. in diameter) in the dark-coloured Suket shales which form the base of the Kaimur series near Neemuch in Central India. Later similar specimens were also collected from another nearby locality named Rampura. These were described by Chapman (1935) under two new genera, *Fermoria* and *Protobolella* which he regarded as belonging to the order Atremata. Chapman recognised three species of *Fermoria* (*F. minima, F. granulosa,* and *F. capsella*) and one of *Protobolella* (*P. jonesi*). M. R. Sahni (1936) has cast doubt on the affinity of these fossils with the brachiopods. He has combined *Fermoria* and *Protobolella* in one genus *Fermoria* and merged Chapman's different species in the single species *Fermoria minima.* Sahni suggests raising this group of fossils to the rank of a new family, Fermoriidae, of undetermined relationship.

Although the organic nature of the fossils discovered by Jones cannot be subjected to doubt, their position within the animal kingdom is not uncontested. B. F. Howell regarded them as plants (Chapman, *loc. cit.*, pp. 113-114) and compared them tentatively with the Middle Cambrian blue-green alga, *Morania* of Walcott. The test of incineration provided support for his view that the specimens were plant remains; in contrast the shell of a Middle Cambrian phosphatic specimen of *Acrothele* did not burn. Carbonisation, however, does not invariably indicate plant matter. According to Chapman (*loc. cit.*, p. 112) chitin gets carbonised like any plant matter, and he cites the examples of the carbonised carapace of *Marella* from the Middle Cambrian of British Columbia and valves of *Lingula* and *Lingulella* which are known to get converted into anthracite.

In the Rohtas limestone (Semri series) at Banjari in the Sone valley R. C. Misra and G. S. Bhatnagar (1950) have discovered carbonaceous structures of a roughly circular outline. The average diameter of the specimens is 26 mm. which is nearly four times that of the discoid fossils collected by Jones. Misra and Bhatnagar regard their specimens to be plant remains.

In 1946 K. P. Rode described a number of conical shell-like structures which he referred to a new species, *Hyolithes rohitaswei.* The specimens were found in the limestone at the top of the Rohtas stage in the Sone valley, three miles west of Ramdhera.

Dark spherical bodies measuring up to 145μ have been observed by Misra and Bhatnagar (*loc. cit.*) in thin sections of the Vindhyan limestones. They have been found in the glauconitic limestone of the Lodhwara hill north of Karwi, and in the Rohtas limestone from Banjari. The authors compare these bodies with 'algal dust' described in 1941 by Alan Wood (cited by Misra and Bhatnagar, 1950) from the Carbonaceous limestones of England. In the Lodhwara hill limestone Misra (1949) has also seen small rounded, ovoid, or sausage-shaped bodies filled with glauconite. The walls of these bodies are said to be carbonised, and Misra considers them to be casts of some organisms. In thin sections of the Banjari limestone he has also discovered (1949, Fig. 2) a slender verticillate structure with a globular head. This specimen is believed by Misra to represent some alga belonging to the Dasycladaceae.

A very interesting discovery of microfossils has been made by A. K. Ghosh and A. Bose (1950) in the olive shale belonging to the upper part of the Semri series of the Mirzapur district. The microfossils comprise carbonised fragments of wood with simple pits of variable size, wood with bordered pits, non-carbonised bordered-pitted elements with rays, and several monolete spores.

Bright coaly matter (vitrain) was discovered more than 20 years ago by C. S. Fox in the Bijaigarh shales (lower Kaimurs) of the Sone valley. Samples of the Bijaigarh shale containing lenticles of vitrain are reported to have been collected from the Vindhyan scarps west of the quarries of the Portland Cement Company of

Japla. The vitrain on analysis yielded 65·62% of fixed carbon; however it showed no vegetable structure and the lenticles were 'quite unrecognisable from the palaeontological point of view' (Auden, 1933, p. 182). Unfortunately, no sample of this Vindhyan coal is now available for examination by the palaeobotanical techniques. In March, 1951, we made a careful search for its occurrences in the Vindhyan scarps at Banjari and Baulia, the latter being the place where the quarries of the Portland Cement Company are situated. The search, however, proved fruitless. In a letter dated the 10th October, 1951, the late Dr. Fox informed one of us that the coal was found in very small amounts. Only 5 gm. of it was extracted with difficulty from several pounds of shale taken to Calcutta (see Fox, 1931, p. 26).

K. Jacob of the Geological Survey of India (1949, pp. 202-203) has reported the occurrence of 'fairly large pieces of fossil wood' in ferruginous sandstones collected by G. V. Rao from the top of a hill near Gugri in Maihar, Central India. The sandstones are believed to belong to the Upper Bhander series. According to Jacob thin section of the wood did not reveal any clear structure; but in preparations of the woody elements teased out in clove oil bordered pits were clearly visible. The same preparations contained some spores with tri-radiate marks. These discoveries, in the words of Jacob, would be of outstanding importance were it not for the doubt attached to the provenance of the samples collected by Rao. Jacob suspects that the samples may have come from younger strata overlying the Vindhyan system at Gugri.

Present Investigation

A. Material and Methods.

Except for the scattered records mentioned above no attempt at a systematic search for fossils in the Vindhyan rocks had been made when our work started. Moreover, it is only of late that microfossils have been included in the search. The present investigation cannot claim to be an exhaustive one, but we have examined rock samples from all the four main sub-divisions of the Vindhyans, viz. the Semri, Kaimur, Rewah and the Bhander series (see list below).

Samples.	Horizon.
25/920, 25/921	Sirbu shales (Bhander series).
25/911	Jhiri shales (Rewah series).
45/310, 45/312	Panna-Jhiri shales (Rewah series).
21/410, 21/411,* 36/230 ..	Suket shales (Kaimur series).
1358, 1986	Rohtas stage (Semri series).
4074, 4921, 4973, 4986, 7523 ..	Kheinjua stage (Semri series).

The above samples and a shale numbered 36/198 (from the lower Vindhyans, exact horizon not known) were supplied by the Geological Survey of India. The samples listed below were collected by the authors from the Vindhyans of the Sone valley (March, 1951) and of Central India (February, 1952).

Samples.	Horizon.
Black thinly laminated shale from Jamunapani near Banjari (Dehri-Rohtas Light Railway). Black papery shale from a gorge west of the quarries of the Portland Cement Co. at Baulia.	? Bijaigarh shales (Kaimur series).

* These samples were examined by Messrs. D. C. Bhardwaj and R. N. Lakhanpal.

Samples.	Horizon.
Dark-coloured shales from (1) nala, cutting behind Chauki village, 4 miles from Rampura; (2) culvert of the Tilsoi river, about 1/2 mile from Rampura dak bungalow.	Suket shales.
Limestone from the quarries at Banjari.	Rohtas stage.

Two methods of investigation were employed: (1) maceration, and (2) preparation of thinly-ground sections for microscopic examination. The maceration was generally carried out in commercial nitric acid (of about 70% strength), Schultze's mixture (nitric acid+potassium chlorate), hydrochloric acid, or hydrofluoric acid. The macerated shale was then treated with ammonium hydroxide. Both in the selection of the samples and in the operations carried out during maceration and mounting of the material on the slides, every precaution was taken to avoid external contamination. The ground sections were made in every case both along and across the bedding plane of the rock. The sections as well as the macerated material were examined unstained. Fifteen to twenty slides were prepared from the macerated material of each sample.

B. Description of the microfossils.

Of the twenty samples examined only two, namely the Sirbu shale (25/921) and the Suket shale collected by us from the vicinity of Rampura have yielded microfossils. The Geological Survey of India gives the locality of sample 25/921 as 'just east of Saia, 12 miles West of Bhilsa', Central India.

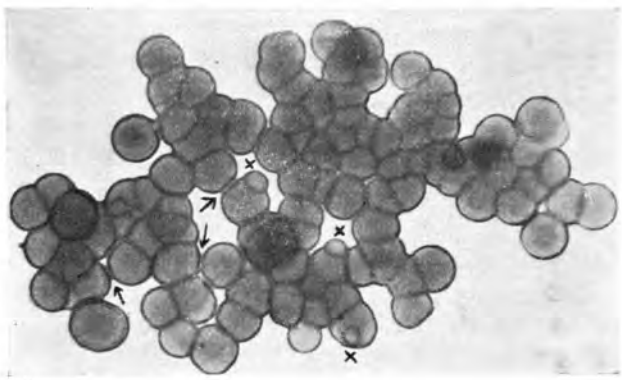
Algal remains.

(i) ? *Cyanophyceae.*—The algal remains shown in Figs. 1–5, 7–9 and 9*a* were obtained by maceration of samples of the Sirbu and the Suket shales in commercial nitric acid for about fifteen days followed by treatment with ammonium hydroxide for 2-3 hours. After the removal of the gross mineral particles the macerated material was mounted in glycerine jelly and in Canada balsam.

The specimens occur abundantly in the slides. The individual cells are spherical. Their size is variable, the most common diameters being 2μ, 3·5μ and 7μ. Single cells are met with but they are much more frequently seen in colonies of two or more closely aggregated individuals (Figs. 2–4). The aggregations occur in two forms: (i) a thin tabular colony formed of closely packed cells, which under the low magnifications of the microscope superficially looks like a piece of membrane (Figs. 5, 8); and (ii) a complex of more or less branched threads (Figs. 7A, 9).

Most of the tabular colonies show the form of the individual cell clearly under the higher powers of the microscope (Fig. 1). The cell-sheath must have been mucilaginous from the way the cells are seen held together. The cells in a colony either retain their spherical shape or get flattened by the pressure of their neighbours, in this way frequently presenting a polygonal outline in surface view. Sometimes the cells appear not to be in direct contact but connected by a narrow isthmus (Figs. 1 and 4, see near arrows).

In the second or the 'dendritic' type of the colony the form of the cells is generally not well preserved. This is also the case in some of the tabular colonies. The condition seems to have resulted either from the diffluent nature of the cell-sheaths or from bad preservation. In some cases the obliteration of the cell walls has proceeded to the extent of making a part or whole of the colony look like a flat structureless membrane (Fig. 8, near arrows). In fact, were it not for the presence



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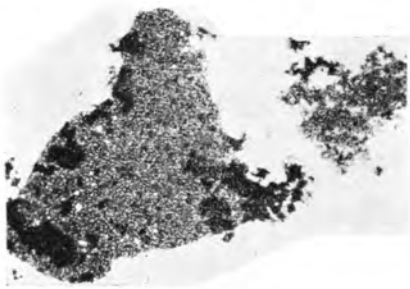

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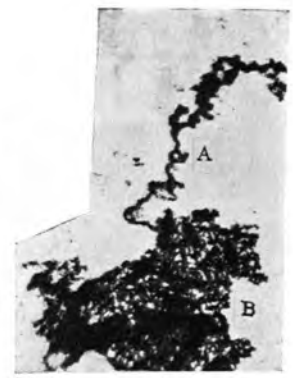

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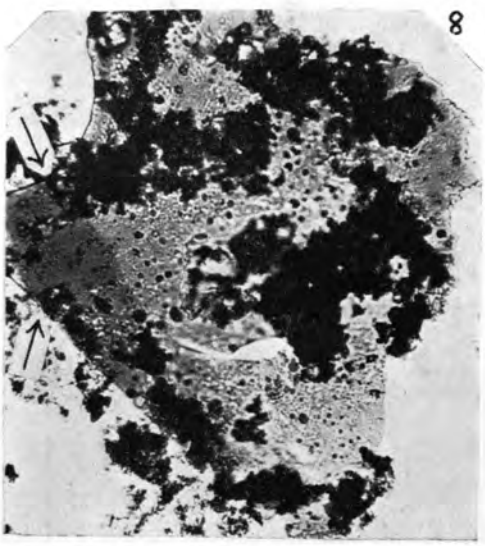

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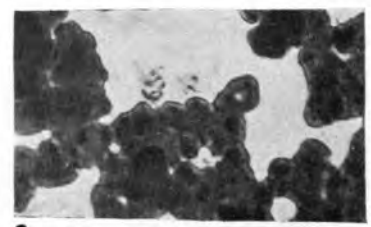

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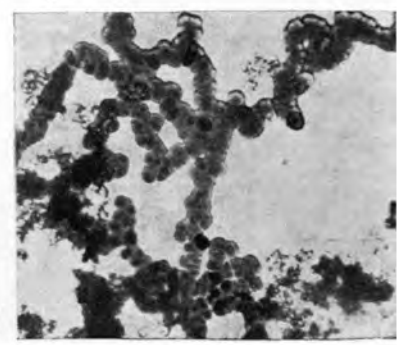

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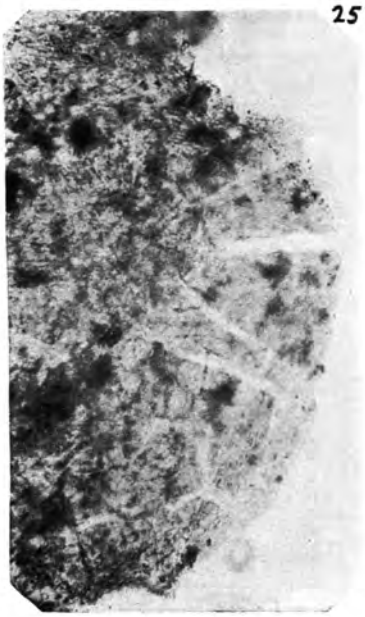

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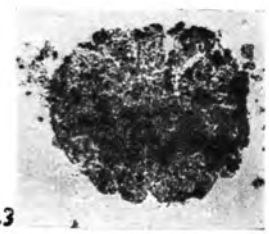

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in the slides of transitional stages (Fig. 10) it would be impossible to identify the structureless fragments with the ones showing cell outlines.

A peculiar feature seen in many of the cells is a rounded protuberance (Fig. 1 near XX). The protuberances show a variation in size which conveys the impression of growth. The phenomenon may be likened to the budding of the cells of yeast, but it is difficult to say whether the outgrowths in the fossils have resulted from a process of abstriction.

The cells of the 'dendritic' forms are similar to those forming the flat colonies. The cells do not aggregate to form threads of uniform thickness but give rise to numerous bulges and short, blunt branch-like outgrowths. The threads themselves curve and loop variously. There are many specimens (Fig. 7B) which show a condition intermediate between that of the colonies in Figs. 9 and 5. The 'dendritic' forms thus most probably represent early stage which later on grew into sheet-like expanses of the alga.

In a vertical section the colonies may be single layered or in places show more than one layer of cells. Areas of more than one layer of cells, however, are never extensive. They can be distinguished in surface view as patches of darker colour.

Apart from the macerated material the colonies have also been met with in a thin section of the Sirbu shale (25/921). This section (Fig. 6) along the bedding plane of the shale shows a few spherical cells of a colony, very similar to those discovered in the macerated material. Although the preservation of the cells in the section is not good the resemblance in form, size, and colour between these and the ones shown in Figs. 1–4 is striking.

Affinities.—The nearest comparison of these fossils is with the Cyanophyceae. The single cells as well as the colonial forms are very suggestive of the habit of some of the palmelloid types of the Chroococcales (cf. Fritsch, 1945, Fig. 304 1, J.). There is no evidence of a common mucilage envelope in the Vindhyan fossils. Cell division was probably the chief method of multiplication by which an extensive prostrate system was developed. But the rather frequent occurrence of rounded protuberances in the cells is a feature of interest here. This is an uncommon phenomenon among the blue-green algae. In *Rosaria ramosa*, a New Caledonian genus of the Stigonematales Carter (1922, Pl. 4, Figs. 2–6) has recorded growth by the budding of the apical cells; but there is no other similarity between this alga and the fossils. The living species has a characteristic habit of long slender filaments only one cell in width. Budding was perhaps an accessory mode of multiplication in the fossil forms. The Vindhyan specimens probably represent a primitive group of algae closely related if not belonging to the Cyanophyceae.

The microfossils described below were obtained from the Sirbu shale (25/921) by macerating it in hydrofluoric acid. The slides were mounted in Canada balsam and glycerine jelly.

(ii) *Fusiform bodies.*—A large number of these peculiar barrel shaped bodies have been met with in the slides. The individuals are on the whole fusiform in shape (Figs. 16-17, 19–21). The ends are flattened but in some of the specimens they are seen broken into a number of finger-like projections (Fig. 16). In several cases the body is seen divided along the shorter axis into two symmetrical halves, the line of division often coinciding with a slight constriction of the sides (Figs. 16-17, 21). The specimens measure up to 38 μ along the longer axis and 17·5 μ along the shorter. Fig. 18 shows two specimens seemingly joined end to end.

It is difficult to determine the relationship of these fossils. The shape is suggestive of desmids, especially in the case of the specimens where the division of the body into two halves is seen. The modern Desmidioideae with the exception of one species are restricted to fresh waters.

(iii) *Round bodies.*—These are thin walled and somewhat flattened (Figs. 14–15). They are present in different sizes (the average specimens measure 31μ in diameter) but all of them are very much larger in diameter than the cells of colony shown in Fig. 1. No colonial forms of these have been discovered. It is possible that they represent some unicellular algae.

(iv) *Disc-like forms.*—Fig. 23-24 show disc-like forms 105μ in diameter. The surface is cracked, but the circular outline of the specimen is clear. An interesting feature of the specimens is the presence of a fine concentric striation along the periphery (Fig. 25) somewhat similar to the 'growth lines' described in *Fermoria*. Walcott (1919) has figured plant masses of blue-green algae such as *Nostoc* and *Anabaena* flattened and dried on card. These often take the form of circular discs of different sizes. It is possible that the Vindhyan specimens also represent similar plant masses flattened by fossilisation.

Fungal spores.

Small oval spores probably of fungi (Fig. 11–13) have been discovered in thin sections of the Sirbu shale (25/921). They measure 2·5μ–3·5μ along their longer axis. In some cases a curved mark is seen on the spore. This probably represents a fold in the spore wall.

Filamentous body.

Another thin section of the same shale contains a septate filament (Fig. 22) with thin and rather shrunken walls and tapering ends. The cells measure 5–7μ in width in the middle of the filament.

C. Mode of preservation of the specimens.

So far form is a guide the specimens just described appear to be plant structures. There is no evidence to show that any part of the original plant matter is preserved in the fossils. They are probably mineral casts formed of a reddish or brownish translucent substance which surprisingly resists mineral acids like nitric and hydrofluoric acids. When examined in polarised light all the specimens shown in the plates are isotropic under crossed nicols, and with the polariser alone no pleochroism is seen.

Owing to the minute size of the specimens tests for determining their chemical composition have not been practicable. It has, however, been possible to apply the test of incineration in one case, viz. to the colonies recovered from the Suket shale (Fig. 9*a*). A number of such colonies were subjected to red heat in a platinum crucible. The fact that they did not burn shows that they are mineral casts.

The case of *Fermoria* forms an interesting parallel. Here there is an external coaly layer covering a subtranslucent foundation. The inner layer consists of angular flakes of pale horn-brown colour which are isotropic under crossed nicols (Chapman, *loc. cit.*, p. 111). We think this inner layer possibly represents a mineral infilling similar to that which has formed the casts in the present microfossils. This is supported by the test of incineration which we have applied to several specimens of *Fermoria* collected recently from the vicinity of Rampura. Even after the application of red heat for several minutes the flaky layer did not disappear.

In the case of the present fossils only the mineral cast has been left. The original plant matter was probably not preserved. But if it did leave a carbonaceous film like the layer of carbonised organic matter in *Fermoria*, it

must have been of a very fragile nature. Such carbonaceous films can be easily destroyed by the action of macerating fluids.

The age of the Vindhyans in the light of plant fossil evidence.

Except the groups of small oval spores (Figs. 11–13), which are probably fungal, and the filamentous body shown in Fig. 22, the plant remains described above seem to be algal in nature. Among these the affinities of the fusiform bodies (Figs. 16–21) and the rounded bodies (Figs. 14, 15) are not known. The microfossils shown in Figs. 1–10 indicate a strong affinity with the Cyanophyceae. This is an archaic group which has persisted with little alteration during long epochs of the earth's history (Fritsch, 1945, p. 768). Representatives of the blue-green algae are known from the Cambrian period onwards and the group is even believed to extend to the pre-Cambrian times. The only other algal remains described from the Vindhyans are by Misra (1949) and Misra and Bhatnagar (1950). These authors have described an alga belonging to the Dasycladaceae and minute spherical bodies which they compare with 'algal dust'. Fossil forms of the Dasycladaceae are known from the Ordovician onwards.

Taken as a whole, the algal remains so far discovered are not in conflict with an early Palaeozoic age ascribed to the system on the basis of stratigraphical data. As there is little doubt regarding the organic nature of these discoveries, we can safely agree with Wadia (1939, p. 101) and Reed (1947, p. 420) that at least a part of the Vindhyan system should be included within the Cambrian. The algal remains mentioned above do not provide sufficient ground for lifting the Vindhyans to a horizon younger than this.

We find it too early to express an opinion on the vascular flora described by A. K. Ghosh and A. Bose (1950) from the Vindhyans. The discovery is of very great interest, involving, as it does, questions of fundamental importance both to botany and geology. For the elucidation of these we must await further data.

Postscript.—Since the manuscript of this paper was submitted to the press we have received a copy of a note in *Nature* by A. K. Ghosh and A. Bose (1952) describing spores and tracheids from a shale of Upper to Middle Cambrian age in Kashmir. This shale contains, apart from the microflora now described, *Tonkinella* and *Obolus*-like brachiopods. Ghosh and Bose (*loc. cit.*) remark: 'These data obtained in India as well as those recorded in the Swedish "Kolm" and the U.S.S.R. all taken together tend to suggest an earlier phylogeny of vascular plants, going back to the Cambrian period and not the Silurian-Devonian period as generally supposed.' As time passes, perhaps more data of similar nature will become available from strata of pre-Cambrian or Cambrian age. Till we have data sufficient to be convincing, the question of the origin of vascular plants as early as the Cambrian must, in our opinion, remain *sub judice*.

Summary.

Microfossils assumed to be algal and fungal remains are described from the Suket and the Sirbu shales. The previous records of life in the Vindhyan strata are reviewed. The sum total of the evidence of the plant remains supports the view that the Vindhyans are of an early Palaeozoic (Cambrian) age.

Acknowledgements.

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Explanation of Plates.

(*All the photographs are untouched.*)

Plate III.

1–9. ? Cyanophyceae.

1. A typical unbranched colony. ×1445.
2. A single cell. ×906.
3. A two-celled colony. ×906.
4. Another colony containing about a dozen cells. ×1230.
5. A colony under low magnification. The close aggregation of the cells forms sheet-like expanses. ×90.
6. An aggregation of a few cells observed in a thin section of the Vindhyan shale. ×916.
7. Another colony under low magnification. A, a branched form. B, a sheet-like structure with cells more loosely packed than in fig. 5. ×90.
8. One of the sheet-like structures. The cell outlines are not everywhere distinct. The portion to which the arrows point shows a complete obliteration of the cells, giving the appearance of a structureless membrane. ×221.
9. A typical branched colony. ×373.

9*a*. Another branched colony (Suket shales). ×1445.

Plate IV.

10. ? Cyanophyceae: A part of specimen in fig. 8 (near top right hand corner) enlarged to show the form of the cells which in other parts of the specimens have become obliterated. ×896.

11–13. Groups of fungal spores observed in a thin section of the Vindhyan shale. 11, ×1761; 12, ×1619; 13, ×996.

14–15. Rounded bodies (probably unicellular algae). ×414.

16–21. Fusiform Desmid-like bodies. Fig. 18 shows two specimens joined end to end. ×679.

22. A filamentous body observed in a thin section of the Vindhyan shale. ×1059.

23–24. Disc-like forms. The cracks in the peripheral region are due to the pressure of the coverglass on the specimen. ×62.

25. A portion of the specimen in fig. 24 further enlarged. The surface near the periphery shows concentric striation. ×174.

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