Table 1. Composition of modified BBM

<table>
<thead>
<tr>
<th>Part I</th>
<th>Gram per litre solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaNO₃</td>
<td>3.0</td>
</tr>
<tr>
<td>MgSO₄·7H₂O</td>
<td>1.5</td>
</tr>
<tr>
<td>KH₂PO₄</td>
<td>2.0</td>
</tr>
<tr>
<td>CaCl₂</td>
<td>0.1</td>
</tr>
<tr>
<td>K₂HPO₄</td>
<td>3.0</td>
</tr>
<tr>
<td>NaCl</td>
<td>0.1</td>
</tr>
</tbody>
</table>

(10 ml of each stock solution to 940 ml of distilled water)

<table>
<thead>
<tr>
<th>Part II</th>
<th>Gram per litre solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₃BO₃</td>
<td>11.42</td>
</tr>
<tr>
<td>FeSO₄·7H₂O</td>
<td>0.82</td>
</tr>
<tr>
<td>ZnSO₄·7H₂O</td>
<td>0.40</td>
</tr>
<tr>
<td>MnCl₂·4H₂O</td>
<td>0.43</td>
</tr>
<tr>
<td>(NH₄)₂MoO₄·4H₂O</td>
<td>0.20</td>
</tr>
<tr>
<td>CuSO₄·5H₂O</td>
<td>1.57</td>
</tr>
<tr>
<td>Co(NO₃)₂·6H₂O</td>
<td>0.98</td>
</tr>
<tr>
<td>EDTA</td>
<td>15.00</td>
</tr>
<tr>
<td>KOH</td>
<td>3.10</td>
</tr>
</tbody>
</table>

(1 ml of each stock solution to the part I solution)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agar</td>
<td>15.0</td>
</tr>
<tr>
<td>Glucose (d-glucose)</td>
<td>10.0</td>
</tr>
</tbody>
</table>

Salazinic acid was not detected in mycobiont or photobiont cultures of *B. setschwanensis*. It was detected only in cultured tissues which were composed of both bionts. We believe that the production of salazinic acid in cultured *B. setschwanensis* tissues is based on a relationship between mycobiont and photobiont and photobiont plays an important role in the production of salazinic acid.

3. Deason, T. B. and Bold, H. C., *Exploratory Studies of Texas Soil Algae*, University of Texas, Austin, 1960, pp. 70.

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Earliest complex life on earth: New look from fossil discoveries

One of the instructive examples of controversy regarding the time of the earliest evolution of complex life on earth may be seen with the one billion-years or more (Proterozoic) age for the multicellular worm-like trace fossil1 and the Cambrian, supposedly 545 m.y. old, tiny-shelled animal fossil2 findings from the lower Vindhyan rocks in central India. The sharp contrast in ages inferred seems to collectively call for reassessment of the age of the Vindhyan rocks itself, and eventually a new look into the explosion of early life having complex form. But now it may not be a serious problem in the light of the following. Firstly, in the seventies and eighties too, the impressions of animal fossils belonging to the annelids were discovered from the Rohtas Formation, lower Vindhyan3 and from the much older Bijawar Group rock (around 2000 m.y. old).2 Particularly, the metailian trace fossils in Bijawar were examined by A. Seilacher in the eighties. Hence, the much talked about report of multi-cellular Proterozoic life4 in the late nineties is not new enough to be considered astounding. Secondly, the evolution of complex life during Proterozoic is further corroborated by another noteworthy record of spongy body-fossil, possibly of animal origin, from the Semri Porcella- nite Formation, Kheinjua Shale Formation and Rohtas Limestone Formation of Vindhyan5. These remains show psilate or perforated body of triangular to sub-triangular shape. Although these discoveries cannot be underrated, there still persists some speculation on the less likely probability of 'backing of life's clock by a large span of time'. At present, this is uncalled for, because it is logographically deduced that these recent discoveries clearly confront with the conventional viewpoints on the Cambrian life explation6, which invariably also helps to a great extent to rule out suspicion on the Proterozoic age of the lower Vindhyan, primarily by means of some modern geochronological data. Thus, a major fret about the want of modern radiometric dating expressed in various critiques7,8 and subsequent discussions9,10,11 may not be of crucial significance while appraising the earliest complex life. Yet, in this respect some of the opinions, which have been seriously placed in these critiques on the recent fossil discoveries, deserve scrutiny; so that the opinions rendered are not misconceived during a healthy debate on the earliest evolution of the complex life and also future research necessitating age revision of the Vindhyan, mainly on the basis of tiny-shelled animal fossils.

According to Brasier7 there could be a big gap in age between the Kheinjua Sandstone (1.1 b.y.), containing fossilized worm burrows, and the overlying...
shelly fossil bearing Rohtas Limestone (545 m.y.). Azmi\(^2\) says that this is not possible because the limestone layers of the uppermost Rohtas Formation conformably overlie (without interruption of sedimentation) the trace fossil-bearing sandstone unit of the Kheinju Formation. On the contrary, it would be pertinent to note that there is a discontinuity between these two formations\(^3\) as represented by ubiquitous occurrence of breccia. However, considering modern geochronological data, viz. the 1067 m.y. old kimberlite intrusion\(^4\) in other parts of the rocks of the two formations, the discontinuity in sedimentation appears incorporeal in a sense that the ages of these rock formations ought to be at least 1070 m.y. old.\(^5\) Rb-Sr dating\(^6\) of less than 2 \(\mu\)m illite-rich clay fractions from the subsurface core samples (depth 529.5–538.5 m) of the Rohtas Limestone Formation has been recently conducted with precision (MSWD = 0.20), and the isochron age of 939 \(\pm\) 22 m.y. is deemed meaningful for the age of diagenesis after deposition and compaction of sedimentary rock. These dates reply to a vital probe by Bowring\(^7\), a geochronologist at the Massachusetts Institute of Technology, who contended that about 1.1 b.y. age of the rock is primarily due to dating of 1.1 b.y. old rock grains (obviously glauconite which had been dated in the 1960s) that in fact got incorporated in the much younger rocks. It lacks merit for it shows that only the studies providing young ages are reliable whereas most, if not all, of the results pointing to older ages are doubtful. In a similar attempt to maintain the lower age of Vindhyan, Banerjee and Frank\(^8\) suggested K–Ar date close to 620 m.y. According to Paul Renne, a geochronologist at the Berkeley Geochronology Centre, this date is obtained through incorrect procedure without considering the weathering aspect. In the field also, the rocks dated are highly weathered. In fact, this is the reason for the young age.

In a nutshell, it may be said that in most of the attempts made so far to resolve the controversy, due attention towards possible resetting of the isotopic signature was not given. Besides, it was also once believed\(^9\) that magnetostratigraphy could be a useful means to demarcate Precambrian–Cambrian boundary consistent with the fossil discovery. But this tool too points to 1150 m.y. age to the upper Rohtas Formation\(^10\), which is in reasonable agreement with 1070 Ma (ref. 6) age proposed earlier. Thus, the discovery of younger than Proterozoic shelly fauna\(^11\) may not be validated well in tune with 545 m.y. They might represent the most primitive (1070 m.y. old) ancestral fossil of animal lineage belonging to the earliest Cambrian\(^12\).

The paradox with the dating of very old 'detrital' glauconite present within the very young rock unit, that is, early Cambrian, may be explained by looking at the mode of occurrence and origin of glauconite. It occurs in more than 30 m thick lithological sequences of the Kheinju Formation in a repetitive fashion, particularly in different horizons of sandstone having intermitten siltstone and quartzite barren of glauconite\(^13\), and is commonly formed as an 'authigenic' constituent of marine sediment. At the present state of knowledge enormous amount of detrital glauconite is not still adequately recognized. Moreover, it is least possible that the detrital glauconite would behave like the resistant zircon mineral, sometimes known for preserving relict isotopic age signature of its old source rock. Hence, the geochronological result from glauconite mineral though representing diagenetic age, is tenable. Perhaps it is for this reason that the radiometric dating of glauconite mineral, particularly from the rock formation where the multicellular worm earlier dwelled upon, has been of pivotal importance for Seilacher, Bose and Pflug\(^1\) in fixing > 1 b.y. age of origin to the worm, in spite of the fact, as advocated by Brasier\(^2\), that the traces of complex animal activity have been during the 550–600 m.y. old region. Also, the interpretations made by Seilacher, Bose and Pflug\(^1\) and Tondon and Kumar\(^3\) are not unrealistic because these have helped to establish a long-standing anticipation of Windley\(^4\) that accounts for the occurrence of the more complex multicellular metazoa in the mid-Proterozoic rocks.

Although the aforementioned account enhances our understanding of the Proterozoic age for the reported trace fossil bearing rocks, including those enriched with certain types of small shelly fossil and brachiopod, it is surprising to read the remark in a commentary\(^5\) that the latter ones discovered by Azmi represent artifacts. In the same commentary Azmi, on the contrary, explains that the examples cited in his paper\(^6\) are indeed fossils and those considered to be artifacts by Conway Morris at Cambridge are not part of the published study. It is then axiomatically suitable for reinstating the genuineness of his fossils. Subsequent discussions brought out by Kerr\(^7\) too show that many palaeontologists are standing by Azmi, stating that the problem on authenticity of the fossils may be

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**Figure 1.** SEM photograph of a new Proterozoic body fossil, *Oldhamia*. The mystery associated with this was the fact that, one considered the structure similar to *Oldhamia* trace fossil, while the other opposed the relation of structure to any trace fossil.
due to contamination of samples or a misinterpretation of data. This may be true because the fossils in Maihar area, according to Azmi 9, are extracted from shale within porcellaneite and not from the earlier reported cherty limestone. The claim thus made is not firmly rejected by all. Also, we must realize that all fossils cannot be deemed artifacts of only the known true fossils. If artifacts, they must also be like those that are not at least known in various body fossils. Since this is not the case, the claim by Azmi may have likely arisen on factual ground; hence more fossils could be recovered and published in April 1999 after a symposium on Vindhyan stratigraphy held in Lucknow during March 1999.

We may now get an undisputable Proterozoic age of the lower Vindhyan rocks and its spatial relation to the small shelly fossils and in particular the multi-cellular worms. If this is in corollary to Pflug’s perception 10 – suggesting that in terms of more than 1 b.y. age alone the discovery of tracks 1 cannot be blown out of water – then the presence of much complex life during Proterozoic becomes an important aspect of investigation. Until now, as opined by Azmi himself 9, no one has ever cared to study shelly fossils because the rocks were believed to be very old. Thus, it aptly bespeaks that scientists always expected simpler life in the Proterozoic, quite akin to those present in the Archaean time. This may be the reason for underestimating H. C. Jones’ earliest report of brachiopods in 1907 from the lower Vindhyan rocks of Central India. Also, the submillimeter-sized ‘scaly’ fragments of the soft body fossil of Oldhamia, which I had discovered from the Proterozoic Gangpur Group metapelite rock, were at times held dubious, not because the regular structural features were doubtful (Figure 1), but mainly because the complex biogenic structure militate against the very old age of the rock in which it is found. If it is taken in a lighter vein, I may mention that such a dilemma was not faced when the age and the size of the fossil were kept undisclosed. The radiating fan-like structure with grooves and ridges (Figure 1) was nevertheless upheld and appraised by Rosanne M. Lindholm, University of Houston, as that of Oldhamia. Accordingly, this fossil is likely to be the ancestral representative of the early Cambrian megaspheric Oldhamia. Such a possibility appears justifiable, since there can be no early Cambrian megafossils without having their roots in the Proterozoic time. Besides, the problem that the Proterozoic example cited in Figure 1 is a part of the body fossil and the early Cambrian types are trace fossils, could at best be tackled logically by considering the latter as fossils of mould and/or cast nature rather than sensu stricto trace fossils.

The unanimous realization to accept researches on various new and morphologically complex Proterozoic life are warranted. The vast Precambrian time span of ~ 3400 m.y. cannot entirely be dominated by simplest life without significant Proterozoic evolution. This appears reasonable particularly in the light of the following: (i) after about 1800 Ma an effective ozone layer formed in the atmosphere which prevented penetration of DNA-damaging ultraviolet radiation and thus allowed the invertebrates to develop 19. At this point, if 2000-m.y. old metazoan activity is recalled, it becomes evident that the ozone layer must have existed even before 1800 m.y., i.e. at around 2000 m.y. age. (ii) A recent research news 20 suggests that the earliest life on earth was more like the complex cells of animals and plants than the bacteria normally regarded as life’s most ancient ancestors. Later, vertebrates also evolved, that too in Proterozoic. A supportive evidence for this may be provided from the latest discovery of the oldest unambiguous vertebrate fossil 21. Explicitly the fossil is that of a full-fledged vertebrate – more advanced than some vertebrates alive today. As a result, fossils of even older vertebrates can be unearthed in rocks dating from well before 540 Ma which might be placed at about 750 Ma in the Neoproterozoic erathem. This situation is explicable by an observation (made in point (i)) that helps to push the time of ozone layer formation to further 200 million years back, by virtue of which the time span of 1250 m.y. necessary for vertebrate evolution is maintained.


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