ETHOLOGICAL INTERPRETATION OF ICHNOGENUS *ZOOPHYCOS* MASSALONGO

R. M. BADVE, M.A. GHARE and K. G. KULKARNI
Department of Geology and Palaeontology, M.A.C.S. Research Institute, Pune 411004, India.

ABSTRACT

Planar or helical structures assigned to the ichnogenus *Zoophycos* Massalongo, represent complex biogenic activity. The mechanism by which these traces are formed is, however, not well understood. Hence to study the mode of formation of these traces, a well-preserved specimen of *Zoophycos*, collected at Walakhavas locality and coming from Jumara Formation (= Callovian to Oxfordian) (Dhosa Oolite member), Jurassic of Kutch, was cut along planes of activity.

A critical study revealed that the *Zoophycos* forming organism, a soft-bodied animal, produced the trace by positioning itself along the axis of concentrically formed trace. Sediment has been scanned efficiently from below-upwards and successively away from the centre, thus representing ethological function of both fodinichnia and domichnia.

Interpretations regarding formation of *Zoophycos* given by other workers have been reviewed in the light of characters seen in the Kutch specimen.

INTRODUCTION

ZOOPHYCOS, although known for more than 125 years, is a highly debated ichnogenus as it lacks information on two points; first, there is a confusion regarding its type. Häntzschel[1] pointed out that for want of a monographic work on this ichnogenus, correct synonyms of different species and even different genera which are likely to be synonymous with *Zoophycos* are not known. Secondly, the exact mechanism by which the trace is produced is not clear. As a result, several explanations have been offered regarding the interpretation of this trace. This genus was considered as plant remains[2] and an inorganic or mechanical origin of this ichnogenus was proposed by Nathorst[3]. However, its biogenic origin was recognised during the last century. This view has been commonly held[2,4–6]. It was suggested[7] that *Zoophycos* and other radiating forms *e.g. Paleospira* and *Spirophyton*, in fact, represent imprints of prostomial parts of sabellids which are sedentary marine polychaetes. On the basis of morphological differences three genera *viz Zoophycos* Massalango, *Palaeospira* Plicka and *Spirographis* Viviani have been proposed.

While studying ichnofossils from the Jurassics of Kutch, we have collected ten specimens of *Zoophycos* exhibiting spirally coiled spreite. A specimen of *Zoophycos* developed in fine-grained, buff-coloured limestone at the top of Jumara Formation[8] (Dhosa Oolite Member) at Walakhavas has been selected for a detailed study by making variously oriented sections. The main emphasis is given to discern the mode of formation rather than taxonomic evaluation of the specimens with us. Two specimens collected from coarse-grained ferruginous sandstone of Upper Jhuran Formation[8] at Rudramata can be assigned to *Zoophycos*, however, exhibiting exactly the reversed development *i.e.* the trace is widest at the top. Considering the total extent of the trace fossil horizons in the Jurassic rocks of Kutch, we intend to acquire more material for taxonomic work. Hence, we defer here to comment on taxonomy and restrict our studies to the mode of formation of this trace.

INTERPRETATION OF SCANNING MECHANISM

Zoophycos traces represent a complex feeding structure having planar or helical nature. These traces are not merely fodinichnia but also represent domichnia. It is commonly assumed, by most of the workers, that the *Zoophycos* traces have been produced by soft-bodied worm-like animal lacking in preservable hard parts. The surface expression of the *Zoophycos* is usually concentrically arranged ridges and furrows forming sometimes lobate patterns (figure 5). In some specimens the ridges and furrows are not conspicuous and trace appears as fine scratches arranged concentrically.

Oriented sections

To study the pattern of the trace and its three-dimensional aspect, a specimen was cut along planes

of activity represented by tunnel-like structures exhibiting C-shaped fillings. The first cut was taken at right angles to the bedding plane *i.e.* a vertical section parallel to the axis, revealing a series of crescent-shaped markings, referred to as lamellae, which move away from the centre towards the periphery (figure 2). The next two cuts were again taken at right angles to the bedding plane and to the first cut and away from the axis (figures 1, 4). The exposed crescent-shaped lamellae, indicate progression from within the sediment towards the surface. The fourth one was taken parallel to the first but on the opposite side, where crescent-shaped lamellae are exposed, again indicating development of the trace from the centre towards the periphery (figure 3). This trace, however, is at a higher level than the one exposed on the front side. Being in continuation with each other, all these traces really represent an inclined plane along which the sediment was scanned. Hence, one more cut was planned, passing through the exposed lamellae. On this newly exposed surface the scanned areas appeared as light to dark cherry red brush strokes (figures 6, 7). the structure of the trace shows lack of a systematic pattern in scanning the material.

The traces on the vertical races as aligned crescent-shaped markings are nothing but the cross-sections of the areas worked out along the inclined plane. A rather irregular and wavy nature on different faces is directly related to the scanned areas. Another point noted is that the upper side of the trace, in cross section, shows plastering of the scanned sediment. Though usually the scanning appears to be restricted to a major plane, some of the probes appear to deviate from the major plane, thereby giving a flexuous nature to the lamellae (trace) in cross-section. However, the animal appears to have adhered to two conditions, (a) the trace progresses deeper into the sediment along the inclined plane and, (b) all these traces converge towards the centre.

Assuming that the animal is sedentary and located at the axis of the trace, the animal pierces the sediment along a definite inclined plane for some distance with a tentacle-like organ. The sediment is scanned in the upward direction along the same plane withdrawing the probe-organ to its initial position. Then the second probe is sent in the same manner, usually adjacent to the first one, again scanning the sediment from below upwards. The probe-organ is not completely withdrawn each time, but is, repeatedly, partially withdrawn and new adjacent areas are scanned, thus giving unequal areas of scanning. However, finally the probe is completely withdrawn and again pierced through fresh areas. Thus the new probes carried out are away from the centre. The entire structure is thus built from bottom to top and from centre towards periphery with the probes being sent in the downward direction.

In the present case the probes are sent in the anticlockwise direction but trace developes in clockwise direction, as it is produced from bottom towards top.

DISCUSSION

To summarise briefly, the *Zoophycos* traces resulted due to scanning of the sediment, for food, by a sedentary animal. Thus the trace is a fodinichnia and also domichnia. There is no marginal tube present in this form. If we assume the presence of a marginal tube and the axial stationary tube producing a spiral spreite, then the spreite is merely rearranged sediment, like, *Rhizocorallium*, which is not scanned for food. However, in the present specimen, the sediment is scanned systematically more and more away from the centre and from below upwards. Traces having larger diameter and deeper penetration indicate older forms.

Plicka[7] interpreted radiating and spirally-arranged structures as prostomia of sabellid worms proposing three genera *viz Zoophycos* Massalongo, *Palaeospira* Plicka, *Spirographis* Viviani. His classification is based on the nature of the gill rays. However, an objection can be raised to this sort of interpretation. Had these structures been prostomia of sabellids, they would have been preserved as structures parallel to the bedding plane and not as structure rising spirally upwards, because it is difficult to understand how discarded prostomia stood erect till they were completely buried by sediment. Was the sedimentation rate in every case so rapid as to bury the prostomia rapidly vertically? Can any organism survive under such heavy rates of sedimentation? Even hard and elongated gastropod shells never occur preserved in vertical position but always lie down parallel to the bedding plane. A similar view has been put forth by Bradley[9]. If Plicka's classification is to be accepted then the specimens described by other authors as *Zoophycos* will have to be placed under a separate genus as they are not bodyfossils.

The preservation of structures spiralling upward in the sediment undoubtedly reveals the trace fossil nature rather than of prostomium as supposed by Plicka.

The relation between *Zoophycos* and *Umbellula* as discussed by Bradley[9] is difficult to visualise. The

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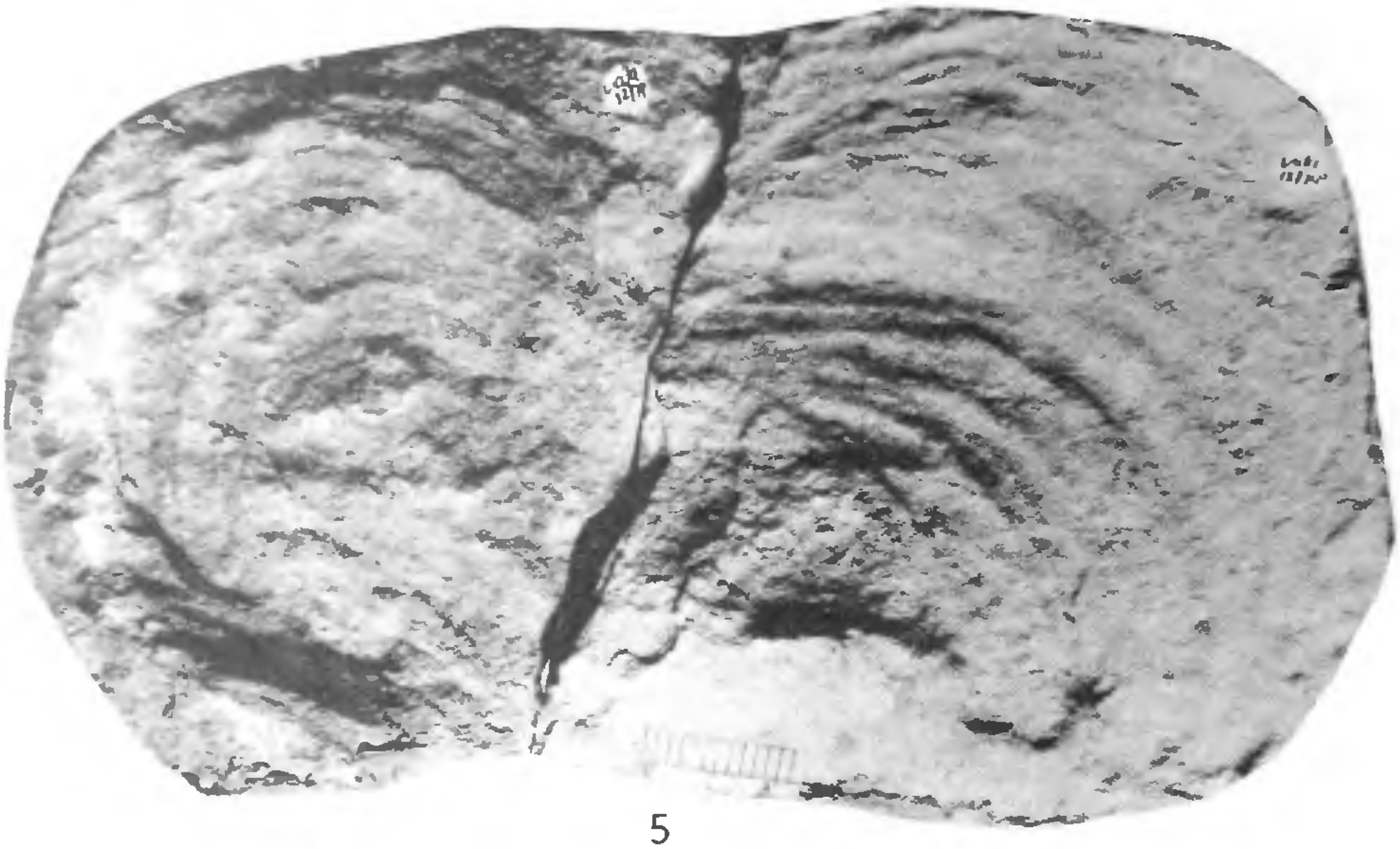
Figures 1–4. 1. Cross-section of spreite showing crescent shaped markings which flay out at the lower end × 2, **2.** Wavy cross section indicating change in levels of scanning. × 1.5, **3.** Oblique section of the spreite does not show perfect crescent-shaped markings × 2, **4.** Both cross and longitudinal sections of spreite seen on the same face indicating change in direction × 2.



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Figures 5, 6. 5. Surface expression of the ichnogenus *Zoophycos* Massalango exhibiting concentric ridges and furrows. × 0.5, **6.** Section along plane of scanning showing irregularly scanned areas × 0.7.

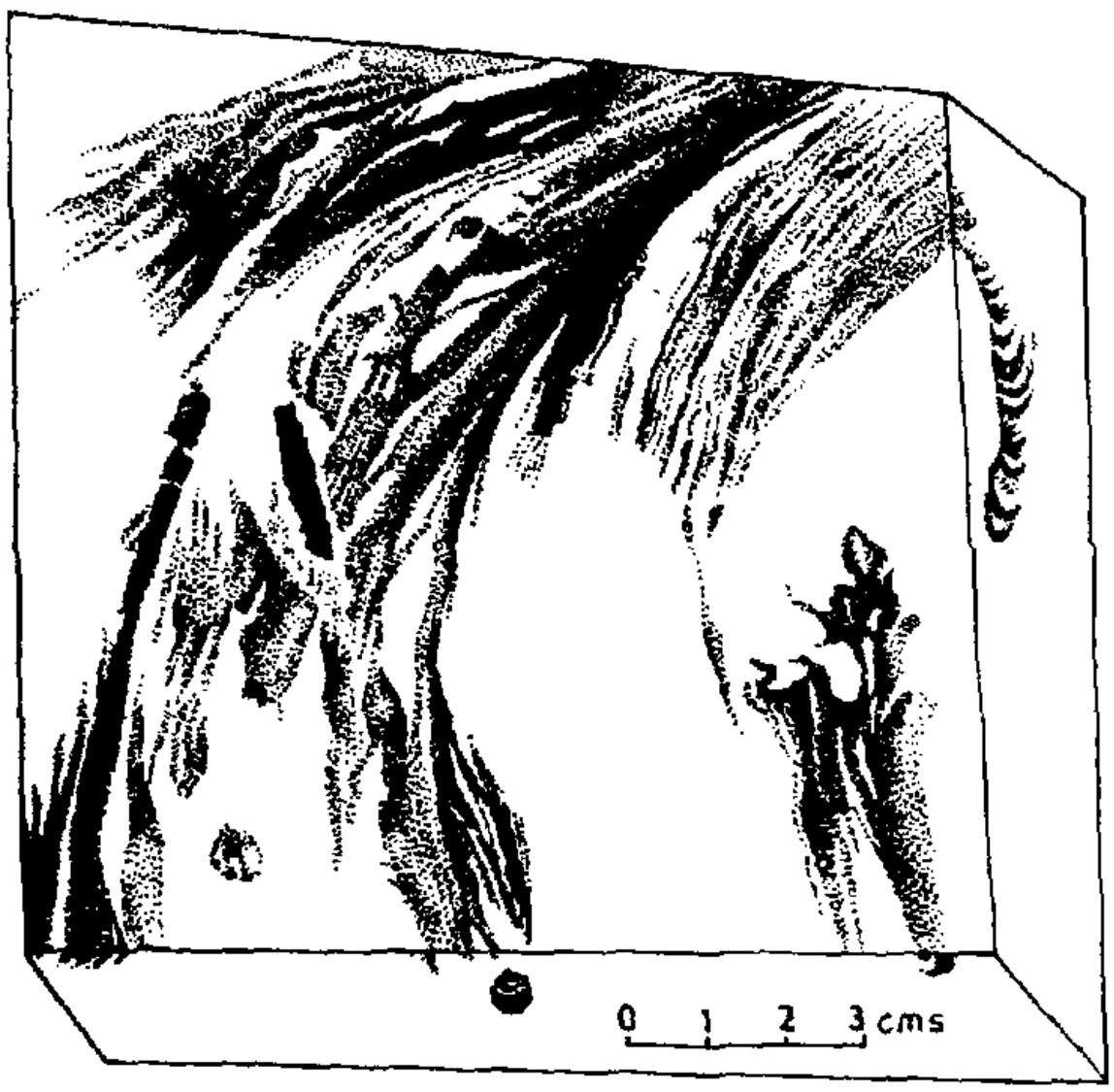

Figure 7. Line drawing of figure 6 × 0.5.

irregular areas of scanning and flaying out of the scan marks cannot be explained by the mechanism proposed by him for the development of the trace. Mere peristaltic movement of the peduncle cannot give rise to the converging pattern of the worked out areas as seen in our specimen. Moreover, the ovoid impressions, considered to be of the bulb at the end of the peduncle and of siphonozooids, observed by him are totally absent in our specimen.

Bromley and Ekdale[10] have reconstructed the complete *Zoophycos* trace from the parts of spreite preserved as flint nodules. The relation between the marginal tube and the two limbs, which open on the surface, is not very clear in their reconstruction. Similarly, development of spreite parallel to the marginal tube as shown by them (figure 1–4)[10] needs confirmation by cutting the specimen along exposed portions of the lamellae.

Simpson[6] visualised mode of formation of *Zoophycos* traces in a similar way as described above. However, the main difference lies in the development of major and minor lamellae. In our specimen we do not find highly differentiated regular pattern of major and minor lamellae as illustrated and described by Simpson[6]. It is not clear, from the description given by him that, whether, he has actually cut the specimens along the plane of major lamellae, and has observed the relation between the major and minor lamellae, or it is interpreted only on the basis of cross section of minor lamellae. The cross-section exhibiting arrangement of the lamellae, in our specimen, is more or less identical to figure 2 illustrated by Simpson[6]. But the section along the plane of the so-called major lamellae does not correspond with figure 3 illustrated by him.

Kern and Warme[11] observed that in thin mudstone beds specimens with low or nearly horizontal spiral spreite occurs, while in thick beds the individual penetrates to greater depths. Thus this difference may not be specific but only represents ecomorphs of the same species. Thus we are led to consider the pattern of scanning the sediment to be the main criterion for speciation. The irregular mode of sediment scanning or highly specialised way as described by Simpson[6] may prove to be different lineages.

ACKNOWLEDGEMENT

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