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Asymmetry of *Zoophycos* burrows as a way-up criterion—a reconsideration

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ABSTRACT

The asymmetric fill of *Zoophycos* spreiten observed in cross-sections cannot always be used as a reliable geopetal indicator. Rather, the use of the entire burrow system is more reliable because of the asymmetry of the whole trace fossil.

OBSERVATIONS

Based on detailed observations on the internal structure of *Zoophycos* (Massalongo, 1855) spreiten in cross-sections, Pudsey (1983) recognized a marked asymmetry of the sediment fill. By analysing these biogenic structures retrieved from Neogene sediments during Deep Sea Drilling Project Leg 78 A, Pudsey found that this asymmetry can be used as a geopetal indicator. However, an evaluation of the more general applicability of this way-up indicator to other sedimentary sequences has not yet been proven. This is the purpose of this brief observation: the asymmetry of the fill structure was analysed in detail on a 600 m long DSDP core, and examples from the literature were examined critically.

Pudsey's model has been tested on biogenic sedimentary structures in deposits cored during DSDP Leg 93 at Site 605, which is located on the North American continental margin off New Jersey (for exact location see Leg 93 Scientific Party and Leg 94 Scientific Party, 1984). The major portion of the Early Tertiary to Late Cretaceous sediments at this site was continuously deposited with the exception of two slumped intervals and some minor turbidites. The autochthonous deposits are strongly burrowed by *Zoophycos*, with up to 10–20 spreiten per metre (Wetzel, 1985). Within the 600 m long cored interval, approximately 5,000 spreiten were checked with respect to their asymmetry. About 90% of the spreiten structures in the autochthonous sediments are filled as described by Pudsey (1983) with the long limb of the lamellae downwards (a in Fig. 1). However, *c*. 10% of the spreiten show an inverse asymmetry in the fill structure, with the long limb of the lamellae pointing upwards (b in Fig. 1) independently of the position within the whole structure. However, close to the vertical part of the burrow a higher percentage of inversely asymmetric spreiten fill seems to occur (Fig. 3).

Inverse asymmetry of the spreiten fill has also been found in *Zoophycos* specimens reported from Recent to Devonian sediments, for instance:

Quaternary: Wetzel & Werner (1981, fig. 9);
Tertiary: this paper;
Cretaceous: Ekdale & Bromley (1983, figs 4 and 10). Besides the figured examples, Bromley found that more than 10% of the *Zoophycos* spreiten in the Danish chalk show an inverse asymmetric fill (Bromley, pers. comm.);
Devonian: Chamberlain (1978, figs 113 and 116)

Furthermore, the inversely asymmetric spreiten fill occurs in shallow water to deep-sea environments.

These examples indicate that the asymmetry of spreiten filling alone is not a completely reliable way-up indicator. However, the low percentage of inversely asymmetric spreiten fills seems relatively unimportant for deciphering the behaviour of the *Zoophycos*-producing animal. However, as geopetal criterion even a low percentage of exceptions (about 10%) may result in an incorrect tectonic interpretation.

The inverse asymmetry is probably due to a real inversely asymmetric fill that is related to the

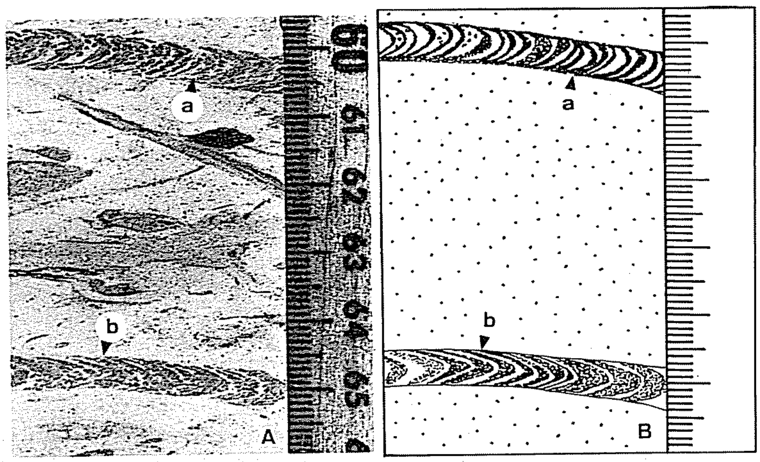

Fig. 1. *Zoophycos* spreiten in cross-section showing asymmetric fill structure; (a) 'normal' asymmetry with the long limb of the lamellae downwards as described by Pudsey (1983), (b) 'inverse' asymmetry with the long limb of the lamellae upward. The sediment is undisturbed, so both types of asymmetric fill are features of the internal structure of the *Zoophycos* burrow. (A) Photograph of DSDP Site 605, core 16, section 4, 0·595–0·66 m. (B) Schematic drawing of (A).

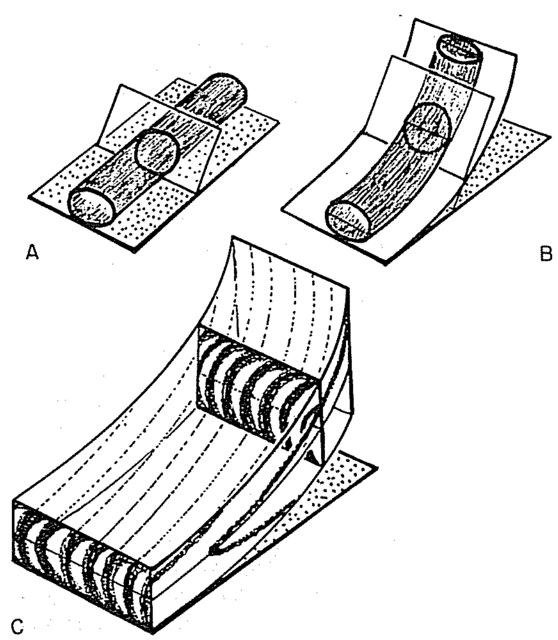

Fig. 2. Effects of cutting on the visual internal structure of burrows. (A) Oblique cutting of a tube transverse-ellipsoidal in shape produces a circular cross-section in the cutting plane. (B) Oblique cutting of a curved tube transverse-ellipsoidal in shape produces an asymmetrical cross-section in the cutting plane because the upper part of the tube has a larger curvature than the lower part. (C) Schematic drawing of the effects shown in (A) and (B) on a section of a *Zoophycos* spreiten.

burrowing behaviour, because cutting effects of inclined spreiten will result in an only slightly apparent asymmetry (Fig. 2). Consequently, the general application of *Zoophycos* as a geopetal indicator should include additional criteria:

(1) statistical evaluation (when possible) of the asymmetry of *Zoophycos* spreiten (see above);
(2) serial sections of the burrows to eliminate apparent asymmetry caused by cutting; and
(3) evaluation of the orientation of the entire *Zoophycos* burrow, which is clearly an asymmetrical structure (Fig. 3).

It is worth noting that many other burrow types, often associated with *Zoophycos*, are asymmetrical and can be used as geopetal indicators. These include *Chondrites*, *Scolicia*, *Teichichnus* and *Thalassinoides* (Häntzschel, 1975).

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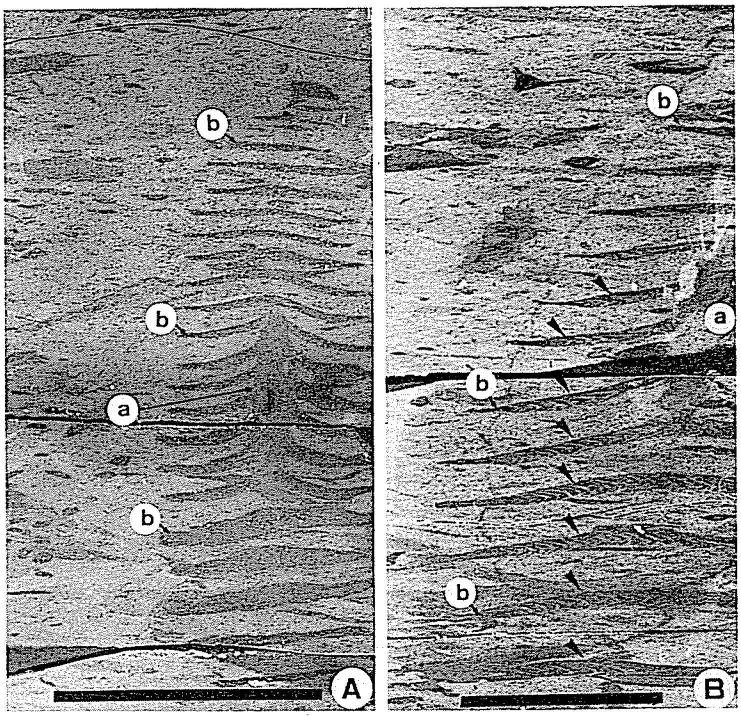

Fig. 3. Asymmetric aspects of an entire *Zoophycos* burrow system useful as way-up criteria: (1) increasing thickness and diameter of spreiten downwards, (2) asymmetric connection between the axial portion of the burrow (a) and the feeding spreiten (b), and especially (3) the spatial relationship between the first feeding spreiten and the formerly existing seafloor (not shown here, see fig. 6, p. 191 in Wetzel & Werner, 1981). 'Inverse' asymmetric fill structures are marked with arrows. (A) DSDP Site 605 core 50, section 3, 0·62–0·71 m. (B) DSDP Site 605, core 45, section 3, 1·025–1·13 m (scale on both photographs = 0·03 m).

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