RE-EVALUATION OF THE ICHNOGENUS *HELMINTHOPSIS* – A NEW LOOK AT THE TYPE MATERIAL

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ABSTRACT. The type material of *Helminthopsis* Heer, 1877 has been examined. The ichnospecies established by Heer (1877) are unsuitable for representing this ichnogenus. *Helminthopsis magna* (subsequently designated type ichnospecies by several authors) and *Helminthopsis intermedia* are specimens of *Scolicia* isp. de Quatrefages, 1849, while *Helminthopsis labyrinthica* is a three-dimensionally complex graphoglyptid quite unlike *Helminthopsis* auctt. and very similar to *Spirocosmorhaphe helicoidea* Seilacher, 1989. However, because of its popularity and its distinctive morphology, and in the interests of nomenclatural stability, *Helminthopsis* is retained by erecting a new ichnospecies on the basis of material in Heer's collection. *Helminthopsis hieroglyphica* isp. nov., although never formally published by Heer (only *in litteris*), was labelled as such by him in his collection, and is proposed here as the type ichnospecies. *Helminthopsis* is normally preserved in hyporelief, but seldom in full relief. Trace fossils in full relief preservation having a morphology similar to *Helminthopsis* were grouped into the (ichno)genus *Theobaldia* by Heer (1877). Although *Theobaldia* has page priority over *Helminthopsis*, the name has hardly ever been used and we declare *Theobaldia* an abandoned senior synonym in order to maintain nomenclatural stability.

THE ichnogenus name *Helminthopsis* is very popular among sedimentologists and palaeontologists, and has been in use continuously since its introduction by Heer (1877). The three ichnospecies assigned there by Heer (*H. magna*, *H. intermedia* and *H. labyrinthica*) in fact belong to different ichnogenera and cover a wide range of morphotypes. The choice of *Helminthopsis magna* as the type ichnospecies by Ulrich (1904), Andrews (1955), and Fillion and Pickerill (1990) led to the ichnogenus being interpreted on the basis of Heer's (1877, pl. 47) inadequate illustration; *Helminthopsis* became used for irregularly meandering trace fossils. *Helminthopsis* of authors has thereby become a separate concept from *Helminthopsis* Heer. To overcome this inaccurate usage, many authors gave their own definition of *Helminthopsis* based on their own understanding of the ichnogenus, but not on Heer's. *Helminthopsis* auctt. has come to comprise several elements that are not included in Heer's original diagnosis, for example 'unbranched, irregularly winding or meandering, horizontal burrows or trails that do not touch or cross themselves. Only one order of meandering may be present. Burrow-fill massive' (Fillion and Pickerill 1990, p. 36).

The uncertain use of *Helminthopsis* continued after Książkiewicz (1977) introduced the new ichnospecies *Helminthopsis abeli* and designated it as the type of the ichnogenus. But his lectotype shows narrow meanders (in contrast to his own description) and the specimen is too small to allow the course of the burrow to be evaluated with certainty; the fragment probably belongs to the ichnospecies *Cosmorhaphe* cf. *Cosmorhaphe helminthopsidea* (Sacco, 1888; compare with Seilacher 1977, fig. 3e; see below). The specimen had been figured previously by Abel (1935) without name, and as *Helminthopsis* (without ichnospecies name) by Häntzschel (1962, 1975).

This demonstrable need of a type ichnospecies highlights an unfortunate decision of the ICZN (Ride *et al.* 1985) to provide ichnogenera with genus-group status, whereby they need no type species, a situation that has been deplored by other workers (Kelly 1990; Rindsberg 1990). Herein, we treat *H. hieroglyphica* as the type ichnospecies of *Helminthopsis*. After all, this is not the first time ichnologists have had to take the law into their own hands (Sarjeant 1979; Bromley 1990).

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Heer's type material is preserved in the Geological Institute of the ETH, Zürich, and is easily accessible. An examination of this material revealed the true nature of *Helminthopsis* Heer, but resulted in a dilemma; the only valid ichnospecies of *Helminthopsis* is in fact a complex trace fossil which is significantly different in the geometrical pattern from most of the trace fossils for which the name has been applied so far. We attempt to resolve the *Helminthopsis* dilemma by basing the ichnogenus on *H. hieroglyphica*, an ichnospecies named but not published by Heer. Among Heer's collection, material under this name includes specimens that show the morphology of *Helminthopsis* as understood today by authors, as opposed to that of the type material of Heer's published ichnospecies. This rather unusual nomenclatural procedure is necessary to retain the stability of the widely used name *Helminthopsis*.

TAXONOMIC HISTORY

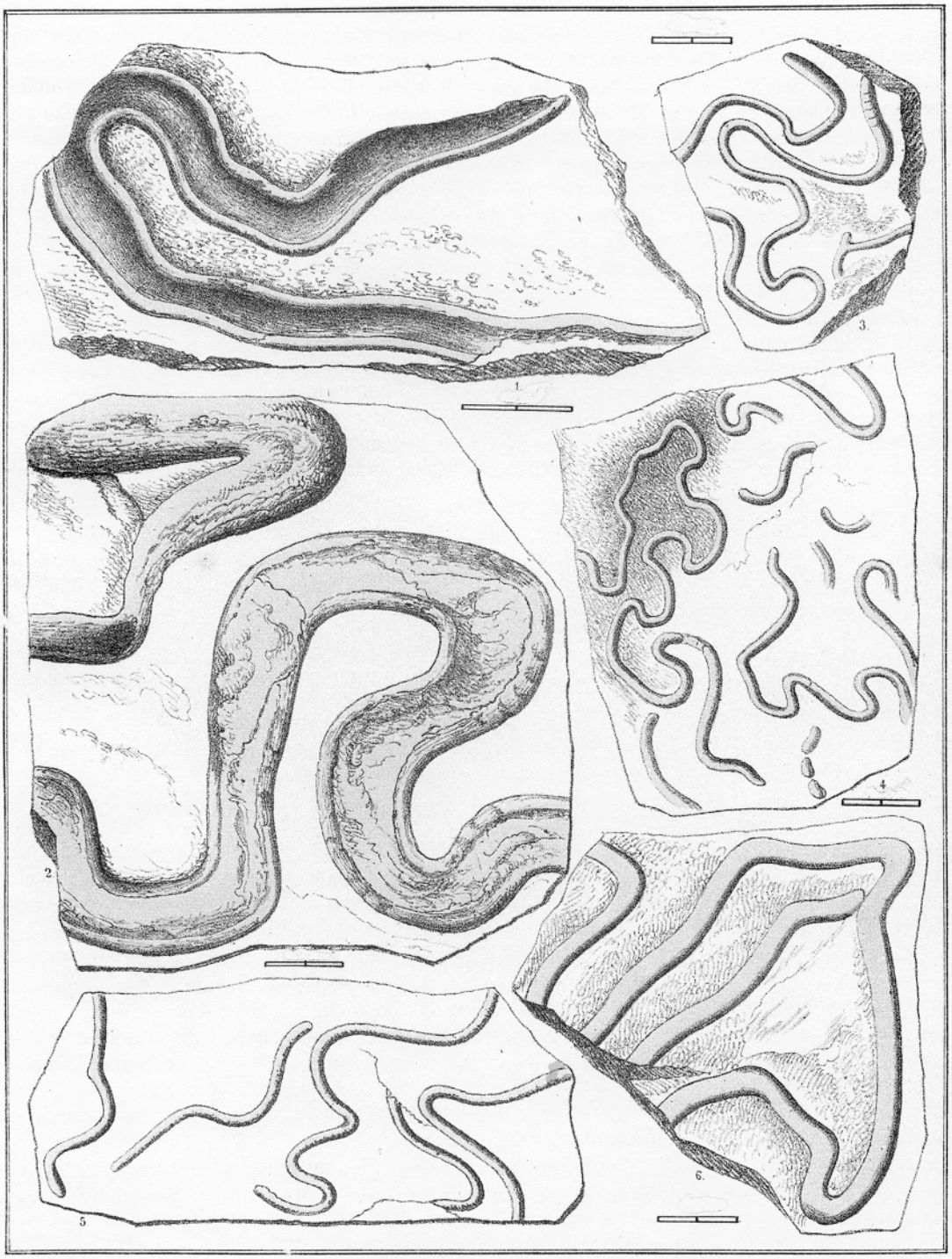
Helminthopsis was erected by Heer (1877) for what he interpreted as a group of fossil algae having a gyrate or curved shape and a diameter ranging from 2 to 20 mm. With respect to the diameter of the fossils and their curvature, Heer defined three different species; *H. magna*, *H. intermedia*, and *H. labyrinthica* (Text-fig. 1). He did not designate a type species, but in his genus description he only referred to *H. magna*, which was therefore later chosen as the lectotype (Ulrich 1904; Andrews 1955; Fillion and Pickerill 1990).

Nathorst (1881) and Maillard (1887) recognized that most of the fossils described as algal remains are in reality trace fossils. When Maillard studied Heer's material, he was informed by Heer about a planned change of the name *Helminthopsis labyrinthica* to *H. hieroglyphica*, to avoid confusion with *Helminthoida labyrinthica*. On the labels of the specimens figured by Heer is written '*Helminthopsis hieroglyphica Helminthopsis labyrinthica in opere*' (*in opere* means 'in the completed work', i.e. Heer 1877). Consequently, Maillard (1887, p. 37) wrote '*Helminthopsis hieroglyphica* Heer (*labyrinthica* dans Heer) mais ce nom fut changé par l'auteur lui-même, pour éviter confusions avec forme du Flysch' (*Helminthopsis hieroglyphica* Heer (*labyrinthica* in Heer), the name has been changed by the author himself to avoid confusion with a[nother trace fossil] form of the Flysch). However, Heer (1877) introduced the name *H. labyrinthica* and never published the change in name in a taxonomically valid way (cf. Wilckens 1947), so the name *H. labyrinthica* has to be retained for the specimens figured by Heer (1877, p. 47, figs 3–5) and covered by his descriptions.

Sacco (1888) examined *Helminthopsis* in more detail and stated on page 174 '...,e non sarebbe improbabile che si trattasse solo di impronte del passagio di animali striscianti' (...it is not unlikely that [these fossils] were produced by crawling animals). He gave an emended taxonomy and pointed out that the 'canal-like forms of *Helminthopsis* must be grouped together with *Taphrhelminthopsis* Sacco'. This is the case for *H. magna*, as he explained in the chapter on *Taphrhelminthopsis*. *Taphrhelminthopsis*, however, is a preservational variant of *Scolicia* (Smith and Crimes 1983). Moreover, Sacco (1888) stated that Heer rejected the ichnospecies *Helminthopsis labyrinthica* because of the similarity in name with *Helminthoida labyrinthica*, but Heer did it invalidly only *in litteris*. Sacco (1888) used *H. hieroglyphyca*, but each time he used a spelling (*hieroglyphyca* (p. 175), *hieroglyfica* (p. 175), *hjeroglyphyca* (p. 192)) which is different from Heer's proposed name. Unaware of Sacco's (1888) work, Ulrich (1904) and Andrews (1955) suggested using *H. magna* as the type ichnospecies. At least since Ulrich (1904), the ichnogenus *Helminthopsis* has been universally used to describe curved, irregularly meandering trace fossils.

Seilacher (1977) reiterated the opinion that *H. magna* is very similar in size and shape to *Scolicia*; Książkiewicz (1977) also agreed with Sacco (1888) that it is *Taphrhelminthopsis*. Later, Fillion and Pickerill (1984) referred to the observation of Sacco (1888) and the suggestion of Książkiewicz (1977). But subsequently, Fillion and Pickerill (1990) gave another emended diagnosis and referred to *H. magna* as type ichnospecies.

Further complications were provided by Häntzschel (1962, 1975) who illustrated *Helminthopsis* in the *Treatise on invertebrate paleontology* (Häntzschel 1962, p. 197, fig. 4*a*; 1975, fig. 44, 2*b*) by



TEXT-FIG. 1. *Helminthopsis*. Material as figured by Heer (1877, pl. 47; scales added by the authors); the drawings do not reflect all details of the original pieces (see Text-figs 2–4). Scale bars represent 20 mm.

a specimen which may be classified as *Cosmorhaphe* Fuchs, 1895. It shows a narrow semi-regular meander pattern and is probably *Cosmorhaphe helminthopsidea* Sacco, 1888; the sample is too small to allow the recognition of second-order meanders, but the trace is nearly identical with respect to meander width, height and radius and tube width to the *C. helminthopsidea* figured by Seilacher (1977, fig. 3*e*). The specimen under discussion was originally figured by Abel (1935, fig. 261B), but without an ichnotaxon. Seilacher's claim (1977, p. 299, paragraph on *Helminthopsis lobata*) that Abel's (1935, fig. 261B) specimen had been originally figured by Ulrich (1904) is an error; Ulrich figured no specimen of *Helminthopsis* sp., and Abel (1935) stated in the caption of figure 261B that his specimen had been found near Vienna (and not in Alaska). Książkiewicz (1977) re-figured Abel's specimen (Książkiewicz 1977, text-fig. 21*d*) and introduced for it the new name *Helminthopsis abeli*. He then suggested establishing *H. abeli* as the type ichnospecies of *Helminthopsis*, although it was not one of Heer's species. Furthermore, he defined the specimen mentioned above as lectotype, but this specimen shows narrow meanders and does not match his ichnospecies description (p. 117) 'loosely winding with a tendency to meandering'. Because of the discrepancies between the description and the lectotype given by Książkiewicz (1977), we suggest abandoning *H. abeli* as type ichnospecies of *Helminthopsis* and that topotype material from Heer's collection should instead be used.

OCCURRENCE

The type material of *Helminthopsis* was found in Ganei (Swiss coordinates 767 660/211 640), at the foot of the Schesaplana in rockfall blocks which probably derived from a location with the coordinates (767 520/212 320). Stratigraphically, Heer (1877) assumed a Jurassic age for the Ganei Shales. The area was first mapped in detail by Trümpy (1916), who found the Ganei Shales in a north-penninic tectonic position, the deposits being flysch, from coarse grained breccia to mud-turbidites. Later Nänny (1948) and Thum and Nabholz (1972) grouped the Ganei Shales into the Ruchberg Serie which has a Palaeocene to early Eocene age. Occurring below a thrust, the strata are strongly compacted and locally sheared. Some of the material described by Heer (1877) was collected by himself, but other specimens had previously been brought to him by G. Theobald (as mentioned by Heer), having been collected at Ganei.

THE MATERIAL COLLECTED BY HEER AND ITS ICHNOTAXONOMY

The description of the genus *Helminthopsis* by Heer (1877, p. 116) is based on the material figured by Heer (1877, pl. 47), shown here in Text-figure 1. The three ichnospecies of *Helminthopsis* Heer belong to different ichnogenera. To clarify the taxonomy we will repeat the original diagnoses and comment on the type material. The original diagnoses are as follows:

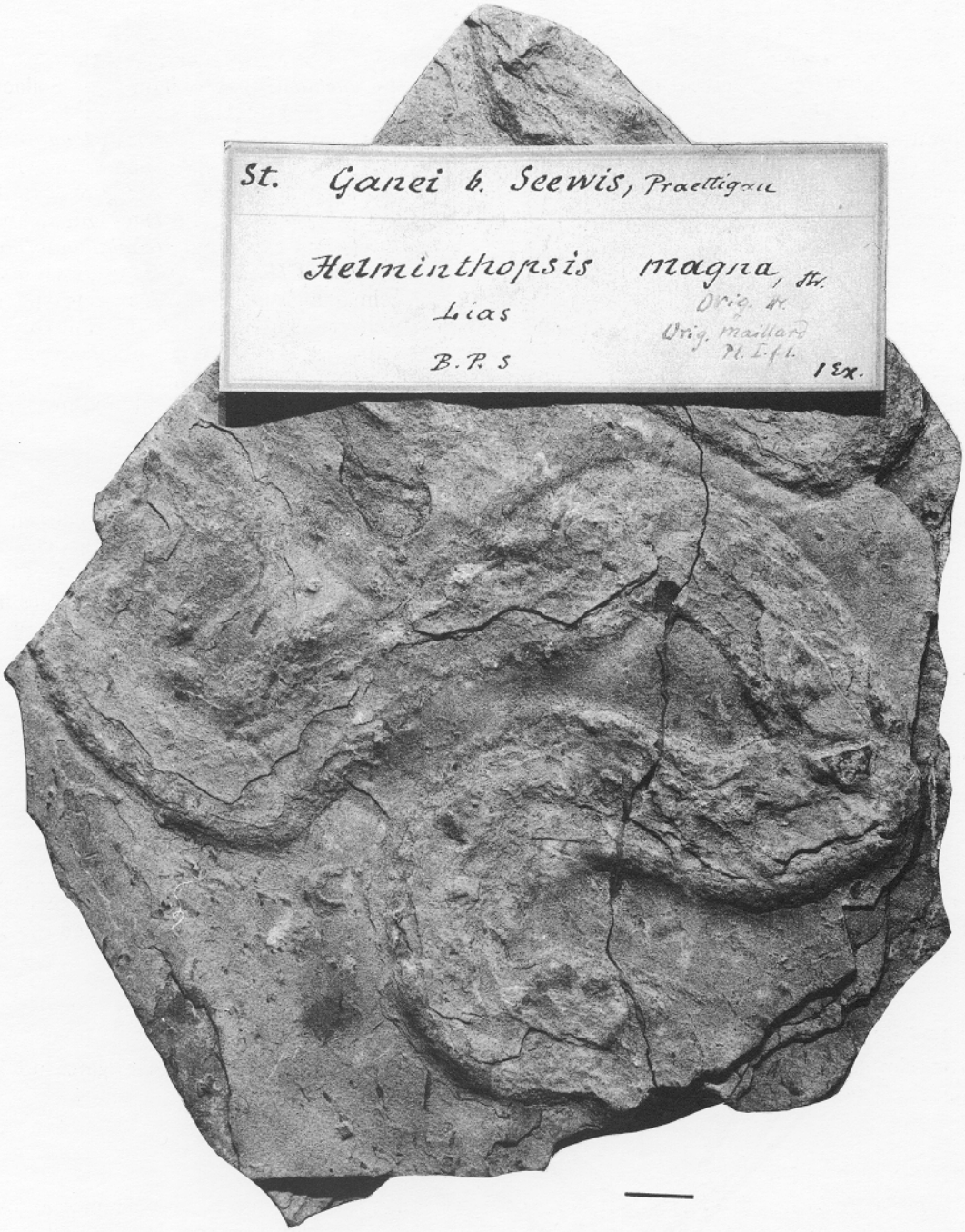
Helminthopsis *Heer, 1877, p. 116*

'Frons simplex, valde elongata, fistulosa, cylindrica, gyrosa.' Simple foliage, very elongate, tubular, cylindrical, gyrate.

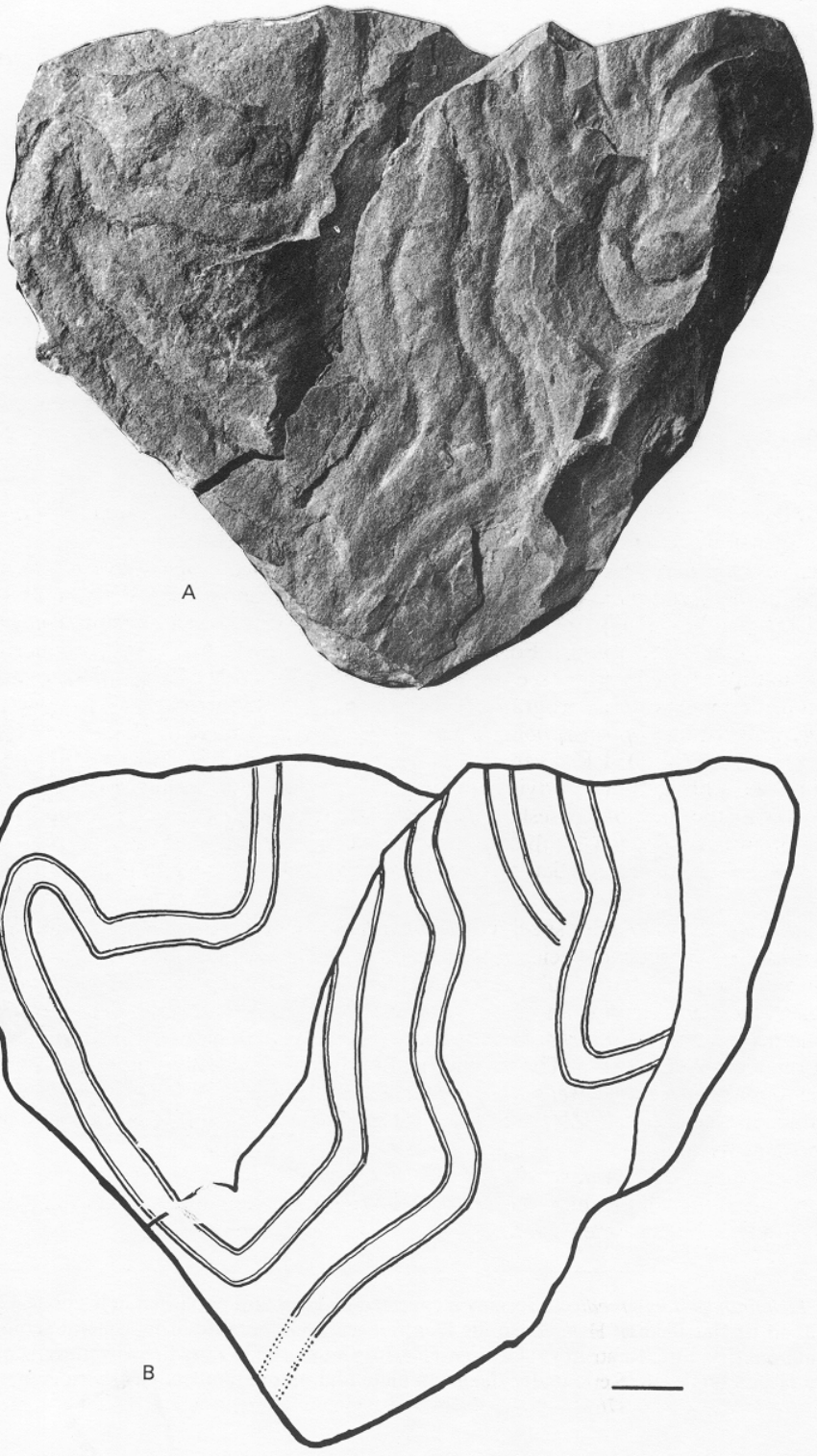
Helminthopsis magna *Heer, 1877, p. 116*

'*Helminthopsis* fronde fistulosa, 15–20 mm. lata, praelonga, valde flexuosa, hippocrepice gyrosa.' *Helminthopsis* having tubular foliage, 15–20 mm wide, very long, with numeous flexures, gyrate like a horseshoe.

The holotype of *H. magna* is a poorly preserved specimen (Text-fig. 2) of *Scolicia* isp. de Quatrefages, 1849. Sacco (1888) also made this observation, and Seilacher (1977, p. 297) stated '...*Helminthopsis*, the type species of which (*Helminthopsis magna* Heer) seems to be a *Scolicia* rather than a graphoglyptid'. Our observations confirm the opinions of Sacco and Seilacher.



TEXT-FIG. 2. *Helminthopsis magna* Heer. Specimen collected by Heer and published in his plate 47 figure 2; this specimen has to be classified as *Scolicia* isp. de Quatrefages, 1849 because of its general geometry, bilobate form, and internal structure. Repository: Geologisches Institut der ETH Zürich, Switzerland; collection of the originals to Heer's book (1876/77) under the given plate and figure numbers. Scale bar represents 10 mm.



TEXT-FIG. 3. For caption see opposite.

Helminthopsis intermedia *Heer, 1877, p. 116*

'*Helminthopsis* fronde cylindrica, 6 mm. lata, elongata.' *Helminthopsis* having cylindrical foliage,' 6 mm wide, elongate.

H. intermedia is represented by a poorly preserved specimen, distorted by tectonic shearing and a small fault. Heer's drawing does not correctly represent the specimen and *H. intermedia* has in fact to be classified as *Scolicia* isp. (Text-fig. 3). Furthermore, because of its infrequent use it can also be regarded as *nomen nullum*.

Helminthopsis labyrinthica *Heer, 1877, p. 116*

'*Helminthopsis* fronde cylindrica, 2–3 mm. lata, valde flexuosa, gyrosa, gyris hippocrepicis.' *Helminthopsis* having cylindrical foliage, 2–3 mm wide, with numerous flexures, curved gyrately, or with horseshoe-like gyres.

H. labyrinthica is the only ichnospecies introduced by Heer (1877) which really justifies the definition of a new ichnogenus. *H. labyrinthica* is a loosely meandering form with horseshoe- or Ω-like turns. Typically, on bedding planes, it is a discontinuously preserved tube with short interruptions, but juxtaposed tubes also occur for short distances (Text-fig. 4). Thus, the producing animal must have left the bedding plane in a vertical direction and so *H. labyrinthica* must be a part of a three-dimensional burrow system. The short interruptions and juxtaposed tubes (observed on a nearly identical specimen) were interpreted by Seilacher (1977) as loops. However, he did not place his material in *H. labyrinthica*, but classified it as new ichnospecies *Cosmorhaphe helicoidea* (Seilacher 1977, p. 298, fig. 3*g*). Seilacher (1989) later introduced the ichnogenus *Spirocosmorhaphe* for this and similar trace fossils. For *Spirocosmorhaphe*, Seilacher (1989) deduced the three-dimensional nature of the burrow (see comment by Pickerill and McCann 1989), gave a satisfying explanation for the behavioural programme, and classified such burrows as belonging to the group of graphoglyptids. In fact *Spirocosmorhaphe helicoidea* is very similar to *H. labyrinthica* in pattern, shape, and size (Text-fig. 4). However, the congeneric nature of both traces could not have been recognized by Seilacher without studying the type material of Heer, because Heer's drawings do not show the kinks at the base of horseshoe-like turns and the occurrence of 'secondary' juxtaposed concave tubes (in plan view) accompanying the convex-shaped tube at the base of the horseshoe-like turns. These elements are particularly important for Seilacher's ichnogenus *Spirocosmorhaphe*.

H. labyrinthica is the only ichnospecies of *Helminthopsis* which has no senior synonym, and hence should be utilized as type ichnospecies. So the congeneric nature of *H. labyrinthica* and *S. helicoidea* produces a real dilemma. If the rules of priority are applied, Seilacher's *S. helicoidea* is a junior synonym of *H. labyrinthica* and can therefore be suppressed. Alternatively, Seilacher's ichnospecies may be renamed as *Spirocosmorhaphe labyrinthica* (Heer), the characteristic geometrical pattern residing in the ichnogenus name. The geometrical pattern is decidedly different from that of most trace fossils to which the name *Helminthopsis* has been applied. In order to provide nomenclatural stability in accordance with ICZN rules (Ride *et al.* 1985), the ichnogenus *Helminthopsis* should retain its present usage.

To solve the evident dilemma, we suggest using topotype material in Heer's collection as a basis for the definition of the ichnogenus *Helminthopsis*, to avoid further confusion with respect to Heer's initial description. The specimen we designate as type ichnospecies covers the present use of the

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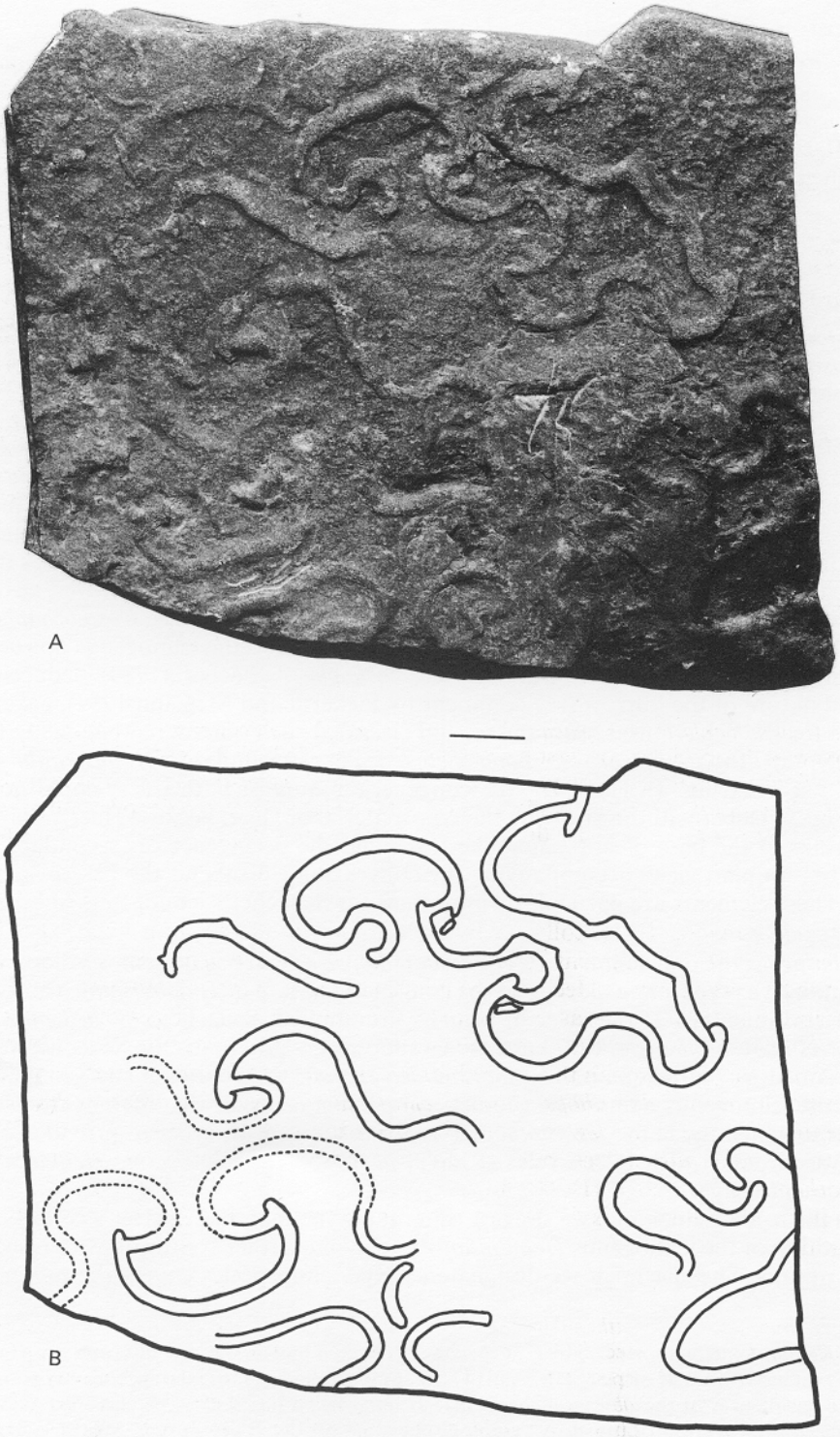
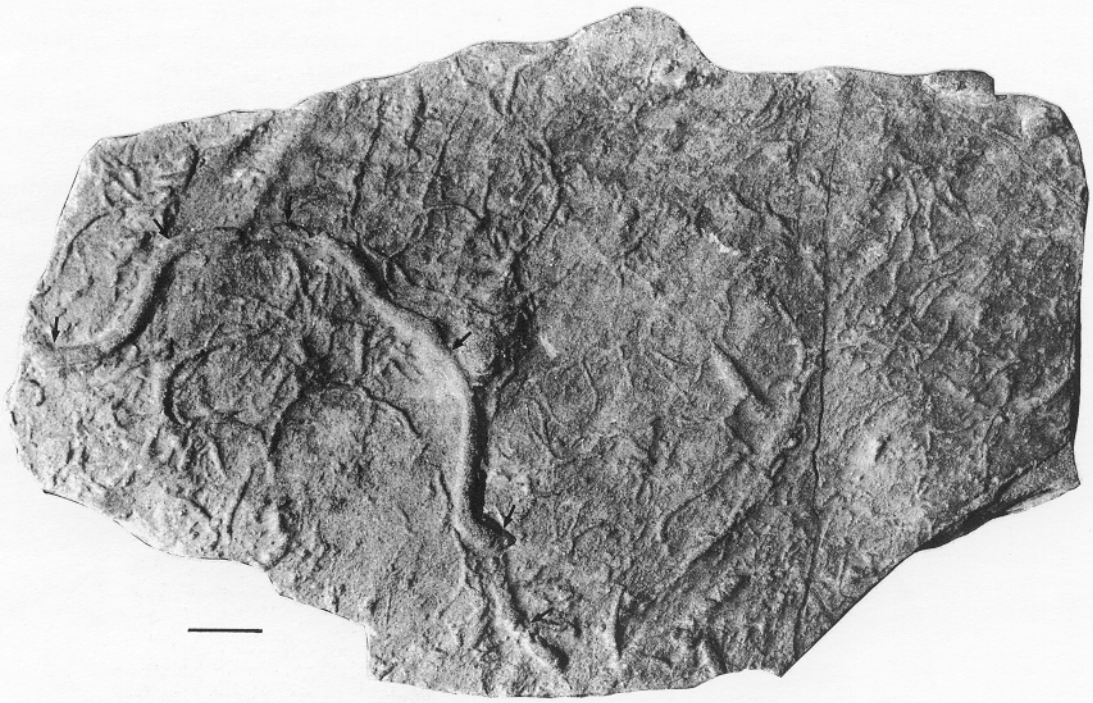
TEXT-FIG. 3. *Helminthopsis intermedia* Heer. A, specimen collected by Heer. B, our interpretation as line drawing which clearly differs from that of Heer (1877, pl. 47, fig. 6; see Text-fig. 1, 6); the specimen is poorly preserved; however, the parallelism of the strings suggests that *H. intermedia* has also to be classified as *Scolicia* isp. in *Subphyllochorda* preservation. Repository: Geologisches Institut der ETH Zürich, Switzerland; collection of the originals to Heer's book (1876/77) under the given plate and figure numbers. Scale bar represents 10 mm.



TEXT-FIG. 4. For caption see opposite.



TEXT-FIG. 5. *Helminthopsis hieroglyphica*. The large, irregularly meandering trace fossil is the designated holotype (arrows); the specimen was first figured by Maillard (1887, pl. 2, fig. 4). The densely packed, small trace fossils are of uncertain taxonomy, we suppose 'mycellia' as described by Wetzel (1983) or juvenile *Helminthopsis*? Repository: Geologisches Institut der ETH Zürich, Switzerland; collection of the originals to Maillard's publication (1887) under the given plate and figure numbers. Scale bar represents 10 mm.

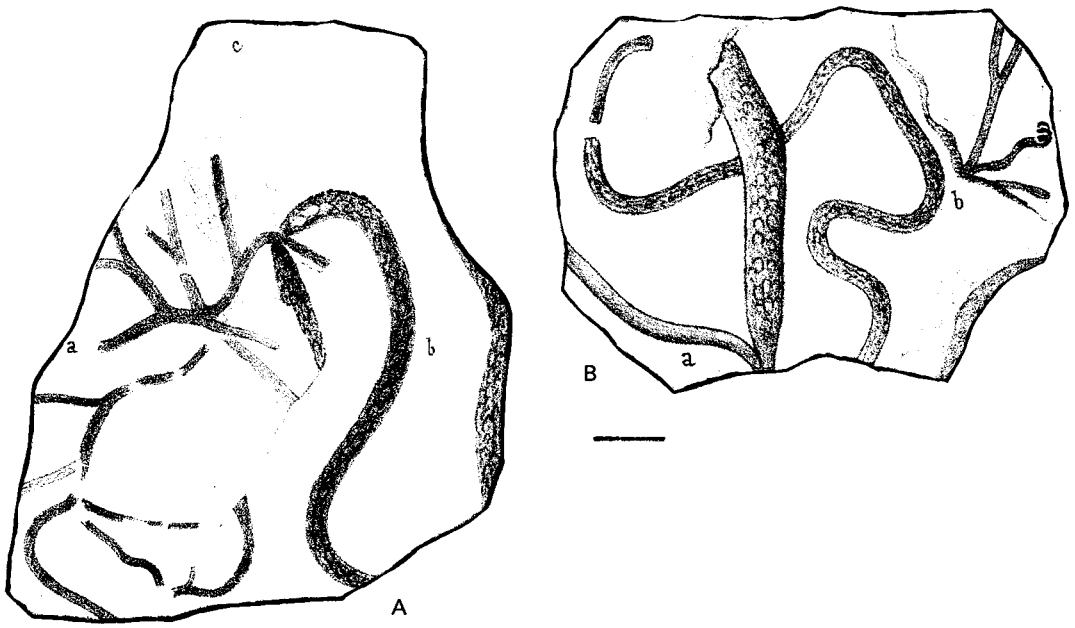
ichnogenus *Helminthopsis*. It was collected by Heer at the type locality and labelled as *Helminthopsis hieroglyphica* (without the comment *Helminthopsis labyrinthica in opere*, see above). This specimen was not figured or described by Heer, but Maillard (1887, pl. 2, fig. 4) subsequently figured it, and briefly described it in the captions as '*Helminthopsis hieroglyphica* which is a slightly curved trace...' (without a comment on a previous name). Because this specimen was not figured by Heer, there is no synonymy or congenerity with the figured *H. labyrinthica* specimens. Therefore we establish this specimen as holotype of *Helminthopsis hieroglyphica*, and propose that ichnospecies as the type for its ichnogenus. Furthermore we suggest (in accordance with ICZN, Article 23b) that the ichnospecies *H. labyrinthica* becomes a senior synonym of *Spirocosmorhaphe helicoidea* as *Spirocosmorhaphe labyrinthica* (Heer). In this way, the ichnogenus *Helminthopsis* Heer can be retained in its present use, and is defined by the ichnospecies *H. hieroglyphica*, collected by Heer at the type locality.

TEXT-FIG. 4. *Helminthopsis labyrinthica* Heer. A, specimen collected by Heer. B, line drawing by the authors of the larger specimen figured by Heer (1877, pl. 47 fig. 4; see our Text-fig. 1, 4); note that the drawing by Heer does not show all details of the specimens, especially the sharp kinks and the discontinuity of the tube which provide clear evidence that *H. labyrinthica* is identical to *Spirocosmorhaphe* isp. Seilacher, 1989. Repository: Geologisches Institut der ETH Zürich, Switzerland; collection of the originals to Heer's book (1876/77) under the given plate and figure numbers. Scale bar represents 10 mm.

Książkiewicz (1977) described some trace fossils as *H. hieroglyphica* and referred explicitly to Maillard (1887, pl. 2, fig. 4, and *non* pl. 1, fig. 2) in his description. Later Fillion and Pickerill (1984, 1990) and Crimes and Crossley (1991) ascribed specimens to *H. hieroglyphica*, which are all similar to the specimen collected by Heer and on which we base the new type ichnospecies. In their ichnotaxonomy, these authors referred to *H. hieroglyphica* Heer *in* Maillard (1887) but this ignores the fact that the change in name as mentioned by Maillard is invalid.

The tube of the holotype of *H. hieroglyphica* (Text-fig. 5) is not strictly attached to the bedding plane, which indicates that the trace was produced at varying depths within the sediment. This observation has the important implication that different modes of preservation can occur. In addition to burrows produced shallowly within the sediment and preserved in convex hyporelief (e.g. the type material), a full relief or concave epirelief preservation for deeply emplaced burrows is possible as reported by Chamberlain (1971) and Crimes *et al.* (1981).

With this last implication in mind, we were not surprised to discover in Heer's collection a trace fossil having the geometry and size of *Helminthopsis* in full relief preservation, but named *Theobaldia raetica* (Heer 1877, pl. 44, fig. 15*b*). The type material of *T. raetica* was found at the same locality as *Helminthopsis*, so we cannot leave this discussion without also dealing with *Theobaldia* (Text-fig. 6).



TEXT-FIG. 6. *Theobaldia raetica* Heer, as figured by Heer (1877), the specimens showing all details of *Helminthopsis*, but in full relief preservation. A, *Theobaldia raetica*, shown on plate 44, figure 1, resembles *Helminthopsis hieroglyphica*. B, *Theobaldia raetica*, shown on plate 44, figure 15*b*, resembles *Helminthopsis abeli*. The apparent branching is false. Specimen figured as B is lost, repository for specimen figured as A; Geologisches Institut der ETH Zürich, Switzerland; collection of the originals to Heer's book (1876/77) under the given plate and figure numbers. Scale bar represents 10 mm.

Heer (1877, p. 114) believed that *Theobaldia* was a fossil alga, having stems and leaves; so he included there fossils composed of tubes which he interpreted as stems, and *Chondrites* which he interpreted as leaves (cf. Häntzschel 1965, p. 92). If the *Chondrites* parts are disregarded, the remaining tubes have to be grouped into different ichnogenera.

Theobaldia raetica as shown by Heer (1877, pl. 44, fig. 1) can be classified as *Helminthopsis hieroglyphica* whereas the specimen shown on plate 44, figure 15*b* is similar to *Helminthopsis abeli* (see below).

Theobaldia minor resembles a part of *Nereites* isp. (described as a faecal ribbon form of *Scalarituba* by Chamberlain and Clark 1973, p. 678), but the specimens are too small to evaluate their true taxonomy.

Theobaldia circinalis (pl. 44, figs 7–10, *non* figs 11–14) has to be grouped with *Spirophycus* isp.; for the other specimens (pl. 44, figs 11–14) the taxonomic affinities are unclear, because Heer enhanced the structures on the original (rock) material with black ink.

Although *Theobaldia* has page priority over *Helminthopsis*, the former has been seldom used. The sparse use of these taxa and the doubtful combination of different taxa into one justify the removal of the senior synonym and the retention of the junior synonym.

CONCLUSIONS

1. The three species of *Helminthopsis* defined by Heer belong to two different ichnogenera.
(a) *H. magna* (type ichnospecies of Ulrich 1904; Andrews 1955; Fillion and Pickerill 1990) and *H. intermedia* are junior synonyms of *Scolicia* isp. de Quatrefages, 1849 and should be removed.
(b) *H. labyrinthica* is a senior synonym of *Spirocosmorhaphe helicoidea*, which is a graphoglyptid. To declare *H. labyrinthica* as senior synonym would entirely alter the understanding of the name *Helminthopsis* in its present use. In order to provide nomenclatural stability we would abandon this ichnospecies for *Helminthopsis* and regard it as *Spirocosmorhaphe labyrinthica*.

2. Instead, we define *Helminthopsis* on the basis of *H. hieroglyphica*, a name proposed but never validly introduced by Heer because he did it only *in litteris*. The holotype was collected by Heer at the same locality as yielded the 1877 specimens.

3. *H. hieroglyphica* corresponds closely to *Helminthopsis* auctt., and in choosing it we follow the lead of Fillion and Pickerill (1984, 1990) and Crimes and Crossley (1991).

4. The ichnospecies diagnosis is given below. The introduction of *H. hieroglyphica* as type ichnospecies is necessary because the lectotype of the ichnospecies *Helminthopsis abeli* is problematical.

5. The holotype of *Helminthopsis abeli* Książkiewicz, 1977 does not match the description, which requires irregular widely winding meanders as an important criterion; in fact the holotype shows narrow regular meanders. In our opinion the holotype has to be placed within *Cosmorhaphe* because it is nearly identical with respect to meander width, height and radius and tube width to the *Cosmorhaphe helminthopsidea* figured by Seilacher (1977, fig. 3*e*). However, the specimen is too small to detect a second-order meandering and hence its taxonomy remains uncertain.

6. *H. hieroglyphica* is not strictly attached to the bedding plane and hence various modes of preservation of *Helminthopsis* can occur. Normal preservation is in convex hyporelief (including the topotype material); full relief preservation is also possible.

7. Heer placed full relief preservation in *Theobaldia raetica*. However, *Theobaldia* is a problematical taxon which combines tubular trace fossils (stems) and *Chondrites* (leaves) into alga species. Even if the *Chondrites* elements are disregarded, the ichnospecies of *Theobaldia* belong to different ichnogenera. Although all the ichnospecies of *Theobaldia* are senior synonyms, we suggest declaring them as invalid senior synonyms because they have not been mentioned except by Andrews (1955)

and Häntzschel (1962, 1965, 1975), and are problematical in their combination of two trace fossil ichnogenera.

SYSTEMATIC ICHNOLOGY

Ichnogenus *Helminthopsis* Heer, 1877

non 1851 *Helminthopsis irregularis* (Schafhäutl), pl. 9, fig. 10 [= *Helminthopsis* isp., Schafhäutl, 1851].
non vp 1877 Theobaldia raetica Heer, p. 114, pl. 44, fig. 1 [= *Helminthopsis hieroglyphica* isp. nov.].
non 1877 *Theobaldia raetica* Heer, p. 114, pl. 44, fig. 15*b* [similar to *Helminthopsis abeli*, the specimen is lost].
non v 1877 Helminthopsis magna Heer, p. 116, pl. 47, figs 1–2 [= *Scolicia* isp. de Quatrefages, 1849].
non v 1877 Helminthopsis intermedia Heer, p. 116, pl. 47, fig. 6 [= *Scolicia* isp. de Quatrefages, 1849].
non 1888 *Helminthopsis antiqua* Sacco, p. 175, pl. 2, fig. 10 [probably = *Helminthopsis* isp. Schafhäutl, 1851].
non 1895 *Helminthopsis involuta* de Stefani *in* de Stefani *et al.*, pl. 14, fig. 1 [= *Spirorhaphe involuta* de Stefani, 1895 *in* de Stefani *et al.* 1895].
non 1895 *Helminthopsis barbeyana* de Stefani *in* de Stefani *et al.*, pl. 14, fig. 2 [= *Helminthopsis abeli* Książkiewicz, 1977].
non 1904 *Helminthopsis ?labyrinthica* Ulrich, p. 144, pl. 20, figs 2–3 [= *Cosmorhaphe lobata* Seilacher, 1977].
non 1904 *Helminthopsis magna* Ulrich, p. 144, pl. 21, figs 1–2 [= *Scolicia plana* Książkiewicz, 1970; identified by R. Pickerill, pers. comm. 1994].
non 1933 *Helminthopsis ?concentrica* Azpeitia Moros, p. 46, pl. 12, fig. 23 [= *Spirorhaphe involuta* de Stefani, 1895 *in* de Stefani *et al.* 1895].
non 1933 *Helminthopsis sinuosa* Azpeitia Moros, p. 45, pl. 14, fig. 24B [= *Cosmorhaphe sinuosa* Azpeitia Moros, 1933].
non 1947 *Helminthopsis labyrinthica* Wilckens, pl. 9, fig. 4 [= *Helminthopsis crassa* Schafhäutl, 1851 = *Helminthorhaphe crassa* (Schafhäutl) Seilacher, 1977].
non 1960 *Helminthopsis curvata* Katto, p. 333, pl. 35, fig. 1 [there described as *Tosahelminthes curvata* = *Helminthoida crassa* Schafhäutl, 1851 = *Helminthopsis crassa* (Schafhäutl) Seilacher, 1977].
non 1964 *Helminthopsis toyoensis* Katto, pl. 7, fig. 3 [figured specimen does not allow an exact classification and hence, is regarded as *nomen dubium*; R. Pickerill, pers. comm. 1994].
non 1967 *Helminthopsis* Macsotay, p. 31, fig. 30 [fig. 30 left = *Helminthoida* sp. Schafhäutl, 1851; fig. 30 middle = *Cosmorhaphe helminthopsidea* Sacco, 1888?; fig. 30 right = *Helminthorhaphe japonica* (Tanaka) Seilacher, 1977].
non v 1968 Helminthopsis granulata Książkiewicz, p. 7, pl. 4, fig. 2 [see below].
*v 1968 Helminthopsis tenuis Książkiewicz, p. 7, pl. 4, fig. 1.
non 1971 *Helminthopsis akkesiensis* Tanaka, pl. 2, fig. 2; pl. 3, fig. 4 [previously = *Magarikune akkesiensis* Minato and Suyama, 1949, today = *Cosmorhaphe* isp.; the specimens are too small for an exact taxonomic classification].
non v 1977 Helminthopsis abeli Książkiewicz only text-fig. 21*a*; pl. 12, fig. 5 [= *Cosmorhaphe helminthopsidea* Sacco, 1888].
v 1977 Helminthopsis abeli Książkiewicz, p. 117, text-fig. 21*c*; pl. 12, fig. 5.
non v 1977 Helminthopsis irregularis Książkiewicz, p. 119, text-fig. 22, pl. 12, fig. 2 [= *Helminthoida* isp., Schafhäutl, 1851].
non v 1981 Helminthopsis isp. Wetzel, p. 9, figs 4–5 [= *Phycosiphon incertum*, see Wetzel and Bromley 1994, p. 1400].
non v 1983 Helminthopsis isp. Wetzel, p. 290 [= *Phycosiphon incertum* von Fischer-Ooster, 1858, see Wetzel and Bromley 1994, p. 1400].
non v 1984 Helminthopsis isp. Wetzel, p. 599 [= *Phycosiphon incertum* von Fischer-Ooster, 1858, see Wetzel and Bromley 1994, p. 1400].
non 1986 *Helminthopsis tunluensis* Yang, pl. 1, fig. 5 [= *Helminthoida miocenica* Sacco, 1886].
non 1986 *Helminthopsis yushuensis* Yang, pl. 3, fig. 7 [= *Helminthoida miocenica* Sacco, 1886].
non 1989 *Helminthopsis sigmoideus* Wang, p. 28, fig. 2 [partly preserved specimen; because the exact burrow course cannot be ascertained it is regarded as *nomen dubium*; R. Pickerill, pers. comm. 1994].

non v 1990 Helminthopsis horizontalis (Kern) Bromley, pp. 214, 232, figs 11.20, 12.1, 12.3–12.4, 12.7–12.11 [= *Phycosiphon incertum* von Fischer-Ooster, 1858; see Wetzel and Bromley 1994, p. 1400].

non 1990 *Helminthopsis magna* Dam, p. 130, fig. 7B [probably = *Nereites* MacLeay, 1839, meandering part in faecal string preservation, cf. Chamberlain and Clark 1973, p. 678, pl. 1, fig. 5].

non 1991 *Helminthopsis regularis* Crimes and Crossley, p. 38, figs 4*c–d* and 5*m–n* [= *Cochlichnus anguineus* Hitchcock, 1858].

non 1992 *Helminthopsis* Pattinson, fig. 14A; Pemberton, MacEachern, and Ranger, fig. 7D; Pemberton, Reinson and MacEachern, figs 11D, 12B; Raychaudhuri *et al.*, figs 5G–H [= *Phycosiphon incertum* von Fischer-Ooster 1858, see Wetzel and Bromley 1994, p. 1400].

non 1992 *Helminthopsis/Anchonichnus* MacEachern *et al.*, figs 9E, H, 10H [= *Phycosiphon incertum* von Fischer-Ooster 1858].

non 1993 *Helminthopsis* isp. Miller, fig. 7B [= *Nereites* MacLeay, 1839 = faecal string preservation of *Scalarituba* Weller, 1899, cf. Chamberlain and Clark 1973, p. 678, pl. 1, fig. 5].

Type ichnospecies. Helminthopsis hieroglyphica isp. nov.

Emended diagnosis. Simple, unbranched, elongate, cylindrical tube with curves, windings, or irregular open meanders.

Description. The occurrence of burrow fills that are not strictly attached to the bedding plane indicates varying penetration depth of the burrow producers; shallowly emplaced burrows are normally cast and preserved as convex hyporelief. Crossings have not been observed. Burrow fill cast, seldom revealing faecal pellets, or massive with no indication of an internal structure. In full relief preservation, a subtle lining of fine-grained material can occur.

Remarks. Helminthopsis is a feeding burrow produced normally at shallow depth within sediment probably rich in benthic food. With respect to benthic food availability (Carney 1989) a shallow burrow depth is very likely.

In vertical sections the recognition of *Helminthopsis* is difficult, and confusion especially with *Planolites* could easily occur. *Helminthopsis* differs from *Palaeophycus* and *Macaronichnus* by having no distinct lining or mantle. *Gordia* differs from *Helminthopsis* in its looped form, having many level crossings and never showing meanders (cf. Pickerill and Peel 1990, 1991).

We found that the definition of Heer's different ichnospecies of *Helminthopsis* is in principle based on the geometrical pattern of the trace, whereas fill structure, pre- or post-depositional in origin, and width of the tube are subordinate and inconsistently used characteristics. Therefore, we suggest strictly using the geometrical pattern to define the ichnospecies. However, the strict application of geometric pattern as a taxonomic classifier differs from the concept proposed by Han and Pickerill (pers. comm. 1994) who also used ornamentation as a classifying criterion. Han and Pickerill (in litt.) retain three valid ichnospecies, *H. abeli*, *H. granulata*, and *H. hieroglyphica*, incorporating *H. tenuis* into *H. abeli*. For most of the ichnospecies, an irregular geometrical pattern is mentioned in the diagnosis, so we interpret the suggested ichnospecies in a wide sense and do not define new ichnospecies for each small deviation. According to these guidelines, the following ichnospecies should no longer be in use.

1. *Helminthopsis antiqua* Sacco, 1888. The specimen is too small to identify the complete geometrical pattern. Congenerity with other trace fossils is very likely; it probably represents a meandering part of *Helminthoida crassa*.

2. *Helminthopsis granulata* Książkiewicz, 1968. For various specimens a fill with faecal pellets (e.g. Crimes and Crossley 1991) or a granulation of the burrow margin by body appendages (Książkiewicz 1977) has been reported. As the geometrical pattern is used for classification of *Helminthopsis*, we suggest removing this ichnospecies and incorporating the individual specimens into *H. abeli*, *H. hieroglyphica* and *H. tenuis*. If the fill with pellets is believed to represent the taxobase, it should be placed in *Alcyonidiopsis* Massalongo, 1856. Furthermore, preservational effects may have produced the granulation of *Helminthopsis granulata*; in particular, striations produced by body appendages need a certain sediment consistency to be preserved by turbidity

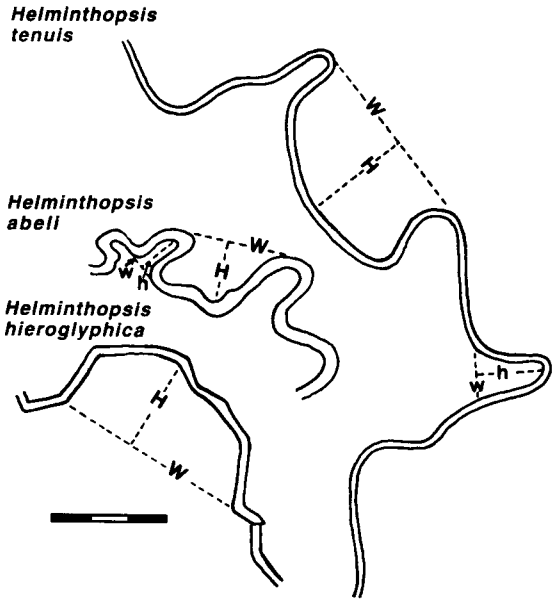
current winnowing and subsequent casting; so the ornamentation of type material of *Helminthopsis granulata* is only preserved on certain parts of the burrow where somewhat protected from the winnowing current.

3. *Helminthopsis irregularis* Schafhäutl, 1851. The tubes are so densely packed that an evaluation of the complete geometrical pattern is difficult, but U-turns and parallel tubes are evident suggesting a congenerity with *Nereites* isp. MacLeay, 1839 (= *Scalarituba* cf. Chamberlain and Clark 1973) or *Helminthoida* cf. *crassa* Schafhäutl, 1851.

4. *Helminthopsis regularis* Crimes and Crossley, 1991. Having regular high-amplitude low-wavelength windings, this should be placed in the ichnogenus *Cochlichnus* which comprises burrows of similar pattern.

5. *Helminthopsis tunluensis* Yang, 1986, and *H. yushuensis* Yang, 1986. Wave-length should not be used as classifying criterion; these specimens should therefore be placed in *Helminthoida* cf. *miocenica*.

6. The following ichnospecies are congeneric with other forms, as explained in the synonymy list: *H. akkesiensis*, *H. barbeyana*, *H. concentrica*?, *H. curvata*, *H. horizontalis*, *H. intermedia*, *H. involuta*, *H. labyrinthica*, *H. magna*, and *H. sinuosa*. Additionally, *H. sigmoideus* and *H. toyoensis* are regarded as *nomina dubia*.



TEXT-FIG. 7. Typical outlines of the valid *Helminthopsis* ichnospecies: *Helminthopsis abeli* (Książkiewicz 1977, text-fig. 21*c*), *Helminthopsis hieroglyphica* (type material) and *Helminthopsis tenuis* (Książkiewicz 1968, pl. 4, fig. 1). Single letters refer to measurements used in Table 1; H, W: height and width of large loops; h, w: height and width of small loops. Scale bar represents 30 mm.

The remaining ichnospecies clearly differ in their geometrical pattern when the type material is compared (Text-fig. 7).

1. *Helminthopsis abeli* Książkiewicz, 1977. This has irregular open meanders and horseshoe-like turns present. After removal of the lectotype (Abel 1935, fig. 261B) we suggest using the co-type (Książkiewicz 1977, pl. 12, fig. 5, no. UJ TF 1321) to define this ichnospecies.

2. *Helminthopsis hieroglyphica* isp. nov. This has irregular low-amplitude windings, partly straight (see below).

3. *Helminthopsis tenuis* Książkiewicz, 1968. This has irregular, high-amplitude windings, but only with U-turns; horseshoe-like turns are not present.

These differences in pattern can be expressed quantitatively (Table 1). It is important, however, to relate the geometrical characteristics of the windings to the tube diameter, otherwise the relationship will become misleading. For instance, if only the curvature of the centre line of the tube

TABLE 1. Geometrical measurements of the three *Helminthopsis* ichnospecies. The tube diameter is related to the body size of the producing animal. Therefore, the measurements of the windings are expressed as multiples of the diameter of the causative tube of the ichnospecies (see Text-fig. 7).

	H. abeli	*H. hieroglyphica*	*H. tenuis*
Small loop		None	
Width	1–2		6–10
Height	2–3		2–5
Wide loop			
Width	4–6	10	20–25
Height	2–4	20	10–15

on an absolute scale is used, *Scolicia* and *Helminthopsis abeli* do not differ. The same is true for *Helminthopsis abeli* and *Helminthopsis tenuis*.

Helminthopsis hieroglyphica isp. nov.

Text-figures 5, 7

v. 1887 Helminthopsis hieroglyphica Maillard, pl. 2, fig. 4.
non v 1887 Helminthopsis hieroglyphica Maillard, only pl. 1, fig. 2 [= *Spirocosmorhaphe helicoidea* Seilacher, 1989].
non 1888 *Helminthopsis hieroglyphyca* Sacco, p. 175, pl. 2, figs 2, 11 [the specimens are too small to identify the complete geometrical pattern; pl. 2, fig. 2 supposedly = *Helminthopsis abeli*; pl. 2, fig. 11 supposedly = *Spirocosmorhaphe helicoidea* Seilacher, 1989].
v. 1977 Helminthopsis hieroglyphica Książkiewicz, p. 119, text-figs 21*i*, *k–o*, pl. 12, fig. 3.
. 1984 Helminthopsis hieroglyphica Fillion and Pickerill, fig. 9*e*.
. 1988 *Helminthopsis hieroglyphica* McCann and Pickerill, p. 337, pl. 4, fig. 3.
. 1990 Helminthopsis hieroglyphica Fillion and Pickerill, p. 37, pl. 8, fig. 12.
. 1991 Helminthopsis hieroglyphica Crimes and Crossley, p. 38, figs 5*j–l*.
. 1992 *Helminthopsis hieroglyphica* Crimes *et al.*, p. 65, fig. 5A.
. 1993 *Helminthopsis hieroglyphica* McCann, p. 45, fig. 4I.

Repository. Collection of the Geological Institute of the ETH Zürich, Maillard 1887 collection (original for pl. 2, fig. 4).

Diagnosis. Strings 5–10 mm in diameter with irregular windings of low amplitude; the windings are composed of low-angle kinks and straight sections giving the trace a box-shaped fold appearance.

Description. The most characteristic features of this ichnospecies are straight element with often kinky curves giving a box-shaped fold appearance. Somewhat similar forms occur in *Helminthopsis tenuis*, but the strings are much thinner and the box-like arrangement is not so well developed.

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NOTE ADDED IN PROOF

While this contribution was in print, Han and Pickerill (1995) published a paper 'Taxonomic review of the ichnogenus *Helminthopsis* Heer 1877 with a statistical analysis of selected ichnospecies'. These authors based their taxonomic evaluation on the statistical method of 'Fourier Transfer Analysis' (FTA) applied to the course of *Helminthopsis* to distinguish the various ichnospecies. It is a fact that FTA can only be performed on uniquely determined and continuous functions (e.g. Bracewell 1978); therefore burrows having a bell-shaped element or other geometrical pattern, which provides in a coordinate system more tha one y-value for one point on the x-axis (i.e. they are not uniquely determined in x), need to be transformed into a uniquely determined and continuous form. Doing this by the method used by Han and Pickerill causes important geometrical information on the burrow course to be lost while all bell-shaped elements become smoothed-out (see their fig. 3). That this transformation procedure is unsuitable can easily be tested; the forward transformation is uniquely determined, while the backward transformation is not (the statement on this point by Han and Pickerill is wrong), because the inverted function allows the production of more than one burrow course. Consequently, the FT analysis is performed on wrongly produced functions and the results are meaningless. In conclusion, the method applied by Han and Pickerill is not suitable for this specific problem and cannot produce significant results. Thus, the ichnotaxonomy based on this type of transformation method is unreliable. So we suggest our revised taxonomy, which is based on the type material (and not on figures in the literature) and which can be easily performed by everybody because it is based on simple geometrical analysis.

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