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Measurements on Lower Miocene *Sphenolithus* Populations

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With 12 Figures and 2 Plates

Southern Atlantic
Sphenolithus
Miocene
Biometry

Contents

Zusammenfassung

Sphenolithus-Populationen aus den Nannoplankton-Zonen NN 2–5 wurden biometrisch untersucht. Die *Sphenolithus*-Exemplare können im Lichtmikroskop in 5 Typen gruppiert werden. Größe und Größenverhältnisse definieren nicht exakt die Unterschiede zwischen den einzelnen Arten; die Hauptkriterien für die Identifikation liegen im optischen Verhalten der Individuen. Die Populationen zeigen auch einen graduellen Wechsel im Lauf der Zeit und manchmal kommt es auch zu Überlappungen zwischen den biometrischen Mustern.

Abstract

Sphenolithus populations of nine samples from the NN 2–5 nannoplankton zones were biometrically investigated. The *Sphenolithus* specimens can be grouped into five types according to their appearance in the light microscope. The size and the size ratios do not define perfectly the differences between the distinct taxons, the main criteria for the identification are given by the optical behaviour of the specimens. The populations show a gradual change through time and sometimes there is an overlap between their biometrical patterns.

1. Introduction

The description and definition of the calcareous nannoplankton species has no uniform rules: Some important nannoplankton species were described from light microscope investigations in normal light, other specialists also used the optical characteristics of the nannofossil in polarized light, and further more large number of nannoplankton was described from transmission or scanning electron microscope photographs. Thus, it is not always easy to correlate these descriptions with each other and with our own research-material.

On top of this the fossils themselves may deviate from the characteristics of the holotype. However, if a large population of the respective species is at our disposal, it always contains some specimens which can easily be correlated with the holotype.

The situation is not so simple in nannoplankton assemblages of low diversity and abundance. One has to face the problems above in working with Lower Miocene nannoplankton from epicontinental sediments at higher latitudes. Such important genera as *Discoaster* and *Sphenolithus* are rare – 2–3 specimens/sample – or are lacking at all. The identification of the single, sporadic specimens of *Sphenolithus* has a special significance in such cases.

In the NN 2–5 nannoplankton zones the determination of the zone depends mainly on the proper identification of rare, sometimes dissolved or overgrown *Sphenolithus* specimens, which do not appear always in their "holotype-form".

For the proper determination of the index-fossils *Sphenolithus belemnos* and *S. heteromorphus* I decided to measure their characteristics in large populations, to observe their optical behaviour and to examine, whether there was any morphological overlap between these forms and whether they were biometrically different.

A similar attempt to distinguish two species from a large population using biometric methods was made earlier by TOWE (1979). He observed a total transition between *Sphenolithus moriformis* and *S. radians*, though the holotypes have different features. TOWE's investigations however did not take account of the optical behaviour of the respective species.

2. Materials and Method

Two series of samples were placed at my disposal: sites DSDP 516 and DSDP 362 from the South-Atlantic. I am greatly indebted to M.P. AUBRY-BERGGREN, F. PROTO-DECIMA and M. BÁLDI -BEKE for ensuring this material.

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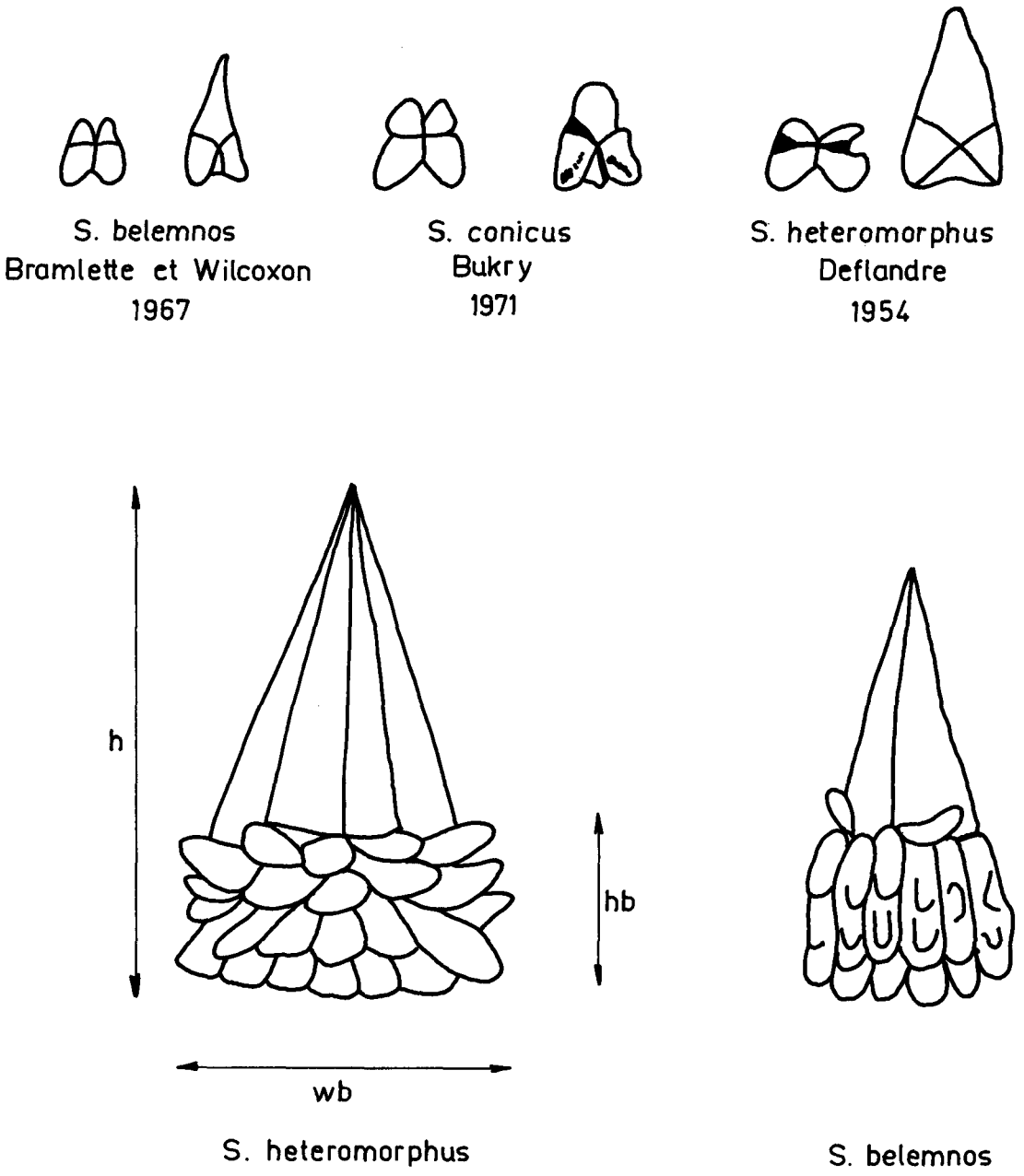

Fig. 1: Extinction pattern of some *Sphenolithus* species in polarized light at 0° and 45° angle to the polarizer after the photographs of the holotypes. Construction of *S. belemnos* and *S. heteromorphus* after ROTH, FRANZ & WISE (1971).

The following samples were studied:

DSDP site 516

22–2, 110–112 cm – NN 5
25–2, 70– 72 cm – NN 4/3 boundary
26–1, 60– 62 cm – NN 3
27–1, 70– 72 cm – NN 3
29–1, 133–135 cm – NN 3/?
38–1, 70– 72 cm – NN 2 with *Discoaster drugii* and *Triquetrorhabdulus carinatus*

DSDP site 362

35–5 – NN 5
37–6 – NN 4
38–5 – NN 3

The age-determinations were made by AUBRY-BERGGREN, PROTO-DECIMA and the author.

Measurements were carried out by light microscope and by using photographs. Not all *Sphenolithus* specimens and species were measured, only those with an elongate shape. Usually 50–80 specimens per sample were measured. *Sphenolithus conicus*, rare specimens of *S. dissimilis* and *S. delphix* were measured together with the larger populations of *S. belemnos* and *S. heteromorphus*.

Three characteristics of the shape were taken into account (Figure. 1): the height (**h**) of the total specimen (base and apical spine), the height of the base (**hb**) and the width of the base (**wb**), all three in side-view. The extinction-pattern of the specimen in cross-polarized light was also noted with a 45° angle between the polarizer and the main axis of the specimen.

Two types of extinction pattern were observed (Fig. 1):

- In the *S. heteromorphus*-type the lower two extinction-arms of the base point toward the two corners of the base at an angle of 80° or more.

- In the *S. belemnos* type the lower two extinction-arms of the base point toward the lower margin of the base, at an angle of less than 80°. *S. conicus* and *S. dissimilis* have an extinction similar to that of *S. belemnos*. The extinction angle of *S. delphix* is between that of *S. heteromorphus* and *S. belemnos*.

The difference of the extinction pattern is due to the construction of the base (Fig. 1). The base of *S. heteromorphus* consists of proximal and lateral elements which radiate from the center of the base in different directions in the manner of a spherolite. The elements, which form a 45° angle to the main axis point towards the corners of the base, causing the extinction-pattern described above. The base of *S. belemnos* consists of nearly vertical column-like elements, which enclose an angle of less than 45° with the main axis (ROTH et al., 1971).

The values measured have been plotted on three diagrams per sample:

h values against **hb**,
h values against **wb**
and
h/hb values against **h/wb**.

h/hb shows the ratio between the lengths of the total specimen and the base, **h/wb** shows the "slenderness" of the specimen. Plotting **h/hb** against **h/wb** on the same diagram we can see the changes in the proportions of the shape being independent from the actual size of the specimen.

3. Selection of types

Sample 516–31, 70–72 cm

Common *S. capricornutus* and *S. moriformis* characterize the *Sphenolithus* assemblage. A few *S. conicus* occur together with very rare and not typical *S. belemnos*. Bifurcated and trifurcated specimens were also found. The sample does not contain enough of the concerned *Sphenolithus*-species, so no diagrams were drawn.

Sample 516–29–1, 133–135 cm (Fig. 2)

The main *Sphenolithus* of this sample is a form near to *S. conicus* (A-type). Its extinction is *S. belemnos*-type, only a few specimens show *S. heteromorphus*-type extinctions. **hb** is always greater than half of **h**. The width of the base is equal with the total height or slightly less.

The few typical *S. belemnos* have more slender shape. **wb** values are half of the height or slightly more (B-type). There is a slight overlap between the two forms.

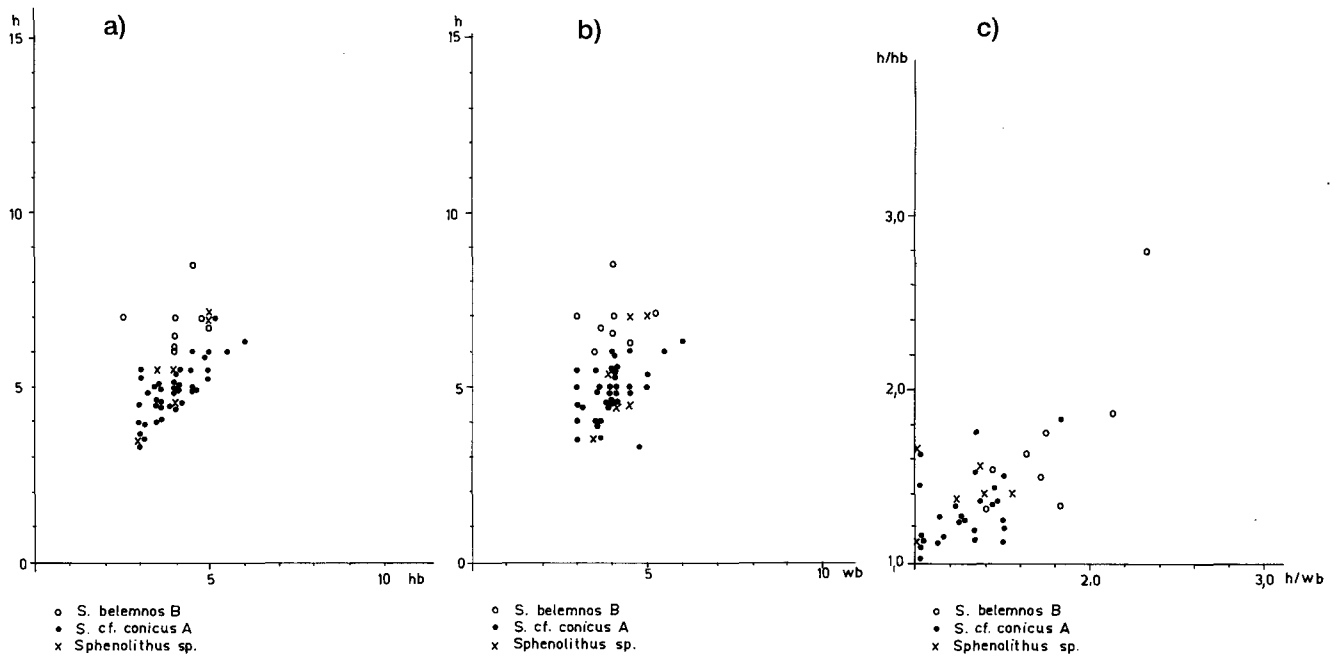

Fig. 2: DSDP 72/516/29/1.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.
X = forms with a shape of *S. conicus* and *S. heteromorphus*-like extinction.

Sample 516–27–1, 70–72 cm (Fig. 3)

The bulk of the *Sphenolithus*-population consists of *S. moriformis* and *S. belemnos*. The typical *S. belemnos*-like extinction-pattern was observed on both the long, slender (B-type) and short, robust (A-type) forms. The h may exceed 3–4 times the hb value, though a number of specimens show less than h = 2·hb proportions.

The situation is similar in the h-wb relation. The quantity of B-type in the sample is much greater than that of A-type. Rare specimens of the more robust form display *S. heteromorphus*-like extinction pattern. The transition between slender and robust forms is gradual.

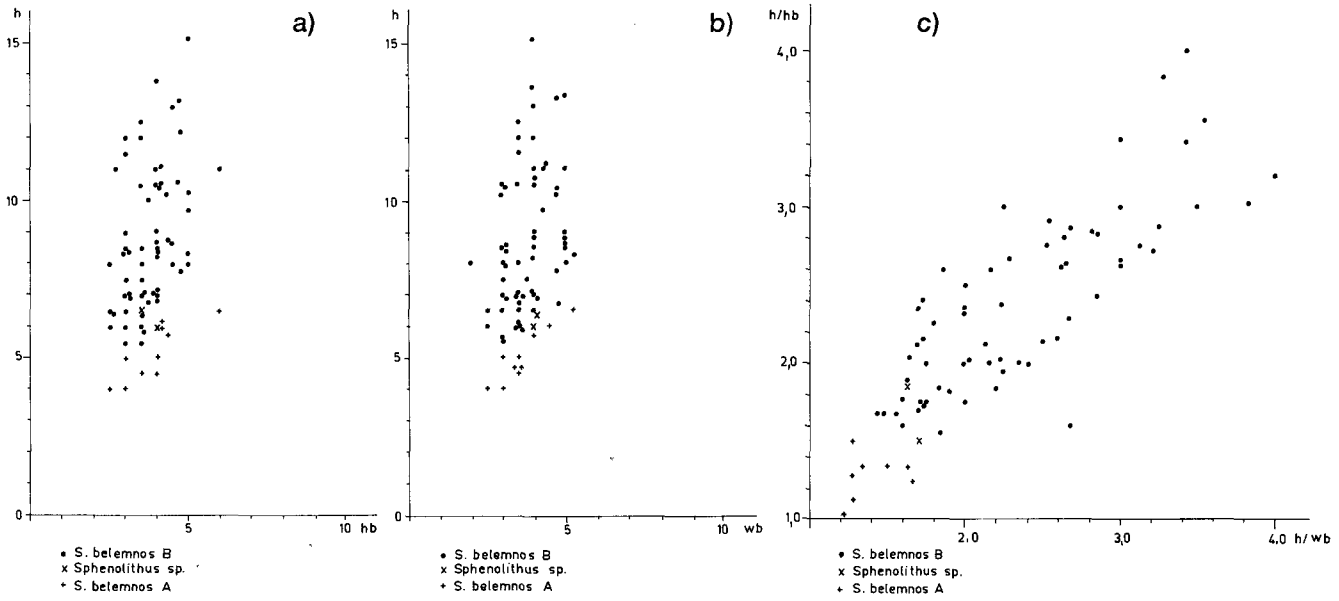

Fig. 3: DSDP 72/516/27/1.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.
X = forms with a shape of *S. conicus* and *S. heteromorphus*-like extinction.

Sample 516–26–1, 60–62 cm (Fig. 4)

S. moriformis and *S. capricornutus* were not measured. The most common form is robust with a *S. heteromorphus*-like extinction pattern. Its h-value hardly exceeds the hb and wb values (*S.* cf. *S. heteromorphus*, C-type). The few specimens of *S. conicus* (A-type) differ from the C-type of *S.* cf. *heteromorphus* only in their *S. belemnos*-like extinction.

Rare *S. belemnos* show a more slender shape. Its h/hb and h/wb proportion is between 1,5–2,0 (B-type). Their biometrical position can be well distinguished from the C-type of *S.* cf. *S. heteromorphus*.

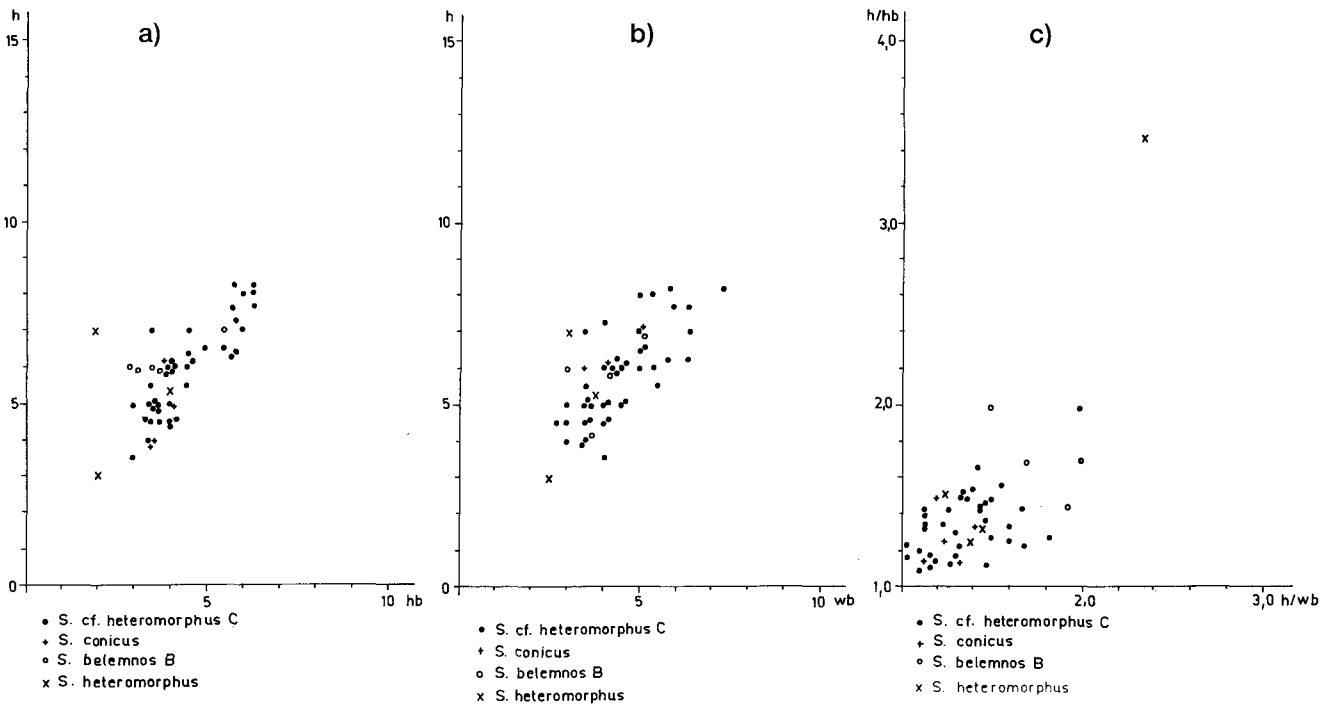

Fig. 4: DSDP 72/516/26/1.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

Sample 516–25–1, 70–72 cm (Fig. 5)

The most common isometric form is *S. moriformis*. The only elongated *Sphenolithus* of this sample is *S. heteromorphus*. A slender and robust form (D and E-type) was subjectively checked during the measurings and was found to show a full transition on the diagram.

The more robust forms have a **h/hb** ratio about 2/1 and **h/wb** ratio about 1,5–2,0/1. The slender forms display **h/hb** and **h/wb** ratios between 2–4. Among the long, slender variants of *S. heteromorphus* a special form is common with a long, drop-like apical spine. Rare specimens of *S. belemnos* demonstrate the same proportions as in the samples before.

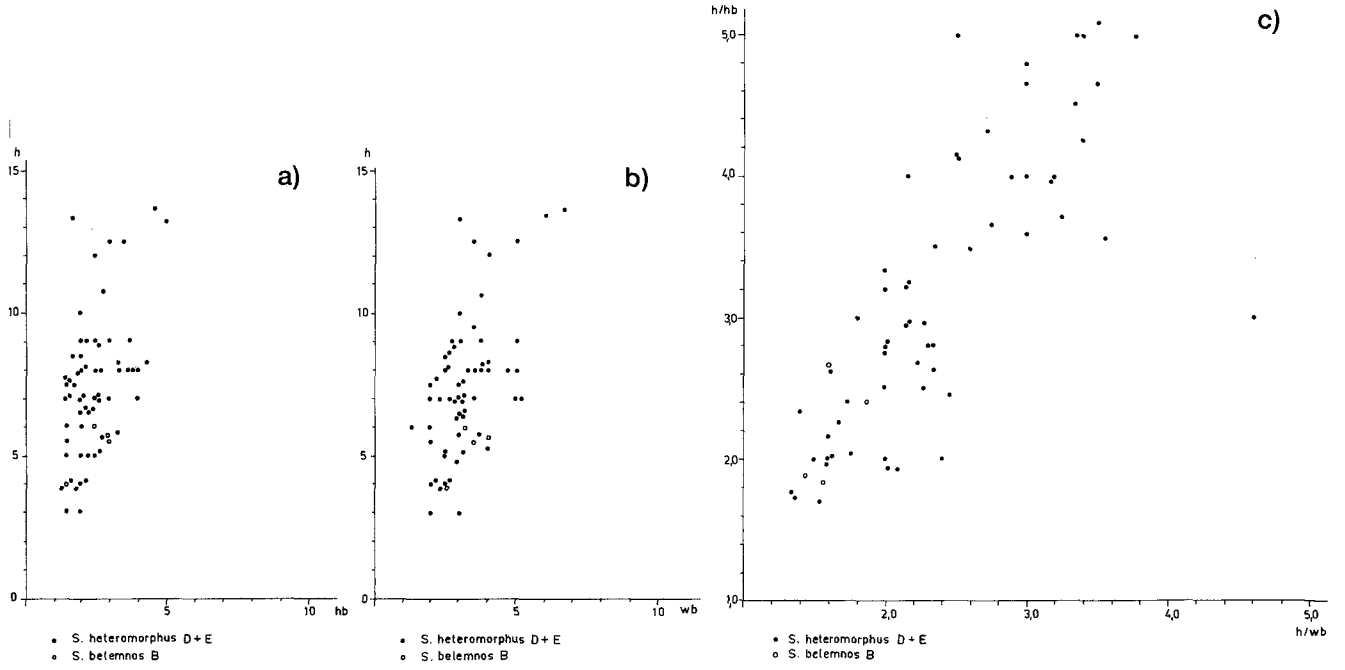

Fig. 5: DSDP 72/516/25/1.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

Sample 516–22–2, 110–112 cm (Fig. 6)

Besides *S. moriformis*, the *Sphenolithus* population of this sample consists solely of the uniform E-type of *S. heteromorphus*. The **h/hb** values fall inbetween 2 and 3, **h** exceeds about twice the **hb** values. Extremely elongated forms and the drop-like apical spines are lacking.

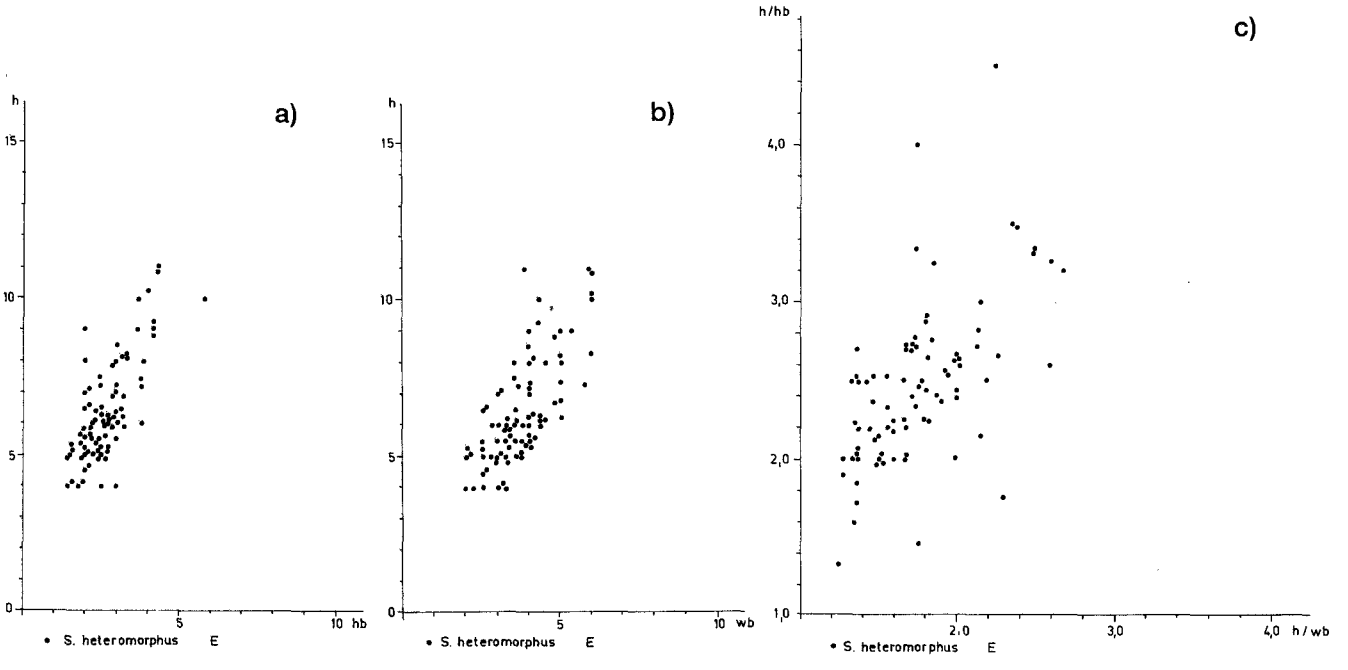

Fig. 6: DSDP 72/516/22/2.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

Sample 362–38–5, cc (Fig. 7)

Typical forms of *S. belemnos* are abundant, however the population shows a great variability in size and shape: **h/hb** and **h/wb** varies between 1–3 (B-type). Robust *S.*cf. *heteromorphus* (type C) occurs in the sample too, with a base-height and base-width equal or near to the total height. The population of the C-type seems to be well-distinguished from the B-type of *S. belemnos* on the **h/hb-h/wb** diagram.

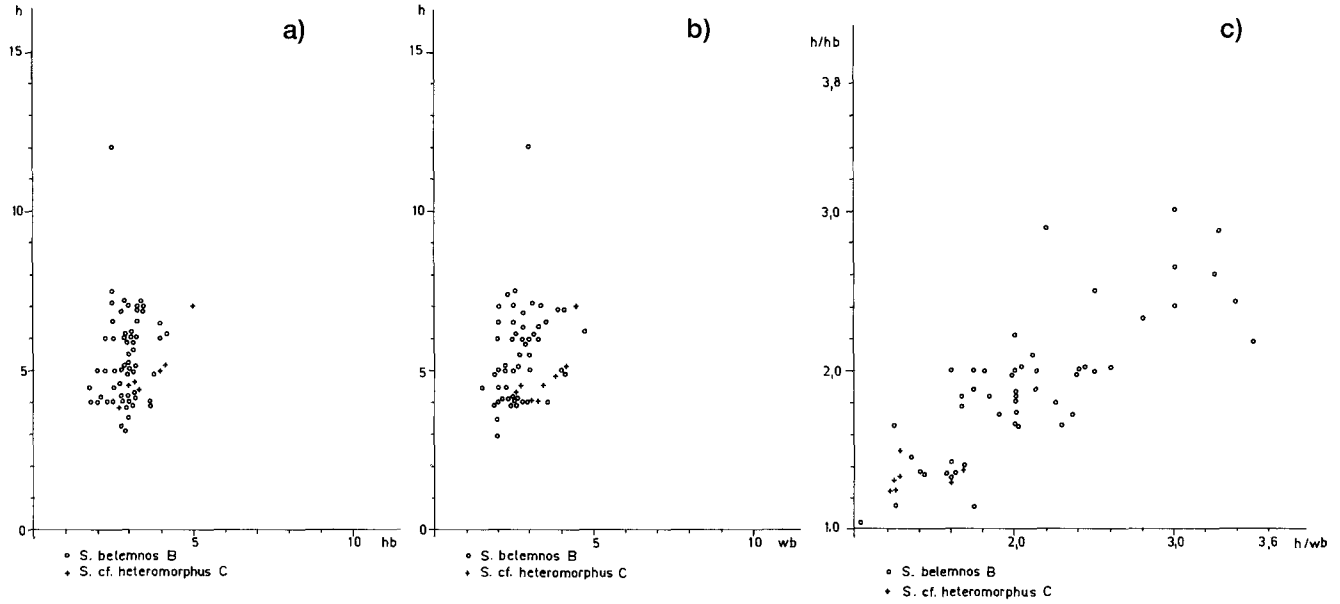

Fig. 7: DSDP 40/362/38.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

Sample 362–37–6, cc (Fig. 8)

The population consists of slender (D-type) and robust (E-type) forms of *S. heteromorphus*. Contrary to the initially subjective distinction of the two types, no break was observed biometrically between the two types.

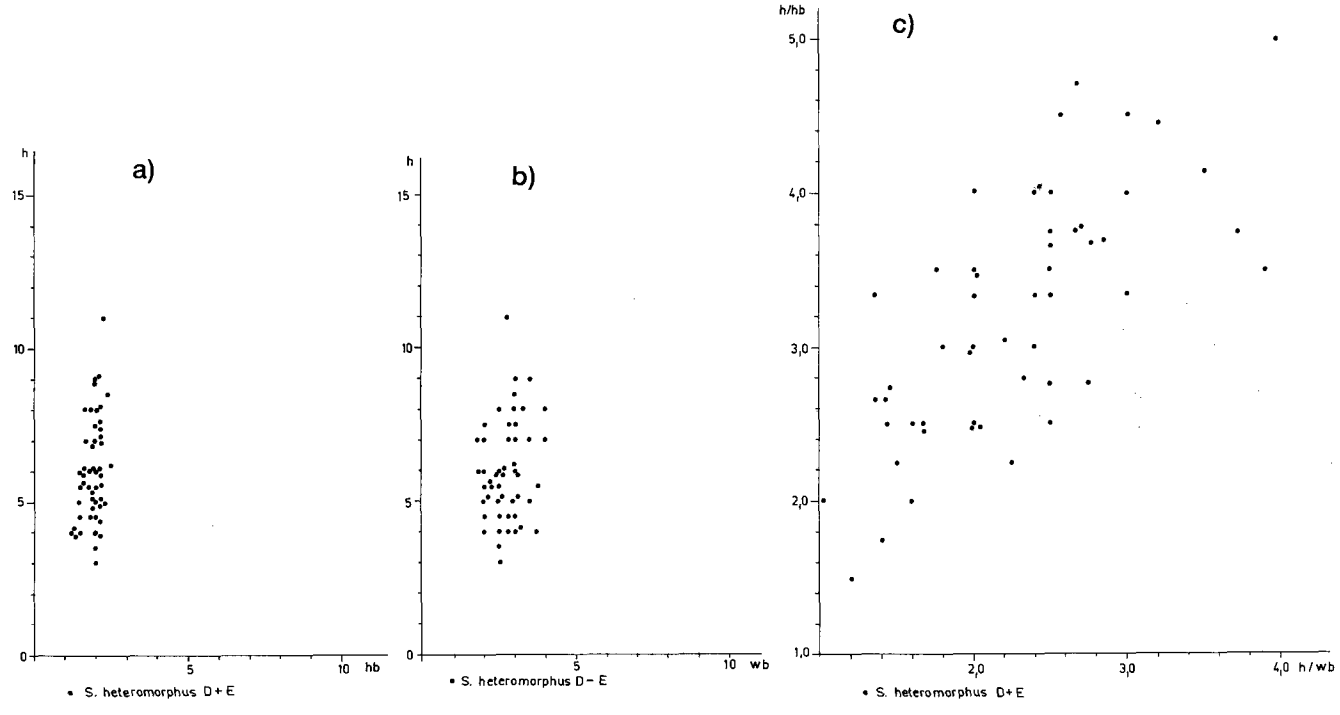

Fig. 8: DSDP 40/362/37.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

Sample 362–35–5, cc (Fig. 9)

The *Sphenolithus heteromorphus* population of this sample consists exclusively of E-types, thus only 25 specimens have been measured. The robust specimens have **h/hb** and **h/wb** values not exceeding 3/1.

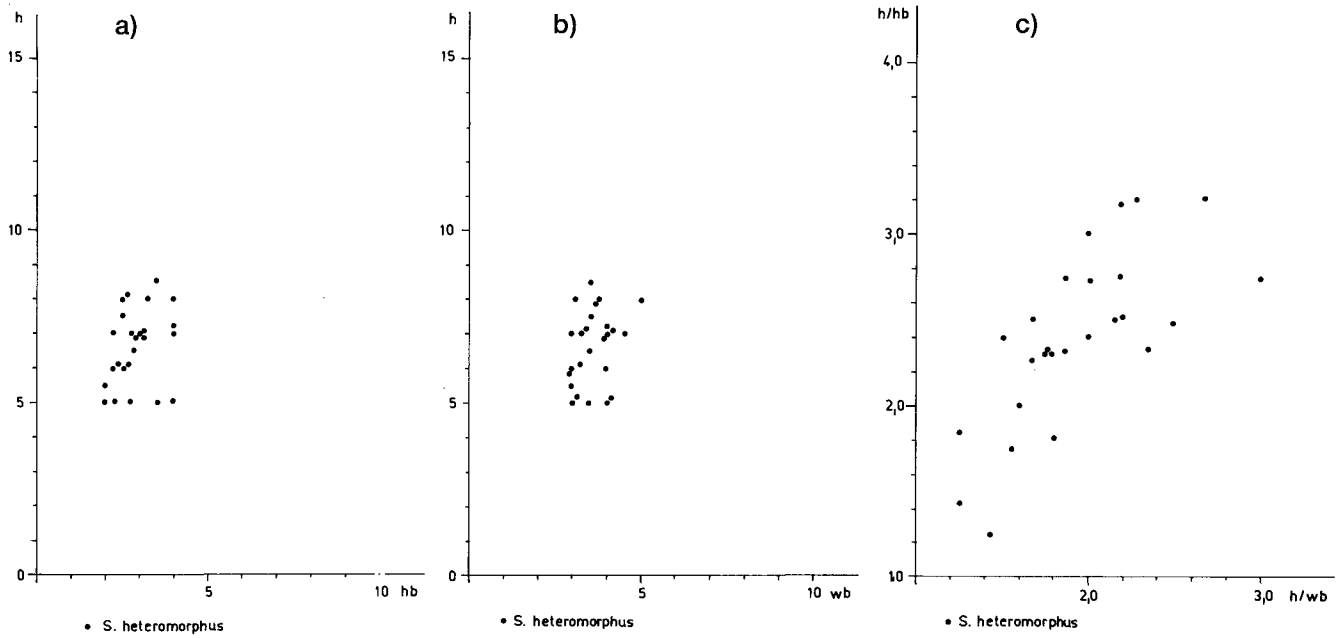

Fig. 9: DSDP 40/362/35.
a) h values plotted against hb; b) h values plotted against wb; c) h/hb values plotted against h/wb.

4. Conclusions

❶ As a conclusion of the measurements it appears that the Lower Miocene *Sphenolithus* species cannot be distinguished by purely biometric methods. The parameters of the species – size and size-ratios – overlap each other or show gradual transitions from one to the other as shown in Figs. 10–12.
This graduality can be observed well in the NN 3 assemblages of both sites. A great number of specimens produce all varieties between two extremes, i. e. *S. conicus* (A-type) and *S. belemnos* (B-type).

❷ An attempt was made to separate the *S. belemnos* – *S. heteromorphus*-like specimens into types:
A: *S. belemnos/S. conicus*. Relatively small, robust specimens with a short apical spine and wide base. Their extinction differs from that of *S. heteromorphus*.
B: *S. belemnos*, with a more elongated shape. Its **h/hb** and **h/wb** ratios are greater than those of type A.
C: *S. heteromorphus* with an extremely robust shape (**h** and **wb** are almost equal).
D: *S. heteromorphus*, with an elongated shape and long, slender apical spine.
E: *S. heteromorphus* with a robust shape. Its **h/wb** value is between that of C and D-types. Its apical spine is longer than that of the C-type, but shorter than that of the D-type.
The biometrical areas of *S. belemnos/S. conicus* (A and B-types) and *S. heteromorphus* (C, D and E-types) overlap each other fairly. A noticeable break has shown up between *S. belemnos/S. conicus* and *S.* cf. *heteromorphus* (C-type) in sample 362–38–5. The C-type is separated from the B-type *S. belemnos* by its more robust appearance and a different extinction, while it differs from the A-type *S. belemnos/S. conicus* only in its extinction. Otherwise, their proportions in shape are very similar.
Though differing in extinction, the long, slender *S. belemnos* (B-type) and the D and E-type *S. heteromorphus* have a very similar shape. However, the D-type *S. heteromorphus* is usually more elongated than *S. belemnos* (B-type) and its **h/hb** ratio is greater, too.

❸ Both *S. conicus/S. belemnos* and *S. heteromorphus* show an evolution through time. (It is possible, that these forms might have varied in space, too, but this paper deals only with S-Atlantic material).
The *S. belemnos/S. conicus* group appears in the NN 3(?) sample with the dominance of the A-form: **h/hb** = 1,1–1,2. In this sample the slender B-form is sporadic only. In the NN 3 samples the height of the specimens and their **h/hb** – **h/wb** values reach their maximum. The size of *S. belemnos* shortens again near to the NN 3/4 boundary, its "slenderness" **h/wb** decreases too.
S. heteromorphus-like forms appear near to the end of the NN 3 zone (*S.* cf. *heteromorphus*, C-type). The C-type is characterized by a very short apical spine, its **h/hb** is hardly more than 1. The **hb** and **wb** values are almost equal. At the NN 3/4 boundary the group reaches its maximum height: some of the specimens exceed 15 microns! However the whole population is strongly variable in size and proportion. The **h/hb** values vary between 1,5–3,5, the **h/wb** between 1,5–3,0. There is a smooth transition

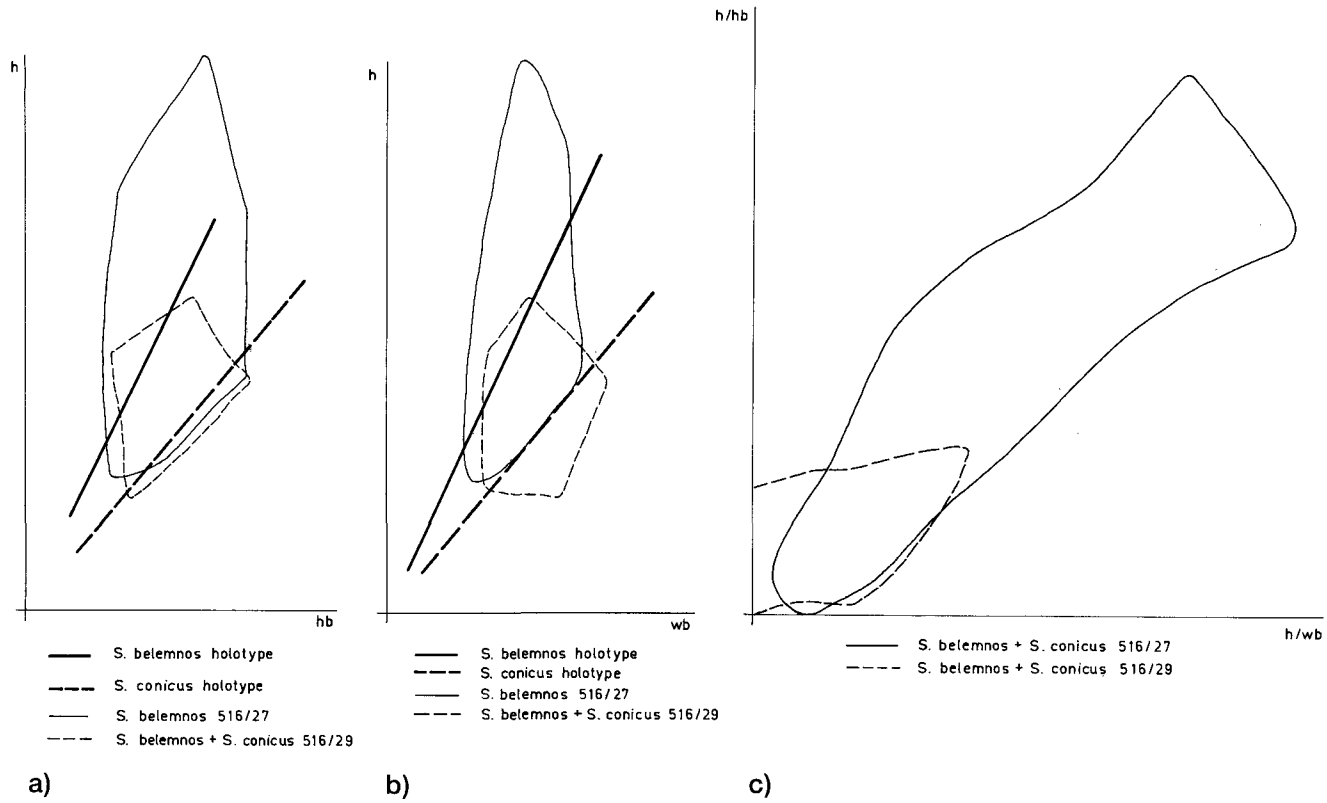

Fig. 10: DSDP 72/516/29 and 27.
a: biometrical fields, h plotted against hb; b) biometrical fields, h plotted against wb; c) biometrical fields, h/hb plotted against h/wb.

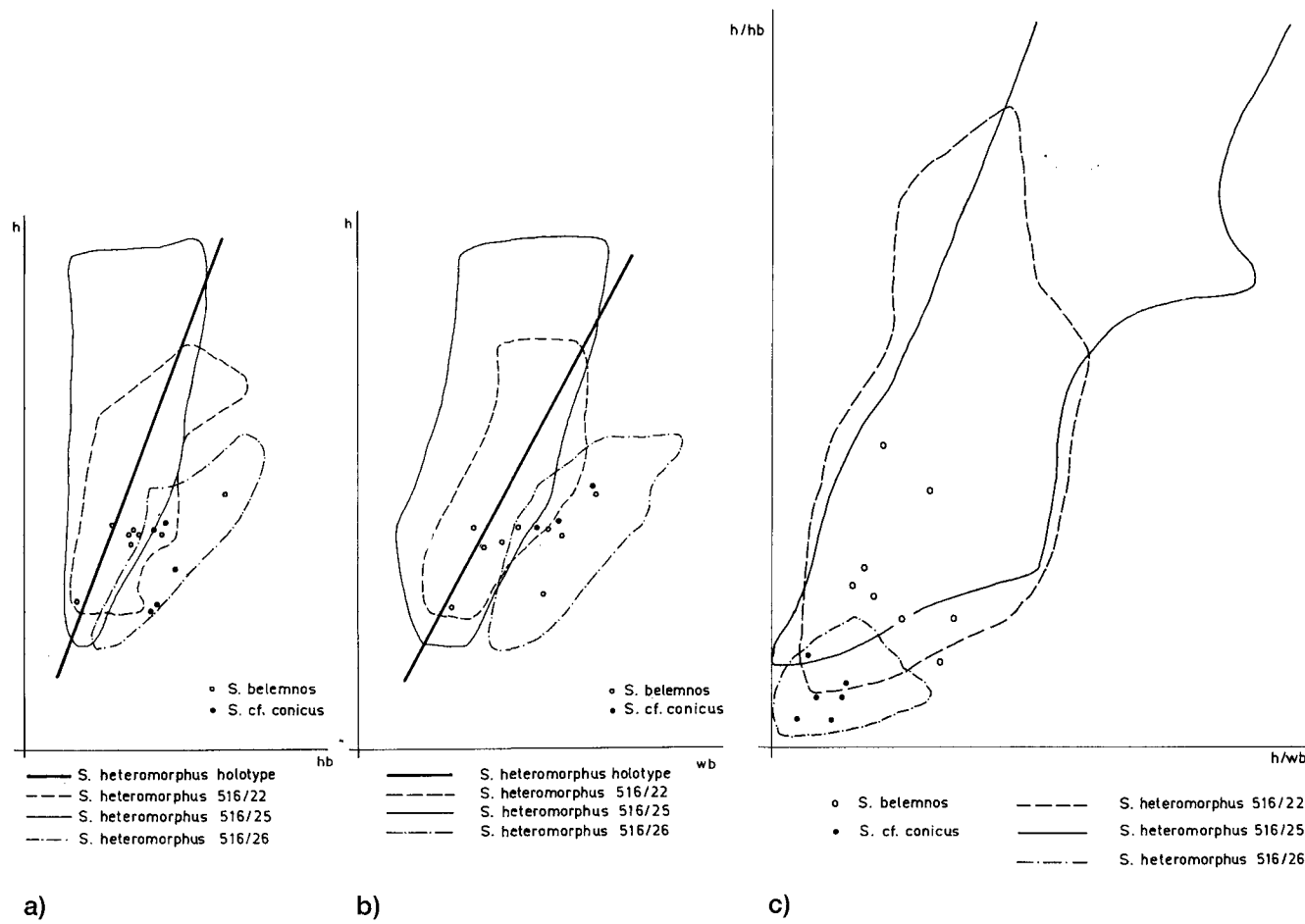

Fig. 11: DSDP 72/516/22, 25 and 26.
a: biometrical fields, h plotted against hb; b) biometrical fields, h plotted against wb; c) biometrical fields, h/hb plotted against h/wb.

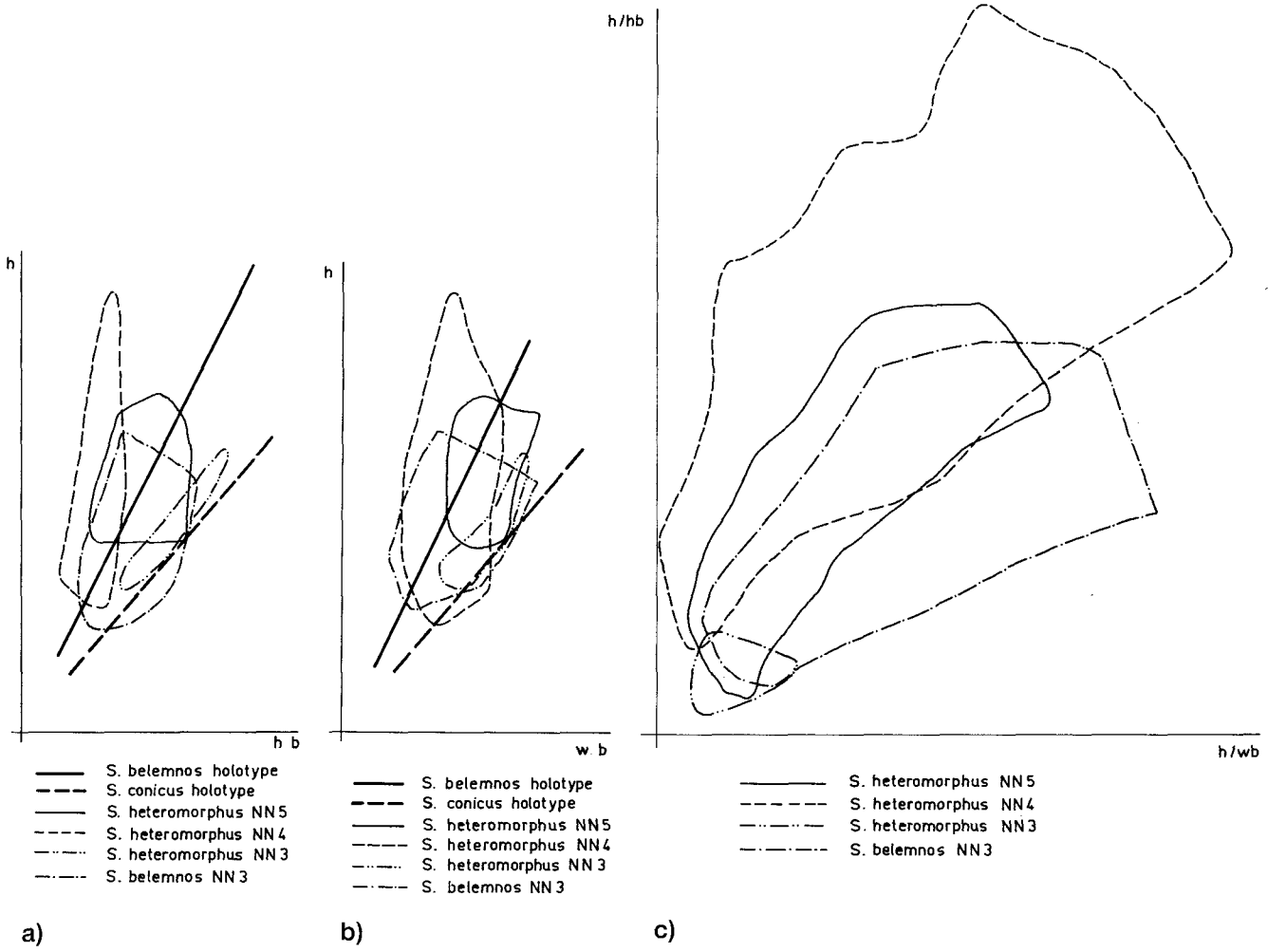

Fig. 12: DSDP 40/362/38, 37 and 35.
a: biometrical fields, h plotted against hb; b) biometrical fields, h plotted against wb; c) biometrical fields, h/hb plotted against h/wb.

between the robust E and slender D-forms (by the way, the compressed E-type is more slender than the C-forms of the NN 3 zone). A decrease in size and "slenderness" was observed in the NN 5 samples, which means a predominance of the E-type (Figs. 11–12).

❹ As a general trend, an interesting relation was observed between the **h**, **hb** and **wb** values: at increasing values of **h/hb**, the **h/wb** values do not show the same increase. This means, that the longer the apical spine, the more slender will be the entire fossil, since the width of the base does not keep up with the increase of the apical spine. The same relation exists also between **h** and **hb**: the increase of the length is mainly due to the increase of the apical spine, while the height of the base remains the same.

The results – or negative results – of this paper are, that parameters chosen for the analysis of the considered *Sphenolithus* species do not define perfectly the differences between the distinct taxons. It seems, that the optical characteristics yield more diagnostic informations for their identification. The investigations also indicated that significant changes occurred in the size and shape of *Sphenolithus* populations through time at the same geographic position.

In the provinces, where the tropical *Sphenolithus* species are rare, the stratigrapher has to be aware of the possibility of misinterpretation due to the gradual transitions and partial overlaps between different species. He must not use single, dissolved or overcalcified specimens for determination of zones.

Acknowledgements

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TOWE, K. M.: Variation and systematics in calcareous nannofossils of the genus Sphenolithus. – Amer. Zool., **19**, 555–572, 1979.

Plate 1

Fig. 1: *Sphenolithus* cf. *belemnos*, type A.
0° to the nicols, DSDP 72/516/29.

Fig. 2: *Sphenolithus* cf. *belemnos*, type A.
45° to the nicols. DSDP 72/516/29.

Fig. 3: *Sphenolithus* cf. *conicus*, type A.
0° to the nicols. DSDP 72/516/29.

Fig. 4: *Sphenolithus* cf. *conicus*, type A.
45° to the nicols. DSDP 72/516/29.

Fig. 5: *Sphenolithus* cf. *belemnos*, type A.
45° to the nicols. DSDP 72/516/29.

Fig. 6: *Sphenolithus belemnos*, type B.
45° to the nicols. DSDP 40/362/38.

Fig. 7: *Sphenolithus belemnos*, type B.
45° to the nicols. DSDP 40/362/38.

Fig. 8: *Sphenolithus belemnos*, type B.
45° to the nicols. DSDP 72/516/27.

Fig. 9: *Sphenolithus belemnos*, type B.
45° to the nicols. DSDP 72/516/27.

Fig. 10: *Sphenolithus belemnos*, type B.
45° to the nicols. DSDP 72/516/27.

Fig. 11: *Sphenolithus* cf. *heteromorphus*, type C.
0° to the nicols. DSDP 72/516/26.

Fig. 12: *Sphenolithus* cf. *heteromorphus*, type C.
45° to the nicols. DSDP 72/516/26.

Fig. 13: *Sphenolithus* cf. *heteromorphus*, type C.
45° to the nicols. DSDP 72/516/26.

Fig. 14: *Sphenolithus* cf. *heteromorphus* transitional form between type B and C.
45° to the nicols. DSDP 40/362/38.

Fig. 15: *Sphenolithus* cf. *heteromorphus*, type D with drop-like apical spine.
45° to the nicols. DSDP 72/516/25.

Fig. 16: *Sphenolithus* cf. *heteromorphus*, type D with drop-like apical spine.
45° to the nicols. DSDP 72/516/25.

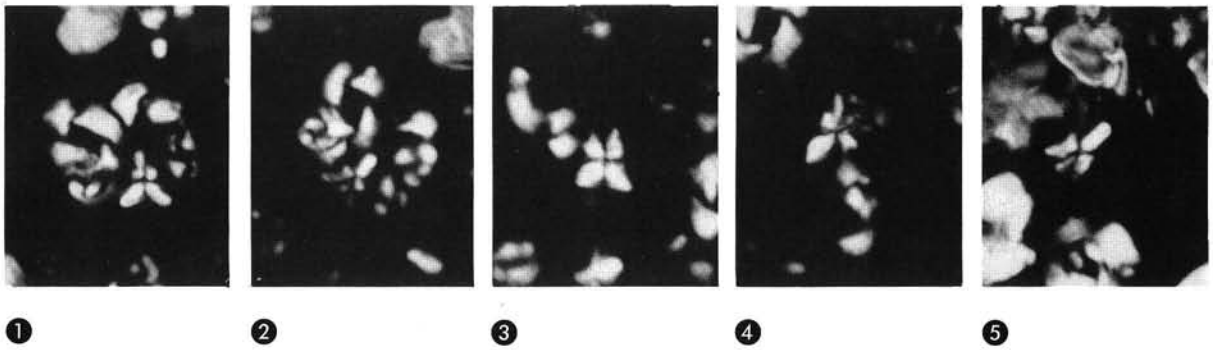
Fig. 17: *Sphenolithus* cf. *heteromorphus*, type D.
45° to the nicols. DSDP 72/516/25.

Fig. 18: *Sphenolithus* cf. *heteromorphus*, type E.
45° to the nicols. DSDP 72/516/22.

Fig. 19: *Sphenolithus* cf. *heteromorphus*, type E.
45° to the nicols. DSDP 72/516/22.

Fig. 20: Two specimens of *Sphenolithus heteromorphus*, type E.
45° to the nicols. DSDP 72/516/22.

All magnifications ×1800.
All photographs made between crossed nicols.



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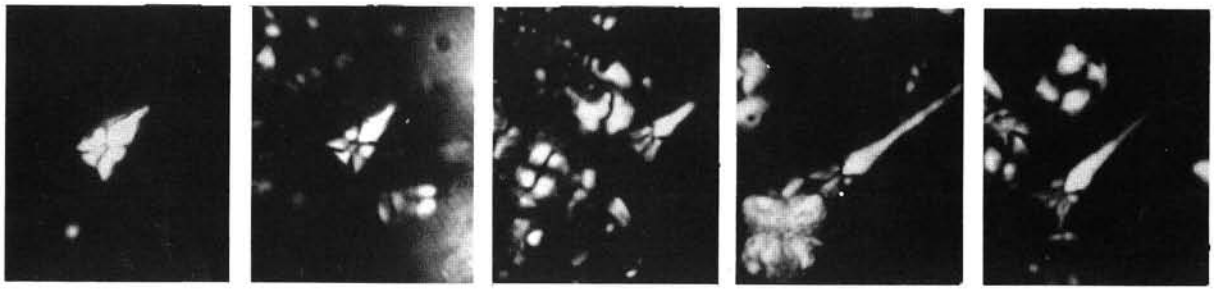

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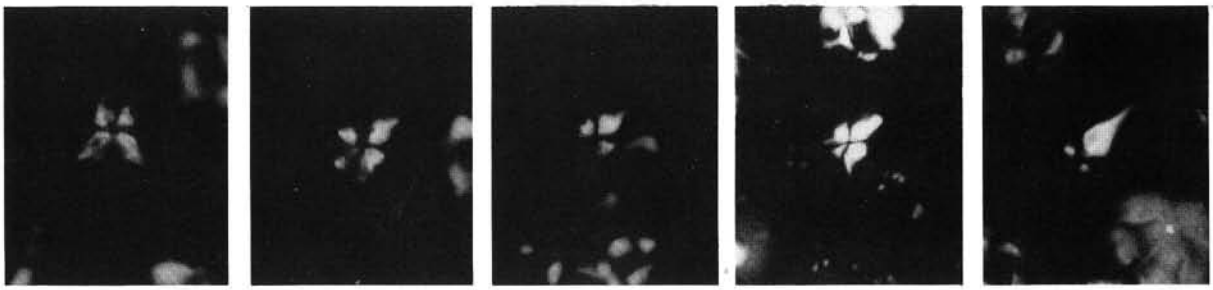

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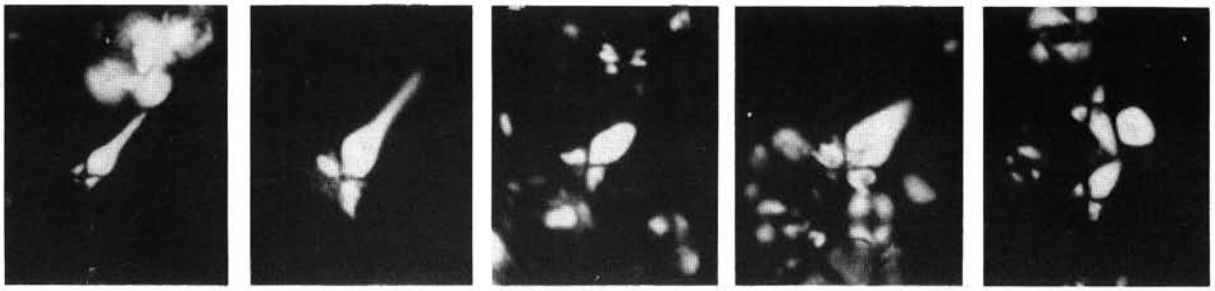

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Plate 2

Figs. 1,2,3: *Sphenolithus delphix* BUKRY.
45° to the nicols. DSDP 72/516/29.

Fig. 4: *Sphenolithus dissimilis* BUKRY & PERCIVAL.
45° to the nicols. DSDP 72/516/29.

Figs. 5,6: *Sphenolithus capricornutus* BUKRY & PERCIVAL.
0° to the nicols. DSDP 72/516/38.

Figs. 7,8: *Sphenolithus moriformis* (BRÖNNIMANN & STRADNER) BRAMLETTE & WILCOXON.
0° to the nicols. DSDP 72/516/22.

All magnifications ×2000.
All photographs made between crossed nicols.

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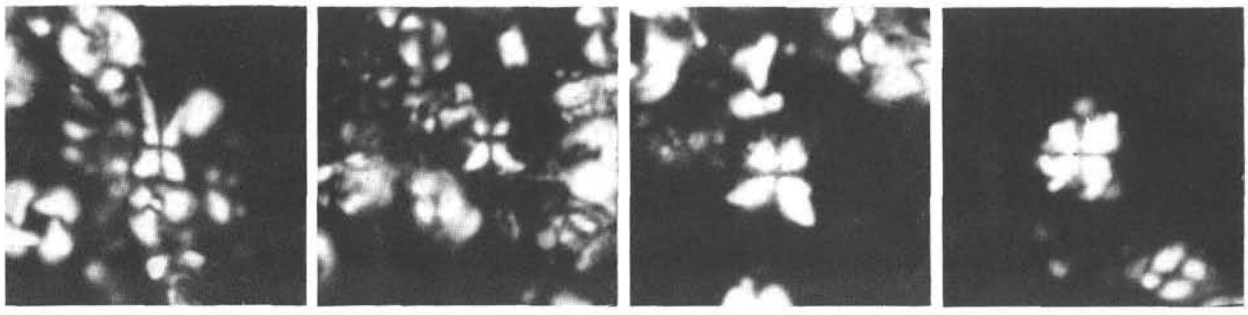

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