Taxonomic notes on the diatoms (Bacillariophyceae) of the Gross Barmen thermal springs in South West Africa/Namibia

F.R. Schoeman and R.E.M. Archibald*
National Institute for Water, Research, Council for Scientific and Industrial Research, P.O. Box 395, Pretoria, 0001 Republic of South Africa

Accepted 7 December 1987

The diatom flora in two series of samples collected, one in 1961/2 and the other in 1983, from the thermal spring complex at Gross Barmen near Okahandja in South West Africa/Namibia are documented. Taxonomic notes are provided for most of the 63 taxa recorded, and each taxon confirmed as present is illustrated with light microscope photographs. One new species, Navicula pseudosydomii sp. nov., and one new variety, Anomoeoneis sphaerophora var. magnifica var. nov., are described. The structure of the diatom assemblages in the two series of samples is discussed briefly, and comments are made on the influence of temperature on the distribution of species in thermal waters.

Hierdie ondersoek dokumenteer die diatoomflora in twee reekse monsters wat in 1961/62 en 1983 respektiewelik versamel is by ‘n warmwaterbron te Gross Barmen naby Okahandja in Suidwes-Afrika/Namibië. Taksonomiese aanteekeninge word voorsien vir meeste van die 63 waargenome taksa en elke takson wat as teenwoordig bevestig is, word met ligmikroskoopfoto’s geïllustreer. Een nuwe spesie, Navicula pseudosydomii sp. nov., en ‘n nuwe variasit, Anomoeoneis sphaerophora var. magnifica var. nov., word beskryf. Die stukkering van die diatoombevolkingsafstelling in die twee reekse is kortlik bespreek, en kommentaar word gelewer oor die invloed van temperatuur op die verspreiding van spesies in warmwaterbronne.

Keywords: Anomoeoneis sphaerophora var. magnifica var. nov., Bacillariophyceae, diatom assemblages, Navicula pseudosydomii sp. nov.

*To whom correspondence should be addressed

Introduction
Thermal and mineral springs have captured the imagination of people for centuries on account of their therapeutic effects. In many places throughout the world such springs have been the focal point around which towns or health spas have developed. In southern Africa the fate of most thermal springs is much the same, and very few remain in their natural or pristine state.

In South West Africa/Namibia a large number of thermal springs have been identified, and many of these formed the subject of a study by Cholnoky (1966), who investigated their diatom flora. In the course of his study, Cholnoky described several new taxa and commented on rare or interesting species. We have re-examined many of these taxa, and it is obvious that Cholnoky misidentified a number of them, while his concepts of other taxa have become outdated. In order to re-appraise his new taxa, it is necessary to examine material with the electron microscope (EM). Unfortunately, while the permanent mounts prepared from Cholnoky’s material collected for this study are present in the diatom collection of the National Institute for Water Research (NIWR), Pretoria, the original samples have been lost, leaving no original unmounted material for EM study.

Therefore, when an expedition to collect diatom samples from previously uncovered areas of South West Africa/Namibia was planned, a number of sites sampled by Cholnoky were included with the primary objective of obtaining new material from these sites for EM study. At the same time, due to a renewed interest in the diatom flora of springs, attention was also paid to thermal springs in the central and southern regions of South West Africa/Namibia, which were not covered by Cholnoky’s study.

One group of springs sampled on this expedition was the thermal springs at Gross Barmen. These are of particular interest for a number of reasons. Firstly, they are one of the best-known thermal springs in this region. Secondly, they are the only springs sampled on both this occasion and on the previous sampling trip undertaken about 20 years earlier by Cholnoky (1966). Thirdly, in the intervening period between Cholnoky’s study and the present one the Gross Barmen thermal springs have been fully developed as a health and pleasure resort. As a result we may expect changes in the diatom flora of the spring complex.

The main purpose of this study is to provide an account of the diatoms of the Gross Barmen thermal springs, examining the changes that might have occurred over a period of 20 years. In order to make a meaningful comparison between the diatom communities present when Cholnoky’s samples were collected in 1961 and 1962 and those found in the samples gathered in 1983, it was necessary to re-examine all Cholnoky’s Gross Barmen slides to reconcile his identifications with ours. Such a step is essential, since over a period of 20 years taxonomic revisions of genera and species have resulted in nomenclatural changes. Furthermore, since Cholnoky’s time, opportunities to examine type material and improved facilities, such as electron microscopic observations and a more comprehensive diatom literature, have made greater accuracy in identification possible in the present study. Finally differences in the personal interpretation of diatom descriptions can give rise to differing concepts of a taxon. These factors were therefore taken into account when compiling a new and comprehensive list of the diatom taxa from Gross Barmen. It should be noted that, since the preparation of this manuscript, the most recent account of the diatom family Naviculaceae by Krammer & Lange-Bertalot (1986) has appeared in print. While the authors of this paper may not agree with all the views expressed therein, solutions to some of the taxonomic problems raised in the Gross Barmen study may be found in their book.

This paper presents a comprehensive list of all the diatom taxa recorded from the thermal springs of Gross Barmen, and includes a number of taxa observed on Cholnoky’s slides, which he had evidently missed in his study. Nearly all the taxa recorded in this list have been photographed in the following pages.
order to reduce or eliminate confusion with regard to their identity. The only taxa not illustrated are those recorded by Cholnoky (1966) in his study, but for which we could find no specimens to confirm the identification. In addition to the visual record of these taxa, we have furnished notes for those needing taxonomic comment. The paper also discusses the present composition of the diatom flora of the springs and examines how it has changed over the intervening period.

**Description of study site**

The location of the thermal springs of Gross Barmen in South West Africa/Namibia is shown in Figure 1. These lie on flat ground on the banks of a tributary of the Swakop River about 24 km south-west of Okahandja at latitude 22°7'S and longitude 16°44'E (Ashton & Schoeman 1984, p.51). The site is historically interesting since it is the place where the first mission outpost for the Herero people was built in 1844 by Hugo Hahn, a Rhenish missionary. Following this, there was little development other than the building of a police fort in about 1896 at this site to protect ox-wagon convoys travelling between Walvis Bay and Okahandja. During the early 1950's the area surrounding the thermal springs and mission ruins was acquired by the South West African/Namibian Administration. Finally, the recreational and therapeutic potential of the thermal springs was fully exploited with the completion in 1977 of a health spa and recreation centre.

At the time Cholnoky (1966) made his collection of diatom samples from the Gross Barmen thermal springs in 1961/62, the site was undeveloped. Water from the thermal springs flowed first into a pool fringed with reeds and sedges, from there into a small crude bath, and then into a large pool flanked by *Hyphaene* palms (Figure 2), which was used as a swimming pool. From the swimming pool the water flowed into a number of impoundments and finally

![Figure 1](image-url)

**Figure 1** The Gross Barmen thermal springs near Okahandja in central South West Africa/Namibia (SWA/N). The two smaller maps above show the location of the springs, (a) in relation to Windhoek, Okahandja and the Swakop River and (b) in relation to neighbouring states in southern Africa. The larger map (c) below shows the lay-out of the health and recreational complex as it is today, and Schoeman's sampling sites (G 89-93) in this system.
into a small swampy stream, which discharges into the Missions River and thence into the Swakop River (Gevers et al. 1963).

Following the development of the thermal springs the site was greatly changed. The main spring (Figure 1c - A) has been enclosed by a circular, stone well-like structure. From there the thermal waters are piped underground to the thermal hall (Figure 1c - C), after which they flow underground by gravity to the modern open air swimming pool, built on the site of the old swimming pool and still flanked by the same *Hyphaene* palms (Figure 1c - B). Overflow water from the swimming pool drains into the large impoundment below the pool, and from there if follows the route to the Swakop River as described above. As a result of confining the thermal waters to an underground pipe system in the new development, most of Cholnoky's sampling sites (SWA 30-32, see below) no longer exist.

A comprehensive account of the geology, climate and chemistry of the spring waters of this region is given by Gevers et al. (1963), while a more recent analysis of the thermal waters was reported by Ashton & Schoeman (1984).

**Materials and Methods**

The material examined in this study comprises two sets of samples from the Gross Barmen thermal springs and its immediate surroundings. The first set forms part of a large number of samples collected by Cholnoky (1966) from springs in South West Africa/Namibia and Botswana in August 1961. They consist of four samples (SWA 30-33) from the channels conveying the warm spring water to an earth dam impoundment. A fifth sample (SWA 101), collected by O.O. Hart in February 1962 from the phytoplankton of the impoundment, was also examined by Cholnoky. Brief descriptions of these diatom sampling sites are given below.

**SWA 30 (NIWR 162/3235):** The main spring stream some 5.0 m from the spring source. pH 7.8. Temperature in the spring 65°C.

**SWA 31 (NIWR 162/3236):** A marshy spring near the main spring with slightly cooler water.

**SWA 32 (NIWR 162/3237):** The common channel of the springs.

**SWA 33 (NIWR 162/3238):** The large impoundment collecting the spring waters.

**SWA 101 (NIWR 166/3305):** Plankton sample from the impoundment collecting the spring water.

In our notes on various taxa we have referred to one other sample, relevant to Gross Barmen, which has not been included in the list above. This is sample SWA 34 (NIWR 162/3239), which was collected about 1.5 km below the earth dam from the channel carrying effluent water from the impoundment, and is consequently not directly related to the spring itself. In the present survey we have no comparable sample.

The second set of samples was collected by Schoeman in October 1983. Schoeman's sampling sites could not be correlated exactly with those sampled earlier by Cholnoky (1966) because the modern developments around the springs have destroyed the latter. Consequently, on the map in Figure 1 only the new sampling sites are shown. They are described as follows:

**G 89 (NIWR 503/10058):** Diatoms from stones within the enclosure constructed around the main spring source. pH 7.1. Temperature 66°C. Conductivity 260 mS m⁻¹.

**G 90 (NIWR 503/10060):** Diatoms from submerged reed stems in large reed-fringed impoundment collecting the spring water after it had passed through the mineral baths.

**G 91 (NIWR 503/10062):** Diatoms from muddy substrate of small pools in vlei-like area below the dam. Water was stagnant and had a strong H₂S odour.

**G 92 (NIWR 504/10064):** Diatoms from muddy substrate in a large pool below dam, filled with stagnant, saline water. pH 9.5. Temperature 48°C. Conductivity 1 000 mS m⁻¹.

**G 93 (NIWR 504/10066):** Diatoms from decaying reeds in a densely reeded area fed by seepage water from the earth dam.

Diatom samples from the latter set were gathered by scraping the algal growth from the substrate, placing it in a glass vial, and preserving it with 4% (v/v) formaldehyde. In the laboratory the diatoms were cleaned and permanently mounted in Naphrax (R.I. = 1.7 when dry) following the method described by Cholnoky (1968). The diatom slides were examined with a Zeiss Standard RA research microscope, and specimens were photographed with an Olympus photomicrographic system model PM-10AD using Kodak Panatomic-X film.

For transmission (TEM) and scanning (SEM) electron microscope studies, the procedures used were described by Schoeman & Archibald (1976, 1977b).

Chemical analysis of the spring water was not undertaken in Cholnoky's (1966) earlier survey, although he recorded pH and temperature readings for most of his sampling sites. In contrast, during the present study a water sample was collected from the source of the main spring. This was analysed in the laboratory following procedures described by Ashton & Schoeman (1984). At the remainder of the sampling sites measurements of pH, conductivity and water temperature were carried out in situ wherever possible. pH measurements were obtained with an Orion 201 portable pH meter equipped with a glass electrode. Conductivity readings were taken with a portable Werkstätten D812 conductivity meter. Measurements of water temperature were obtained using a standard mercury thermometer graduated in 0.1°C intervals.
Abbreviations and terminology

When referring to various materials or slides examined, we have used certain abbreviations as prefixes to the sample or slide numbers. These are:

NIWR — slides belonging to the diatom collection of the National Institute for Water Research in Pretoria.

VHS — slides belonging to van Heurck’s (1884–87) ‘Types du Synopsis des Diatomées de Belgique’.

Terminology used in this paper follows that suggested by the working party on diatom terminology (Anonymous 1975; Ross et al. 1979).

Taxonomic account

Effective and valid transfer of information can only be achieved if there is absolute clarity as to what is being communicated. In diatom taxonomy such clarity does not always exist with regard to the concept of a taxon bearing a particular binomial combination. It is, however, essential in any floral survey or ecological study that the organisms involved should be identified accurately. The task of the diatom taxonomist is therefore to ensure this accuracy through clarifying the concepts of the relevant taxon. Identification of a taxon comprises two processes. The first is determining to which taxon the specimens belong using descriptions, illustrations and type material etc. for comparisons, and secondly, determining the correct name for the taxon by following the rules of the international code of botanical nomenclature (cf. Voss et al. 1983). This is not an easy task as many descriptions are inadequate, illustrations can be misleading (particularly drawings) and type material is not always readily available. Added to this is the complication of subjectivity in the interpretation of what constitutes a particular species or taxon, i.e. the lumpers and the splitters.

To overcome most of these problems to a certain extent we have photographed every taxon that we observed in both Cholnoky’s (1966) samples and those collected for this survey. No illustrations have been given for those taxa recorded by Cholnoky’s samples (SWA 30–33, 101) we observed a number of taxa not recorded by him. These are recorded here, but will not be found in Cholnoky’s (1966) account.

The following taxa have been observed in the thermal springs of Gross Barmen.

*Achnanthes exigua* Grunow (Figures 3–6)


Dimensions: length 7,0–14,0 µm, breadth 4,0–6,0 µm. Transapical striae: raphe valve 26–31 in 10 µm near the centre (slightly denser at the poles), rapheless valve 25–28 in 10 µm near the centre (up to 30 in 10 µm at the poles).

Samples: SWA 30, 32, 33, 101; G 89, 90, 92, 93.

*Achnanthes minutissima* Kützing (Figures 7–10)


Dimensions: length 8,0–18,5 µm, breadth 2,5–3,5 µm. Transapical striae: raphe valve 28–30 in 10 µm (up to 32 in 10 µm at the poles), rapheless valve 30 in 10 µm (up to 33 in 10 µm at the poles).

Samples: SWA 101; G 89.

*Amphora* sp. [affin. *luciae* Cholnoky] (Figures 11, 12)


Cholnoky (1966, p.172) claimed to have identified *Amphora coffeaeformis* (Agardh) Kützing from two samples collected at Gross Barmen. We have shown previously (Archibald & Schoeman 1984, p.83) that Cholnoky’s concept of *A. coffeaeformis* was somewhat confused. It was therefore not surprising that we were unable to find any specimens of the true *A. coffeaeformis* in Cholnoky’s Gross Barmen samples, although a few specimens of a taxon (Figures 11, 12) resembling it were observed. We have not been able to identify this taxon with certainty, but relate it very closely to certain forms of *Amphora luciae* Cholnoky, itself a problematic taxon. Archibald (1983, p.48) pointed out that, after examining Cholnoky’s type material, it appeared that *A. luciae* was based on two distinct elements. He therefore amended Cholnoky’s original description to include only the smaller forms (viz. Cholnoky’s 1966, figs 58, 59) as *A. luciae*. The Gross Barmen specimens (Figures 11, 12) agreed in all essential respects with this amended description, but subtle differences in valve shape, the more pronounced dorsal curvature of the central pores, and the greater maximum valve lengths prevent us from identifying them with certainty as *A. luciae*. It should be remembered, however, that *A. luciae* has not been observed frequently, and therefore the differences seen in the Gross Barmen specimens may fall within the range of variation of *A. luciae*. Specimens similar to those from Gross Barmen have previously been recorded under this name from the Swakopmund sewage works (Schoeman 1972, p.69, fig. 5) in South West Africa/Namibia.

Dimensions: length 19,0–26,5 µm; breadth 3,5–4,5 µm; transapical striae on the dorsal side 20–24 in 10 µm near the centre and 24–30 in 10 µm at the poles, on the ventral side 28–30 in 10 µm.

Samples: SWA 30, 32.
Amphora thermalis Hustedt (Figures 13–17)
Hustedt 1949, p.111, pl.11, figs 1–3.
Archibald & Schoeman 1988, manuscript in preparation.
In this study we consider *Amphora hartii* Cholnoky (1963, p.30, figs 1–3) as conspecific with *A. thermalis* Hustedt. Evidence for this will be presented in a paper still in preparation.

Dimensions: length 18,0–41,0 μm; breadth 4,0–6,0 μm; transapical striae on the dorsal side 24–28 in 10 μm near the centre and 30–36 in 10 μm at the poles, on the ventral side 24–28 in 10 μm.

Samples: SWA 30–33, 101; G 91, 92.

Amphora veneta Kützing (Figures 18–22)

Dimensions: length 11,5–43,0 μm; breadth (valve) 4,0–6,0 μm; transapical striae on the dorsal side 26–29 in 10 μm near the centre, wider apart at the centre (18–25 in 10 μm) and slightly denser at the poles (28–30 in 10 μm), on the ventral side 24–30 in 10 μm near the centre but somewhat denser at the poles where they are not always clearly visible.

Samples: SWA 30, 32, 33, 101; G 90, 93.

*Anomoeoneis sphaerophora* complex

In his discussion of the genus *Anomoeoneis* Pfister, Hustedt (1931–59, p.738) commented that numerous ‘varieties’ had been named on account of the great variability within the genus. The truth of this statement became obvious when we tried to identify as correctly as possible the many different examples of a group of taxa embraced in what we have called the ‘*Anomoeoneis sphaerophora*’ complex. In the literature the taxonomic ranks of the components of this complex have changed from time to time according to different schools of thought. At the end of the last century Cleve (1895, p.6) recognized three separate species, viz. *A. sphaerophora* (Kützing) Pfister, *A. sculpta* (Ehrenberg) Pfister and *A. polygramma* (Ehrenberg) Cleve (= *A. costata* (Kützing) Hustedt). Later Hustedt (1931–59, p.740) divided the complex into *A. sphaerophora* with its varieties (including *A. sculpta* as a variety) and *A. costata*. More recently Patrick & Reimer (1966) followed Hustedt’s taxonomy, while Gasse (1975, pl. 33, figs 1–6) preferred to consider the taxa as varieties of *A. sphaerophora*, and Schmid (1977) regarded them as forms of *A. sphaerophora*. The scope of this paper does not permit a full discussion of the merits and demerits of these views, and we have not been able to examine type material of any of these taxa. Consequently, we have decided to follow Hustedt’s taxonomic interpretation of this complex in so far as our observations allow.

The numerous examples of this complex observed in the Gross Barmen samples strongly resembled each other in certain points, but in other respects they showed a wide range of variation. In the Gross Barmen specimens we have discerned four relatively distinct groups, to which we have accorded the rank of variety. These are discussed separately below. To avoid a problem encountered with Schmid’s (1977) discussion of these taxa, where her use of different magnifications for her illustrations makes size differences between the taxa difficult to conceive, we have retained the same magnification (×1 500) for the illustrations of all our examples of this complex. The following groups were identified.

*Anomoeoneis sphaerophora* var. *sphaerophora* (Kützing) Pfister (Figures 23–28)

The first problem to be resolved was the development of a good concept of the nominate variety. Kützing’s (1844, p.95, pl.4, fig. 17) original description and illustration show that the valve of this variety is elliptic-lanceolate in outline with rostrate-subcapitate apices. The length of the valve is 45,7 (his illustration)—83,6 μm (text). Nothing is said of the striae. However, Grunow (in van Heurck 1880–83, pl.12, figs 2, 3) depicted a valve identified as the nominate variety with the same valve outline. Dimensions of similar valves on van Heurck’s (1884–87) slide No. 124 (= NIWR 7/124) have a range of 60,0–65,0 μm for length, 19,5–20,0 μm for width, and they have 16–18 transapical stria in 10 μm. These specimens (e.g. Figures 23 & 24) show that the transapical striae are composed of discrete puncta arranged in undulating longitudinal rows, fairly evenly spaced towards the margins but more irregularly and widely spaced near the axial area. Between the more widely spaced puncta of the striae, as well as in the central area (excluding the central nodule), faint shadow puncta (depressions according to Schmid 1977, p.320) occur. Along the axial area on either side of the raphe there is a prominent row of puncta, each one corresponding with a stria. The van Heurck examples agree very closely with Hustedt’s (1931–59, p.740, fig. 1108a) description of *A. sphaerophora*, and thus for the present we accept these specimens as representing the nominate variety as truly as possible.

In the Gross Barmen samples we did not find any forms corresponding exactly with the van Heurck examples. Figures 25–28 depict valves which approach the nominate variety most closely. They have the typical valve outline and the construction of the central area corresponds well, but they appear to be smaller and the nature of their striae differs. The stria puncta in these specimens are more regularly and closely spaced and continue with little interruption from the valve margin to the axial area. As a result the row of pores on either side of the axial area is not so conspicuous in the Gross Barmen forms, and there appears to be an absence of the shadow puncta (depressions) in the striae and in particular the central area. For the present we consider these examples as representatives of the nominate variety in Gross Barmen.

Dimensions: length 41,5–68,0 μm; breadth 13,0–19,5 μm; transapical striae 18–20 in 10 μm near the centre and 20–22 in 10 μm at the poles.

Samples: SWA 32, 33, 101; G 91.

*Anomoeoneis sphaerophora* var. *biceps* (Ehrenberg) Cleve (Figures 29–43)

The majority of the Gross Barmen specimens (Figures 31–43) assigned to the ‘*Anomoeoneis sphaerophora*’ complex, and occurring in nine out of the ten samples examined, have been placed in the variety var. *biceps*. They were identified as such because they corresponded very closely with examples of *Navicula sphaerophora* var. *biceps* (= *Anomoeoneis sphaerophora* var. *biceps*) on van Heurck’s (1884–87) slide No. 123 (= NIWR 7/122). Two examples of the latter are shown in Figures 29 and 30. This designation, however, presents some taxonomic problems. Hustedt (1931–59, p.740) considered the var. *biceps* as synonymous with the nominate variety. In contrast, amongst the Gross Barmen specimens we did not find any intermediates between those valves designated as var. *biceps* (Figures 31–43) and those we accept as the nominate variety (Figures 25–28). Our examples of the var. *biceps* have lanceolate valves with more or less conically rostrate poles, as opposed to the more elliptic valves with subcapitate apices of var. *sphaerophora*. There were also fairly
clear differences in the nature of the striae. In the var. biceps from Gross Barmen the structure of the striae is quite variable. Basically, however, the valve striae consists of a marginal region in which puncta development is complete, then a relatively wide area in which the striae continue as shadow puncta (depressions), and finally each stria ends in a prominent punctum at the edge of the axial rib. The latter form the conspicuous row of puncta on either side of the axial area, which is far more distinct in the Gross Barmen specimens of var. biceps than in the nominate variety. In many of our examples the region occupied by the shadow puncta gives the impression of lateral areas similar to those found in the var. sculptra (see below). Construction of these central areas, though often masked by the more conspicuous presence of the shadow puncta, is typical of the nominate variety.

On account of these differences we prefer to keep the specimens illustrated in Figures 31-43 separate from the nominate variety, but use the name var. biceps out of convenience for the present. We are not in a position to compare our examples with the type material of Navicula biceps Ehrenberg, nor have we been able to examine the relationship of this variety with Anomoeoneis sphaerophora var. guentheri O. Müller (1899, p.302, pl.12, figs 6–9).

Dimensions: length 30,5–76,0 µm; breadth 12,0–16,5 µm; transapical striae near the centre 16–22 in 10 µm.

Samples: SWA 30–33, 101; G 90–93.

Anomoeoneis sphaerophora var. magnifica var. nov. (Figures 44–47)

In four of the Gross Barmen samples examined in this study we observed some very large specimens (Figures 44–47) of a form resembling the nominate variety reasonably closely in respect of valve outline, construction of the central area, and striae structure. This form undoubtedly belongs to the ‘A. sphaerophora’ complex, but we have not been able to identify it with any of the other three varieties composing this complex discussed here. Their large size (length 85,0–131,5 µm, breadth 28,0–37,5 µm) clearly separates them from the nominate variety, var. sphaerophora (length 41,5–68,0 µm, breadth 13,0–19,5 µm) and from the var. biceps (length 30,5–76,0 µm, breadth 12,0–16,5 µm). In respect of size, this large form is more comparable with the var. sculptra (length up to 200 µm and breadth up to 60 µm — cf. Hustedt 1931–59, p.741), although the Gross Barmen specimens of this variety (see below) appear to represent the shorter examples of the taxon. Nevertheless, var. sculptra can be distinguished fairly readily on the grounds of valve shape and the presence of the large, apparently structureless lateral areas, which do not appear in the large form under discussion.

Searching the literature for other records of this large form, we could find only two other references to similar specimens. Gasse (1975, pl.33, fig. 1) illustrated this taxon from East Africa under the name var. sphaerophora, but did not comment on its large size or taxonomic status. On the other hand, Schmid (1977, p.322, figs 19, 20, 49, 51) found a few examples of this large form in the Neusiedlersee, which agreed with specimens she observed in a sample collected independently by her from Gross Barmen. Schmid considered these specimens as initial cells (Erstlingszellen) of A. sphaerophora f. costata [= A. costata (Kützing) Hustedt], although she recognized that the Gross Barmen specimens differed in valve outline and structure from the typical 'lake forms' of f. costata. Comparison of our examples from Gross Barmen (Figures 44–47) with specimens of Navicula bohemica Ehrenberg [= Anomoeoneis costata (Kützing) Hustedt] on van Heurck’s slide No. 123 (= NIWR 7/123; see Grunow in van Heurck 1884–87, p.39) confirmed Schmid’s latter observations in this respect. Two examples from the van Heurck slide (Figures 48, 49) show that A. costata is rhombic in outline with broadly rounded poles in contrast to the lanceolate valves having rostrate poles of the Gross Barmen specimens. A further difference between the two taxa can be found in their striae structure. In A. costata there are narrow lateral extensions of the central area between the axial row of puncta and the striae of the striae (see especially Figure 48). This is a feature not observed in our large Gross Barmen form. For a number of reasons we cannot accept Schmid’s concept that these very large specimens are initial cells of A. costata. Firstly, we did not observe a single example of A. costata in the Gross Barmen samples, which is contrary to what one would expect if these large forms were indeed initial cells. Secondly, we did not find any valves that could be considered as intermediates between our large form and A. costata. A further factor mitigating against these large specimens being initial cells is the fact that the characteristic structure of the valve remained constant over a relatively wide range in valve size (see dimensions below), i.e. over a number of vegetative divisions. This suggests that this large taxon forms a genetically stable unit, which does not at any stage exhibit the characteristics of A. costata. Furthermore, in the series of valves observed from Gross Barmen, particularly in sample SWA 101, it appeared that, as the valves diminished in length, they became relatively broader and the outline was simplified with the protracted poles becoming less prominent. This accords with Getilier’s (1932, p.175) observations of trends in diatom valve characteristics during subsequent vegetative divisions. Reflecting on these points we conclude that these large specimens should be considered as a distinct variety, and not merely as a form or one extreme of the natural range of variability of the nominate variety. Consequently, we propose to call this new variety Anomoeoneis sphaerophora var. magnifica var. nov. The description of this new variety is as follows:

Valves lanceolate with broad rostrate poles having somewhat flatly rounded apices; length 85,0–131,5 µm, breadth 28,0–37,5 µm. Raphe straight and broadly filiform with fairly prominent central pores and large curving terminal fissures deflected to the same side of the valve. Axial area relatively broad and linear; central area large and asymmetrical, somewhat larger and extending to the margin on one side of the valve. Transapical striae radial over most of the valve, becoming parallel or slightly convergent at the poles, 15–18 in 10 µm, distinctly punctate with puncta arranged in undulating rows, somewhat close together near the margins of the valve and becoming more widely and irregularly spaced as they approach the axial area; striae reaching the axial area where the last punctum of each stria is more prominent, thus forming a conspicuous longitudinal row of pores on either side of the axial area.

Valvae lancelolatae, polis late rostratis et apicibus lenitior cum planatis; 85,0–131,5 µm longae, 28,0–37,5 µm latae. Raphe late filiformis, directa; poris centralibus prominentibus; fissuris terminalibus magnis arcuatis ad marginem eadem deflexis. Area axialis pro ratione lata linearisae; area centralis magnam asymmetricam, in latere uno valvae aliquanto maior et ad marginem extensa. Striae transapicales pro parte maxima radiales, ad polos versus parallelae vel lenitier convergentes, 15–18 in 10 µm, punctatae distincte, punctis in serialibus undulatis ordinatis, ad marginem versus aliquanto approximatis, ad aream axialem versus latoriobus irregularibus; striae ad aream axialem extensae ubi punctum ultimum striae utraque prominentius est, sic series longitudinalis conspica punctorum in latere alterutero areae axialis faciens.
Habitat: In the mineralized, thermal spring waters at Gross Barmen near Okahandja in South West Africa/Namibia.

Type slide No. NIWR 503/10060 (G 90) in the NIWR Collection, Pretoria, South Africa.

**Anomoeoneis sphaerophora** var. *sculpta* (Ehrenberg) O. Müller (Figures 50–52)

Hustedt 1931–59, p.741, fig. 1109.

We have designated the fourth member of the Gross Barmen ‘*A. sphaerophora* complex as the var. *sculpta*. We have for the present followed Hustedt’s (op. cit.) taxonomy for this taxon, according it the rank of variety, because, although it occurred in a number of samples together with the other varieties discussed above, it retained its valve characteristics (see Figures 50–52) without any intermediate forms being observed. The raphe structure, the single row of prominent pores on either side of the axial area, the asymmetrical central area and the striae puncta arranged in undulating longitudinal rows communicates its basic affinity to the ‘*A. sphaerophora*’ complex. However, its considerably larger size, relatively broader valves and valve shape immediately distinguish it from the var. *sphaerophora* and the var. *biceps*. The very broad apparently structureless lateral areas, and, to a lesser degree, the valve shape separates this taxon from the var. *magnifica*. The broad lateral areas in the var. *sculpta* contain very faint shadow puncta (very shallow depressions), which at certain levels of focus and illumination intensities make these regions appear structureless.

In order to satisfy ourselves that our concept of the var. *sculpta* accorded with earlier interpretations of this taxon, we examined a large number of examples on van Heurck’s (1884–87) slide No. 123 (NIWR 7/123) containing *Navicula sculpta* Ehrenberg (= *A. sphaerophora* var. *sculpta*). Apart from rather more acute apices in the van Heurck examples (Figures 53, 54), our specimens were indistinguishable from those on the van Heurck slide.

Dimensions (Gross Barmen examples only): length 61.5–88.5 μm; breadth 28.0–32.5 μm; transapical striae 14–16 in 10 μm.

Samples: SWA 32, 33, 101.

**Brachysira vitrea** (Grunow) comb. nov. f. *lanceolata* (Mayer) comb. nov. (Figures 55–61)

Hustedt 1931–59, p.752, fig. 1114d (as *Anomoeoneis exilis f. lanceolata* Mayer). Patrick & Reimer 1966, p.380, pl.33, fig. 12, 13 [as *Anomoeoneis vitrea* (Grunow) Ross].

Round & Mann (1981) have justified the resurrection of the genus *Brachysira* for those taxa of the genus *Anomoeoneis* which have a structure similar to *Navicula aponina* (Kützing) Kützing (1844) = *Brachysira aponina* Kützing (1833–36); cf. Kramer & Lange-Bertalot 1985, p.14, pl.1, figs 6–11, 18). A number of years previously, Ross (1947, p.197) and Ross in Patrick & Reimer (op. cit.) explained why ‘*vitreus*’ is the correct epithet for *A. exilis* (Kützing) Cleve [= *B. exilis* (Kützing) Round & Mann]. However, for some reason the correct generic name and the legitimate specific epithet have not yet been used in combination. Kramer & Lange-Bertalot (1985, p.11) argue against transferring the *A. vitrea* – *A. serians* – *A. zelensis* group of species to the genus *Brachysira* for fear of making unnecessary synonyms. They justify their standpoint on the grounds that, if a reappraisal of the *Naviculaeaceae* is undertaken, it may result in a further regrouping of the species. Unfortunately, the rules of the international code of botanical nomenclature do not provide for the conservation of names until such time as the family or genus has been revised. We therefore follow Round & Mann (1981) in their typification and separation of the genera *Anomoeoneis* and *Brachysira*, and believe that there is a much stronger link between *B. aponina* Kützing and *B. vitrea* (Grunow) comb. nov. than Kramer & Lange-Bertalot suggest. Thus we use the new combination *Brachysira vitrea* (Grunow) comb. nov. f. *lanceolata* (Mayer) comb. nov. for the taxon observed at Gross Barmen.

Figures 55–61 illustrate the range in size and valve shape of specimens found in sample SWA 31. Under the light microscope these valves appear to have the structure characteristic of *B. vitrea* (Hustedt 1931–59, p.751, figs 1114a–c as *Anomoeoneis exilis*; Patrick & Reimer 1966, p.380, pl.33, figs 12, 13 as *A. vitrea*) but lack the capitale poles. In this respect they accord more closely with the f. *lanceolata* (Hustedt op. cit. p.752, fig. 1114d as *A. exilis f. lanceolata*; Germain 1981, p.164, pl.62, figs 5–8 as *A. vitrea*). We have compared typical capitale forms of *B. vitrea* from the Pretoria Salt Pan (vide Schoeman & Ashton 1982b, p.27, figs 6–9, 46–48, 66–78 as *A. exilis*) with the lanceolate Gross Barmen specimens, but could find no essential structural differences. The lanceolate forms from Gross Barmen also appear to be very similar to a recently described species, *Anomoeoneis garrantis* Lange-Bertalot & Kramer (vide Kramer & Lange-Bertalot 1985, p.12, pl.1, figs 1–5).

Apparently the latter can only be distinguished from the lanceolate forms of *B. vitrea* when viewed through scanning electron microscopy (SEM). The only point of distinction between *A. garrantis* and *B. vitrea* is the presence of spines on the valve surface in the latter (vide Schoeman & Ashton op. cit. figs 66–74; Kramer & Lange-Bertalot op. cit. pl.1, fig. 17). Since we cannot study the Gross Barmen specimens under SEM (no unmounted material of Choelnóky’s sample SWA 31 available), we prefer to identify the Gross Barmen examples for the present as *B. vitrea* f. *lanceolata*.

Dimensions: length 12.5–32.0 μm; breadth 4.0–5.5 μm; transapical striae near the centre (32)34–37 in 10 μm.

Samples: SWA 30–32, 101; G 89.

**Caloneis molaris** (Grunow) Krammer (Figures 62–65)

Krammer & Lange-Bertalot 1985, p.18, pl.10, fig. 9. Schoeman & Ashton 1982a, p.87, figs 31–42, 123–126 [as *Caloneis clevei* (Lagerstedt) Cleve].

Schoeman (in Schoeman & Ashton op. cit.) suggested that Hustedt’s (1930, p.236, fig. 359) concept of *Caloneis clevei* was incorrect. This was based on their examination of a slide (A–GC 92550 in the collection of the Academy of Natural Sciences, Philadelphia) made from Lagerstedt material collected at Liefde Bay, Spitzbergen. The single valve of *Caloneis clevei* observed on this slide (Figures 66a, b) shows clearly the difference between Lagerstedt’s taxon and Hustedt’s concept of the species as illustrated in Figures 62–65 of this study. More recently, Kramer (in Kramer & Lange-Bertalot op. cit. pl.10, figs 8, 9) has made the same observation after examining a slide prepared from Spitzbergen material (presumably Lagerstedt material) in the Krasske collection. Our specimen from the Philadelphia slide conforms in all respects with Kramer’s example (see his figure 10.8) on the Krasske slide. Kramer has shown, furthermore, that Hustedt’s concept of *C. clevei* is identical to the type specimens of *Navicula molaris* Grunow, a species which until now has been known as *Pinnularia molaris* (Grunow) Cleve. We therefore accept Kramer’s transfer of the species, *P. molaris*, to the genus *Caloneis*, and the inclusion of all specimens conforming to Hustedt’s concept of *C. clevei* under the new combination of *Caloneis molaris* (Grunow) Krammer.
Dimensions: length 24.0–69.0 μm; breadth 7.0–12.0 μm; transapical striae 20–22 in 10 μm throughout the valve.

Samples: SWA 31–33, 101; G 89.

*Diploneis* sp. (Figure 67)
The distinction between *Caloneis bacillum* (Grunow) Cleve and its closely related taxa is often nebulous, making precise identification of some specimens difficult. In this regard a single valve (Figure 67) observed in this study agreed with *C. bacillum* in valve shape, dimensions and striae density, but the shape of the axial area and the convergent apical striae did not conform to the commonly accepted concept of *C. bacillum* (cf. Hustedt 1930, p.236, fig. 360). We have therefore refrained from identifying this example to species level.

Dimensions: length 31.0 μm; breadth 8.0 μm; transapical striae near the centre 21–22 in 10 μm, and 22 in 10 μm at the poles.

Samples: G 90.

*Cyclorella meneghiniana* Kützing (Figures 68–70)

Dimensions: diameter 13.0–17.0 μm; 6–8 striae in 10 μm.

Samples: G 90, 93.

*Cymbella microcephala* Grunow (No figure)
From his analysis sheets (NIWR collection) it appears that Cholnoky saw only one example of this species in his sample SWA 101. We were unable to find any examples of this species to confirm its presence, and so have not illustrated it.

Dimensions: length 17.0 μm; breadth 4.0 μm; transapical striae 26 in 10 μm on the dorsal side.

Samples: SWA 101.

*Cymbella pusilla* Grunow (Figures 71–75)
Hustedt 1930, p.354, fig. 646.

Dimensions: length 20.5–29.0 μm; breadth 5.0–6.5 μm; transapical striae near the centre on dorsal and ventral sides 16–17(18) in 10 μm, and up to 20 in 10 μm at the poles.


*Diploneis oblongella* (Naegeli *ex* Kützing) Cleve
(Figure 76)
Patrick & Reimer 1966, p.413, pl.38, fig. 8.
Hustedt 1931–59, p.671, figs 1065a–k [as *D. ovalis* (Hilse) Cleve].

The only *Diploneis* species recorded by Cholnoky (1966, p.182) from his Gross Barmen samples was *D. subovalis* Cleve found in sample SWA 101. However, while searching this sample for a specimen to confirm this identification, we came across three specimens of *D. oblongella*, the best of which is illustrated in Figure 76. The striae composed of a single row of puncta, one of the characters distinguishing this species from *D. subovalis*, are clearly seen in this illustration. Since *D. oblongella* (as *D. ovalis*) was recognized by Cholnoky (op. cit. p.181) from other springs in South West Africa/Namibia, it suggests that, due to the scarcity of this species in sample SWA 101, he failed to see any when he examined the slide.

Dimensions: length 16.0–21.5 μm; breadth 10.5–11.5 μm; transapical striae 13–16 in 10 μm near the centre and 16–17 in 10 μm near the poles; striae with 16–22 puncta in 10 μm in a single row.

Samples: SWA 101.

*Diploneis subovalis* Cleve (No figure)
Hustedt 1931–59, p.667, figs 1063a, b.

In the Gross Barmen material this species is very rare. From his analysis sheets (NIWR collection) Cholnoky appears to have seen only one specimen on slide No. SWA 101 (cf. Cholnoky 1966, p.182), while in the most recently collected samples we did not record it at all. In our re-examination of Cholnoky's slide SWA 101 we found a single example covered with debris, making it unsuitable for photography. Nevertheless, this specimen showed striae with the typical *D. subovalis* character, i.e. each stria consisting of a double row of pores arranged alternately.

Dimensions: length 43.0 μm; breadth 14.0 μm; transapical striae near the centre of the valve 12 in 10 μm.

Samples: SWA 101.

*Epithemia argus* (Ehrenberg) Kutzing var. *longicornis* (Ehrenberg) Grunow (Figure 77)
Hustedt 1930, p.384, figs 727c, d.
Patrick & Reimer 1975, p.234, pl.3, fig. 3.

Cholnoky (1966) recorded this species from Gross Barmen only in sample SWA 101.

Dimensions: length 78.0–98.0 μm; breadth 13.0–14.0 μm; about 1.5 primary costa in 10 μm and 10–12 transapical striae in 10 μm.

Samples: SWA 32, 101.

*Fragilaria brevistriata* Grunow var. *elliptica* Héribaud
(Figures 78–80)
Héribaud 1903, p.74, pl.10, fig. 11.
Hustedt 1931–59, p.169, fig. 676f.

Cholnoky (1966, p.184) recorded three *Fragilaria* taxa from all but one of his Gross Barmen samples. These taxa were *F. construens* (Ehrenberg) Grunow, its var. *subsalina* Hustedt and *F. pinnata* Ehrenberg. However, on examining the relevant samples (SWA 30, 32, 33, 101) not a single example of the above-mentioned taxa was observed. Instead, the taxon illustrated in Figures 78–80 was found relatively frequently in all these samples. While Cholnoky may well have seen the three taxa he recorded, it is surprising that he should have overlooked the taxon most commonly present on these slides. We therefore suggest that Cholnoky actually saw this taxon, but identified it differently in each of the samples.

The small *Fragilaria* species have recently been the focus of greater attention, with a number of diatomists trying to resolve the taxonomy of the *F. construens-pinnata-brevistriata-elliptica* group (Haworth 1979; Poulin et al. 1984; Rosen & Lowe 1981). These studies did not throw much light on the identity of our specimens, which are linear-elliptical with broadly rounded poles and short marginal striae, thus leaving a relatively broad axial area. These characteristics, as well as their small dimensions and their striae counts, place our specimens in the taxon *F. brevistriata* var. *elliptica* Héribaud.

Dimensions: length 5.9–9.0 μm; breadth 2.5–3.5 μm; transapical striae 14–17 in 10 μm.

Samples: SWA 30, 32, 33, 101.

*Gomphonema affine* Kützing — *G. gracile* Ehrenberg complex (Figures 81–92)
Figures 81–92 illustrate a series of valves which show characteristics of a number of *Gomphonema* taxa without fully agreeing with any of them. We have consequently experienced great difficulty in naming them. The specimens illustrated in this series were observed in four samples from Gross Barmen (SWA 33, 101, and G 90, 93). It is evident
from his illustrations (Cholnoky 1966, p.184, figs 21, 22) and by reference to his original analysis sheets that Cholnoky identified the examples from slide No. SWA 33 (see Figures 81, 82, 85, 86) as *G. clevei* var. *javanicum* Husttedt (1937-38, p.441, pl.27, figs 6-13). On the other hand, although it is not specifically stated in his paper (Cholnoky op. cit. p.185), we believe by inference from his analysis sheets that Cholnoky assigned the larger examples of this series found in sample SWA 101 (e.g. Figure 90) to *G. gracile* Ehrenberg.

Having personally examined slides SWA 33 and SWA 101, we are convinced that Cholnoky's choice of *G. clevei* var. *javanicum* for specimens in this series is quite incorrect. However, in the past we would have had little hesitation in agreeing with Cholnoky's identification of some of the valves in this series as *G. gracile* (see Schoeman et al. 1984, p.198, figs 44-48). Nevertheless, in trying to clarify our concept of *G. gracile* by scrutinizing examples of this species on slides in the well-known slide collections of Cleve & Möller (1877-82), van Heurck (1884-87) and Tempère & Peragallo (1889-95), and by thoroughly surveying the literature, we have been left with a very confused concept of *G. gracile*. Patrick & Reimer (1975, p.132) commented that this species is highly variable in respect of dimensions and striae density, but is very consistent with regard to the outline of the valve and poles, and the shape of the central and axial areas. Both Patrick & Reimer (op. cit. pl.17, figs 1-3) and Husttedt (1930, p.376, fig. 702) illustrate *G. gracile* as having narrowly lanceolate valves with acutely rounded poles. In contrast, the Gross Barmen specimens (Figures 81-92) are more or less distinctly rhomboid in outline and are usually slightly cymbelloid in shape. In this respect the Gross Barmen specimens bear a greater resemblance to Husttedt's (1937-38, p.438, pl.28, figs 9-11) illustrations of *G. gracile* from Java, Bali and Sumatra. However, whether the latter are true representatives of this species is difficult to say. In addition to differences in valve outline, it would appear from Patrick & Reimer's (op. cit.) description of *G. gracile* that the Gross Barmen specimens are relatively broader than would be acceptable for this taxon.

Taking valve shape into consideration, our specimens agree more closely with *G. affine* Kützing (1844, p.86, pl.30, fig. 54). An example of the latter from Kützing's type material from Trinidad (BM slide No. 18653) has been illustrated photographically by Germain & le Cohu (1981, p.168, pl.1, fig. 13). This valve shows an outline very similar to various examples from Gross Barmen. Striae counts of the Gross Barmen specimens (11-14 in 10 μm) accord closely with those for *G. affine* (10-13 in 10 μm), but some of our individuals are somewhat shorter (minimum length 21.0 μm) and the valves of even the largest specimens appear to be relatively narrower (breadth 5.5-9.0 μm) than their counterparts in *G. affine* (breadth 7.0-11.0 μm).

We also cannot equate our specimens from Gross Barmen with *G. affine* var. *insigne* (Gregory) Andrews (1970, p.A.20, pl.3, figs 12-16) on account of the more widely spaced striae in the latter (6-9 in 10 μm). Striae density is ostensibly the only criterion separating the var. *insigne* from *G. affine*, but even then Patrick & Reimer (op. cit. p.134) claim to have found specimens of var. *insigne* with 10-12 striae in 10 μm.

Another species to be taken into account here is *G. amoenum* Lange-Bertalot (in Krammer & Lange-Bertalot 1985, p.42, pl.35, figs 1-6; pl.42, figs 7, 8), which also falls into the ambit of the 'G. affine' group of taxa. The Gross Barmen specimens clearly resemble *G. amoenum* in valve shape, but have proportionately narrower valves than the latter, and have a size range, which, although overlapping with that of *G. amoenum*, tends towards the smaller specimens. Differences in their autecology may also provide grounds for separation. The Gross Barmen specimens were found in fairly saline water below a hot spring, whereas *G. amoenum* is apparently an alpine form from waters low in electrolytes.

The difficulty experienced in confidently identifying the Gross Barmen specimens as any one of the above-mentioned taxa has shown the great need for a thorough revision of the taxonomy of these closely related taxa. Until greater clarity is obtained in this regard, we prefer not to make a firm choice of name for the specimens, although from our present observations, we would be inclined to favour *G. affine*.

Dimensions: length 21.0-55.5 μm; breadth 5.5-9.0 μm; transapical striae near the centre 11-14 in 10 μm and at the poles 16-20 in 10 μm.

Samples: SWA 33, 101; G 90, 93.

**Gomphonema gracile** Ehrenberg


**Gomphonema parvulum** (Kützing) Grunow (Figures 93-99)

In an earlier paper, Schoeman et al. (1984, p.196, figs 27-34 as 'G. gracile Ehrenberg – *G. parvulum* complex') figured a series of forms from the vicinity of the Pretoria Salt Pan, which agree in dimensions and valve shape with the range of dimensions recorded for the Gross Barmen specimens (Figures 93-99) in this survey. However, for reasons similar to those expressed by Schoeman et al. (op. cit. p.197) we prefer to identify the Gross Barmen examples as *G. parvulum*.

Dimensions: length 14.5-33.5 μm; breadth 4.5-5.5 μm; transapical striae 14-18 in 10 μm near the centre and 20-24 in 10 μm at the poles.

Samples: SWA 32, 33, 101.

**Gomphonema subclavatum** (Grunow) Grunow (No figure)

Cholnoky (1966, p.185 as *G. longiceps* var. subclavatum) recorded this species from Gross Barmen in sample SWA 101. We examined this slide but found no specimens which could be related to this species. We are therefore uncertain as to whether it is really present here.

Sample: SWA 101 (?).

**Hantzschia amphioxys** (Ehrenberg) Grunow (Figure 100)

Hustedt 1930, p.394, fig. 747.

The Gross Barmen specimens, which are small and relatively densely striated (24-30 in 10 μm), do not fall within the range of 13-20 striae in 10 μm cited by Hustedt (op. cit.). However, Lund (1946, p.96, figs 13A-D, F) has shown that in this taxon a wide range in size, form and striation density (14-25 in 10 μm) exists. The smaller (21-36 μm long) and more densely striated (24-28 in 10 μm) valves recorded by Archibald (1983, p.128) are in agreement with our present observations.

Dimensions: length 26.0-33.0 μm; breadth 6.0-7.5 μm; striae 6-9 in 10 μm; striae 24-30 in 10 μm.

Samples: SWA 30, 32; G 92.

**Mastogloia elliptica** (Agardh) Cleve var. dansei (Thwaites) Cleve (Figures 101, 102)

Hustedt 1930, p.217, fig. 318.

Patrick & Reimer 1966, p.300, pl.20, figs 20-23.

Dimensions: length 32.0–47.0 μm; breadth 11.5–13.0 μm; transapical striae 15–16 in 10 μm near the centre and 16–18 in 10 μm at the poles; striae puncta 12–20 in 10 μm; loculi 8–9 in 10 μm.

Samples: SWA 32, 33; G 93.

*Navicula brasiliensis* (Cleve) Cleve f. *platensis* (Frenguelli) Hustedt (Figure 103)


Frenguelli in Frenguelli & Cordini 1937, p.96, text fig. 9c (as var. *platensis* Frenguelli).

Cholnoky (1966, p.194, figs 53–55) recorded a number of specimens under the name *Navicula platensis* (Frenguelli) Cholnoky from Gross Barmen (sample SWA 101: see our Figure 103) and various other samples from springs in South West Africa/Namibia (e.g. Figures 104, 105). In an earlier paper on diatoms from Windhock, Cholnoky (1963a, p.34, fig. 12) raised Frenguelli’s (op. cit.) *Navicula brasiliensis* var. *platensis* to the rank of species, basing his decision on Cleve’s (1894, p.139) description of *N. brasiliensis* and on comments made by Hustedt (1949, p.91, pl.5, figs 13–15).

Unfortunately, it is obvious that, when Cholnoky and Hustedt wrote their respective accounts, neither had examined Cleve’s type material of *N. brasiliensis* (Cleve) Cleve 1881, p.4, pl.1, fig. 4 under *Cymbella brasiliensis*; type slide Cleve & Möller 1877–82, No. 193). Had they done so, Cholnoky’s criteria for differentiating the two taxa as distinct species would have been found to be groundless.

Having examined numerous specimens (see Figures 106–108) on Cleve & Möller’s slide No. 193 (= NIWR 69/1369), labelled as containing *Cymbella (?)* *navicula* Cleve [= *Navicula brasiliensis* (Cleve) Cleve 1884, p.139], it is clear that Cleve’s (1881, p.4, pl.1, fig. 4) original diagnosis and illustrations were accurate in some respects, but not in others. These inaccuracies or omissions were partially corrected in Cleve’s (1894, p.139) later description, while further improvements were made subsequently by Hustedt (1961–66, p.764). An important inaccuracy in both of Cleve’s descriptions was in the nature of the raphe or ‘median line’, which was described as being straight. The raphe branches in *N. brasiliensis* from Cleve’s type slide (Figures 106–108) are in fact somewhat curved. This completely negates Cholnoky’s (1963a, p.34) first criterion for the elevation of the var. *platensis* to species level. In this respect the construction of the raphe in Cleve’s *N. brasiliensis* is identical to the Gross Barmen specimens (e.g. Figure 103). The formation of the axial and central areas was Cholnoky’s second criterion for separating the two taxa, but he did not elaborate further on this point. We can only assume that Cholnoky considered the narrow linear axial area, somewhat dilated at the central nodule, as Cleve (1894, p.139) described these areas, to be significantly different from the narrow lanceolate central area expanded into an elongate elliptical central area described by Hustedt (1949, p.91) for the var. *platensis*. Again comparison of the Gross Barmen specimens (Figure 103) with *N. brasiliensis* (Figures 106–108) revealed no differences between them. Finally, with no additional comment, Cholnoky merely claimed that differences in striae density constituted sufficient grounds to separate them as species. From our observations of *N. brasiliensis* in Cleve’s material (Cleve & Möller slide No. 193) the striae density at the centre of the valve and at the poles agrees entirely with Hustedt’s (1949, p.91) counts for the var. *platensis*. Furthermore, our counts of striae (20–22 in 10 μm) on the Cleve specimens, taken between the centre of the valve and the poles, tally exactly with Cleve’s (1881, 1894) observations. The striae counts taken from the Gross Barmen and other South West African/Namibian specimens conformed entirely with those of *N. brasiliensis*. In summary therefore, using all Cholnoky’s differentiating criteria, we were unable to find any to separate *N. platensis* (Gross Barmen examples) from *N. brasiliensis*. Although this may be so, the Gross Barmen specimens are not identical in all respects with the type specimens of *N. brasiliensis*. How then do they differ? In contrast to the broadly lanceolate valves of *N. brasiliensis* which generally have slightly rostrate, subacute poles, the valves of the Gross Barmen specimens are linear-elliptical with relatively broad rostrate poles. In this respect they conform almost exactly to Frenguelli’s (1937) description of the var. *platensis*.

It is noteworthy that, in searching for better specimens to illustrate Cholnoky’s concept of the forms designated by him as *N. platensis*, the variation in size and valve shape of specimens from different South West African/Namibian samples was considerable, but all specimens were identical to *N. brasiliensis* in raphe structure, shape of the axial and central areas, and in the structure and density of the transapical striae. In sample SWA 72 (Cholnoky 1966, p.167) some exceptionally narrow valves (6.5–8.0 μm) were observed (Figures 104, 105). At the other extreme, in sample SWA 97 from Windhock (Cholnoky 1965a, p.29 = sample No. 1; no specimen illustrated), we found some large linear-elliptical to linear forms with very broad scarcely rostrate poles. The shape of these valves places them closer to Frenguelli’s taxon. However, since it appears that the only features distinguishing the typical *N. brasiliensis* from the Gross Barmen and other South West African/Namibian examples are valve shape and, for some specimens, the proportionately narrower valves, we prefer to follow Hustedt’s taxonomic ranking of *forma* for Frenguelli’s taxon. We therefore designate the specimens from Gross Barmen as *N. brasiliensis* f. *platensis*.

Dimensions: Under this heading we first record the dimensions of the Gross Barmen specimens, and then, for comparative purposes, we present the range in dimensions for examples of *N. brasiliensis* observed on Cleve & Möller’s slide No. 193.

f. *platensis* from Gross Barmen: length 42.0–49.0 μm; breadth 10.0–11.0 μm; transapical striae near the centre 22 in 10 μm, more widely spaced at the centre, and 24 in 10 μm at the poles.

*N. brasiliensis* (Cleve) Cleve (type material): length 28.0–55.0 μm; breadth 9.5–13.0 μm; transapical striae 20–22 in 10 μm near the centre, more widely spaced at the centre, and 24 in 10 μm at the poles.

Samples: SWA 101.

*Navicula* sp. [affin. *cincta* (Ehrenberg) Ralfs] (Figures 109–113)

Identification of the taxon illustrated in Figures 109–113 is extremely difficult, and we have not been able to place it with certainty in any taxon known to us. We do, however, believe that it should be associated with *Navicula cincta* (Ehrenberg) Ralfs, which is itself a taxon needing clarification with regard to its precise identity. The true concept of *N. cincta* has been the subject of recent discussion since it is one of the most difficult taxa in the genus *Navicula* to identify correctly. Carter (1979, pls 1–3) re-examined various slides supposedly containing *N. cincta* or its varieties, including material from Franzenbad, which may be a part of Ehrenberg’s original sample, and drew a series of valves to illustrate the forms present. Lange-Bertalot (1980b, p.37, pl.7, figs 1–19 as *N. cari* var. *cincta*) supplemented Carter’s illustration of examples from Franzenbad with a series of photographs from the same material.
In their general characteristics, the Gross Barmen specimens (e.g. Figures 109–113) approach very closely a number of examples illustrated by Carter and Lange-Bertalot. They differ most strikingly by the strong contrast in the direction of the striae. In most of the specimens illustrated by Carter and Lange-Bertalot the polar striae vary from more or less parallel to weakly convergent. In all examples from Gross Barmen the striae change relatively abruptly from strongly radial near the centre to strongly convergent at the poles. Nevertheless, Cholnoky (1966, p.187, figs 24, 25) apparently identified these species as *N. cincta*. This taxon was found only in Cholnoky's material from Gross Barmen.

Dimensions: length 20,5–25,5 μm; breadth 4,0–4,5 μm; transapical striae near the centre 12 in 10 μm and 12–13 in 10 μm near the poles.


*Navicula cohnii* (Hilse) Lange-Bertalot & Bonik (Figure 114)

Lange Bertalot & Bonik 1978, p.33, pl.1 figs 8, 9; pl.2, figs 8–10.

Having examined Rabenhorst's exsiccatia material (Alg. Eur. No. 962) with light and electron microscopes, Lange-Bertalot & Bonik (op. cit.) claim that *N. cohnii* contrasts sharply with *N. mutica* Kützing in the relationship between the position of the stigma and the direction in which the central pores of the raphe branches are turned. In *N. cohnii* the central pores turn away from the isolated stigma, whereas in *N. mutica* the central pores are deflected towards the stigma. This contrast and the position of the stigma relative to the valve margin, nearer to the middle of the valve in *N. cohnii* and closer to the valve margin in *N. mutica*, are in Lange-Bertalot & Bonik's opinion sufficient grounds to make a clear distinction between the two species. For this reason Lange-Bertalot & Bonik (op. cit.) maintain that *N. cohnii* should be treated as an independent species, and not as a variety or form of *N. mutica* (e.g. Hustedt 1961–66, p. 583).

We observed one specimen (Figure 114) in which the central pores turn away from the stigma which lies removed from the valve margin. These features would therefore place this specimen in *N. cohnii*.

Dimensions: length 11,0 μm; breadth 6,0 μm; transapical striae near the centre 22 in 10 μm.

Samples: G 92.

*Navicula cuspidata* (Kützing) Kützing var. *ambigua* (Ehrenberg) Cleve (No figure)


Although this taxon was recorded by Cholnoky (1966) from sample SWA 101, we were unable to confirm its presence by personal observation of a specimen. We do, however, accept that it may be rare in this sample.

Sample: SWA 101.

*Navicula sp.* [affin. *cuspidata* (Kützing) Kützing var.]

See: *Navicula sp.* [affin. *halophila* var. – *cuspidata* var.]

*Navicula elbak* O. Müller (Figures 115–122)

O. Müller 1899, p.311, pl.12, figs 19–22.

Archibald 1983, p.162, figs 33, 34, 270–275, 537.

In his report on diatoms from springs in South West Africa/Namibia, Cholnoky (1966, p.190) recorded a species under the name *Navicula gregaria* Donkin, which was apparently found abundantly in a number of samples. On examining the relevant samples from Gross Barmen (SWA 32, 33, 101), it was evident that he had made a mistake in the identity of this species, as we did not observe a single example of *N. gregaria* (vide Schoeman & Archibald 1978, figs 1–41).

Using sample SWA 33 as a marker, since 'N. gregaria' was clearly the dominant *Navicula* out of the three species in this genus recorded from this sample (Cholnoky op. cit., p.219), we were able to identify this species as *N. elbak* O. Müller. On checking the remaining two samples from Gross Barmen, supposedly containing 'N. gregaria', we again found the taxon to be *N. elbak*.

*N. elbak* seems to be a relatively rare species, endemic to Africa (Hecky & Kilham 1973; Compère 1975, 1984; Krammer & Lange-Bertalot 1985), and we have had difficulty in finding reasonable illustrations of this species in the literature to confirm our identification. As far as we are aware, nobody has recently studied O. Müller's type material, if still available, and so present identifications are based on interpretations of O. Müller's description and drawings. O. Müller's (op. cit., pl.12, figs 19–21) illustrations depict a narrowly lanceolate valve with rostrate poles, straight raphe branches set in a narrow, linear axial area, which is scarcely widened at the central nodule, and transapical striae that are parallel to weakly radial throughout. Gasse (1975, pl.35, figs 12–15) photographically illustrated a range of valves very similar in valve outline and dimensions to the Gross Barmen specimens (Figures 115–121). The latter were not quite as distinctly rostrate as shown by O. Müller. Nevertheless, in the Sundays River of the eastern Cape Province in South Africa, Archibald (op. cit.) found valves with identical structure and dimensions, of which some had distinctly rostrate poles. Such valves would accord very closely with O. Müller's description and drawings. We are therefore confident that the specimens observed in the Gross Barmen samples can be identified with O. Müller's *N. elbak*.

In a recent discourse on the taxonomy of *N. halophila* (Grunow) Cleve, Krammer & Lange-Bertalot (1985, p.73, pl.23, figs 22–24) find the taxonomic delimitation of *N. elbak* difficult to define, and hint at a closer relationship with *N. halophila*. At this stage, however, we do not attribute to it any more intimate a relationship than that it belongs to the section *Naviculaceae orthostichae*. For further comments on its taxonomy, see under *N. halophila* and *N. simplex*.

As mentioned above, this species appears to be an African one, but records from southern Africa are few. Fritsch & Rich (1930, p.101, fig. 3F) recorded the species from a number of localities in Griqualand West, but while their drawing of *N. elbak* conforms in most respects to our concept of the species, the deflection of the central pores of this specimen is uncharacteristic. We are therefore not certain whether this feature was actually seen, or whether it indicates a different taxon. The only positive records of this species from southern Africa are those of Archibald (1983, p.162) from the Sundays River, and Krammer & Lange-Bertalot (1985, p.176) from South African stock drinking troughs. It is not known whether Cholnoky misidentified this species in any other instances, but his records of *N. gregaria* from South West Africa/Namibia will have to be reviewed to determine the distribution of this species more accurately.

Dimensions: length 20,0–39,5 μm; breadth 4,5–5,5 μm; transapical striae near the centre 20–24 in 10 μm, and generally slightly denser at the poles (up to 24 in 10 μm).

Samples: SWA 32, 33, 101; G 90, 93.

*Navicula exilissima* Grunow (No figure)


Cholnoky (1966, p.189) recorded this species from the Gross Barmen sample SWA 32. We could not confirm this
Navicula sp. [affin. halophila (Grunow) Cleve var. – cuspidata (Kützing) Kützing var.] (Figures 123–126)

Figures 123–126 illustrate examples of a taxon found in both sets of diatom samples collected from the Gross Barmen hot springs. A re-examination of Cholnoky’s (1966, p.190) material showed that he identified this taxon as N. halophila (Grunow) Cleve, 1925. (Cleve, Gastro 1957, pl.35, figs 1, 2) held the same opinion with regard to two valves illustrated with a structure and shape identical to those from Gross Barmen. However, having examined the type slide (van Heurck 1884–87: slide No. 12 = NIWR 1/12) of N. halophila (cf. van Heurck 1885, p.100) we are concerned that the specimens from Gross Barmen do not represent the true N. halophila. Valves of this species on the van Heurck slide are distinctly rhombic in outline with acutely rounded poles. This valve shape is clearly depicted by Hustedt (1961–66, p.65, fig. 1209, and the largest specimen in Fig. 1210), and is obviously much different from the elliptical lanceolate valves with fairly short rostrate poles of the Gross Barmen specimens. It is clear from an unpublished study of further South West African/Nambian samples that Cholnoky was aware of the rhombic outline of the true N. halophila. Rhombic valves from this unpublished study (sample SWA 232) were used by Schoeman & Archibald (1977a, figs 1–18) to illustrate their concept of N. halophila. We therefore find it difficult to understand why Cholnoky (op. cit.) identified the Gross Barmen specimens of this taxon as N. halophila without further taxonomic comment. It also leaves the problem of how the Gross Barmen taxon should be identified.

On scanning the literature we have found diverse opinions with regard to the Gross Barmen taxon or forms similar to it. These can be divided broadly into two schools of thought. Some authors identify them as a variety or form of N. halophila, such as N. halophila f. subcapitata (Østrup) Kolbe (e.g. Cholnoky 1960, p.64, fig. 198 as var.; Compère 1975, p.237, fig. 174; Schoeman & Ashton 1982a, p.88, figs 43–46), while others have placed them in various sub-specific ranks of N. cuspidata (Kützing) Kützing. For example, O. Müller (1899, pp.310, 311, pl.12, figs 16–18) identified similar forms as N. cuspidata var. ambigua f. subcapitata and N. cuspidata var. lanceolata, while Germain (1966, p.215, figs 2–4) called them N. cuspidata var. curta f. rostrata. The Gross Barmen specimens do not completely fit the original descriptions and illustrations of any of these taxa.

The Gross Barmen specimens cannot be equated with N. halophila var. subcapitata Østrup (1910, p.29, pl.1, fig. 22) because they are much larger, particularly breadthwise, and are more elliptical in shape and have relatively short rostrate poles. On the other hand, we are reluctant to suggest a closer link with N. cuspidata on account of the strongly convergent striae near the poles and the lack of hooked central pores in the Gross Barmen specimens. In this regard, it is interesting that Hustedt (1949, p.81) found N. cuspidata var. ambigua (Ehrenberg) Cleve abundantly in the thermal springs of May-ya-Moto in the Belgian Congo (Zaire). On examining a slide (NIWR 593/18) that we prepared from some of Hustedt’s material No. 31 from May-ya-Moto (cf. Hustedt, op. cit. p.40) we observed specimens conforming exactly to those from Gross Barmen, and therefore deduce that Hustedt named them N. cuspidata var. ambigua. On the grounds mentioned above we cannot agree with Hustedt’s identification, and are therefore left without a firm identification for this taxon. Since we do not have the resources to identify these specimens more accurately at present, we have left our options open.

Dimensions: length 41.0–61.0 μm; breadth 11.0–14.5 μm; transapical striae near the middle of the valve 18–20(22) in 10 μm, and near 20–24 in 10 μm at the poles; the striae contain 24–30 puncta in 10 μm.

Samples: SWA 30–32; 101; G 90, 91.

Navicula kotschyi Grunow (Figures 127–132)

Grunow 1860, p.538, pl.4, fig. 12.

Cleave & Grunow 1880, p.41 (as N. kotchesiana Grunow).

Van Heurck 1880–83, pl.10, fig. 22 (as N. kotchesiana Grunow).

Krammer & Lange-Bertalot 1985, pl.23, fig. 15.

Krammer & Lange-Bertalot (op. cit. p.73) have recently reached the conclusion that N. kotschyi Grunow is conspecific with N. grimmii Krassske, and that Hustedt’s (1930, p.275, fig. 454; 1961–66, p.597, fig. 1601) concept of the former was incorrect, and represents a new species, N. pseudokotschyi Lange-Bertalot (in Krammer & Lange-Bertalot 1985, p.88, pl.23, figs 13, 14). Although we have not personally examined type material of these two species, we have accepted Krammer & Lange-Bertalot’s (op. cit.) opinion. We do so, however, with some reservation, as a result of certain discrepancies in the literature.

Grunow (1860, p.538, pl.4, fig. 12) originally described and illustrated N. kotschyi as a small Navicula with, among other attributes, capitulate apices and 14–16 striae in 10 μm at the centre (up to 20 in 10 μm at the poles. In a later work on this species, but under the name N. kotchesiana, Grunow (in Cleave & Grunow 1880, p.41) indicated finer striaion (19–23 in 10 μm) than given in his original description. At about the same time a drawing of N. kotchesiana (= N. kotschyi) by Grunow was reproduced by van Heurck (1880–83, pl.10, fig. 22). This depicted a lanceolate-elliptical valve with relatively broad rostrate, but not capitulate poles. It appears from these references to Grunow’s works that there is some discrepancy in the valve morphology and striae counts of N. kotschyi. Without examining Grunow’s slides we cannot be certain that Grunow observed any forms intermediate between typical forms and those displaying the discrepant characteristics, or whether we are actually dealing with two different taxa.

However, assuming that Krammer & Lange-Bertalot (op. cit.) are correct in their opinion that N. grimmii is conspecific with N. kotschiyi, and if we consider the two varieties of N. grimmii described by Hustedt (1961–66, p.769, fig. 1742), we find that N. grimmii has more or less the same range in valve morphology as that described above for N. kotschiyi. Krassske (1925, p.45, pl.1, fig. 14 as N. grimmii) himself depicted valves of N. grimmii with distinctly capitulate poles, which would conform more to the clearly capitulate form of N. kotschiyi in Grunow’s (1860, pl.4, fig. 12) original illustration. Hustedt (op. cit.) did not appear to have observed intermediates between N. grimmii var. grimmii and the var. rostellata Hustedt, and interestingly found the latter in thermal streams, often abundantly, from tropical regions. In the Gross Barmen samples we observed specimens conforming to N. grimmii var. rostellata of Hustedt and to Grunow’s drawing of N. kotschiyi in van Heurck (1880–83, pl.10, fig. 22). Cholnoky (1966, p.190, figs 28–30, 32–40), however, claimed that in his samples of diatoms in springs from South West Africa/Namibia he could demonstrate a morphological series linking N. elephantis Cholnoky (1963a, p.34, figs 13, 14), N. grimmii var. rostellata and N. grimmii into a single morphologically variable taxon. We could not substantiate this from the Gross Barmen samples, but it might explain the discrepancies in Grunow’s various comments and illustrations of N.
kotschyi discussed above. We recognize the need for more detailed studies into the relationships of these taxa, but accept for the present the name *N. kotschyi* for our specimens.

Dimensions: length 12.5–26.5 μm; breadth 5.0–7.0 μm; transapical striae near the centre 18–22 in 10 μm, and 22–24 in 10 μm at the poles.

Samples: SWA 32, 33, 101; G 93.

*Navicula minima* Grunow (Figure 133)


Schoen & Ashton 1982b, p.31, figs 23, 24, 53, 54.

A single specimen of this taxon was observed.

Dimensions: length 9.0 μm; breadth 3.0 μm; transapical striae 26–27 in 10 μm near the centre and up to 30 in 10 μm at the poles.

Samples: G 90.

*Navicula pseudosydowii* sp. nov. (Figures 134–138)

Valves narrowly lanceolate with relatively acutely rounded apices; length 22.0–32.5 μm, breadth 4.0–5.5 μm. Raphe branches filiform and straight; central pores close together, small and inconspicuous; terminal fissures not clearly observed, but appear to curve in the same direction. Axial area near the poles very narrowly linear, expanding into a relatively long narrowly lanceolate area in the middle of the valve; central area a somewhat ill-defined, asymmetrical transverse area, in which the central one or two striae are irregularly shortened, and generally appear fainter and more diffuse than the other striae. Transapical striae fairly coarse, radial over most of the valve, becoming convergent at the poles; 13–14 in 10 μm near the centre and slightly denser at the poles (14–16 in 10 μm). Striae usually distinctly punctate but occasionally in some planes of viewing seen to be lineolately punctate, with puncta arranged in longitudinal rows more or less parallel to the valve margin. A longitudinal line of variable length may often be seen cutting across a few of the striae near the centre of the valve.

Valvae anguste lanceolatae, apicibus leviter acutis; 22.0–32.5 μm longae, 4.0–5.5 μm latae. Raphe filiformis, directa; poris centralibus parvis, inconspicuis, approximatis positis; fissuris terminatis non haud observatis sed probabiliter ad idem direc­tionem curvatis. Area axialis ad polos anfibias, medio in partem anguste lanceolata expania; area centrali nonnulli indistincta irregulari transversa, una vel duobus strisis centralibus irregulariter abbreviatis et generaliter dilutioribus. STriae trans­apicales satis crassae, in parte medio radiales, ad polos versus con­gentes; in parte medio 13–14 in 10 μm, ad polos versus leviter densiores (14–16 in 10 μm). Striae plerumque indistincte punctatae sed interdum perspicue lineolato-punctatae, punctis in serialibus longitudinalibus ad marginem valvae plusminusque parallellis ordin­atis. Striae paucae in parte medio valvae saepve linea longi­tudinalis longitudinis variabilis percutitae.

Habitat: in the mineralized thermal spring waters at Gross Barmen near Okahandja in South West Africa/Namibia.

Type slide No. 504/10064 (G 92) in the NIWR collection, Pretoria, South Africa.

The above diagnosis describes a new taxon as it was ob­served with the light microscope. Using transmission electron microscopy (TEM) the features observed above were confirmed and greater clarity was obtained with regard to some of them. The valves have a relatively high mantle which passes into a fairly strongly convex valve face. This explains why the puncta of the striae are not usually distinct. Examined from directly above, the convexity of the valve face reduces the apparent spaces between the puncta so that the light microscope cannot resolve them distinct­ly. In contrast, when a portion of the valve mantle or face becomes flattened or the valve is tilted to view a more evenly flat surface, the lineolate puncta become more distinct. In the TEM micrographs (Figures 137, 138) the central area is clearly seen as a transverse rectangular area. These micro­graphs also show that the short longitudinal lines traversing the striae near the central nodule, may be lateral extensions of the central area. This seems to be the case in Figure 137. However, in Figure 138 the development of this longitudinal line is variable. It may penetrate across one or two striae adjacent to the central area, or it may skip one or two striae before manifesting itself as a break in the puncta of the next stria or striae. In some instances the longitudinal line may be absent. Under the light microscope, this feature is not always observed due to the convexity of the valve face.

In samples collected from other South West African/Namibian springs (SWA 68, 207, 208) Cholnoky (1966, p.187) identified this species as *N. ammophila* Grunow. However, although we do not have a clear concept of *N. ammophila*, we cannot accept Cholnoky’s identification on account of the presence of a central area and the charac­teristic longitudinal lines crossing some of the striae near the central area in *N. pseudosydowii*. The latter feature, in particular, has prevented us from identifying our species with any other taxa known to us.

The taxon showing the greatest similarity to this new species from Gross Barmen is *N. irregularis* Gasse (1975, Vol. 2, p.25; Vol. 3, p.34, figs 14–16). The latter, however, differs in its somewhat broader valves (5.0–7.0 μm broad), the more widely spaced (10 in 10 μm) and coarsely punctate striae, and the slightly curved raphe branches.

Also showing features resembling the Gross Barmen species is *N. eymei* Coste & Ricard (1982, p.290, pl.2, fig. 4; pl.3, figs 34, 35). *N. eymei* is, however, a much larger di­atom (40.0–45.0 μm long, 8.0–9.0 μm broad) with coarser stria­tion (7–8 striae in 10 μm).

Finally, the name of this new species, *N. pseudosydowii*, suggests a relationship to *N. sydowii* Cholnoky (1963b, p.244, pl.8, figs 20–23; pl 9, figs 12, 13). Cholnoky’s species is, in contrast, smaller (9.5–20.0 μm long and 3.0–5.0 μm broad; cf. Archibald 1983, p.209, figs 337–341), has no central area, and has no longitudinal line crossing the striae near the central nodule.

Despite a careful search of the literature, we have not been able to find any other taxon with which we could iden­tify the Gross Barmen species. The structure of the striae, as may be inferred from the TEM micrographs (Figures 137, 138), i.e. an internal transverse groove with a series of longitudinally aligned, narrow, lineate puncta opening to the exterior, place this species in the group *Navicula lineo­latae* Cleve.

Samples: G 92.

*Navicula pupula* Kützing (Figures 139–141)

Schoen & Archibald 1979, *N. pupula* pp.1–5, figs 1–64.

Dimensions: length 25.0–33.5 μm; breadth 7.0–7.5 μm; transapical striae 22–27 in 10 μm near the centre and at the poles.

Samples: SWA 30–33, 101; G 93.

*Navicula rostellata* Kützing (Figure 142)


This taxon was rare in one of the Gross Barmen samples.

Dimensions: length 38.0–42.0 μm; breadth 9.5–10.0 μm; transapical striae 13.0–14.0 in 10 μm near the centre and up to 16 in 10 μm at the poles (striae with 32–34 puncta in 10 μm).

Samples: G 89.
Navicula seminulum Grunow (No figure)

In sample SWA 101 we observed a single specimen of this taxon, which was not previously recorded from Gross Bar­men by Cholnoky (1966). The specimen observed was poorly preserved, and therefore not suitable for photo­graphy.

Dimensions: length 14,0 µm; breadth 4,0 µm; transapical striae 22 in 10 µm.
Samples: SWA 101.

Navicula simplex Krasske (Figures 143-148)
Krasske 1925, p.51, pl.2, fig. 33.
Hustedt 1949, p.93, pl.5, figs 6-8.

In a number of samples containing Navicula elkab O. Müller and Navicula sp. [affin. halophila var.], a third taxon be­longing to the section Naviculae orthostichae was found. We have tentatively identified this taxon as N. simplex Krasske, understanding fully that it does not agree com­pletely with either Krasske's (op. cit.) original diagnosis or with his drawing. We base our identification on three spec­imens illustrated by Hustedt (op. cit.) in his study of diatoms from the Belgian Congo (Zaire). The Gross Barmen spec­imens (Figures 143-148) have the same valve shape, dimen­sions and striae counts as those from the Belgian Congo study. In contrast, Krasske's (op. cit.) diagnosis of N. sim­plex indicates a much larger species with somewhat coarser striation (length 34-38 µm; breadth 8-10 µm; transapical striae 16 in 10 µm).

The relationship of N. simplex to N. halophila is not clear at present. According to Lange-Bertalot (1979, p.204, figs 67, 68) and Krammer & Lange-Bertalot (1985, p.73, pl.23, figs 19-21), N. simplex is synonymous with N. halophila. We are not, however, entirely convinced with their view­point, since we could not find any intermediates between the N. simplex valve shapes and the more rhombic and generally larger valves of N. halophila. The N. simplex valves found in the Gross Barmen samples were more closely related to, and therefore more difficult to dif­ferentiate from, N. elkab (see above; Figures 115-122) than to the forms referred to in this study as Navicula sp. [affin. halophila var.] (Figures 123-126). They differ from N. elkab in their more elliptical valve shape, giving it slightly broader valves, and somewhat more widely spaced striae, which are also coarser in their appearance. The differences are subtle, but usually can be appreciated best when ob­served alongside each other. Gasse (1975, pl.35, figs 16-19) has illustrated a number of valves under the name N. sim­plex, but, unfortunately, the photographic reproduction makes it difficult to examine these specimens critically. They do not appear to be the same taxon as found under this name in the Gross Barmen samples. Gasse's specimens appear to have a much closer affinity to N. elkab, par­ticularly the smaller forms with more distinctly rostrate poles (vide O. Müller 1899, pl.12, figs 21, 22).

Although Cholnoky (1966) did not record N. simplex from Gross Barmen, we observed a number of specimens from his sample No. SWA 33 (Figures 143, 144). We suggest, therefore, that Cholnoky either did not see this taxon or he included it with N. gregaria sensu Cholnoky (= N. elkab) in his report.

Dimensions: length 24,5-27,0 µm; breadth 6,0-6,5 µm; transapical striae near the centre 18-22 in 10 µm, and 20-24 in 10 µm near the poles.
Samples: SWA 33; G 90, 91, 93.

Navicula soodensis Krasske (Figures 149-152)
Krasske 1927, p.272, pl.10, figs 20-22.
Hustedt 1961-66, p.277, fig. 1408.
Hustedt 1931-39, p.793, fig. 1138 (as Stauroneis legleri Hustedt).

On a number of occasions Cholnoky (1962, p.46, fig. 64; 1966, p.196, figs 59, 60), Schoeman & Ashton (1982a, p.89, fig. 47) and Archibald (1983, p.207, figs 329-331) have suggested that N. soodensis and Stauroneis legleri Hustedt are conspecific, and that the latter is therefore a synonym of N. soodensis. This opinion is still endorsed in the present paper, though it should be emphasized that our obser­vations are based solely on a literature survey, and that we have not yet had the opportunity to examine the type material of either of these taxa.

The structure of the striae and the central area as seen under TEM is shown in Figures 151 and 152. Each stria is composed of a single row of elliptical areolae, 45-56 in 10 µm. The central area is a relatively narrow and irregularly shaped fascia, which may have one or more striae of variable length on one or both sides of the valve.

Dimensions: length 22,0-28,0 µm; breadth 4,5-6,0 µm; transapical striae 16-19 in 10 µm near the centre and slightly denser up to 22 in 10 µm, at the poles.
Samples: SWA 32; G 92.

Navicula sp. (Figures 153-156)
In a few samples from the two Gross Barmen collections, a small Navicula taxon was observed (Figures 153-156). We have not been able to identify it adequately with any taxon known to us through the literature, despite its affinities with certain species.

Under the light microscope the valves are linear­elliptical with relatively broadly rounded poles; 11,5-17,5 µm long, 3,0-3,5 µm broad. The raphe is straight and fili­form with closely placed central pores which are distinct but not markedly differentiated from the raphe fissure; ter­minal fissions were not observed. The axial area is narrowly linear, widening slightly to a narrow linear-lanceolate area round the central nodule; a central area is absent. The transapical striae are not clearly punctate, and are radial in the middle of the valve, becoming slightly convergent at the poles; 19-22 striae in 10 µm near the centre and denser towards the poles, 24-26 in 10 µm; the spacing of the central striae is usually irregular and wider, sometimes more con­spicuously so, on one side of the valve.

Figures 156a and 156b illustrate a damaged valve of this taxon viewed with TEM. This valve shows that each stria is composed of a single row of longitudinally orientated, nar­rowly elliptical puncta (40-60 in 10 µm), either set within a shallow groove in the basal siliceous layer or between two costa. A terminal fissure of the raphe is faintly visible at the lower pole of the valve (Figure 156b) where it is de­flected through an angle of 90° towards the left hand mar­gin of the valve in the illustration.

Valves, as described above, bear an affinity to N. kuri­panensis Hustedt (1937-38, p.270, pl.20, figs 23, 24) in valve shape and striae density, but are smaller and do not have parallel striae. At the other end of the size range, the Gross Barmen specimens resemble N. pseudomuralis Hus­tedt (op. cit., p.245, pl.19, figs 25-27), but the latter is a smaller species and also has parallel striae. The unknown taxon from Gross Barmen conforms most closely to the de­scription and illustration of N. manifesta Hustedt (1939, p.633, fig. 101). This Hustedt species is apparently very rare, since one may infer from the description that Hustedt saw only one specimen, and, apart from one other dubious record (Foged 1973, p.73, pl.29, figs 19-21), has not been
observed again. Hustedt's species differs from the Gross Barmen specimens only in its larger dimensions (about 24 μm long and about 4.5 μm broad) and striae that appear to be less conspicuously radial towards the middle of the valve. Nevertheless, since *N. manifesta* (= *N. utland-shoerniensis* VanLandingham 1975, p.2660) is poorly known, even as far as its autecology is concerned, and since we have not been able to examine its type specimen, we have not identified the taxon from Gross Barmen with it. We prefer to leave their identity open for the present. In this regard it is interesting that, while examining a slide (NIWR 593/18), prepared from Hustedt's material No. 31 collected at the warm springs of May-ya-Moto in Zaire (Hustedt 1949, p.40), we observed a number of examples identical to this unknown taxon from Gross Barmen. Unfortunately, none of the *Navicula* species listed by Hustedt (op. cit. p.41) as occurring in the May-ya-Moto springs can be identified with our taxon. The identity of the Gross Barmen form therefore remains unknown.

The fact that this small *Navicula* species was reasonably abundant in sample G 92 begs the question as to whether Cholnoky (1966) observed it, and placed it under another name, or whether he did not see it at all. We do know that this taxon is present in the material Cholnoky examined, since we have observed the occasional specimen on slide No. SWA 32 (= NIWR 162/3237).

**Samples:** SWA 32; G 92, 93.

*Navicula standeriella* Archibald (Figures 157-165)


*N. standeriella* is a member of a group of closely related taxa in which there has been much taxonomic confusion. The taxonomy of this species, its structure and relationship to *N. insociabilis* Krasske, *N. monoculata* Hustedt, *N. tenera* Hustedt and *N. umpatica* Cholnoky has been dealt with in some detail by Schoeman & Archibald (op. cit.).

A re-examination of Cholnoky's samples from Gross Barmen showed that he misidentified *N. standeriella* as *N. fritschii* Lund (a synonym of *N. insociabilis*) in sample SWA 32, as *N. insociabilis* in sample SWA 101, and, furthermore, failed to record it in samples SWA 30 and 33.

The striae structure of *N. standeriella* is shown in Figure 164 (TEM micrograph of a specimen from sample G 89). For comparative purposes, a micrograph of an example from Lesotho (Figure 165) is also shown. Note should be taken of how the areolae on the concave side of the longitudinal axial costa near the central nodule characteristically split into two distinct puncta.

Dimensions: length 6.5-15.0 μm; breadth 4.0-5.0 μm; transapical striae 18-22 in 10 μm.

**Samples:** SWA 30, 32, 33, 101; G 89, 93.

*Navicula veneta* Kützing (Figures 166-170)


Considering their general valve shape, structure and dimensions, our examples from Gross Barmen (Figures 166-170) clearly belong to the *N. cryptocephala* Kützing complex of varieties as described by Hustedt (1930, p.295). Recently, however, Lange-Bertalot (1979) and Krammer & Lange-Bertalot (1985) have raised several of these varieties to the rank of species. Based on their observations, we believe that our examples (particularly Figure 166) relate best to *N. veneta* Kützing. Lange-Bertalot (op. cit.) emphasized that in *N. veneta* the central area is not circular but expanded transapically, although this may not always be very obvious (cf. Lange-Bertalot's fig. 72). In this respect our examples differ slightly from those of Lange-Bertalot in that the central area is usually expanded transapically on one side of the central nodule, while on the other side it may develop into a lanceolate shaped area due to the regular shortening of the central striae (Figures 167, 168, 170). Notwithstanding this difference, we prefer to relate our specimens to *N. veneta*.

Dimensions: length 15.5-20.0 μm; breadth 5.0-5.5 μm; transapical striae 14-16 in 10 μm near the centre and 15-17 in 10 μm at the poles. The striae consist of 31-35 areolae in 10 μm.

**Samples:** G 89.

*Nitzschia alexandrina* (Cholnoky) Lange-Bertalot & Simonsen (No figures)


Cholnoky 1958, p.258, figs 29, 30 (as *N. elliptica* var. *alexandrina*).

Cholnoky (1966, p.201, figs 76-79) recorded this taxon from Gross Barmen under the name *N. elliptica* var. *alexandrina*. However, despite a careful re-examination of his slides, relevant to this study (SWA 30-33, 101), we failed to find a single valve to confirm this record. We therefore examined Cholnoky's slide No. SWA 34 (= NIWR 162/3239), made from material collected about 1.5 km below an earth dam retaining the Gross Barmen spring water. This slide contained a diatom population completely dominated by the taxon Cholnoky (op. cit.) identified as *N. elliptica* var. *alexandrina* (88.5%), and from which Cholnoky selected the specimens for his illustrations (cf. Cholnoky 1966, figs 76-79). The latter should be compared with our Figures 202, 204, 208, 212 and 213, which are examples from the same slide (SWA 34). We believe that these rather broad elliptical forms were misidentified by Cholnoky, and place them instead with *N. pusilla* Kützing, which is discussed more fully below.

*Nitzschia amphibia* Grunow (Figures 171, 172)

Hustedt 1930, p.414, fig. 793.

Schoeman et al. 1984, p.199, figs 72-86.


Dimensions: length 21.0-38.0 μm, breadth 4.0-5.0 μm; fibulae 7-9 in 10 μm; transapical striae 16-18 in 10 μm with 18-24 puncta in 10 μm.

**Samples:** SWA 32, 101; G 90, 92, 93.

*Nitzschia angusteforaminata* Lange-Bertalot (Figures 173-176)

Lange-Bertalot 1980a, p.43, figs 44-51, 127-132.

On re-examining the taxa recorded by Cholnoky (1966) from the hot springs of Gross Barmen, it became clear that his new species *N. steynii* Cholnoky (1966, p.207, figs 96-103) was founded on two distinct elements. A reasonably critical appraisal of Cholnoky's illustrations of *N. steynii* is sufficient to recognize two fairly distinct valve shapes. One group of valves (Cholnoky's figs 96, 98, 99) have linear-elliptical valves with cuneately attenuating poles, while the second group (Cholnoky's figs 97, 100-103) are lanceolate to linear-lanceolate or somewhat constricted at the centre and have poles protracted into relatively acute rostrate apices.

Under the light microscope further differences between the two groups were revealed. In the first group the transapical striae consist of fine puncta, not easily resolved, arranged in longitudinal rows which are more or less parallel to the apical axis. From Cholnoky's original pencil sketches of the specimens (in the NIWR collection) falling into this group, it is evident that he saw and noted the
parallel arrangement of the striae, it appears that he might have adapted the arrangement of the puncta in the final drawings to suit the description of the new species better. In the second group the transapical striae have very distinct puncta, which are often transapically elongated, and which are arranged longitudinally in undulating rows.

Valve shape and nature of the striae are the two characters which most easily distinguish the two groups. With regard to the other diagnostic features, valves of the first group appear to be generally shorter and narrower in relation to the valves of the second group. The density of the fibulae and transapical striae are more or less the same and cannot be used as further points of distinction. These similarities, however, cannot be employed to equate the two groups as one taxon.

Although separating the two elements incorporated by Cholnoky into *N. steynii* is relatively easy, deciding which of the two should be retained as *N. steynii* is more of a problem. Cholnoky (op. cit.) did not designate a specific slide as the type, but listed three (SWA 30, SWA 36, SWA 71) as containing the species. However, examination of these slides provided no better clue to Cholnoky’s true concept of the species. Other criteria must therefore be taken into account in trying to typify *N. steynii*.

Fortunately the problem is fairly easily resolved by comparing the two elements in *N. steynii* with other known *Nitzschia* taxa. We were thus able to identify the valves of the first group, having linear to linear-elliptical outlines and cuneate poles, with *N. angusteforaminata* Lange-Bertalot (op. cit.). The valves of the second group, being more lanceolate in shape and having distinctly punctate striae, could not be equated with any other known taxon, and are therefore retained as *N. steynii*. A description and typification of the latter will be found below.

Valves of the first group, now identified as *N. angusteforaminata* (Figures 173–176), appear to conform very closely to the description of this species in terms of their morphology and structure, but larger examples, reaching lengths of up to 47.0 µm, were observed. On the other hand, specimens with a somewhat smaller size range have been recorded from streams in the vicinity of the Pretoria Salt Pan (Schoeman et al. 1984, p.202, fig. 23). Dimensions: length 16.5–47.0 µm; breadth 3.5–4.0 µm; fibulae 9–11(12) in 10 µm, central fibulae evenly spaced; transapical striae (21)22–24 in 10 µm, not distinctly punctate.

Samples: SWA 30, 32.

*Nitzschia apiculata* (Gregory) Grunow
(Figures 177, 178)
Hustedt 1930, p.401, fig. 765.
Dimensions: length 34.0–39.0 µm; breadth 5.0–6.0 µm; fibulae and transapical striae 16 in 10 µm.
Samples: G 93.

*Nitzschia elegans* Grunow
(Figures 179, 180)
Coste & Ricard 1982, p.293, pl.6, fig. 15.

Only a few small examples were seen in one sample. Dimensions: length 11.0–12.5 µm; breadth 2.5–3.0 µm; fibulae 12–15 in 10 µm; transapical striae 30–32 in 10 µm with 30–34 puncta in 10 µm.
Samples: G 89.

*Nitzschia frustulum* (Kützing) Grunow (No figure)
From Cholnoky’s analysis sheet (NIWR collection) it appears that he recorded this taxon from Gross Barmen in only one sample (SWA 101). We examined a slide prepared from this material, but found no specimens which could be related to this species. We are therefore uncertain whether *N. frustulum* is actually present here.

Samples: SWA 101 (?).

*Nitzschia hungarica* Grunow (Figures 181, 182)

Although Cholnoky (1966, p.202) recorded this species from other springs in South West Africa/Namibia, he did not observe it in any of his samples from Gross Barmen. Nevertheless, there is a possibility that Cholnoky mis-identified this species as *N. plicatula* Hustedt (see comments on this species below). Thus, while searching through Cholnoky’s slide No. SWA 32 (= NIWR 162/3237) for the taxon he identified as *N. plicatula*, we found two examples of *N. hungarica* (Figures 181, 182) which agree entirely with our concept of the species (Schoeman & Archibald op. cit.). This species was not found in any of the remaining samples from Gross Barmen.

Dimensions: length 64.5–95.5 µm; breadth 8.0 µm; fibulae 8–10 in 10 µm; transapical striae 16–17 in 10 µm.
Samples: SWA 32.

*Nitzschia sp. [affin. intermedia] Hantzsch*
(Figures 183–186)

We have not been able to identify precisely the taxon illustrated in Figures 183–186, but place them in the *Nitzschia intermedia* Hantzsch complex of taxa proposed by Lange-Bertalot (op. cit.). He believes that *N. intermedia* is an extremely variable taxon, in which many of the variations had been described as new species (see also Lange-Bertalot & Simonsen 1978, p.61). As a result of this very broad range in forms Lange-Bertalot (op. cit.) amended the description of *N. intermedia* to take into account all the taxa now included in this complex. Our specimens from Gross Barmen (Figures 183–186) agreed with this description in terms of dimensions and density of striae and fibulae, but were often slightly sigmoid in valve view, and always distinctly sigmoid in girdle view. This gives rise to some uncertainty as to the validity of this identification. Nevertheless, Lange-Bertalot (pers. comm.) claims that he has found numerous examples of more or less sigmoid populations of normally linear taxa. Consequently, the sigmoid character of these specimens may not be very significant.

This taxon also appears to have a close affinity with *N. steynii* Cholnoky (see below), which was found fairly commonly in some Gross Barmen samples examined by Cholnoky (1966, p.207, figs 97, 100–103). The two taxa differ, however, in that *N. steynii* did not display sigmoid valves in either valve or girdle view, and in the structure of its striae. In *N. steynii* the striae are composed of relatively coarse, roundish to transapically elongated puncta, compared to the small, round but easily resolved puncta in this taxon. *N. steynii* also appears to be a shorter and relatively broader species.

Dimensions: length 47.0–110.0 µm; breadth 4.0–4.5 µm; fibulae 10–11 in 10 µm; transapical striae 23–25 in 10 µm.
Samples: G 91, 92.

*Nitzschia linears* W. Smith (Figures 187–189)
Hustedt 1930, p.409, fig. 784.

Only a few examples of this taxon were observed, but these showed a fairly wide range of variation. Figure 189
illustrates a valve in girdle view.
Dimensions: length 73,0-154,0 µm; breadth 5,0-7,0 µm; fibulae 8-12 in 10 µm; transapical striae 26-33 in 10 µm.
Samples: SWA 33.

*Nitzschia microcephala* Grunow (Figures 190–194)
Hustedt 1930, p.414, fig. 791.
In his Gross Barmen samples Cholnoky (1966, p.204, figs 86-88) identified a taxon, shown here in Figures 190–194, as *N. liebetruhii* Rabenhorst & Grunow. However, the true identity of *N. liebetruhii* appears to be controversial (Lange-Bertalot 1977, p.261; 1980a, p.53 — comments under *N. quadrangulara*). Nevertheless, Cholnoky’s forms do not fit either of the possibilities suggested for this species by Lange-Bertalot. The Gross Barmen specimens (Figures 190–194) have more linear valves with relatively broadly rostrate to capitate apices. Such valves conform more closely to *N. microcephala* Grunow, although they do not agree entirely with Hustedt’s (op. cit.) description. Lange-Bertalot (1980a, p.51), has indicated that striae counts can be greater (36–41 in 10 µm) and density of the fibulae can be more variable (9–19 in 10 µm) than given in Hustedt’s description. Taking these factors into account, we have identified the Gross Barmen forms illustrated here as *N. microcephala*.

Dimensions: length 6,5-17,0 µm; breadth 2,5-3,0 µm; fibulae (8)10-12(14) in 10 µm; transapical striae (30)31–34(35) in 10 µm, puncta not observed.
Samples: SWA 30–33, 101; G 89.

*Nitzschia palea* (Kützing) W. Smith (Figures 195–201)
Dimensions: length 21,0-47,5 µm; breadth 3,0-5,0 µm; fibulae 12–14 in 10 µm; transapical striae 34-38+ in 10 µm.
Samples: SWA 30, 101; G 93.

*Nitzschia plicatula* Hustedt (No figures)
Hustedt 1953, p.151, figs 1, 2.
Cholnoky (1966, p.206) recorded this species from one sample (SWA 32) collected at Gross Barmen. Consulting his original analysis sheet for this sample, it appears that he saw only one specimen measuring 37,0 µm long, 6,0 µm broad and having 11 fibulae and 22 transapical striae in 10 µm. These dimensions indicate a specimen much smaller than Hustedt’s (op. cit.) diagnosis allows for this species, casting some suspicion on its identity as *N. plicatula*. Despite a careful search of Cholnoky’s slide No. SWA 32 (= NIWR 162/3237), we could not find anything answering to the description of this species with these dimensions. Instead a few specimens of *N. hungarica* Grunow, a very similar taxon, were observed. These specimens were, however, considerably larger (64,5–95,5 µm long, 8,0 µm broad) than Cholnoky’s example of *N. plicatula*. We were thus not able to confirm Cholnoky’s record of the species from Gross Barmen. Since Cholnoky did not record *N. hungarica* from this slide, it is suggested that he might have misidentified a small example of the latter as *N. plicatula*.
Samples: SWA 32.

*Nitzschia pusilla* (Kützing) Grunow emend. Lange-Bertalot (Figures 202–214)
Lange-Bertalot 1977, p.273, pl.7, figs 1–10; pl.9, figs 5, 6.
It is not within the scope of this paper to undertake a detailed investigation into the taxonomy and nomenclature necessary for this taxon. Lange-Bertalot (op. cit.) presented an interpretation of this taxon based on light microscopical examination of specimens from relevant slides in the various classical collections. He claimed that the correct name for this species is *N. pusilla* (Kützing) Grunow, and included a number of other taxa as synonyms. His opinions regarding the latter are, however, in strong contrast with those of previous workers, as may be seen from the catalogue of synonyms for this species drawn up by Van-Landingham (1978a). Nevertheless, for the present, we have accepted Lange-Bertalot’s concept of *N. pusilla*, based on the evidence of his photographic illustrations of specimens from various gatherings made by Kützing, Grunow, Hilsé and Rabenhorst.

With the exception of sample No. G 89, *N. pusilla* was recorded from all the Gross Barmen samples, as well as one sample (SWA 34 = NIWR 162/3239) collected from the stream about 1,5 km below the earth dam retaining the spring water. Figures 202–214 illustrate a series of valves observed in some of these samples (mainly SWA 34 and G 91). This series agrees well with examples of *N. pusilla* depicted by Lange-Bertalot (op. cit., pl.7, figs 1–10). Comparing our series of valves with the drawings of three very similar, apparently structureless *Nitzschia* species, which Cholnoky (1966, figs 76–85) observed in South West African/Namibian springs, it is evident that we have incorporated the latter into our concept of *N. pusilla*. We have already shown above (see under *N. alexandrina*) that those specimens named by Cholnoky (op. cit., p.201, figs 76–79) as *N. elliptica* var. *alexandrina* are more correctly identified as *N. pusilla*. Likewise, observations of many specimens of *N. etoshensis* Cholnoky (op. cit., p.201, figs 80–83) on the type slide (SWA 94 = NIWR 165/3298) showed that, as a result of a misinterpretation of the shape of the valve apices, Cholnoky had distinguished *N. etoshensis* as a new species. Instead of the acutely rounded poles described and illustrated by Cholnoky for *N. etoshensis*, they usually take on the form shown in the longer examples of *N. pusilla* depicted here in Figures 211–214. Since the shape of the valve apices was the only criterion Cholnoky (1966, p.201) used to distinguish *N. etoshensis* from *N. elliptica* var. *alexandrina* the former cannot be justified as a valid species, and therefore we have also included it in *N. pusilla*. Lastly, Cholnoky (op. cit., p.203, figs 84, 85) identified *N. latens* Hustedt (1949, p.148, pl.13, figs 30, 31) from a number of South West African/Namibian samples, including sample No. SWA 34, which contained *N. elliptica* var. *alexandrina* (see above) in abundance. With many intermediate forms observed, particularly on slide No. SWA 34, we could not find any real differences to maintain these forms as two distinct species in the Gross Barmen samples. Accordingly Cholnoky’s specimens, identified as *N. latens*, have also been drawn into *N. pusilla*.

It is therefore interesting to note that Hustedt originally described *N. latens* along with another hyaline species, *N. elliptica* Hustedt (op. cit., p.148, pl.13, figs 32–34), from the thermal springs of May-ya-Moto. Lange-Bertalot & Simonsen (1978, p.17) have suggested that the latter species is also conspecific with *N. pusilla*. In our preliminary examination of examples of both *N. latens* and *N. elliptica* in a sample from May-ya-Moto (Hustedt op. cit., p.40, material No. 31 = NIWR slide No. 593/18) it would appear that forms intermediate between these two taxa are present, and that there may be justification for uniting them with *N. pusilla*. This, however, needs confirmation through electron microscopical study, since, at this level of investigation, real differences in these hyaline valves can only be detected using this medium.
Schoeman & Ashton (1982a, p.89, figs 59–70, 93–104, 127–129) illustrated a very similar series of valves from the
spring waters feeding the Pretoria Salt Pan, a hypersaline maar lake near Pretoria, which they cautiously identified as having affinity to *N. pusilla*. In the light of our present investigation, however, we are now confident that this series can be identified as *N. pusilla* without further reservation.

Dimensions: length 11.0–41.5 μm; breadth 3.0–4.5 μm; fibulae (12)14–19 in 10 μm, evenly spaced throughout the valve; transapical striae too fine to be observed under the light microscope.

Samples: SWA 30–33, 101; G 90–93.

*Nitzschia quadrangula* (Kützing) Lange-Bertalot (Figures 215–229)

Lange-Bertalot 1980a, p.53, fig. 40.

The taxon illustrated by the specimens shown in Figures 215–229 has been identified as *N. quadrangula*, since it conforms completely to Lange-Bertalot’s (op. cit.) description of the species, which he based on his observation of the type material of *Synedra quadrangula* Kützing (1844, p.63, pl.3, fig. 23), its basionym. The specimens from Gross Barmen, however, showed a greater range in length, i.e. 8.0–29.5 μm long. An almost identical series of valves from the spring feeding the Pretoria Salt Pan has been illustrated by Schoeman & Ashton (1982a, p.90, figs 48–58, 81–92, 130–137) using light and electron microscopy. These valves were tentatively named as *Nitzschia* sp. [affin. *quadrangula*]. The electron micrographs (Schoeman & Ashton’s 1982a, figs 81–92, 130–137) supported the evidence from light microscopy that the central fibulae in this taxon are equidistant and do not therefore indicate a central nodule interrupting the raphe fissure. The implication of this was discussed fully by Schoeman & Ashton in their account of this taxon.

We recorded *N. quadrangula* from all the samples collected on the most recent sampling expedition, as well as in some of the samples (SWA 32, 33, 101) in Cholnoky’s collection from Gross Barmen. Although we cannot be certain, we assume that Cholnoky (1966, p.206, figs 93–95) identified this taxon as *N. perminuta* Grunow, a species he found frequently but seldom abundantly in this study. Cholnoky (op. cit.) illustrated three examples of *N. perminuta* (his figs 93–95) from other sources, but, for some reason on which he did not elaborate, considered them as unusual forms. They appear, however, to be identical to the taxon we call *N. quadrangula*.

Dimensions: length 8.0–29.5 μm; breadth 2.5–3.5 μm; fibulae (10)11–14(15) in 10 μm, equidistantly spaced; transapical striae 24–28(29) in 10 μm.

Samples: SWA 32, 33, 101; G 89–93.

*Nitzschia sigma* (Kützing) W. Smith (Figure 230)

Hustedt 1930, p.420, fig. 813.

This species occurred rarely in one sample.

Dimensions: length 140.0–155.0 μm; breadth 6.5–8.0 μm; fibulae 8–9 in 10 μm; transapical striae 28–30 in 10 μm.

Samples: G 93.

*Nitzschia steynii* Cholnoky emend. (Figures 231–237)

Cholnoky 1966, p.207, figs 97, 100–103 e.p.

Examination of Cholnoky’s type material for this species from Gross Barmen (SWA 30) and from Klein Barmen (SWA 36), another spring system a short distance away, has shown that this species was based on two distinct elements, which can be differentiated primarily on valve shape and striae structure. In this study, these two elements have been separated, one being identified with *N. angusteforaminata* Lange-Bertalot (Figures 173–176; see above), and the other being retained as *N. steynii* Cholnoky (Figures 231–237). In this regard, some of the problems concerning the taxonomy and nomenclature of these two taxa have been discussed above under *N. angusteforaminata*, and, accordingly, there is no need to repeat them here. To accommodate the new concept of *N. steynii* an amended description of the species is required. This is as follows.

Valves linear, linear-lanceolate to lanceolate, sometimes slightly constricted in the middle, with more or less conical, weakly protracted poles having regularly rounded or slightly capitate, and in some planes of viewing somewhat deflected apices; 27.0–54.5 μm long, 4.0–5.0 μm broad. Canal raphe strongly excentric and without a central constriction. Fibulae relatively prominent, evenly spaced throughout the keel, 10–12(13) in 10 μm. Transapical striae 24–25(26) in 10 μm, distinctly punctate, with 20–25 sometimes transapically elongate puncta in 10 μm, aranged in undulating longitudinal rows.

The new concept of *N. steynii* eliminates the narrowly linear valves with cuneately tapering poles, which Cholnoky (op. cit. figs 96, 98, 99) included in his original diagnosis and illustrations. Cholnoky (1966) also suggested a close relationship between *N. steynii* and *N. amphibia* Grunow, but there is little to support this in the new concept of the species. *N. amphibia* is a more robust looking species with very coarse striae which are somewhat more widely spaced (15–19 in 10 μm) than in *N. steynii* (24–25 in 10 μm). The puncta of *N. amphibia* are relatively large and circular, whereas they are finer and irregular in shape in *N. steynii*, often being transapically elongated.

Cholnoky (op. cit.) nominated three slides (SWA 30, SWA 36, SWA 71) as type material for *N. steynii*. Having examined these slides, it was found that slide No. SWA 30 contained predominantly the forms designated now as *N. angusteforaminata* with a few examples of *N. steynii*, and is therefore considered unsuitable as a type slide for *N. steynii*. Slide No. SWA 71 contained so few specimens of either of the two above-mentioned species that it also was rejected as a suitable type slide. Finally, it was found that the third slide (SWA 36) contained a relatively large population of *N. steynii* and very few specimens of *N. angusteforaminata*. We have therefore selected this slide as the new lectotype slide for *N. steynii*.

Lectotype slide: SWA 36 (= NIWR 163/3241).


*Nitzschia umbonata* (Ehrenberg) Lange-Bertalot (Figures 238–241)


This taxon was formerly known under the names *N. stagnorum*, *Rabenhorst* and *N. thermalis sensu* Grunow. However, Lange-Bertalot (op. cit.) has recently shown that these two taxa are synonyms of *Navicula umbonata* Ehrenberg. Therefore, when he transferred them to the genus *Nitzschia*, they were placed under the new combination *Nitzschia umbonata* (Ehrenberg) Lange-Bertalot. In Cholnoky’s (1966, p.206) report on the diatoms from Gross Barmen, he placed specimens of this taxon under the name *N. stagnorum*.

Dimensions: length 73.0–128.0 μm; breadth 7.5–8.5 μm; fibulae 7–8 in 10 μm; transapical striae 23–27 in 10 μm.

Samples: SWA 33, 101; G 91, 93.

*Nitzschia wippfingeri* Cholnoky (Figures 242–249)


Our records indicate that apart from being listed as present in the periphyton of Nyumba ya Mungu reservoir in Tanzania (Bowker & Denny 1978, p.65), this species has only
been recorded from springs at Gross Barmen and at Namutoni in South West Africa/Namibia. Figures 242-245 and 247 illustrate examples of this species from slide No. SWA 33, one of the two slides from Gross Barmen cited by Cholnoky (op. cit.) as type slides for *N. wipplingeri*. In the recently collected material (slide Nos G 90 and 93) specimens (e.g. Figures 246, 248, 249) agreeing with Cholnoky’s description in all respects, except length, were observed. A number of these exceeded Cholnoky’s maximum length, the longest reaching 80,0 \( \mu m \). These longer examples may have taxonomic implications which are discussed briefly here. However, the problems can only be resolved satisfactorily following further light and electron examination of the relevant type materials.

Cholnoky (op. cit.) alluded to an affinity between *N. wipplingeri* and *N. subtilioides* Hustedt (1959, p.438, figs 9–13) apparently distinguishing them on length alone. The longer examples of *N. wipplingeri*, found in the recently collected material, however, makes length differences an insufficient reason for their separation. We therefore suggest that *N. wipplingeri* and *N. subtilioides* are conspecific. Similarly, when the expanded range of variation in *N. wipplingeri* is compared with Hustedt’s (1957, p.353, figs 58–62) amended description of *N. pilitum* there do not appear to be any characteristics to differentiate them. Considering the taxonomy of the latter, Lange-Bertalot (1977, p.272) has added a further complication by equating *N. pilitum* with *N. palea* (Kützing) W. Smith. It is therefore interesting to note that Cholnoky (op. cit.) recognized a superficial likeness between his species and *N. palea*. In a reconsideration of the taxonomic status of these species, two others should be kept in mind. These are *N. diluta* Archibald (1966, p.266, fig. 50; 1971, p.51, figs 197, 198) and *N. stricta* Hustedt (1949, p.136, pl.12, figs 9, 10), which have been suggested to be synonymous with *N. pilitum* (Archibald 1971, p.55, fig. 255).

Dimensions: length 39,0–80,0 \( \mu m \) (mostly 40,0–50,0 \( \mu m \)); breadth 3,0–3,5 \( \mu m \); fibulae (10)12–14(16) in 10 \( \mu m \); transapical striae 34–38 in 10 \( \mu m \).

Samples: SWA 32, 33; G 90, 93.

*Pinnularia appendiculata* (Agardh) Cleve

(Figures 250–252)

Grunow in van Heurck 1880–83, pl. 6, figs 18, 20, 30, 31 [as *Navicula appendiculata* (Agardh) Kützing and the variety, var. *irrorata* Grunow].

This taxon was recorded by Cholnoky (1966, p.209) in three of his Gross Barmen samples. We re-examined these samples and recognized a few examples, three of which are illustrated in Figures 250–252. Searching through the available literature relating to this species, we found difficulty in establishing the true identity of this taxon. For this reason we believe it best to base our identifications on Grunow’s illustrations of *N. appendiculata* and the var. *irrorata* (= *P. appendiculata* — vide Kramer & Lange-Bertalot 1985, p.108) as given in van Heurck’s (op. cit.) synopsis. Our examples also show a strong resemblance to specimens of *Navicula appendiculata* Kg’ seen on two slides in the Rylands (BM 47175) and Dickie (BM 24885) diatom collections kept in the British Museum (Natural History).

Dimensions: length 17,0–31,0 \( \mu m \); breadth 3,5–5,0 \( \mu m \); transapical striae 18–20 in 10 \( \mu m \) near the centre and slightly denser (20–22 in 10 \( \mu m \)) at the poles.

Samples: SWA 30–32.

*Pinnularia globiceps* Gregory var. *krockii* (Grunow) Cleve

(No figures)

Hustedt 1930, p.319, fig. 580.

Although Cholnoky [1966, p.211 as *P. krockii* (Grunow) Hustedt] recorded this taxon from the Gross Barmen sample No. SWA 101, we were unable to find a specimen to confirm this record in our re-examination of the slide. Furthermore, it is clear from his original analysis sheets (NIWR collection) that he saw only one specimen. If the identification was correct, it must be assumed that this taxon is very rare in Gross Barmen thermal springs. In a recent publication Krammer & Lange-Bertalot (1985, p.109) consider the var. *krockii* as synonymous with the nominate variety.

Dimensions: length 23,0 \( \mu m \), breadth 5,0 \( \mu m \); transapical costae 17–18 in 10 \( \mu m \).

Samples: SWA 101.

*Rhopalodia gibberula* (Ehrenberg) O. Müller

(Figures 253–264)

Hustedt 1930, p.391, fig. 742.

Patrick & Reimer 1975, p.191, pl.28, fig. 6.

The Gross Barmen examples of this taxon displayed a wide range in both their valve shape and dimensions. Many of the morphological forms observed could be equated with several of the varieties distinguished by O. Müller (1899). However, Patrick & Reimer (1975, p.192) state that in many cases there appears to be an overlap in the characteristics of O. Müller’s varieties, and that a thorough study of this species may show that these varieties intergrade. We agree with this viewpoint, and have refrained from differentiating our examples into these varieties.

The maximum striae counts (rows of areolae) recorded for our specimens is somewhat greater than the 17 in 10 \( \mu m \) found in some of the basic reference works (e.g. Hustedt op. cit.; Patrick & Reimer op. cit.). However, in some fairly recent studies (Sullivan 1979, p.247; Germain 1981, p.322; Schoeman & Ashton 1982a, p.92) counts of about 20 striae in 10 \( \mu m \) have been cited.

Dimensions: length 36,0–98,0 \( \mu m \); breadth of valves 7,5–11,0 \( \mu m \); 2–5 primary costae in 10 \( \mu m \); 16–20(22) striae (rows of areolae) in 10 \( \mu m \), each striae containing 18–26 areolae in 10 \( \mu m \).

Samples: SWA 30–33, 101; G 89, 90, 92, 93.

*Surirella ovalis* de Brébisson

(Figure 265)

Hustedt 1930, p.441, figs 860, 861.

Germain 1981, p.388, pl.151, figs 1–12.

Cholnoky (1966, p. 215, fig. 122) claimed to have found *S. peisonis* Pantocsek in sample SWA 101 from Gross Barmen. His illustration of this species, however, strongly suggests that this record is a misidentification. In the literature, descriptions and illustrations of *S. peisonis* (Pantocsek 1902, p.96, pl.12, fig. 288; Hustedt op. cit.) depict rather pronounced obovate valves with broadly rounded upper ends (Koppol) and subacute lower ends (Fusspol). During our examination of slide SWA 101 we were unable to find any examples agreeing with this valve shape. Instead we observed a number of valves agreeing with Hustedt’s (1930, fig. 860) and Germain’s (1981, pl.151, figs 1–12) illustrations of *S. ovalis*. As Cholnoky (op. cit.) did not record the latter from Gross Barmen, and the fact that his figure 122 accrues more closely with *S. ovalis*, we conclude that Cholnoky mistook the latter for *S. peisonis*.

Dimensions: length 60,0–73,0 \( \mu m \); breadth 30,5–38,5 \( \mu m \); alar canals 4–5 in 10 \( \mu m \); transapical striae 15–16 in 10 \( \mu m \).

Samples: SWA 101.

*Surirella peisonis* Pantocsek

See under *Surirella ovalis* de Brébisson.
Thalassiosira rudolfii (Bachmann) Hasle (Figures 266–281)

The Gross Barmen specimens (e.g. Figures 266–281) agree with the description of T. rudolfii as amended by Hasle (op. cit.). However, they appear to be confined to the smaller forms of the species (9.0–12.5 μm in diameter), whereas most of the specimens observed by Hustedt (1949, p. 58, pl. 1, figs 6–11 under Coscinodiscus rudolfii) were about 30 μm in diameter. In the Gross Barmen samples this species displayed some variation in the structural features of the valve, and Figures 266–275 portray a few examples to illustrate some of these variations. Our specimens displayed a greater range in the number of marginal strutted processes (5.0–11.5 in 10 μm) than given by Hasle (6.0–8.0 in 10 μm). Variation was also observed in the size of the areolae composing the striae and in the arrangement of the striae on the valve face. In our series of valves, some appeared to have coarser areolae (Figures 266, 267, 272–275) than others (Figures 268–270), while occasionally both coarse and fine areolae are present on the same valve.

The arrangement of the striae on the valve face varied from being clearly grouped into fascicles (Figures 268–270, 272–275) to one that is somewhat more disarrayed (Figures 266, 267, 271). Figures 276–278 and 279–281 illustrate the structure of the valve when viewed with the transmission (TEM) and scanning (SEM) electron microscopes respectively, and confirm Hasle’s (op. cit.) observations. Valve face areolae
Figures 266–281. *Thalassiosira rudolfi* (Bachmann) Hasle. 266–275. LM micrographs of different specimens from various samples collected at Gross Barmen. 276–278. TEM micrographs of a whole valve (276) and enlargements of parts of a valve showing a central strutted process (CSP—277) and the areolar structure (278). 279–281. SEM micrographs of two specimens (279, 280—external views of the same frustule at different degrees of tilt; note central strutted processes (CSP) in Figure 279, and the marginal strutted processes. 281. Internal aspect of a valve; note central strutted process (CSP) and the marginal strutted processes). Figures 266, 268, 269, 271, 272, 274: PH illum. Figures 267, 270: BF illum. Figures 273, 275: OBF illum. Figures 266–275: ×1 500. Figure 276: ×4 000. Figures 277, 278: ×25 000. Figures 279–281: ×5 000.
are larger and more irregularly shaped than those on the mantle (Figures 276–280). The external foramina of the areolae appeared to be fairly wide, while internally the areolae are occluded by a cribra perforated by small roundish porelli arranged irregularly (Figures 277, 278). Marginal strutted processes, found peripherally on the juncture between valve face and mantle, are hollow tubes (Figures 279–281) which do not project conspicuously above the external valve surface, and appear to be supported internally by four struts (Figure 277). The position and number of labiate processes mentioned by Hasle (op. cit.) is not clear from our micrographs.

As far as is known, this species (cited mainly under the name *Coscinodiscus rudolfii*) is restricted to the African continent, being found chiefly in lakes of central and eastern Africa (Bachmann 1938; Hustedt 1949; Richardson 1968; Hecky & Kilham 1973; Mpawenayo 1985; Gasse 1986). It has also been found further north in Lake Chad (Compère 1975), in the Sudan (Bastow 1960) and in Ethiopia (Gasse 1974), although illustrations of the latter (pl.3, figs 3a, 3b) are not convincing as the areolar pattern on the valve face is different. In southern Africa it has been recorded by Cholnoky (1966), Hancock (1973) and Archibald (1983). In the present survey this species and *Navicula elkab* were the dominant species in a seepage from the earth dam storing the Gross Barmen spring waters (sample G 93).

Dimensions: diameter 9.0–12.5 µm; marginal strutted processes 5.0–11.5 in 10 µm; areolae (18)20–24 in 10 µm.

Samples: SWA 33; G 90, 93.

**Ecological comments**

Table 1 summarizes the chemical and physical characteristics of the water in the Gross Barmen thermal springs. This summary comprises an analysis (sampling date unknown) of the thermal waters submitted to us by the authorities at Gross Barmen (pers. comm.), an analysis carried out by Gevers *et al.* (1963), and the analysis of a water sample collected from the eye of the main spring by Schoeman in 1983. These analyses, covering a period of 20 years, indicate a reasonably constant composition of the waters emerging from the main spring.

The main spring at Gross Barmen is considered scalding on account of its very high water temperature (65–66°C); this has remained constant since 1896 (cf. Kent 1949, p.260). It is neutral to weakly alkaline, having pH values varying between 7.1–7.5. With salinities (*sans* Hutchinson 1957, p.553) of about 1 000 g m⁻³, the main spring water can be regarded as slightly mineralized. Sodium is the major cation, while sulphate appears to be the most prominent anion.

Also included in Table 1 is the analysis of the water sample collected at sampling site G 90, which is located in the impoundment collecting the spring waters after they have passed through the swimming pools of the health spa. The salinity at this site is 2 057 g m⁻³; concomitant small changes in the ionic proportions clearly indicate concentration by evaporation, and suggest some differential precipitation of calcium carbonate. The pH of the water at this site was higher (pH 8.45) than in the main spring, while the temperature was 25.6°C. The only other sampling site for which some data is available is site No. G 92 in a large, very shallow seepage pool below the dam. Here the temperature was 48°C and the pH was 9.5.

The composition of the diatom flora found in the main spring eye and at other sites in the thermal spring system at Gross Barmen is shown in Table 2. Considering the constituent taxa in these diatom assemblages, there is nothing remarkable to indicate that they are associated with high to extremely high water temperatures. With the exception of a few taxa whose autecologies are not known, most of those recorded from these warm waters can be found equally abundantly in cold waters. This accords with the observations of other diatomists (Boye Petersen 1928, p.367; Hustedt 1938–39, p.143; Hustedt 1949, p.188) that there is no characteristic diatom flora for thermal waters, neither are there any distinctively thermophilous diatom species. Temperature appears to play a minor role in determining what species are present in thermal springs, and their distribution is more dependent on the physical and chemical characteristics of the individual spring environment.

The diatom community from Gross Barmen, as shown in Table 2, is composed of a relatively small number of taxa (33), of which 24 were common to both Cholnoky’s and Schoeman’s collections. Four taxa, *Cymbella pusilla*, *Gomphonema parvulum*, *Navicula* sp. [affin. *cincta*] and *Nitzschia steynii* were observed only by Cholnoky in his 1961/62 collection; while five taxa, *Cyclotella meneghiniana*, *Navicula pseudosydowii*, *Navicula veneta*, *Nitzschia elegantula* and *Nitzschia* sp. [affin. *intermedia*]

<table>
<thead>
<tr>
<th>Table 1</th>
<th>The chemical and physical characteristics of the thermal spring waters of Gross Barmen examined on various occasions by different people. All concentrations are in g m⁻³ except total alkalinity (g CaCO₃ m⁻³⁻)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The main spring</strong></td>
<td>Gross Barmen authorities</td>
</tr>
<tr>
<td><strong>Sample no.</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Date</strong></td>
<td>?</td>
</tr>
<tr>
<td><strong>Temp °C</strong></td>
<td>65</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>7.5</td>
</tr>
<tr>
<td><strong>Conductivity (mS m⁻¹)</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Salinity (g m⁻³)</strong></td>
<td>1188*</td>
</tr>
<tr>
<td><strong>Na</strong></td>
<td>363</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>22</td>
</tr>
<tr>
<td><strong>Ca</strong></td>
<td>14</td>
</tr>
<tr>
<td><strong>Mg</strong></td>
<td>2</td>
</tr>
<tr>
<td><strong>SO₄</strong></td>
<td>357</td>
</tr>
<tr>
<td><strong>Cl</strong></td>
<td>127</td>
</tr>
<tr>
<td><strong>Total alkalinity</strong></td>
<td>280</td>
</tr>
</tbody>
</table>

*This value is for total dissolved solids rather than salinity as used in the text, but probably reflects the salinity very closely*
were recorded only in Schoeman’s 1983 collection of samples. It is, however, noteworthy that the dominant taxa in Cholnoky’s series of samples (SWA 30–33, 101) were almost always poorly represented in Schoeman’s samples (G 89–93), and vice versa. The only exception to this was *Navicula elkhab*, which attained approximately the same relative abundance level in one sample from Cholnoky’s collection (SWA 33) and in two from Schoeman’s collection (G 90, G 93).

Cholnoky (1966, p.218) remarked that in some hot springs rapid changes in the physical and chemical characteristics of the water occur as it moves away from its point of emergence, and that these changes are manifested in rapid alterations to the diatom assemblages. Careful consideration of Table 2 shows that there is very little similarity between any of the diatom assemblages collected either by Cholnoky or by Schoeman. This lends support to Cholnoky’s remark above, but makes it difficult to determine whether the changes in the diatom assemblages collected in 1983 reflect perturbations of the spring system due to its development, or is evidence of naturally occurring rapid changes in the characteristics of the spring water.

Although we have commented above that no diatom assemblages characteristic of thermal waters have been demonstrated as yet, the similarity between the diatom flora from Gross Barmen in South West Africa/Namibia and those recorded by Hustedt (1949, p.41) from thermal springs at May-ya-Moto in eastern Zaire (Belgian Congo) is remarkable. Of the 26 taxa recorded by Hustedt, no less than 16 have also been noted from Gross Barmen. Taking nomenclatural and taxonomic changes into account (Hustedt’s nomenclature is placed in brackets) these taxa are as follows: *Achnanthes exigua*, *Amphora thermalis*, *Anomoeoneis sphaerophora* (includes the var. *sculpta*), *Caloneis molaris* (= *C. aequatorialis*), *Gomphonema affine* / *gracile* (= *G. lanceolatum*), *Gomphonema parvulum*, *Mastogloia elliptica* var. *dansei*, *Navicula kotchyi* (= *N. grimmeri*), *Navicula aff. halophila/cuspidata* var. = *N. cuspidata* var. *ambigua* — see taxonomic notes above), *Navicula pupula* (= *N. pupula* var. *capitata*), *Nitzschia amphibia*, *Nitzschia pusilla* (includes *N. elliptica* and *N. latens*), *Nitzschia sigma* and *Rhopalodia gibberula*. Apart from *M. elliptica* and *N. sigma*, all these taxa are found in our Table 2, reflecting the most prominent taxa at Gross Barmen. This relatively large number of common taxa suggests that environmental conditions associated with the thermal springs at May-ya-Moto might be similar to those at Gross Barmen.

It would have been interesting to compare the physical and chemical characteristics of the water at the May-ya-

### Table 2

The taxonomic composition and structure of the diatom assemblages in the samples collected from the Gross Barmen thermal springs by Cholnoky in 1961/62 (SWA 30–33, 101) and by Schoeman in 1983 (G 89–93). Values are the relative abundances of each taxon within the diatom assemblage expressed as a percentage. Only those taxa with a relative abundance of 1% or more in at least one sample are shown in the table. The remainder are summed and shown under ‘other species’. + = present in sample, but not in the count.

<table>
<thead>
<tr>
<th></th>
<th>SWA 30</th>
<th>SWA 31</th>
<th>SWA 32</th>
<th>SWA 33</th>
<th>SWA 101</th>
<th>G 89</th>
<th>G 90</th>
<th>G 91</th>
<th>G 92</th>
<th>G 93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achnanthes exigua</td>
<td>0,4</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>0,6</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>0,4</td>
</tr>
<tr>
<td>Amphora thermalis</td>
<td>4,9</td>
<td>0,7</td>
<td>3,9</td>
<td>3,9</td>
<td>0,3</td>
<td>-</td>
<td>-</td>
<td>0,7</td>
<td>3,9</td>
<td>-</td>
</tr>
<tr>
<td>Amphora veneta</td>
<td>+</td>
<td>-</td>
<td>0,7</td>
<td>52,0</td>
<td>2,5</td>
<td>-</td>
<td>0,8</td>
<td>-</td>
<td>-</td>
<td>1,7</td>
</tr>
<tr>
<td>Anomoeoneis sphaerophora</td>
<td>0,8</td>
<td>0,9</td>
<td>1,3</td>
<td>+</td>
<td>1,1</td>
<td>-</td>
<td>+</td>
<td>18,6</td>
<td>16,9</td>
<td>0,2</td>
</tr>
<tr>
<td>Brachysira virea</td>
<td>12,9</td>
<td>85,7</td>
<td>15,4</td>
<td>-</td>
<td>1,1</td>
<td>0,3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Caloneis molaris</td>
<td>-</td>
<td>0,2</td>
<td>2,3</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cyclotella meneghiniana</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cymbella pusilla</td>
<td>4,9</td>
<td>3,3</td>
<td>2,6</td>
<td>-</td>
<td>-</td>
<td>0,3</td>
<td>-</td>
<td>-</td>
<td>0,3</td>
<td>10,8</td>
</tr>
<tr>
<td>Gomphonema affine / gracile</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Gomphonema parvulum</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,3</td>
<td>15,8</td>
<td>5,0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Navicula sp. affin. cincta</td>
<td>1,6</td>
<td>0,5</td>
<td>2,3</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Navicula elkhab</td>
<td>-</td>
<td>-</td>
<td>1,3</td>
<td>15,3</td>
<td>6,1</td>
<td>-</td>
<td>20,2</td>
<td>-</td>
<td>-</td>
<td>25,3</td>
</tr>
<tr>
<td>Navicula kotschyi</td>
<td>-</td>
<td>1,3</td>
<td>1,2</td>
<td>11,9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,6</td>
<td>-</td>
</tr>
<tr>
<td>Navicula affin. halophila'</td>
<td>-</td>
<td>0,5</td>
<td>4,9</td>
<td>-</td>
<td>0,3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>20,1</td>
<td>-</td>
</tr>
<tr>
<td>Navicula pseudosydowii</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Navicula pupula</td>
<td>0,8</td>
<td>0,7</td>
<td>8,8</td>
<td>0,3</td>
<td>13,3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,8</td>
<td>-</td>
</tr>
<tr>
<td>Navicula simplex</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>3,7</td>
<td>0,2</td>
<td>-</td>
<td>-</td>
<td>1,9</td>
</tr>
<tr>
<td>Navicula soodensis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,7</td>
<td>-</td>
<td>-</td>
<td>13,7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Navicula sp.</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11,9</td>
<td>-</td>
<td>-</td>
<td>0,2</td>
</tr>
<tr>
<td>Navicula standeriella</td>
<td>+</td>
<td>1,6</td>
<td>7,5</td>
<td>5,8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1,2</td>
<td>-</td>
</tr>
<tr>
<td>Navicula veneta</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia amphibia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>28,6</td>
<td>-</td>
<td>1,0</td>
<td>0,2</td>
<td>4,3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia elegautana</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3,2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia sp. affin. intermedia</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia microcephala</td>
<td>4,0</td>
<td>0,5</td>
<td>10,8</td>
<td>+</td>
<td>2,5</td>
<td>1,0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia palea</td>
<td>0,4</td>
<td>-</td>
<td>-</td>
<td>3,0</td>
<td>10,0</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0,8</td>
</tr>
<tr>
<td>Nitzschia pusilla*</td>
<td>5,7</td>
<td>7,5</td>
<td>0,6</td>
<td>0,8</td>
<td>-</td>
<td>0,3</td>
<td>37,1</td>
<td>30,3</td>
<td>6,2</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia quadrangula</td>
<td>-</td>
<td>3,6</td>
<td>0,9</td>
<td>2,2</td>
<td>0,6</td>
<td>2,2</td>
<td>3,3</td>
<td>0,7</td>
<td>4,6</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia steinii**</td>
<td>32,0</td>
<td>0,9</td>
<td>7,8</td>
<td>1,2</td>
<td>5,5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia unbonata</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>0,3</td>
<td>-</td>
<td>21,9</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nitzschia wipplingeri</td>
<td>25,9</td>
<td>6,1</td>
<td>20,0</td>
<td>11,7</td>
<td>3,3</td>
<td>0,3</td>
<td>1,6</td>
<td>1,2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rhopalodia gibberula</td>
<td>-</td>
<td>0,3</td>
<td>-</td>
<td>-</td>
<td>0,4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Thalassiosira rudolfii</td>
<td>-</td>
<td>0,4</td>
<td>1,9</td>
<td>3,0</td>
<td>0,3</td>
<td>0,1</td>
<td>0,2</td>
<td>0,4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other species</td>
<td>0,4</td>
<td>1,9</td>
<td>0,3</td>
<td>3,0</td>
<td>0,3</td>
<td>0,1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

* = Nitzschia elliptica var. *alexandrina sensu* Cholnoky 1966; p.201, figs 76–79

** = In SWA 30 and 32 values for *N. steinii* include specimens of *N. angusteforaminata*, which Cholnoky (1966) erroneously combined with *N. steinii* (see text).
Moto thermal springs with those of the Gross Barmen waters, but, with the exception of temperature readings, Hustedt (op. cit.) did not have such data available for the sampling sites at May-ya-Moto. Nevertheless, the former are interesting as the maximum temperature measured at May-ya-Moto was 66°C, precisely the same as that measured by Schoeman at Gross Barmen. Hustedt, however, doubted whether the temperatures given against each of his sample numbers actually reflected the temperature at which the diatoms were living. It is evident that Hustedt (1949, pp.41, 187) did not believe that diatoms could survive temperatures greater than 45°C, despite a report by Erlandsson (1928, p.451) that he had found five diatom taxa in a hot spring in the Russian valley near Lake Kivu, where the temperature was 65°C. In this respect the diatom sample collected at the Gross Barmen thermal spring warrants greater attention.

At Gross Barmen the main thermal spring, having a temperature of 65–66°C, is enclosed by a circular stone wall creating a well-like structure about 1.5 m in diameter around the spring. The water level inside this well is about 1.5 m below the top of the wall, and therefore little heat loss can occur before the water is piped away for use in the spa. A diatom sample (G 89) was collected by scraping the algal growth at water level from the walls of this enclosure. Nine diatom taxa were recorded from this sample (see Table 2), and Achnanthes exigua, forming 86.2% of the diatom association, was clearly the dominant species. Examination of the uncleaned sample revealed that a relatively large number of cells of this species had cell contents within the frustule. Without any other possible source of living diatoms, it is reasonable to assume that cells of A. exigua were living at a temperature of about 60–65°C. A exigua is known to be eurythermal (Patrick & Reimer 1966, p.257) and has been reported frequently from hot springs in the United States of America (Fairchild & Sheridan 1974, p.2).

Hustedt (1937–38, p.196) also recorded this species from numerous thermal springs in Java, Bali and Sumatra, and noted that it was often abundant in springs with temperatures of 40–45°C. In the laboratory Fairchild & Sheridan (op. cit.) investigated the physiology of A. exigua, observing optimum growth at 40°C, while at temperatures of 43–44°C they found that cells survived but did not grow. Whether laboratory studies can be extrapolated exactly to natural conditions is still questionable, but it appears from the evidence given above that diatoms, and especially A. exigua, are capable of tolerating or surviving in waters with temperatures reaching up to about 65°C. This would support Erlandsson’s (1928, p.451) observations from central Africa, and make it more likely that living diatoms could have occurred at temperatures of 66°C in the May-ya-Moto thermal springs in Zaire (cf. Hustedt 1949, p.40).

In the diatom assemblages from the Gross Barmen thermal spring, the species pool is relatively small, and there are very few taxa which occur in one sample only. In broad terms the taxonomic composition of the species pool is determined by the general physical and chemical characteristics of the spring system, and temperature does not play a vital role in this instance. However, when the marked differences in taxonomic composition, as well as structure of the individual assemblages from the different sampling sites, are taken into account, temperature, although still a secondary factor, may play a more decisive role. Sample G 89 was taken from the main spring where the temperature is 65–66°C. At this high level, temperature becomes an all important factor in determining the structure of the diatom assemblage found in this sample. Its exceptionally eurythermal nature enables A. exigua to survive best in these scalding waters. In contrast, at the other sampling sites at Gross Barmen where the waters are cooler, A. exigua loses its competitive advantage, and other factors enable different, but less temperature tolerant taxa, to become more prominent. Temperature per se at these levels, albeit still reasonably hot, becomes once more a minor determinant. Nevertheless, the taxa occurring in these relatively warm waters can still be characterized as eurythermal. Thus, in the diatom assemblage of sample G 92 (see Table 2) found growing in waters with temperatures reaching 48°C (see Table 1), the dominant taxa, such as Anomoeneis sphaerophora, Navicula pseudosydowii, Navicula soodensis, Navicula sp. and Nitzschia pusilla, must be considered as eurythermal.

Apart from sampling site G 90 where the temperature was 25,6°C (Table 1), water temperatures for the remaining sampling sites were not measured.

Evaluating the environmental conditions from the diatom assemblages collected by Schoeman in 1983, some 20 years after Cholnoky’s original study, we do not find any startling differences. However, in contrast to Cholnoky’s (1966) views, all taxa present are pH indifferent to alkaliphilous, thus indicating neutral to slightly alkaline waters. Increased salinity levels in the impoundment and the seepage water pools is readily inferred from the reasonably high relative abundances of certain taxa regarded as meso- to polyeuryhaline oligohalobians or euryhaline mesohalobians (see Simonsen 1962, p.17 for salinity classification). Such taxa are Anomoeneis sphaerophora (including the var. sculpa, Cyclotella meneghiniana, Navicula elka,b, Navicula soodensis and Nitzschia elegantula. Lack of adequate data with regard to the pollution tolerances of most of the species relevant to this study precludes any comments with regard to the trophic or saprobic state of the spring water.

Acknowledgements

The authors wish to express their sincere thanks to the authorities administering the thermal spring complex at Gross Barmen for their permission to collect samples at the main spring and in other nearby water bodies associated with the spring complex, and for the provision of certain data. Our thanks are also extended to colleagues in the Limnology Division of the National Institute for Water Research (NIWR), Mr J.P. Ashton, Mr A.C. Jarvis and Mr T. Fenn for their assistance in collecting the samples. The chemical analysis of the water samples was undertaken by the Inorganic Chemistry Group of the Water Quality Division of the NIWR. Our appreciation is also due to Dr H. Lange-Bertalot for his comments on some unknown taxa; to Dr D.J.B. Killick of the Botanical Research Institute for his help in preparing the Latin diagnoses; and to Ms V.H. Meaton for the photographic prints used in preparing the plates.

This paper is published with the approval of the National Institute for Water Research.

References

ANDREWS, G.W. 1970. Late Miocene nonmarine diatoms from the Kilgore area, Cherry County, Nebraska. U.S. Geol. Survey Prof. Paper 525-A, 24 pp, 3 pls.


