Taxonomic notes on diatoms (Bacillariophyceae) from the Great Usutu River in Swaziland

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

Accepted 9 September 1986

Taxonomical notes and light microscope illustrations are provided for a number of ecologically important diatom (Bacillariophyceae) taxa, as well as a few interesting or rare forms, occurring in the Great Usutu River (Swaziland). A complete list of taxa observed in the samples collected is supplied together with additional information on their relative abundances.

'n Aantal diatoomtaksa (Bacillariophyceae) van ekologiese belang wat in die Groot Usuturivier (Swaziland) voorkom word tesame met 'n aantal interessante en skaars soorte taksonomies bespreek en met ligmikroskoopfoto's geïllustreer. 'n Volledige lys van taksa, wat versamel is, word voorsien met bykomstige inligting oor hul relatiewe voorkomsdigtheid.

Keywords: Bacillariophyceae, diatoms, Great Usutu River, Swaziland, taxonomical notes

*To whom correspondence should be addressed

Introduction

The diatom flora of Swaziland, a small land-locked country, bordering on South Africa and Moçambique, is not well known. Only one previous report (Cholnoky 1962) deals with diatom taxa from Swaziland, found chiefly in samples from two relatively confined areas, as well as from odd localities scattered throughout the country. One of the areas covered by Cholnoky's (1962) report is the Great Usutu River and its tributaries in the vicinity of a kraft pulp mill situated at Bhunya. At that time the pulp mill was still under construction, and had not commenced discharging its effluent into the river.

Some 20 years after the mill had been put into operation, an opportunity arose to test the effects of the discharged effluent on the diatom flora of the Great Usutu River. In this regard Cholnoky's study is invaluable as it provides base line data against which changes can be evaluated. However, in order to detect real changes, account must be taken of different concepts of various taxa brought about as a result either of taxonomic and nomenclatural changes over the last 20 years, misidentifications or personal interpretations of a taxon. Since Cholnoky (1962, pp. 313, 336) illustrated only eight of the 95 taxa (102 according to his taxonomic concepts) he recorded from the Great Usutu River, it is sometimes difficult to correlate his identifications with our present concept of the relevant taxon.

In order to prevent a similar situation in the future, this paper is written to comment on the taxonomy of, and to illustrate photographically those taxa that are considered ecologically important, i.e. they constituted 1% or more of the diatom population in at least one sample. In addition we have included notes and illustrations of a few taxa which we felt warranted particular attention. In this way we demonstrate where present concepts of certain taxa differ from those of Cholnoky, while at the same time providing a pictorial record of the taxa for future reference.

Materials and Methods

The diatom taxa dealt with in this paper were observed in a series of 27 samples collected in August 1981 at eight sampling stations on the Great Usutu River, two sites on the Malkerns irrigation canal and at two sites on one of the two channels (Cascade A) conveying the pulp mill effluent to the Great Usutu River (Figure 1). Detailed descriptions of the stations on the Great Usutu River are given by Archibald & Schoeman (1987). Diatoms were sampled from the stones-in-current and from the sandy/gravelly substrates at each site.

Water for the Malkerns irrigation scheme is abstracted from the Great Usutu River about 2 km below Station 6 and conveyed by canal to Malkerns. Diatoms were sampled where the Bhunya-Luyengo road crosses the canal shortly below the abstraction point (Table 1, sample nos 21, 22), and then again beyond Luyengo where the road crosses the canal for a second time (Table 1, sample no. 16).

Two diatom samples were collected from the Cascade A channel, one from the algal mat growing on the canal walls and kept moist by splash from the warm effluent (Table 1, sample no. 6), and the other sample from algal growth hanging from wire mesh suspended at the side of the foot bridge crossing the cascade (Table 1, sample no. 7).

Methods for the collection of diatom samples, their preparation as permanent mounts, and the calculation of percentage abundances for each taxon in the diatom associations

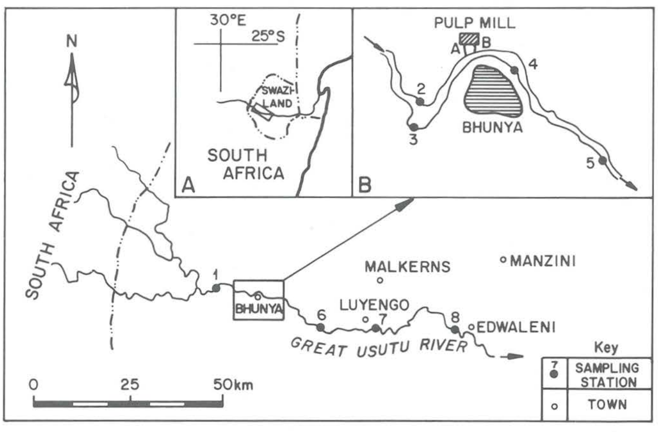


Figure 1 Sampling stations on the Great Usutu River, Swaziland. The positions of Swaziland and the Great Usutu River in southern Africa, are shown in map inset A (study area boxed). The pulp mill effluent canals, Cascades A and B, and sampling stations in the vicinity of the pulp mill are shown in map inset B.

Table 1 The distribution of diatom taxa found in Swaziland from the Great Usutu River, the Cascade A and the Malkerns irrigation canal during this suvey. Symbols used to indicate the approximate range in relative density of each taxon composing the population in a particular sample are: + = recorded only in the species list; r = rare (0 – < 5%); f = frequent (5 – < 20%); c = common (20 – < 50%); a = abundant (50 – 100%). Authorities for species not discussed in text may be found in VanLandingham (1967 – 79)

Station No.	1			2		3		4		5		6					7				8		Cascade A		Malkerns Canal		
Sample No.	1	2	3	4	5	28	29	8	9	10	11	23	24	25	26	27	17	18	19	20	12	13	6	7	21	22	16
Achnanthes																											
engelbrechtii[1]						r	r							+			r										
exigua[1,2]	+		r	r				r		r	r		r	r		r	r			r	r		r	r	r	r	r
lanceolata[1]	+		r	r	r	r	r	r	r	r	r			r		r				r			r	r	r	r	r
linearis[1]																	r			r							
minutissima[1]	a		a	a	a	a	a	f	a	a	c	a	a	c	a	a	a	a	a	a	a	a	a	c	a	a	a
Amphora																											
copulata[1,2]	+																										
fontinalis																								r			
submontana																										r	
veneta var. *capitata*[1,2]	+					r			r		r														r		
Brachysira																											
exilis[1,2]	r			r		r		a	r	r		r	r	r	r	r	r	r	r	f	r		r		r	r	r
Caloneis																											
hyalina								r		r															r		
Capartogramma																											
crucicula[2]										+	+															r	
Cocconeis																											
engelbrechtii								+																			
placentula[1]	+							r			r		r			r	+								r	r	r
thumensis																											r
Cymbella																											
aspera[1]	+			r																							
cistula[1]			r			+					+													r			
javanica[1]	r		r	r		r				r																	
kappii[1]				r								r	r	r	f	r	+			r	r				r	r	r
kolbei[1]	+		r			r		r	r	r	r		f	f		r	r	r	r	r	r	r			r	r	r
microcephala[1]	+		+					r			r	r	r	r	f	r	r	r	r	r	r	r			r	r	r
minuta[1,2]	r	r	r	r				r	r	f	r		f	r		r	r		r	r	+			f	r	r	r
naviculiformis[1]	+												r								r						
perpusilla																									r		
radiosa	+		+																								
turgida[1]	r																		r								
Diploneis																											
oblongella[2]																											r
Eunotia																											
pectinalis[1]																						r			r		
pectinalis var. *minor*[1]								r						r												r	
Fragilaria																											
familiaris[1]	+			r	r	r		r	r	r	r	r	r	r	r	r	r	r	r	r	r		r	r	r	r	r
fragilarioides																								r		r	
vaucheriae[1,2]	r	r	r	r	r	f	f	r	f	f	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
Frustulia																											
rhomboides																											r
tugelae							r																				
vulgaris																							r			r	
vulgaris var. *angusta*																											r
weinholdii	+										+																
Gomphonema																											
clevei[1]	r			r	r	r	r		r	r	r	r	r	r	r	r	r	r		r	r			r			r
constrictum var. *gautierii*													r														
gracile[1]										r			r				r								r		
parvulum	r		r		r	r		r	r	f	f	r	r	r		r		r	r	r	+		r	r	r	r	r
subclavatum[1,2]	f	f	f	r	f	r	r	r	r	r	f	f	r	r	r	r	r	f	r	f	r	c	r	f	r	r	r

Table 1 (Continued)

Station No.	1			2		3		4		5		6					7				8		Cascade A		Malkerns Canal		
Sample No.	1	2	3	4	5	28	29	8	9	10	11	23	24	25	26	27	17	18	19	20	12	13	6	7	21	22	16
Gyrosigma																											
kuetzingii[1]	+																										
scalproides											+																
Hantzschia																											
amphioxys[1]	+																										
Navicula																											
accomoda																									r		
atomus[1]	r		r		r	r	r		r	r	r					r							r		r	r	r
bacillum[1]	+			r							r										r						
capitata						r																					
cari var. *angusta*[1]			r																								r
contenta								+			+																
cryptocephala[1]	+		r		r	r	r			r	r	r	r	f	r	r	r	r		r	r				r	r	r
cuspidata[1]	+						r																				
gregaria[1]										r	r		r					r					r	r	r		r
grimmei	r		r	r							r												r		r		
indifferens			r			r	r		r	r						r							r			r	r
maillardii																				r				r			r
mutica																											r
nyassensis	+																										
pelliculosa														r											r		
promota						r																					
pupula			r							r	r			r		r			r						r	r	
radiosa complex[1,2]	r	r	r	r	r	r	r	r	r	r	r		r	r		r			r	r	r		r	r	r	r	r
rhynchocephala[1]			r				r																	r			
rostellata[1]	+	r		r		+				r	r			r		r	+							r	r	r	r
Navicula																											
schoenfeldii	+																										
schroeteri																									r	r	
seminuloides[1]	r		r			r	r	r	r	r				r					r	r			r		r	r	r
seminulum	r																										
subatomoides[1]	r				r	r	r	+	r		r			r		r			r				r	r	r		
submolesta											r						r										
subrotundata											+																
tantula			r																								
tenelloides										r																r	
tridentula														r					r		r				r		
twymaniana														r													
usutensis[1]	+		+			r	+		r																	r	
zanonii[1]	+					r	r			r			r	r			r		r		r				r	r	r
Neidium																											
affine var.																											
amphirhynchus[1]	+																										
irridis var.																											
vernalis	+																									r	
Nitzschia																											
acidoclinata										r	r	r	r	r					r	r				r	r		
amphibia								r																			
clausii[1]	+																r										
Nitzschia																											
denticula[1,2]	f	r	f	f	r	f	r	r	f	r	f		r	r		r	r			r	r		r	c	r	r	r
dissipata[1]											+																r
frustulum[1]																r									r	r	r
inconspicua[1,2]			r	r					r					r													
intermedia	+																										
levidensis var.																											
victoriae	+																										
microcephala											+																
palea[1]	+		r	r			r				r		r	f		r	r		r		r			r	r		r
rautenbachiae	+																							r			
recta							r																				

Table 1 (Continued)

Station No.	1			2		3		4		5		6					7				8		Cascade A		Malkerns Canal		
Sample No.	1	2	3	4	5	28	29	8	9	10	11	23	24	25	26	27	17	18	19	20	12	13	6	7	21	22	16
Pinnularia																											
gibba[1]	+										r		r	r													
interrupta											r		r			r											r
maior	+																										
microstauron f. *diminuta*																											r
minuta																											r
subcapitata	+		r							r	c		r	r		r	r							r		r	r
Rhopalodia																											
gibberula[1]									r	r																	r
Stauroneis																											
phoenicenteron	+													r													
smithii var. *incisa*						+																					
Surirella																											
angusta											r																
delicatissima											+																
robusta	+																									r	
robusta f. *constricta*	+																										
tenera[1]	+																										
Synedra																											
parasitica var. *subconstricta*	+					+																					
rumpens[1]			+			r	r		+		r	r								r		r					
tenera[1]					r				r	r	r		r								r	r		r	r		r
ulna[1]	r	r	r	r	r		r		r	r	r	r	r	r	+	r	r	r	r	r	r	r	r	r	r	r	r

[1]Taxa from the Great Usutu River common to both Cholnoky's (1962) analysis of 5 samples (Nos 1, 2, 3, 9, 13) and in the present survey
[2]Taxa recorded by Cholnoky (1962) under a different name. See Table 2

have been described elsewhere (Archibald & Schoeman 1987). The slides were examined with a Zeiss Standard RA research microscope, and specimens were photographed with a Reichert Photo-Automatic camera using Kodak Panatomic X film.

Terminology used is that suggested by the Working Party on Diatom Terminology (Anonymous 1975; Ross *et al.* 1979). The abbreviations BM and NIWR preceding a slide number, indicate slides from the collections of the British Museum (Natural History) and the National Institute for Water Research (Pretoria) respectively.

Results and Discussion

Notes and illustrations of those taxa found in the samples collected in August 1981 and considered ecologically important in the Great Usutu River are presented below in alphabetical order. The remaining taxa represented in the samples by the odd or very few specimens, are included in Table 1, where a complete list of all these taxa, together with an indication of their relative abundance in each sample, is given. References used in the identification of the various taxa are listed directly below the name of the relevant taxon.

Achnanthes engelbrechtii Cholnoky (Figures 2 – 4)

Cholnoky 1955, p. 16, figs 1 – 8.
Cholnoky 1959, p. 7, figs 16 – 33.
Archibald 1983, p. 25, figs 75 – 80.
Schoeman & Ashton 1983, p. 192, figs 1 – 3.

The few specimens observed in the Great Usutu River agree with Cholnoky's (1955) original description of the species, but show characteristics corresponding more closely with certain specimens he illustrated subsequently from the western Cape Province (Cholnoky 1959, figs 16, 17, 20). The examples illustrated here show raphe valves (Figures 2 & 3) with reasonably distinct, more or less circular central areas, and a rapheless valve (Figure 4), in which the two central striae on one side of the valve are more widely separated than the rest. Similar specimens have been reported by Archibald (1983) and Schoeman & Ashton (1983). Originally Cholnoky (1955) pointed out the similarity of *A. engelbrechtii* to *A. pinnata* Hustedt (1922, p. 123, pl. 9, figs 15 – 18), and a call for a comparison of the type materials of these two species has been made (Archibald 1983; Schoeman & Ashton 1983). Furthermore, a recent study by Le Cohu & Maillard (1983, p. 148, figs 127, 223) has indicated that *A. engelbrechtii* cannot be distinguished from small specimens (less than 10 μm long) of *A. delicatula* ssp. *hauckiana* (Grunow) Lange-Bertalot & Ruppel (1980, p. 2, figs 1 – 20). It would therefore seem that a more thorough investigation of the taxonomy of *A. engelbrechtii* is required.

Achnanthes exigua Grunow (Figures 5 & 6)

Grunow in Van Heurck 1880 – 83, pl. 27, figs 29, 30.
Hustedt 1931 – 59, p. 386, fig. 832.
Schoeman & Archibald 1977b, *A. exigua* p. 1 – 3, figs 1 – 80.

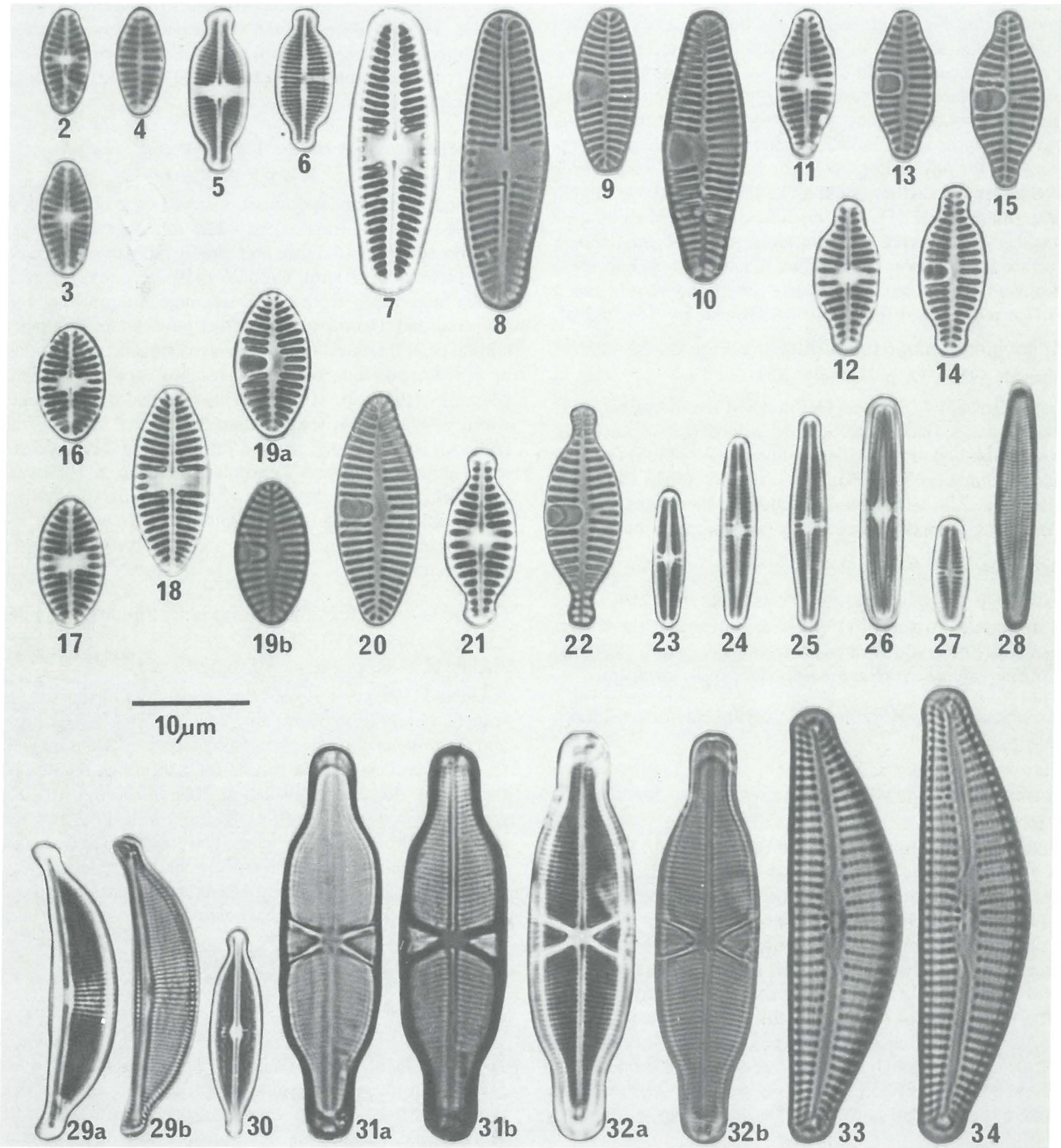
Schoeman & Archibald (1977b) have reviewed and commented extensively on the taxonomy of this species. *A. exigua* var. *heterovalva* is now regarded as part of the natural range of variability of the nominate variety, and is therefore no longer distinguished as a separate variety.

Achnanthes lanceolata (Brébisson) Grunow (Figures 7 – 22)

Hustedt 1931 – 59, p. 408, fig. 863.

This polymorphic species was represented in the Great Usutu

River by a number of morphological variations (Figures 7 – 22), often found together in the same sample. Whether all these forms belong to the natural variability of the nominate variety, or should be considered as valid varieties, or even as independent species is a matter for debate and further research. Figures 7 – 10 illustrate examples of the nominate variety, i.e. *A. lanceolata* var. *lanceolata*, and note should be taken that the characteristic 'hoof-shaped' marking on the rapheless valves (Figures 9 & 10) appears to be a simple depression in the valve wall. In contrast Figures 11 – 15 depict forms agreeing with *A. lanceolata* var. *rostrata* (Östrup) Hustedt, in which this marking on the rapheless valves (Figures 13 – 15) is quite clearly a hooded cavity (see Ross *et al.* 1979, p. 524). This type of structure prompted Moss & Carter (1982) to raise this variety to species level as *A. rostrata* Östrup [1902 (1903), p. 28]. On the other hand Reichardt (1984) preferred to retain this taxon as a variety of *A. lanceolata*, using the hooded cavity as the differentiating characteristic rather than



Figures 2 – 34 LM micrographs of diatoms from the Great Usutu River. **2 – 4.** *Achnanthes engelbrechtii* Cholnoky. **5 & 6.** *Achnanthes exigua* Grunow. **7 – 22.** *Achnanthes lanceolata* (Bréb.) Grunow (see text for distinctions). **23 – 28.** *Achnanthes minutissima* Kützing. **29.** *Amphora veneta* Kützing var. *capitata* Haworth. **30.** *Brachysira exilis* (Kützing) Round & Mann. **31 & 32.** *Capartogramma crucicula* (Grunow *ex* Cleve) Ross. **33 & 34.** *Cymbella kappii* (Cholnoky) Cholnoky. Scale: × 2000. Figure numbers followed by 'a' and 'b' reflect different aspects of the same valve. 2 – 7, 11, 12, 14, 16 – 19a, 21, 23 – 27, 29a, 30, 32a: phase contrast illumination (P.C. Illum.). 8 – 10, 13, 15, 19b, 20, 22, 31a, 31b, 33, 34: bright field illumination (B.F. Illum.). 28, 29b, 32b: oblique bright field illumination (O.B.F. Illum.).

the shape of the poles, but called it by its earlier synonym *A. lanceolata* var. *dubia* Grunow. In addition to the two above-mentioned forms, two others were also noted in the samples. Figures 16 – 20 illustrate forms agreeing with *A. lanceolata* var. *elliptica* Cleve. In these forms the 'hoof-shaped' mark on the rapheless valves (Figures 19 & 20) is also a hooded cavity, which in some specimens appears to have a very wide mouth (e.g. Figure 19b) compared with the cavities in the var. *dubia* (cf. Figures 13 – 15). Finally, there were broadly lanceolate to elliptical forms with distinctly capitate apices (Figures 21 & 22), in which again a hooded cavity (Figure 22) is distinctly present on the rapheless valves. It is evident from the observation of the hooded cavity in other varieties of *A. lanceolata*, and not just in the var. *dubia*, and from the uncertainty with regard to the taxonomic significance of this structure, that a careful re-appraisal of the taxa within the *A. lanceolata* complex is necessary. Although these forms did not appear to be linked by intermediates, there was no evidence for any ecological factor determining which form was present, since they could all be found in a single sample (e.g. sample USU 11). For this reason they were all lumped together in this survey under the name *A. lanceolata*, pending further investigation. In contrast Cholnoky (1962, p. 314) distinguished between the nominate variety and what he called *A. lanceolata* f. *rostrata* (Östrup) Hustedt (= var. *dubia*).

Achnanthes minutissima Kützing (Figures 23 – 28)

Hustedt 1931 – 59, p. 376, fig. 820.

Lange-Bertalot & Ruppel (1980) revised the diagnosis of *A. minutissima* so that this species now includes several previously well-established taxa, such as *A. linearis* (W. Smith) Grunow and *A. microcephala* (Kützing) Grunow. While Cholnoky (1962, pp. 314, 315) distinguished these three taxa, Lange-Bertalot & Ruppel's opinion has been accepted here.

Amphora copulata (Kützing) Schoeman & Archibald

Schoeman & Archibald 1986, p. 426, figs 11 – 53.

Schoeman & Archibald (1986) have shown that the correct name for the taxon formerly known as *A. ovalis* (Kützing) Kützing var. *libyca* (Ehrenberg) Cleve is *A. copulata*.

Amphora veneta Kützing var. *capitata* Haworth (Figures 29a & b)

Haworth 1974, p. 48, figs 6, 19.
Schoeman & Archibald 1978, *A. veneta* var. *capitata* p. 1, figs 1 – 24.

Following an intensive investigation of this variety, Schoeman & Archibald (1978) upheld it as distinct from the nominate variety. They also reported that no confirmed identifications of this taxon had been made from southern Africa. However, in a later paper, Archibald & Schoeman (1984, pp. 83, 101) state that *A. veneta* var. *capitata* is present in this region, but had been misidentified as *A. coffeaeformis* (Agardh) Kützing. The few specimens observed in the Great Usutu River conform entirely to Schoeman & Archibald's (1978) description of the taxon, although the valves are somewhat broader than given in this description. The valves are 23,5 – 29,0 µm long, 4,5 – 5,0 µm broad and have 28 – 32 striae in 10 µm.

Brachysira exilis (Kützing) Round and Mann (Figure 30)

Round & Mann 1981, p. 227.
Hustedt 1931 – 59, p. 751, fig. 1114 (as *Anomoeoneis exilis* (Kützing) Cleve.
Schoeman & Ashton 1982, p. 27, figs 6 – 9, 46 – 48, 66 – 78 (as *Anomoeoneis exilis*).

Round & Mann (1981) have resurrected the genus *Brachysira* to include all taxa of the genus *Anomoeoneis* with a structure similar to *Brachysira aponina* Kützing (1833 – 36, Decas XVI, No. 153). This opinion has been accepted in this investigation and by a number of other diatomists (Coste & Ricard 1982; Kaczmarska & Rushforth 1983).

Capartogramma crucicula (Grunow *ex* Cleve) Ross (Figures 31 & 32)

Ross 1963, p. 59, pl. 1, fig. B; pl. 2, fig. A; text figs 8 – 11.

This species has been recorded fairly frequently from southern Africa but under the name *Stauroneis merrimacensis* Woodhead & Tweed (1960, p. 143), which was a new name for *Schizostauron crucicula* Grunow. In the present study a few fairly typical examples were observed (34,0 – 35,0 µm long, 8,0 – 9,0 µm broad, 24 striae in 10 µm).

Cymbella javanica Hustedt (Figure 36)

Hustedt 1937 – 38, p. 424, pl. 25, figs 1 – 3.

The small number of specimens observed were quite typical in valve shape and length (19,5 – 22,5 µm), but were somewhat broader (5,0 – 5,5 µm) and slightly more densely striate (12 – 14 striae in 10 µm). Cholnoky (1957a, p. 45) reported similar large forms from Natal, reaching 25,0 µm long and 5,5 µm broad. However, in an earlier publication, Cholnoky (1954a, p. 273) claimed to have observed specimens measuring up to 33,0 µm long with 13 transapical striae in 10 µm. Cholnoky (1954b, p. 411, fig. 9) also illustrated an example which he stated was smaller than the normal forms. This specimen is 30 µm long and 6,5 µm broad, and is therefore much larger than Hustedt's maximum dimensions. These two examples cast some doubt on the validity of Cholnoky's identification of these large forms as *C. javanica*. A re-examination of the larger forms is needed to confirm or reject these identifications.

Cymbella kappii (Cholnoky) Cholnoky (Figures 33 & 34)

Cholnoky 1956, p. 61, figs 17 – 20.
Archibald 1983, p. 88, pl. 10, figs 183, 184.

Archibald (1983) commented on the affinities of this species with *C. cistula* (Ehrenberg) Kirchner, *C. turgidula* Grunow and *C. tumidula* Grunow, suggesting a close relationship with *C. cistula* and expressed the need for a thorough revision of this group. Reichardt (1982a, p. 103, pl. 3, figs 16 – 20) reported forms of *C. affinis* Kützing with 1 – 3 isolated stigmata at the centre of the valve. This suggests that *C. kappii* might be connected to this species as well. Due to this uncertainty, the Great Usutu River specimens have been retained under the name *C. kappii*.

Cymbella kolbei Hustedt (Figure 35)

Hustedt 1949a, p. 46, figs 20 – 26.
Archibald 1983, p. 90, pl. 11, fig. 185.
Schoeman, Archibald & Ashton 1984, p. 193.

Schoeman *et al.* (1984) commented on this species which presents an interesting taxonomic problem. It appears that the only feature distinguishing *C. kolbei* from *C. hustedtii* Krasske (1923, p. 204, fig. 11) is the presence of a stigma at the end of the central stria on the ventral side in *C. kolbei* (Hustedt 1949a). This apparently clear distinction has been lost due to Compère's (1980, p. 291, figs 62, 86, 87) description of a new form, *C. hustedtii* f. *stigmata*, which possesses a stigma in the same position as in *C. kolbei*. This confusing situation was further complicated by Compère

(1984, p. 68, fig. 51) when he recognized the probability that his f. *stigmata* is linked with *C. kolbei*. Nevertheless he still preferred to retain his taxon as a form of *C. hustedtii*. This brings into question the validity and significance of the stigma as a taxonomic character. There seems to be little information on the subject, and the literature is not particularly helpful in this regard. Kolbe & Krieger (1942, p. 350, pl. 3, figs 16 – 18) failed to comment on the presence of a stigma in specimens they identified as *C. hustedtii*, although they illustrated examples with this structure. On the other hand, Hirano (1964, p. 200, pl. 5, fig. 22; 1966, p. 31, pl. 2, fig. 9) placed two specimens without stigmata in the species *C. kolbei*. Krammer (1982, p. 15) pointed out that we know nothing of the constancy of stigmata, and thus cautioned the use of this character as a means of uniting or separating taxa. Geissler (1970, p. 515), however, found that, while valve form and design were subject to variation, structural elements, such as mucilage pores, areas and processes, were more constant in character. It is highly likely that stigmata would fall into the latter category. Hendey (1964, p. 55) supplied two definitions for a 'form', one of which defines it as 'the result of genetic instability and may arise suddenly and equally suddenly revert to type'. On the basis of this definition, Compère (1980) implies a certain instability in the presence or absence of a stigma by designating his taxon as a form. An attempt should therefore be made to establish whether the stigma is genetically stable or not. There is no experimental evidence for this in the literature, but empirical observations may hint at the truth. Kingston (1978) studied a population of *C. hustedtii* from Lake Michigan and there was no evidence in this population for the presence of a stigma in any of the specimens. When Compère (1981) compared the Lake Michigan population of *C. hustedtii* with specimens of his new form from the Aïr Mountains, he made it clear that the stigma in his f. *stigmata* distinctly separates them from the Lake Michigan *C. hustedtii*. He thereby implies a constant presence of a stigma in his new form. This suggests that the presence or absence of the stigma in these two populations is constant. If we can conclude from this that the stigma is genetically stable, then this character can be regarded as sufficiently strong to distinguish between taxa at species level. In this study *C. hustedtii* f. *stigmata* is considered synonymous with *C. kolbei*. Finally, it is interesting to note that Coste & Ricard (1982, p. 285, pl. 1, fig. 3) also transferred *C. hustedtii* f. *stigmata* to *C. kolbei*, but retained it as a form of the latter. They do not state, however, how they distinguish it from *C. kolbei*.

The specimens seen in this study were quite typical of Hustedt's description, but show slightly more pronounced subrostrate poles. A single example (Figure 35), measuring 25,0 µm long, 8,0 µm wide and having 10 transapical striae in 10 µm, is illustrated.

Cymbella microcephala Grunow (Figures 37 & 38)

Grunow in Van Heurck 1880 – 83, pl. 8, figs 36 – 39.
Hustedt 1930, p. 351, fig. 637.
Schoeman & Ashton 1983, p. 194, figs 29 – 60.

In a study of two populations of *C. microcephala*, Schoeman & Ashton (1983) found two apparently distinct, but very similar, groups of specimens. The groups were differentiated on morphological detail, and particularly, striae structure when examined under the electron microscope. In Schoeman & Ashton's Group 1 the transapical intercostal grooves have crenulate margins, which, according to Krammer (1982, p. 38, pls 1109 – 1113), are characteristic for the species. In contrast, the groove margin of their Group 2 examples is smooth or straight. Dorsal striae counts near the valve centre in the two groups also differed slightly, being 24 – 26 in 10 µm in Group 1 and 26 – 32 in 10 µm in Group 2. This makes an interesting comparison with Van Heurck's (1885, p. 63) description of the species. Here he states that large forms have 24 striae in 10 µm and small forms 28 – 30 in 10 µm. This raises the question as to whether Van Heurck's circumscription of this taxon possibly includes two distinct forms. Schoeman & Ashton also suggested that an expansion of the valve mantle near the poles into a lip-like structure in the Group 2 specimens was a further distinguishing characteristic between the groups. Krammer (1982, pls 1109, 1110), however, illustrated a number of valves with this polar lip-like expansion, but which are otherwise identical to Schoeman & Ashton's Group 1 examples.

Although the Great Usutu River specimens (Figures 37, 38) have not been examined under the electron microscope, their dimensions (length 17,5 – 23,0 µm, breadth 3,5 – 4,5 µm) and striae counts [24 – 26(28) in 10 µm] suggest they should be placed in Schoeman & Ashton's Group 1.

Cymbella minuta Hilse *ex* Rabenhorst (Figures 39 & 40)

Hustedt 1930, p. 359, fig. 661 (as *Cymbella ventricosa*).
Krammer 1982, p. 22, pls 1026 – 1030.

This ubiquitous species, occurring commonly in southern Africa, was better known as *Cymbella ventricosa* Kützing. However, Reimer (in Patrick & Reimer 1975, p. 48) and Håkansson (1979) have both shown that this combination is a later homonym for *Cymbella ventricosa* (Agardh) Agardh (1830 – 32, p. 9), which actually represents a species of *Rhopalodia*. While Håkansson (1979) called Agardh's taxon *Rhopalodia operculata* (Agardh) Håkansson, Reimer (*op. cit.*) renamed Kützing's taxon as *C. minuta* Hilse *ex* Rabenhorst.

The specimens observed in the Great Usutu River are quite typical, and, since Krammer (1982) has presented a detailed account of its morphology, no further comments are necessary.

Cymbella naviculiformis Auerswald (Figure 41)

Hustedt 1930, p. 356, fig. 635.
Krammer 1982, p. 40, pls 1127 – 1132.

This species occurs fairly frequently in southern Africa, and three typical specimens were recorded in this study. An example is illustrated in Figure 41.

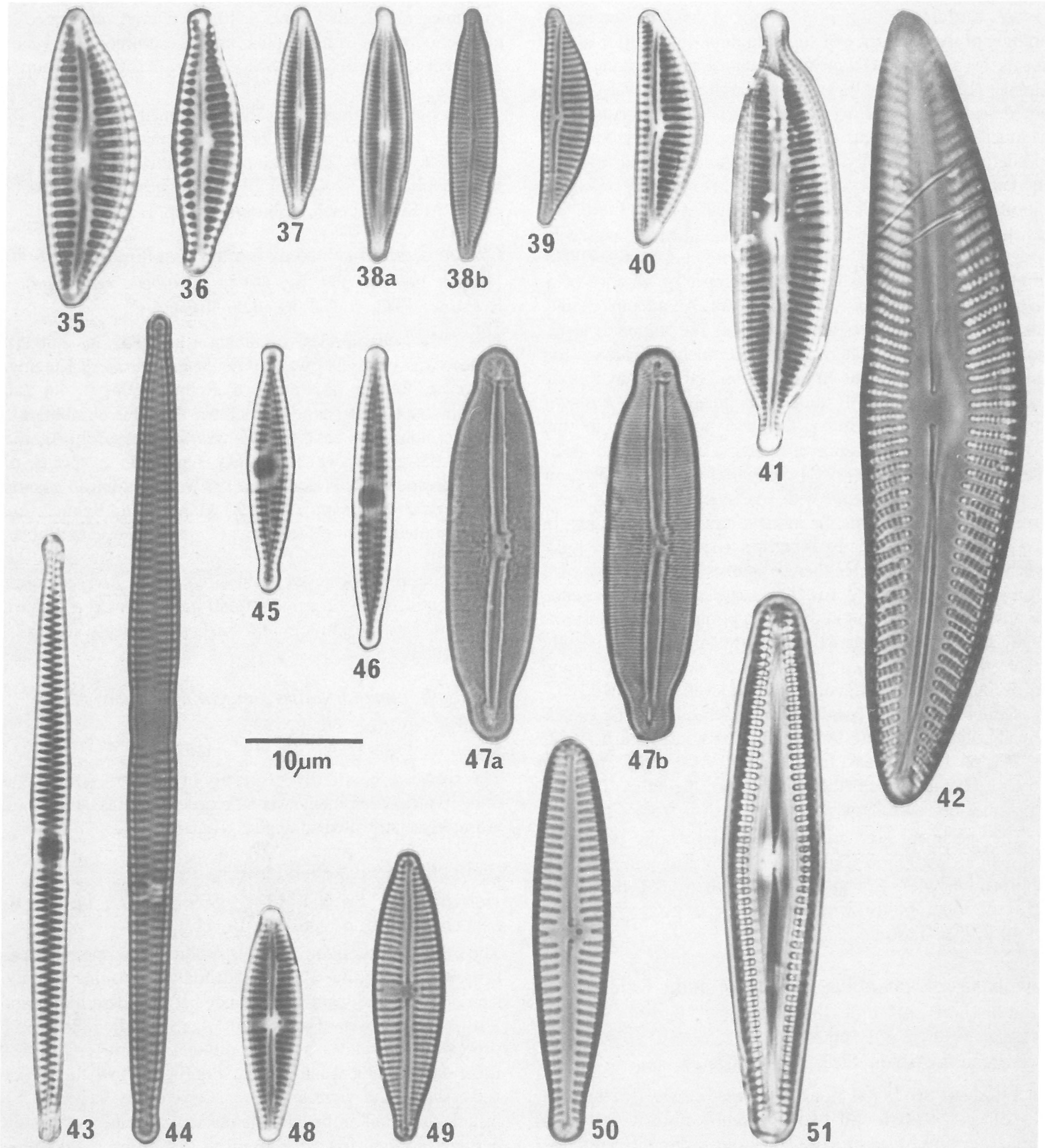
Cymbella radiosa Reichelt (Figure 42)

Hustedt in A. Schmidt 1874 – 1959, pl. 377, figs 8 – 10.
Schoeman 1970, p. 336, figs 10, 11.

The original description and illustration of this species (Reichelt 1904, p. 776, fig. 37) are inadequate due to their brevity, lack of detail and some discrepancy between description and drawing. However, Hustedt (in A. Schmidt 1874 – 1959) drew three specimens from the original material collected at Lake Ngami, Botswana. These specimens show the typical valve shape and wide axial area depicted by Reichelt, but include the detail of the lineolate transapical striae and dorsally curving terminal fissures. Based on this information, a few specimens from the Great Usutu River have been positively identified as *C. radiosa*. The latter fit Reichelt's dimensions and striae count, and agree with Hustedt's drawings in their morphological detail. It is important to note that contrary to Reichelt's description, the transapical striae are fairly strongly radial except for the central ones, which may approach parallel.

This species has been previously recorded from southern Africa, but in some cases the accuracy of the identification may be doubtful. Cholnoky (1957a, p. 46, figs 36 – 39) described a new species from Natal, *Cymbella rautenbachiae*, which he subsequently united with *C. radiosa* (Cholnoky 1960a, p. 239, figs 4, 5). There is, however, some doubt that the Swartkops specimens illustrated by Cholnoky (1960a) truly belong to *C. radiosa*. The main points of difference being the structure of the striae, the width of the central area, and the ventrally curving terminal fissures. Nevertheless, the unification of *C. rautenbachiae* with *C. radiosa*, based on the Natal specimens, seems justified. Further typical examples, which are identical to those in the Great Usutu River, have been reported from the Orange Free State and Lesotho (Schoeman 1969, p. 42, figs 1, 2; 1970).

Another taxon that must be taken into consideration is *C. helvetica* var. *africana* Fritsch & Rich (1924, p. 390, fig. 30, K). From the original drawing and description it appears that



Figures 35 – 51 LM micrographs of diatoms from the Great Usutu River. **35.** *Cymbella kolbei* Hustedt. **36.** *Cymbella javanica* Hustedt. **37 & 38.** *Cymbella microcephala* Grunow. **39 & 40.** *Cymbella minuta* Hilse *ex* Rabenhorst. **41.** *Cymbella naviculiformis* Auerswald. **42.** *Cymbella radiosa* Reichelt. **43 & 44.** *Fragilaria familiaris* (Kützing) Hustedt. **45 & 46.** *Fragilaria vaucheriae* (Kützing) Boye Petersen. **47.** *Frustulia weinholdii* Hustedt. **48 & 49.** *Gomphonema parvulum* (Kützing) Grunow. **50.** *Gomphonema subclavatum* (Grunow) Grunow. **51.** *Gomphonema clevei* Fricke. Scale: × 2000. 35 – 38a, 40, 41, 43, 45, 46, 48, 51: P.C. Illum. 39, 42, 47a, 49, 50: B.F. Illum. 38b, 44, 47b: O.B.F. Illum.

this taxon is probably identical to *C. radiosa*. However, it will be necessary to locate and examine its type material before a firm conclusion can be drawn.

The Great Usutu River specimens are 57,0 – 92,5 μm long, 13,0 – 18,0 μm broad, and have 7 – 9 transapical striae in 10 μm on the dorsal side and 7 – 8 in 10 μm on the ventral side. The striae are composed of 18 – 24 lineolate puncta in 10 μm.

Fragilaria familiaris (Kützing) Hustedt (Figures 43 & 44)

Hustedt 1957, p. 229.
Hustedt 1931 – 59, p. 207, figs 697c, d (as *Synedra rumpens* var. *familiaris* and var. *scotica*).

In reviewing the systematics and taxonomy of the genera *Fragilaria* and *Synedra*, Lange-Bertalot (1980a) has presented illustrations of a number of taxa from type and other material, which he combined under the species *Fragilaria capucina* Desmazières. However, due to our limited knowledge of the taxa discussed by Lange-Bertalot, it is beyond the scope of this paper to verify his opinions. Accordingly, the better known concepts of *F. familiaris* (Kützing) Hustedt, *F. vaucheriae* (Kützing) Boye Petersen and *Synedra rumpens* Kützing, all observed in this study, have been retained. In this investigation, the specimens designated as *F. familiaris* conform better to the description of *S. rumpens* var. *scotica* Grunow (cf. Hustedt 1931 – 59, p. 207, fig. 697d), which are now also united with *F. familiaris* (Hustedt 1957).

The Great Usutu River specimens (Figures 43 & 44) range in length from 30,0 – 91,0 μm and in breadth from 3,0 – 4,5 μm and have 14 – 16(17) transapical striae in 10 μm. The valves are narrow, linear-lanceolate in shape with capitate to subcapitate apices, and are slightly constricted on both sides of the central area, which usually displayed faint 'shadow' striae.

Fragilaria vaucheriae (Kützing) Boye Petersen (Figures 45 & 46)

Boye Petersen 1938, pp. 164 – 170, fig. 1.
Hustedt 1931 – 59, p. 152, fig. 666 (as *Fragilaria intermedia*).
Hustedt 1931 – 59. p. 194, fig. 689 (as *Synedra vaucheriae*).

Although shape and size vary greatly in this species, the specimens observed in this study are uniformly narrow and linear – lanceolate with usually capitate poles in the longer forms. Shorter forms are relatively broader and more linear, while the shortest examples are almost rhombic with rostrate poles. The development of the unilateral central area, characteristic of this species, also varies. The typical arrangement occurs frequently, but often in the longer examples the central area broadens into an apparent fascia across the valve. When this is the case, it sometimes proves difficult to distinguish between the longer examples of this species and the shorter specimens of *F. familiaris* occurring in the same samples.

The Great Usutu River specimens measure 9,5 – 39,5 μm long, 3,0 – 3,5 μm broad and have 14 – 16 transapical striae in 10 μm.

Frustulia vulgaris (Thwaites) De Toni var. *angusta* Cholnoky (Figure 103)

Cholnoky 1954c, p. 214, fig. 61.

The single specimen observed in this study corresponds very closely with Cholnoky's (1954c) diagnosis of the variety, and also possesses the broadly rounded poles depicted by Cholnoky (1957b, p. 63, fig. 59) in a specimen from the Pongola River. However, there is still doubt as to whether this variety can be upheld (cf. Schoeman 1969, p. 45; Archibald 1983, p. 109).

Frustulia weinholdii Hustedt (Figure 47)

Hustedt in A. Schmidt 1874 – 1959, pl. 406, figs 7, 8.
Hustedt 1931 – 59, p. 731, fig. 1101.
Patrick & Reimer 1966, p. 310, pl. 22, fig. 2.

This *Frustulia* species, easily recognized by the lateral extensions of the proximal raphe endings at the slightly excentric central nodule, was once considered a rare species. More recently it has been observed from many parts of the world (Guermeur & Manguin 1953; Wallace 1960; Carter 1962; Patrick & Reimer 1966; Camburn, Lowe & Stoneburner 1978; Coste & Ricard 1982; Foged 1984), substantiating Hustedt's (1931 – 59, p. 731) view that it is probably more widespread than indicated by his purely German records of it. Hustedt's (in A. Schmidt 1874 – 1959) (1931 – 59) drawings show only elliptical forms with broadly rounded extremities, but Wallace (1960, p. 2, pl. 1, figs 3A – F) has illustrated an intergrading series to include forms with rostrate and capitate poles. On account of the latter, *F. weinholdii* may have been confused with *F. vulgaris* (cf. Hustedt 1931 – 59, p. 730, fig. 1100), which is very similar in valve form, if insufficient note is taken of the proximal endings of the raphe. This might explain the sudden greater frequency of new observations of *F. weinholdii*.

Only two examples were found in the Great Usutu River. One of these is somewhat shorter (34,0 μm long) than the minimum length given in the description. This valve is 8,0 μm broad and has 34 – 36 striae in 10 μm.

Gomphonema clevei Fricke (Figure 51)

Fricke in A. Schmidt 1874 – 1959, pl. 234, figs 44 – 46; pl. 266, fig. 35.
Hustedt 1937 – 38, p. 441, pl. 27, figs 14 – 18.

This species, originally described by Fricke (in A. Schmidt 1874 – 1959) from East Africa, is commonly found in southern Africa (Cholnoky 1954b; 1960a; 1960b; 1966; Archibald 1971; Schoeman 1973) and has been recorded previously from Swaziland (Cholnoky 1962). In the Great Usutu River, typical examples (e.g. Figure 51) were observed at all stations, but never in abundance. When a taxonomic review of this species is undertaken a number of other taxa must be taken into consideration. These are *G. frickei*, *G. brachyneura*, *G. sparsistriata* and *G. navicella*, all described by O. Müller (1905) from Malawi (Nyassaland), as well as *G. entolejum* Östrup [1902 (1903)].

Gomphonema parvulum (Kützing) Grunow (Figures 48 & 49)

Hustedt 1930, p. 372, figs 713a – c.

This very common and ubiquitous species has an extremely variable valve outline, and distinguishing between varieties is practically impossible on account of many intermediate forms (*vide* Wallace & Patrick 1950). Accordingly, no attempt has been made to identify the forms found in the Great Usutu River to varietal level. Figures 48 & 49 illustrate the typical valve forms found in this study. In contrast, Cholnoky (1962, p. 323) recorded both *G. parvulum* and its var. *lagenula* from the Great Usutu River.

Gomphonema subclavatum (Grunow) Grunow (Figure 50)

Grunow 1884, p. 46, pl. 1, fig. 12 (not fig. 13 = *G. arcticum*).
Hustedt 1930, p. 375, fig. 705 (as *G. longiceps* var. *subclavata* Grunow).

When Grunow (1884) raised this taxon (previously named *G.*

montanum var. *subclavatum* Grunow in Van Heurck 1880–83 and 1885) to the rank of species, he confused his illustration of this species with his drawing of *Gomphonema arcticum* in the same paper. Grunow, in both text and plate legend, cited pl. 1, fig. 13 as *G. subclavatum* and pl. 1, fig. 12 as *G. arcticum*. However, comparison of these two drawings with his corresponding illustrations of *G. montanum* var. *subclavatum* (in Van Heurck 1880–83, pl. 23, figs 38–41) and *G. arcticum* (in Van Heurck 1880–83, pl. 25, fig. 30), indicates that Grunow erroneously switched the two drawings around. Accordingly, plate 1, fig. 12 in his later paper (Grunow 1884) actually represents *G. subclavatum*, and pl. 1, fig. 13 illustrates *G. arcticum*. This is implied by Cleve (1894, pp. 183 and 188 under *G. exiguum* var. *arctica*) in his references to these two species respectively.

G. subclavatum was one of the most common species recorded in this study.

Navicula atomus (Kützing) Grunow (Figures 53 & 54)

Grunow 1860, p. 552, pl. 2, fig. 6.
Hustedt 1961–66, p. 169, fig. 1303.

Typical specimens were present in small numbers at most stations.

Navicula cari Ehrenberg var. *angusta* (Grunow) Grunow (Figure 52)

Grunow in Van Heurck 1880–83, pl. 7, fig. 17.
Germain 1981, p. 194, pl. 73, fig. 2.

The identity of valves as illustrated in Figure 52 has not been established with certainty. They are placed provisionally in *N. cari* var. *angusta* on the grounds of their close resemblance to Germain's (1981) illustration of this taxon. The specimens seen in this study fit the range of length given in Germain's description, but are broader (9,0 µm) and the striae are slightly more widely spaced (11 in 10 µm). Cholnoky (1962, p. 324) recorded this taxon from the Great Usutu River, but it is not certain whether his concept of the taxon corresponds with the form shown in Figure 52 of this paper.

Navicula contenta Grunow (Figures 55 & 56)

Schoeman & Archibald 1978, *N. contenta* p. 1–3, figs 1–88.

A few typical examples (Figures 55 & 56) were observed.

Navicula cryptocephala Kützing (Figures 57 & 58)

Hustedt 1930, p. 295, fig. 496.

This ubiquitous and very common species occurred in small numbers at nearly all the sampling sites.

Navicula gregaria Donkin (Figure 59)

Schoeman & Archibald 1978, *N. gregaria* p. 1–4, figs 1–41.

Typical examples of this species occurred at a few sampling sites.

Navicula grimmei Krasske (Figure 60)

Krasske 1925, p. 45, pl. 1, fig. 14.
Hustedt 1961–66, p. 769, figs 1742a–d.

Only a few specimens were observed.

Navicula indifferens Hustedt (Figures 61 & 62)

Hustedt 1942, p. 67, figs 27–30.
Hustedt 1961–66, p. 84, fig. 1226.

Specimens, as illustrated in Figures 61 & 62, have been assigned to *N. indifferens* on the basis of the valve shape and dimensions. These specimens are 5,5–7,0 µm long, 2,5–3,0 µm broad, and the transapical striae are not visible under the light microscope.

Navicula maillardii Germain (Figure 63)

Germain 1982, p. 107, pl. 4, figs 19–23.
Schoeman, Archibald & Ashton 1984, p. 199, figs 49–55.

This species was recently described by Germain (1982) from Kerguelen Island, and is distinguished from the very similar *Navicula subtilissima* Cleve on the basis of the striae structure. Schoeman *et al.* (1984) reported a number of specimens agreeing with Germain's description, although they showed a greater range in valve shape. The specimen illustrated here (Figure 63) presents a larger (20,0 µm long), somewhat broader (4,5 µm broad) and slightly more coarsely striate (28 striae in 10 µm) example, which has been assigned to this species. Recently Le Cohu (1985, p. 5) suggested that *N. maillardii* is conspecific with *N. bryophila* Boye Petersen (1928, p. 388, fig. 13). Electron microscope studies of the latter would be necessary to confirm this suggestion.

Navicula pelliculosa (Brébisson *ex* Kützing) Hilse (Figure 64)

Hustedt 1961–66, p. 173, fig. 1305.

In an attempt to clarify the identity of *N. pelliculosa*, Schoeman *et al.* (1976) failed to distinguish between this species and *N. saprophila* Lange-Bertalot & Bonik (1976, p. 312, figs 1c, 2, 8, 9, 29). However, while discussing the latter species in a subsequent publication, Schoeman & Archibald (1980) pointed out the close similarities between *N. pelliculosa* and *N. saprophila*, but retained the two as separate taxa on the basis of valve size and the difference in the angle subtended by the striae to the raphe. While *N. saprophila* has been positively identified from a relatively large number of samples in southern Africa, two specimens from the Great Usutu River constitute the first positive record of *N. pelliculosa* from this region. These two specimens are 11,0 µm long and 4,0–4,5 µm broad.

Navicula pupula Kützing (Figures 65 & 66)

Hustedt 1961–66, p. 120, figs 1254a–q.
Schoeman & Archibald 1979, *N. pupula* p. 1–5, figs 1–71.

Figures 65 & 66 illustrate two typical examples of this species.

Navicula radiosa Kützing complex (Figures 67 & 68)

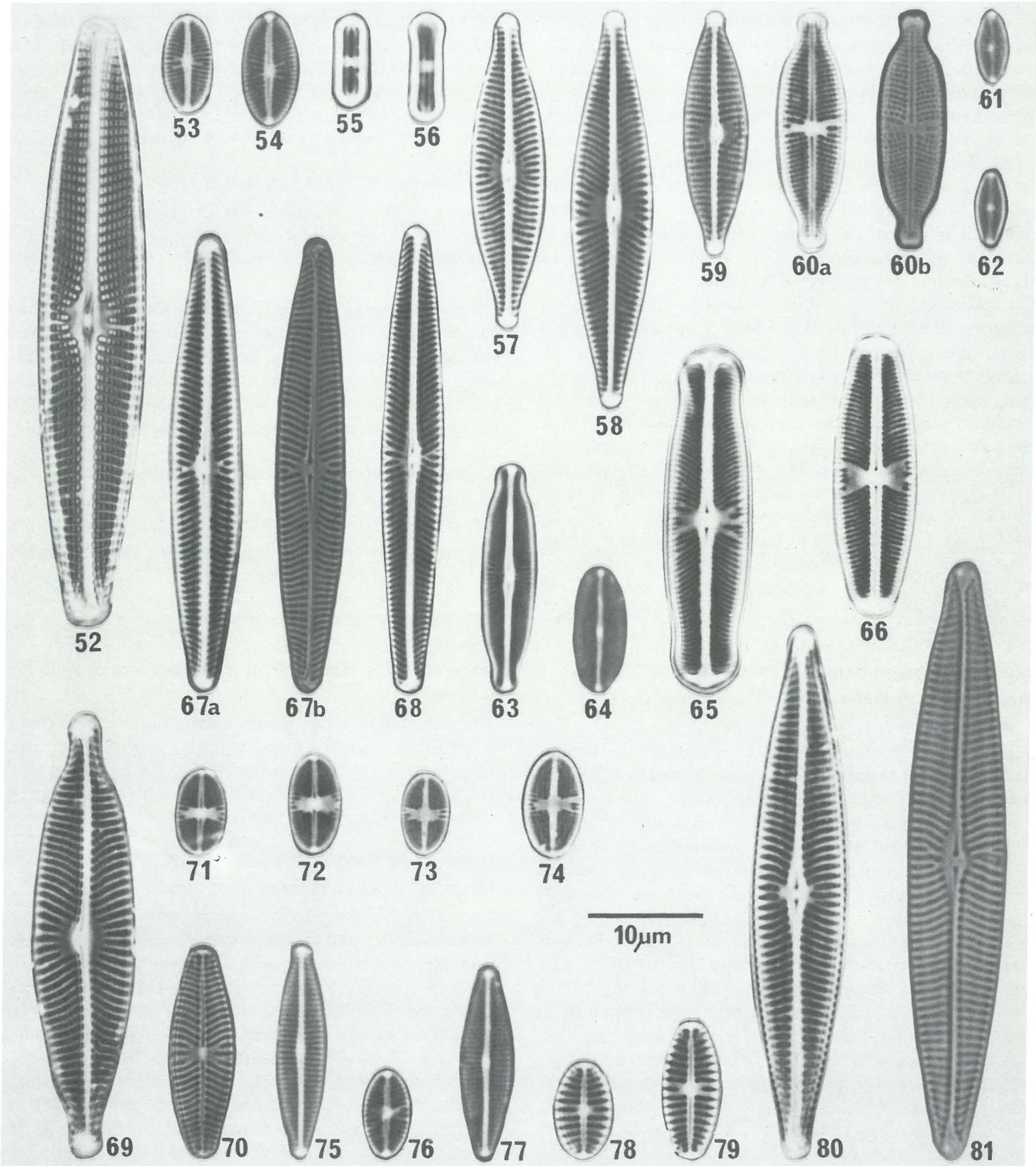
Germain 1981, p. 182, pl. 70, fig. 7.

The identity of the taxon illustrated in Figures 67 & 68 is difficult to determine precisely. Cholnoky (1962, p. 329) identified the same taxon as *N. tenella* Brébisson, but personal observation of specimens from his Swaziland materials (sample Nos 2, 3, 9, 13) as well as examples from this study do not correspond with our concept of *N. tenella*. This concept is illustrated by photographs of *N. radiosa* var. *tenella* given by Germain (1981, pl. 70, figs 8–12) and by the drawing of Patrick & Reimer (1966, pl. 48, fig. 17). In contrast, the Great Usutu River specimens resemble most closely a form of *N. radiosa* considered by Germain (1981, pl. 70, fig. 7) as a transitionary stage to the var. *tenella*. To some extent they also approach *N. radiosa* var. *acuta* (W. Smith) Grunow as seen on Van Heurck's (1884–87) slide No. 86. Since the Great Usutu River specimens cannot be identified more precisely at this stage, it is considered best to include them as closely allied to *N. radiosa* and its varieties.

Navicula rostellata Kützing (Figure 69)
Hustedt 1930, p. 297, fig. 502.

The Great Usutu River examples are identical to specimens observed by Lange-Bertalot (1980b, p. 35, pl. 5, figs 6–8) under the name *N. viridula* (Kützing) Ehrenberg var. *rostellata* (Kützing) Cleve (= *N. rostellata* on the Van Heurck 1884–87, slide No. 87 and in the Kützing material No. 874 = Grunow slide No. 708).

Navicula schoenfeldii Hustedt (Figure 70)
Hustedt 1930, p. 301, fig. 520.
Hustedt 1950, p. 353, pl. 37, figs 34–37.



Figures 52–81 LM micrographs of diatoms from the Great Usutu River. **52.** *Navicula cari* Ehrenberg var. *angusta* (Grunow) Grunow. **53 & 54.** *Navicula atomus* (Kützing) Grunow. **55 & 56.** *Navicula contenta* Grunow. **57 & 58.** *Navicula cryptocephala* Kützing. **59.** *Navicula gregaria* Donkin. **60.** *Navicula grimmei* Krasske. **61 & 62.** *Navicula indifferens* Hustedt. **63.** *Navicula maillardii* Germain. **64.** *Navicula pelliculosa* (Bréb. *ex* Kütz.) Hilse. **65 & 66.** *Navicula pupula* Kützing. **67 & 68.** *Navicula radiosa* Kützing complex. *69. Navicula rostellata* Kützing. **70.** *Navicula schoenfeldii* Hustedt. **71–74.** *Navicula subatomoides* Hustedt. **75.** *Navicula submolesta* Hustedt. **76.** *Navicula subrotundata* Hustedt. **77.** *Navicula twymaniana* Archibald. **78 & 79.** *Navicula usutensis* Cholnolky. **80 & 81.** *Navicula zanonii* Hustedt. Scale: × 2000. 52–60a, 61–67a, 68, 69, 71–80: P.C. Illum. 60b, 67b, 70, 81: B.F. Illum.

Several examples of a taxon (*vide* Figure 70), observed at one sampling station, have been identified as *N. schoenfeldii*. Although the dimensions of these specimens (length 9,5 – 19,0 µm; breadth 5,0 – 5,5 µm) and striae counts (16 striae in 10 µm) do not correspond entirely with those given by Hustedt (1930; 1950) for this species, they are placed here on morphological grounds. The valves are elliptical with broadly rounded to slightly rostrate apices; the striae arrangement at the centre of the valve agrees entirely with the description and illustrations given by Hustedt (1930), and the terminal striae are divided into discrete puncta (Hustedt 1950). These specimens, especially the smaller forms, bear a strong resemblance to *N. usutensis* Cholnoky (discussed below), which occurred in the same sample. Under the light microscope it appears that the only difference between them is in the construction of the central area (compare Figure 70 with Figures 78 & 79 of *N. usutensis*). Cholnoky (1962) apparently failed to recognise *N. schoenfeldii* from his Swaziland material, even though it is present on his type slide (Swazi 9 = NIWR 241/4806) of *N. usutensis* collected from the Great Usutu River (personal examination of the slide). This suggests that Cholnoky may not have distinguished this taxon from *N. usutensis*. The specimens, identified as *N. schoenfeldii* in this study, also appear to be morphologically identical to *N. pseudolagerstedtii* Cholnoky (1960b, p. 75, fig. 236), although here again they are generally smaller and narrower than Cholnoky's species, and the latter shows greater variation at the poles which become distinctly rostrate. Nevertheless on the Cholnoky slide NIWR 241/4806 (= Swazi 9) examples of *N. schoenfeldii* have the same range of valve shape as found in *N. pseudolagerstedtii* from the Okavango (Cholnoky 1966, p. 43, figs 112 – 114). It therefore appears that further detailed study is required to clarify the relationships between *N. schoenfeldii, N. pseudolagerstedtii* and *N. usutensis*. For further considerations in this regard see the comments on *N. usutensis* below.

Navicula subatomoides Hustedt (Figures 71 – 74)

Hustedt in A. Schmidt 1874 – 1959, pl. 404, figs 33 – 35.
Hustedt 1961 – 66, p. 271, fig. 1400.

The taxonomic position of this species is uncertain. Figures 71 & 72 illustrate examples of valves which agree in all respects with Hustedt's (1961 – 66) description of *N. subatomoides*. On the other hand Figures 73 & 74 show valves that are practically identical except that they do not have any raphe visible. Frustules with a valve of each type were also observed on several occasions, suggesting that this taxon should be placed in the genus *Achnanthes*. A similar observation has been made by Reichardt (1984, p. 56, pl. 11, fig. 7). Furthermore, examination of Hustedt's type material of *N. subatomoides* from Wuokatti in Finland (Slide No. Ma 2/60 in the Hustedt collection in Bremerhaven; *vide* Hustedt in A. Schmidt (1874 – 1959) and of specimens from the Garrensee (Hustedt slide No. N13/12 in Bremerhaven; *vide* Hustedt 1950, p. 437, pl. 38, figs 77 – 79) revealed frustules in which one valve had a raphe and the other not. However, it was not absolutely certain that this was the case in every frustule observed. Even in the Great Usutu River specimens, development of the raphe seems to vary. Some valves have a very clear raphe, while in others it appears to degenerate to a short portion visible only near the central pores. It is therefore difficult to determine whether this taxon is a true *Achnanthes* or a *Navicula* in which degeneration of the raphe takes place. This can only be resolved through electron microscopic study of representative examples. Until more positive evidence is presented to the contrary, these Great Usutu River specimens have been retained in the genus *Navicula*.

In this regard it is interesting to note that Cholnoky (1962, p. 329) recorded *N. subatomoides* from most of his samples associated with the Great Usutu River, but not in those collected from his Station 1a – c. In contrast, at this particular site, he (Cholnoky 1962, p. 314, figs 1, 2) observed specimens of *Achnanthes kryophila* Boye Petersen var. *africana* Cholnoky (1960b, p. 15, figs 11 – 16), which appear to strongly resemble the examples of *N. subatmoides* illustrated in Figures 71 – 74 in this study. Once again careful examination of these two taxa is required to determine their relationship.

Valves observed in this study are 7,0 – 11,0 µm long, 4,0 – 5,5 µm broad and have 36 or more striae in 10 µm.

Navicula submolesta Hustedt (Figure 75)

Hustedt 1949b, p. 86, pl. 5, figs 16 – 18.
Hustedt 1961 – 66, p. 253, fig. 1380.
Schoeman & Archibald 1977a, *N. submolesta* p. 1 – 2, figs 1 – 18.

Specimens observed in this study show the more lanceolate valves (Figure 75) illustrated by Schoeman & Archibald (1977a), but retain the fairly distinct rostrate valve poles. The distribution of this species in southern Africa is not precisely known as a number of records of *N. submolesta* are now recognized as misidentifications of *N. accomoda* Hustedt.

Navicula subrotundata Hustedt (Figure 76)

Hustedt 1945, p. 917, pl. 41, figs 30 – 33.
Hustedt 1961 – 66, p. 272, figs 1402a – m.

Although fairly frequently recorded from southern Africa, this species is never abundant.

Navicula twymaniana Archibald (Figure 77)

Archibald 1966, p. 264, figs 41 – 43.
Schoeman & Archibald 1977a, *N. twymaniana* p. 1 – 2, figs 1 – 9.

The distribution of this species appears to be more cosmopolitan than originally thought, having now been recorded from Europe as well (Lange-Bertalot & Bonik 1976, p. 315, figs 1m, 10, 11, 32; Germain 1981, p. 228, pl. 85, fig. 14; Reichardt 1982b, p. 404, pl. 1, fig. 7).

Navicula usutensis Cholnoky (Figures 78 & 79)

Cholnoky 1962, p. 329, fig. 35.

The taxonomic considerations surrounding this taxon are rather involved, and it is beyond the scope of this paper to reach any final conclusion with regard to its true identity. In his earlier study of diatoms from the Great Usutu River, Cholnoky (1962) described this taxon as a new species, *Navicula usutensis*. On examining a syntype slide (NIWR 241/4806 = Swazi 9), now designated as the lectotype slide for *N. usutensis*, it was found that the observed specimens (rare in the sample) do not agree with the dimensions given in Cholnoky's description. These specimens range in length from 8,5 – 14,0 µm and were 4,5 – 5,5 µm broad. They therefore only reach the lower limit set by Cholnoky (1962). Striae counts in these specimens are 14 – 18 (usually 16) in 10 µm over most of the valve, while at the centre they are more distant (about 10 in 10 µm). In the present study a number of examples, identical to those on the lectotype slide, were observed (length 8,0 – 11,5 µm; breadth 4,5 – 5,0 µm; striae 16 in 10 µm). In these and in the lectotype specimens a structural feature, not detected by Cholnoky, was discerned. This is the breaking up of the terminal striae into discrete puncta, which are not always readily visible. This characteristic has important taxonomic implications, and may lead to a name change. Evidence that Cholnoky's species may be identical to *N. paludosa* f. *minor sensu* Reichardt (1982b, pl. 1, fig. 10) or *N. ignota* var. *acceptata* (Hustedt) Lange-Bertalot *sensu* Reichardt (1984, p. 47, pl. 12, fig. 21) must receive careful consideration. Attention should also be given to a closely allied species, *N. schoenfeldii* Hustedt (1930), which occurred on the lectotype slide of *N. usutensis* and in one of the recent Great Usutu River samples (see above). For the present, however, the name *N. usutensis* is retained for this species.

Navicula zanonii Hustedt (Figures 80 & 81)

Hustedt 1949b, p. 92, pl. 5, figs 1 – 5.

The specimens observed in this study (Figures 80 & 81) appear to be quite typical and agree well with Mayama & Kobayashi's (1982, p. 92, pl. 4, fig. 64) photograph of a specimen from slide No. 244/53 in the Hustedt collection in Bremerhaven. Schoeman, Archibald & Ashton (1984, p. 199, figs 62 – 65) have supplied further SEM details on the structure of the valve.

Neidium affine (Ehrenberg) Cleve var. *amphirhynchus* (Ehrenberg) Cleve (Figure 82)

Hustedt 1930, p. 243, fig. 377.
Germain 1981, p. 152, pl. 57, figs 10 – 12.

Two specimens of this variety having clearly capitate poles were observed (Figure 82). Examples with a similar valve shape have also been figured by Germain (1981) and Cholnoky (1957a, p. 69, fig. 189).

Nitzschia acidoclinata Lange-Bertalot (Figures 83 – 85)

Lange-Bertalot 1977, p. 277, pl. 7, figs 19 – 21; pl. 10, figs 1, 2.
Lange-Bertalot & Simonsen 1978, p. 14, figs 145 – 148, 268, 294.

Specimens examined in this study (Figures 83 – 85) agreed in all respects with Lange-Bertalot & Simonsen's (1978) amplified description of the species. In Cholnoky's (1962, p. 332) previous study, specimens identified as *N. perminuta* Grunow probably belong to this species (cf. Lange-Bertalot 1977).

Nitzschia denticula Grunow (Figures 86 – 90)

Hustedt 1930, p. 407, fig. 780.
Schoeman & Ashton 1982, p. 31, figs 27 – 34, 95 – 111.

Figures 86 – 90 illustrate some typical examples of this species, which occurred commonly at all stations studied in this survey. Cholnoky (1962, p. 332) misidentified this species as *Nitzschia interrupta* (Reichelt) Hustedt, an error he frequently made because of a mistaken concept of the latter.

Nitzschia palea (Kützing) W. Smith (Figures 91 – 93)

Hustedt 1930, p. 416, fig. 801.

This cosmopolitan species was not abundant in the present survey, suggesting that little enrichment from organic nitrogenous sources is present.

Pinnularia interrupta W. Smith (Figure 95)

W. Smith 1853, p. 59, pl. 19, fig. 184.
Hustedt 1930, p. 317, fig. 573.

Specimens observed in this study appear to be identical to those recorded by Cholnoky (1962, p. 334), which, on the basis of valve breadth measurements, he considered to be intermediate between *P. interrupta* and its f. *minutissima* (Hustedt) Hustedt.

Pinnularia minuta Zanon (Figure 94)

Zanon 1941, p. 51, pl. 3, fig. 23.

Cholnoky (1958, p. 134, fig. 150) described a form, *P. claasseniae*, which is almost identical to the specimen illustrated here in Figure 94. He subsequently (Cholnoky 1960b) considered his new species to be a later synonym of *P. minuta* Zanon. Although Cholnoky probably never examined Zanon's type specimens, there is no evidence to contradict his later opinion. The example illustrated here (Figure 94) differs from Zanon's original diagnosis in that the valve is linear with almost parallel walls, whereas Zanon's drawing indictes a slightly lanceolate form. On the other hand, Cholnoky (1957a, p. 80, figs 253 – 255) drew three valves of *P. claasseniae* ranging from linear to linear-lanceolate in shape, thereby suggesting that *P. minuta* has a more variable outline. Only one example of this species was observed in the Malkerns Canal.

Pinnularia subcapitata Gregory (Figures 96 – 98)

Gregory 1856, p. 9, pl. 1, fig. 30.
Hustedt 1930, p. 317, fig. 571.
Germain 1981, p. 244, pl. 88, figs 1 – 8.

The correct identity of the specimens depicted in Figures 96 – 98 is uncertain. The authors do not know what Gregory's (1856) concept of *P. subcapitata* was, since the type specimens have not been examined. Furthermore, it is difficult to build an accurate concept of the species from illustrations in the literature as they represent the taxon in such a variety of ways. The Great Usutu River specimens have been identified as *P. subcapitata* because they agree with Hustedt's (1930) description. They also correspond with Germain's (1981) figure 7 on plate 88, and with Patrick & Reimer's (1966, p. 596, pl. 55, fig. 10) drawing. On the other hand, Camburn (1982, p. 377, figs 6 – 8) illustrated an apparently identical form under the name *P. termitina* (Ehrenberg) Patrick & Reimer (1966, p. 595, pl. 55, fig. 6). Camburn (1982) reported having found specimens of the latter up to 61,0 μm in length, but only illustrates examples up to 37,0 μm long. Examples from the Great Usutu River never attained this large size, but range from 26,0 – 54,0 μm long, 6,0 – 7,0 μm wide and have 12 – 13(14) striae in 10 μm. Not having been able to examine type specimens of *P. termitina* or *P. subcapitata*, it would be unwise to comment too critically on the taxonomy of this species. It has therefore been retained under the name *P. subcapitata*, because similar specimens from southern Africa have been identified as such (see Cholnoky 1962, p. 334; Schoeman 1969, p. 64, fig. 83).

Surirella delicatissima Lewis (Figure 99)

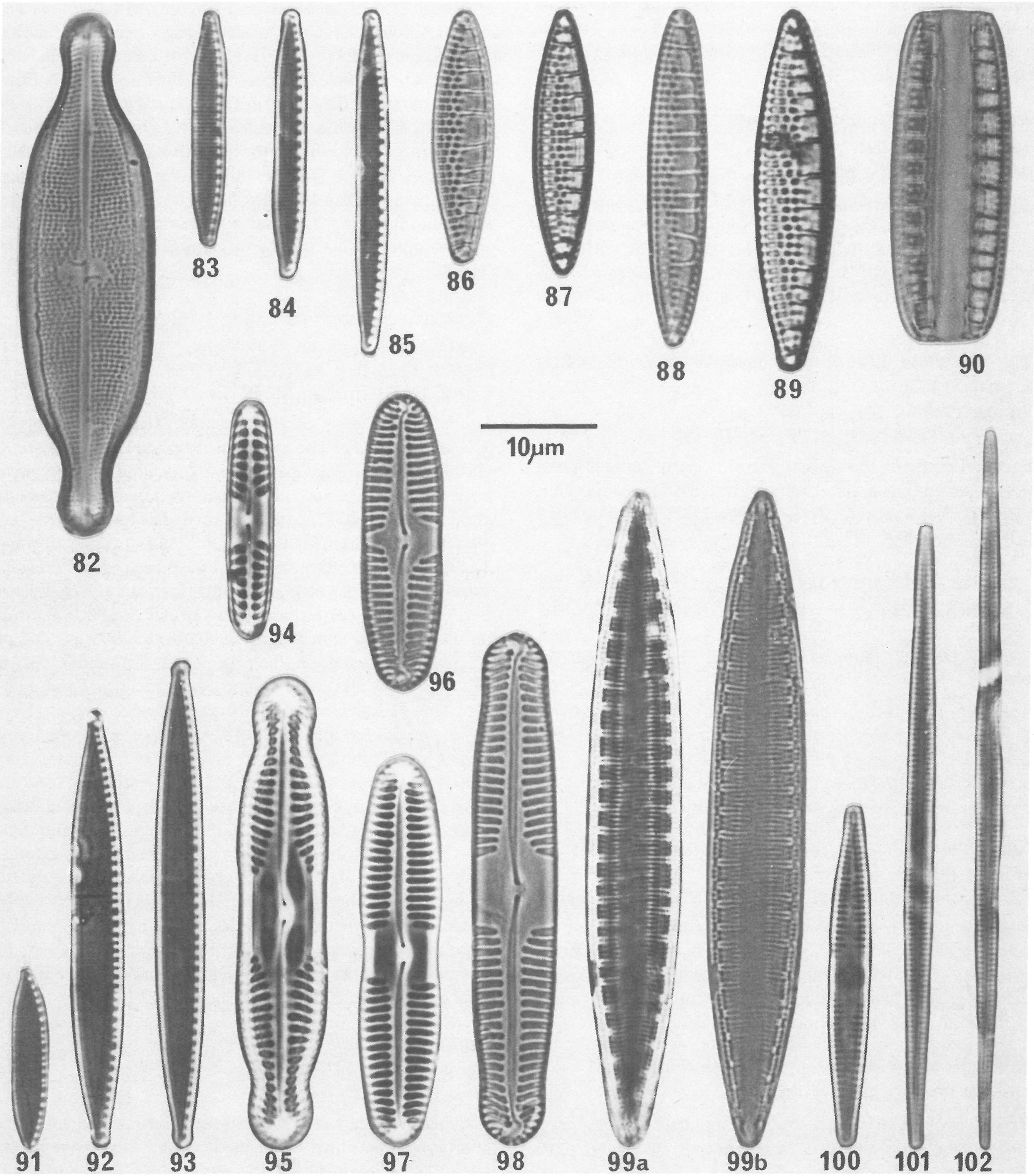
Lewis 1863, p. 343, pl. 3, fig. 4.
Hustedt 1930, p. 436, figs 846, 847.

This seems to be a rare species in southern Africa, with only two previous records being made; one from the Hogsback mountains in the eastern Cape Province (Giffen 1966, p. 147, fig. 88) and the other from the Mont-aux-Sources plateau in Lesotho (Schoeman 1973, p. 234). One specimen (Figure 99) was observed in the Great Usutu River at Station 5. This example measures 58,0 μm long, 8,0 μm broad and has 26 transapical striae in 10 μm, and 4 alar canals in 10 μm.

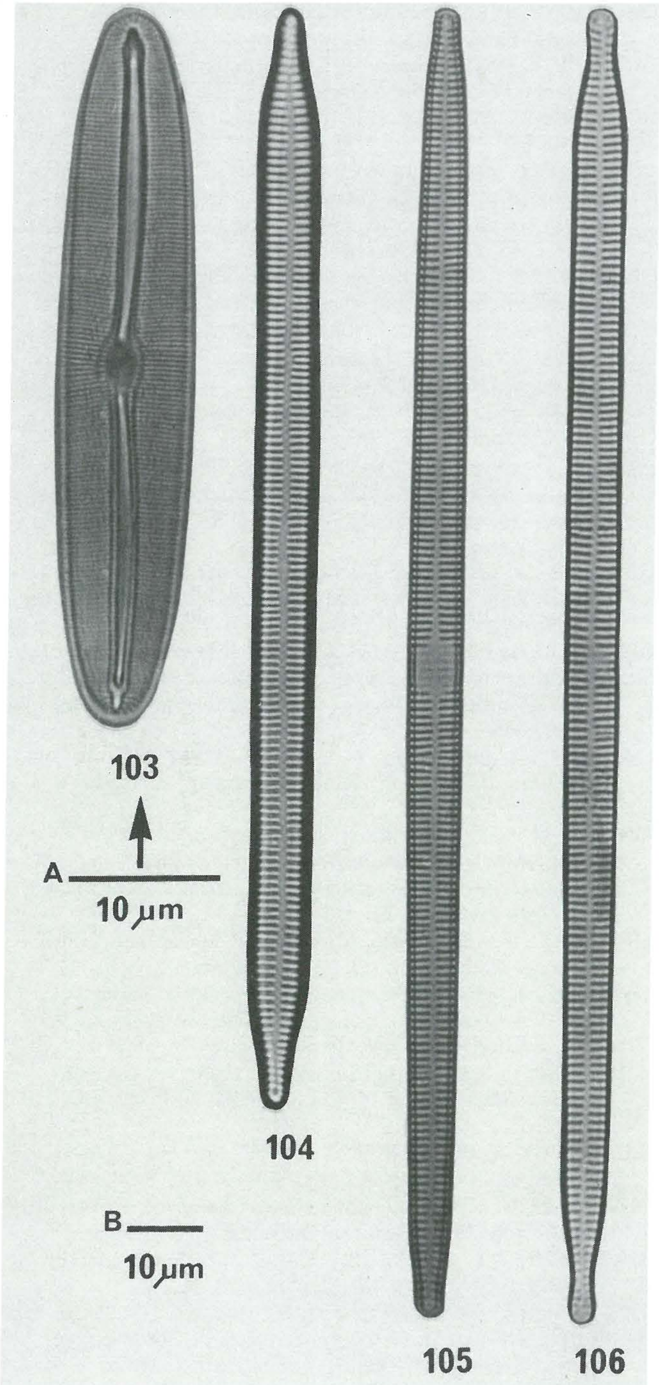
Synedra rumpens Kützing (Figure 100)

Hustedt 1931 – 59, p. 207, figs 697a, b.

Figure 100 exemplifies the forms designated as *S. rumpens* in this study. They compare very closely with the lectotype examples photographed by Lange-Bertalot (1980a, pl. 2, figs 39, 40). Lange-Bertalot (1980a, p. 729) united *S. rumpens* with *Fragilaria capucina*, firstly because he felt that there are no valid grounds to separate the genus *Synedra* from the genus *Fragilaria*, and secondly because he considered that the taxa *F. capucina, F. intermedia, F. vaucheriae* and *S. rumpens* comprize a form continuum making up a single taxon. On the other hand, Round (1984) criticized Lange-Bertalot's views on the unification of these two genera, justifying separation of the two taxa. This paper cannot enter this controversy, and the more familiar concept of *S. rumpens* is retained.



Figures 82 – 102 LM micrographs of diatoms from the Great Usutu River. **82.** *Neidium affine* (Ehr.) Cleve var. *amphirhynchus* (Ehr.) Cleve. **83 – 85.** *Nitzschia acidoclinata* Lange-Bertalot. **86 – 90.** *Nitzschia denticula* Grunow (90 = frustule in girdle view). **91 – 93.** *Nitzschia palea* (Kützing) W. Smith. **94.** *Pinnularia minuta* Zanon. **95.** *Pinnularia interrupta* W. Smith. **96 – 98.** *Pinnularia subcapitata* Gregory. **99.** *Surirella delicatissima* Lewis. **100.** *Synedra rumpens* Kützing. **101 & 102.** *Synedra tenera* W. Smith. Scale: × 2000. 83 – 85, 91 – 95, 97, 99a, 100 – 102: P.C. Illum. 82, 86 – 90, 96, 98, 99b: B.F. Illum.



Figures 103 – 106 LM micrographs of diatoms from the Great Usutu River. **103.** *Frustulia vulgaris* (Thwaites) De Toni var. *angusta* Cholnoky. **104 – 106.** *Synedra ulna* (Nitzsch) Ehrenberg. Scale A (Figure 103): × 2000; Scale B (Figures 104 – 106): × 1000. 103, 106: O.B.F. Illum. 104, 105: B.F. Illum.

Synedra tenera W. Smith (Figures 101 & 102)
Hustedt 1931 – 59, p. 211, fig. 703.

This species appears to be widespread in southern Africa.

Synedra ulna (Nitzsch) Ehrenberg (Figures 104 – 106)
Hustedt 1931 – 59, p. 195, figs 691A a – c.

This well-known cosmopolitan species was found in small numbers in nearly every sample collected in this survey.

Conclusions

The present study of the diatom flora of the Great Usutu River covers a stretch of river from above the pulp mill at Bhunya to a point downstream of the mill near Edwaleni.

Table 2 Diatom taxa found during the present survey of the Great Usutu River, Swaziland, that were previously recorded by Cholnoky (1962) under a different name

Name used in this survey	Cholnoky's (1962) name
Achnanthes exigua	*Achnanthes exigua* var. *heterovalvata* (sic)
Achnanthes lanceolata	*Achnanthes lanceolata* f. *rostrata*
Achnanthes minutissima	*Achnanthes linearis* and *Achnanthes microcephala*
Amphora veneta var. *capitata*	*Amphora coffeaeformis*
Amphora copulata	*Amphora ovalis* var. *libyca*
Brachysira exilis	*Anomoeoneis exilis*
Caloneis hyalina	*Caloneis chasei*?
Capartogramma crucicula	*Stauroneis merrimacensis*
Cymbella minuta	*Cymbella ventricosa*
Diploneis oblongella	*Diploneis ovalis*
Fragilaria vaucheriae	*Fragilaria intermedia*
Gomphonema parvulum	*Gomphonema parvulum* var. *lagenula*
Gomphonema subclavatum	*Gomphonema longiceps* var. *subclavatum*
Navicula radiosa complex	*Navicula tenella*
Nitzschia denticula	*Nitzschia interrupta*

Twenty-two samples were collected from this section of the river course, and 97 diatom taxa were recorded in them. In addition, two samples from the Cascade A channel and three from the Malkerns irrigation canal yielded a further 14 taxa. A complete list of all these taxa, together with some indication of their relative abundances in each sample, is presented in Table 1. In his earlier survey Cholnoky (1962) recorded 95 taxa (taking account of the most recent taxonomic opinions) from 5 samples (Nos 1, 2, 3, 9, 13) collected within the same stretch of river (tributaries excluded). Of Cholnoky's recorded taxa, 53 were still found in the Great Usutu River 20 years later. These taxa are indicated in Table 1 by the superscript (1), and it will be seen that they generally represent the more prominent taxa in the diatom associations from each station. Those taxa recorded for the first time in the present study, or found only by Cholnoky in 1962, were usually rare in their occurrence.

It is inevitable that, over a period of twenty years, the nomenclature of some taxa will change as a result of new concepts or new interpretations of diagnoses and illustrations. A second superscript (2) following a specific entry in Table 1 therefore indicates in which of the Great Usutu River taxa this has taken place. Comments on such occurrences can be found in the text, and Cholnoky's corresponding names for these taxa are presented in Table 2.

Finally, analysis of the structure of the diatom populations at the selected stations on the Great Usutu River, showed that, with the exception of the diatom populations from the sandy substrate at Station 4, there was a remarkable constancy in the populations throughout the stretch of river examined both in terms of component taxa and in their relative abundances in the populations (Archibald & Schoeman 1987). Furthermore, comparison of the present populations with those analysed by Cholnoky (1962, p. 350, Table 3) demonstrated that the nature of the diatom associations in that particular stretch of the Great Usutu River had undergone very little change over 20 years, despite the discharge of pulp mill effluent into the river during this period.

Acknowledgements

Sincere thanks are extended to Mrs V.H. Meaton for producing the final photographic prints. This paper is published with the approval of the National Institute for Water Research.

References

AGARDH, C.A. 1830 – 32. Conspectus criticus Diatomacearum, Parts 1 – 4, 66 pp. Lundae.

ANONYMOUS. 1975. Proposals for a standardization of diatom terminology and diagnoses. *Nova Hedwigia* Suppl. 53: 323 – 354.

ARCHIBALD, R.E.M. 1966. Some new and rare diatoms from South Africa. *Nova Hedwigia* Suppl. 21: 253 – 273.

ARCHIBALD, R.E.M. 1971. Diatoms from the Vaal Dam catchment area, Transvaal, South Africa. *Botanica mar.* Suppl. 14: 17 – 70.

ARCHIBALD, R.E.M. 1983. The diatoms of the Sundays and Great Fish Rivers in the eastern Cape Province of South Africa. *Biblthca diatomol.* 1: 1 – 362, 34 pls.

ARCHIBALD, R.E.M. & SCHOEMAN, F.R. 1984. *Amphora coffeaeformis* (Agardh) Kützing: a revision of the species under light and electron microscopy. *S. Afr. J. Bot.* 3: 83 – 102.

ARCHIBALD, R.E.M. & SCHOEMAN, F.R. 1987. Observations on the influence of a kraft pulp mill effluent on the diatom flora (Bacillariophyceae) of the Great Usutu River, Swaziland, after twenty years of operation. *J. Limnol. Soc. sth. Afr.* (in press).

BOYE PETERSEN, J. 1928. The aërial algae of Iceland. In: The Botany of Iceland, ed. Rosenvinge, L.K. & Warming, E. Vol. 2, part 2, pp. 325 – 447. J. Frimodt, Copenhagen.

BOYE PETERSEN, J. 1938. *Fragilaria intermedia – Synedra vaucheriae* ? *Bot. Notiser* 1938: 164 – 170.

CAMBURN, K.E. 1982. Subaerial diatom communities in eastern Kentucky. *Trans. Am. microsc. Soc.* 101: 375 – 387.

CAMBURN, K.E., LOWE, R.L. & STONEBURNER, D.L. 1978. The haptobenthic diatom flora of Long Branch Creek, South Carolina. *Nova Hedwigia* 30: 149 – 279.

CARTER, J.R. 1962. Diatom notes. More unusual British forms. *The Microscope* 13(9): 231 – 237.

CHOLNOKY, B.J. 1954a. Diatomeen und einige andere Algen aus dem 'de Hoek'-Reservat in Nord-Transvaal. *Bot. Notiser* 1954: 269 – 296.

CHOLNOKY, B.J. 1954b. Neue und seltene Diatomeen aus Afrika. *Öst. bot. Z.* 101: 407 – 427.

CHOLNOKY, B.J. 1954c. Diatomeen aus Süd-Rhodesien. *Port. Acta biol.* (B) 4: 197 – 228.

CHOLNOKY, B.J. 1955. Diatomeen aus salzhaltigen Binnengewässern der westlichen Kaap-Provinz in Südafrika. *Ber. dt. bot. Ges.* 68: 11 – 23.

CHOLNOKY, B.J. 1956. Neue und seltene Diatomeen aus Afrika. II. Diatomeen aus dem Tugela-Gebiete in Natal. *Öst. bot. Z.* 103: 53 – 97.

CHOLNOKY, B.J. 1957a. Neue und seltene Diatomeen aus Afrika. III. Diatomeen aus dem Tugela-Flusssystem, hauptsächlich aus den Drakensbergen in Natal. *Öst. bot. Z.* 104: 25 – 99.

CHOLNOKY, B.J. 1957b. Beiträge zur Kenntnis der südafrikanischen Diatomeenflora. *Port. Acta biol.* (B) 6: 53 – 93.

CHOLNOKY, B.J. 1958. Beiträge zur Kenntnis der südafrikanischen Diatomeenflora. II. Einige Gewässer im Waterberg-Gebiet, Transvaal. *Port. Acta biol.* (B) 6: 99 – 153, 7 pls.

CHOLNOKY, B.J. 1959. Neue und seltene Diatomeen aus Afrika. IV. Diatomeen aus der Kaap-Provinz. *Öst. bot. Z.* 106: 1 – 69.

CHOLNOKY, B.J. 1960a. Beiträge zur Kenntnis der Ökologie der Diatomeen in dem Swartkops-Bache nahe Port Elizabeth (Südost-Kaapland). *Hydrobiologia* 16: 229 – 287.

CHOLNOKY, B.J. 1960b. Beiträge zur Kenntnis der Diatomeenflora von Natal (Südafrika). *Nova Hedwigia* 2: 1 – 128.

CHOLNOKY, B.J. 1962. Ein Beitrag zu der Ökologie der Diatomeen in dem englischen Protektorat Swaziland. *Hydrobiologia* 20: 309 – 355.

CHOLNOKY, B.J. 1966. Die Diatomeen im Unterlaufe des Okawango-Flusses. *Nova Hedwigia* Suppl. 21: 1 – 102.

CLEVE, P.T. 1894. Synopsis of the Naviculoid diatoms, Part 1. *K. svenska Vetensk.-Akad. Handl.* 26(2): 1 – 194.

COMPÈRE, P. 1980. Algues de l'Aïr (Niger). *Bull. Jard. bot. nat. Belg.* 50: 269 – 329.

COMPÈRE, P. 1981. Ultrastructural aspects of the frustule of some forms of *Cymbella hustedtii* Krasske. In: Proceedings of the sixth symposium on recent and fossil diatoms, ed. Ross, R. pp. 155 – 165. Otto Koeltz, Koenigstein.

COMPÈRE, P. 1984. Some algae from the Red Sea Hills in north-eastern Sudan. *Hydrobiologia* 110: 61 – 77.

COSTE, M. & RICARD, M. 1982. Contribution a l'étude des diatomées d'eau douce des Seychelles et de l'ile Maurice. *Cryptogamie: Algologie* 3: 279 – 313.

FOGED, N. 1984. Freshwater and littoral diatoms from Cuba. *Biblthca diatomol.* 5: 1 – 243.

FRITSCH, F.E. & RICH, F. 1924. Contributions to our knowledge of the freshwater algae of Africa. 4. Freshwater and subaerial algae from Natal. *Trans. R. Soc. S. Afr.* 11: 297 – 398.

GEISSLER, U. 1970. Die Schalenmerkmale der Diatomeen — Ursachen ihrer Variabilität und Bedeutung für die Taxonomie. *Nova Hedwigia* Suppl. 31: 511 – 535.

GERMAIN, H. 1981. Flore des diatomées (Diatomophycées) eaux douces et saumâtres du Massif Armoricain et des contrées voisines d'Europe occidentale, 444 pp. Société nouvelle des éditions Boubée, Paris.

GERMAIN, H. 1982. Quatre Navicules du groupe des Subtilissimae (Diatomophyceae). *Cryptogamie: Algologie* 3: 105 – 111.

GIFFEN, M.H. 1966. Contributions to the diatom flora of southern Africa. II. Diatoms from the Hog's Back region of the Amatola Mountains, eastern Cape Province, South Africa. *Nova Hedwigia* Suppl. 21: 123 – 150.

GREGORY, W. 1856. Notice of some new species of British fresh-water Diatomaceae. *Q. Jl Microsc. Sci.* 4: 1 – 14.

GRUNOW, A. 1860. Ueber neue oder ungenügend gekannte Algen. Erste Folge. Diatomaceen, Familie Naviculaceen. *Verh. k. k. zool.-bot. Ges. Wien* 10: 503 – 582.

GRUNOW, A. 1884. Die Diatomeen von Franz Josefs-Land. *Denkschr. math.-naturw. Classe K. Akad. Wiss.* 48: 53 – 112.

GUERMEUR, P. & MANGUIN, E. 1953. Note sur quelques diatomées rares ou nouvelles. *Öst. bot. Z.* 100: 540 – 547.

HÅKANSSON, H. 1979. Examination of diatom type material of C.A. Agardh. *Nova Hedwigia* Suppl. 64: 163 – 168.

HAWORTH, E.Y. 1974. Some problems of diatom taxonomy in Scottish Lake sediments. *Br. phycol. J.* 9: 47 – 55.

HENDEY, N.I. 1964. Bacillariophyceae (Diatoms). In: An introductory account of the smaller algae of British coastal waters, Fishery Investigations, series 4, part 5, 317 pp. & 45 pls. Her Majesty's Stationery Office, London.

HIRANO, M. 1964. Freshwater algae of Afghanistan. Results Kyoto Univ. Scientific Expedition to the Karakoram and Hindukush 3: 167 – 245.

HIRANO, M. 1966. Freshwater algae from north-eastern part of Afghanistan. Results Kyoto Univ. Scientific Expedition to the Karakoram and Hindukush 8: 15 – 54.

HUSTEDT, F. 1922. Bacillariales aus Innerasien. In: Southern Tibet, ed. Hedin, S. Vol. 6, Botany, pp. 107 – 152. Lithographic Institute of the General Staff of the Swedish Army, Stockholm.

HUSTEDT, F. 1930. Bacillariophyta (Diatomeae). In: Die Süsswasser-Flora Mitteleuropas, ed. Pascher, A. Part 10, 466 pp. G. Fischer, Jena.

HUSTEDT, F. 1931 – 59. Die Kieselalgen. In: Kryptogamen-Flora von Deutschland, Österreich und der Schweiz, ed. Rabenhorst, L. Vol. 7, Part 2, 845 pp. Akademische Verlagsgesellschaft Geest & Portig K. – G., Leipzig.

HUSTEDT, F. 1937 – 38. Sytematische und ökologische Untersuchungen über die Diatomeen-Flora von Java, Bali und Sumatra. Systematischer Teil. *Arch. Hydrobiol.* Suppl. 15: 131 – 177, 187 – 295, 393 – 506.

HUSTEDT, F. 1942. Aërophile Diatomeen in der nordwestdeutschen Flora. *Ber. dt. bot. Ges.* 60: 55 – 73.

HUSTEDT, F. 1945. Diatomeen aus Seen und Quellgebieten der Balkan-Halbinsel. *Arch. Hydrobiol.* 40: 867 – 973.
HUSTEDT, F. 1949a. Diatomeen von der Sinai-Halbinsel und aus dem Libanon-Gebiet. *Hydrobiologia* 2: 24 – 55.
HUSTEDT, F. 1949b. Süsswasser-Diatomeen. In: Exploration du Parc National Albert, Mission H. Damas (1935 – 36), Fasc. 8, 199 pp. & 16 pls. M. Hayez, Bruxelles.
HUSTEDT, F. 1950. Die Diatomeenflora norddeutscher Seen mit besonderer Berücksichtigung des holsteinischen Seengebiets. V – VII. Seen in Mecklenburg, Lauenburg und Nordostdeutschland. *Arch. Hydrobiol.* 43: 329 – 458.
HUSTEDT, F. 1957. Die Diatomeenflora des Fluss-systems der Weser im Gebiet der Hansestadt Bremen. *Abh. naturw. Ver. Bremen* 34: 181 – 440.
HUSTEDT, F. 1961 – 66. Die Kieselalgen. In: Kryptogamen-Flora von Deutschland, Österreich und der Schweiz, ed. Rabenhorst, L. Vol. 7, Part 3, 816 pp. Akademische Verlagsgesellschaft Geest & Portig K. – G., Leipzig.
KACZMARSKA, I. & RUSHFORTH, S.R. 1983. The diatom flora of Blue Lake Warm Spring, Utah, U.S.A. *Biblthca diatomol.* 2: 1 – 123.
KINGSTON, J.C. 1978. Morphological variation of *Cymbella delicatula* and *C. hustedtii* from northern Lake Michigan. *Trans. Am. microsc. Soc.* 97: 311 – 319.
KOLBE, R.W. & KRIEGER, W. 1942. Süsswasseralgen aus Mesopotamien und Kurdistan. *Ber. dt. bot. Ges.* 60: 336 – 355.
KRAMMER, K. 1982. Valve morphology in the genus *Cymbella* C.A. Agardh. In: Micromorphology of diatom valves, ed. Helmcke, J. – G. & Krammer, K. Vol. XI, 1 – 49, pls 1024 – 1148. J. Cramer, Vaduz.
KRASSKE, G. 1923. Die Diatomeen des Casseler Beckens und seiner Randgebirge, nebst einigen wichtigen Funden aus Niederhessen. *Bot. Arch.* 3: 185 – 209.
KRASSKE, G. 1925. Die Bacillariaceen-Vegetation Niederhessens. *Abh. Ber.* (LVI) *Ver. Naturk. Cassel* 84 – 89. Vereinsjahr 1919 – 25: 1 – 119.
KÜTZING, F.T. 1833 – 36. Algarum aquae dulcis Germanicarum, Decas I – XVI. Exsiccatae, text without page numbers (39 pp.). C.A. Schwetschkii et Fil., Halis Saxonum.
LANGE-BERTALOT, H. 1977. Einer Revision zur Taxonomie der Nitzschiae lanceolatae Grunow. Die 'klassischen' bis 1930 beschriebenen Süsswasserarten Europas. *Nova Hedwigia* 28: 253 – 307.
LANGE-BERTALOT, H. 1980a. Zur systematischen Bewertung der bandförmigen Kolonien bei *Navicula* und *Fragilaria*. *Nova Hedwigia* 33: 723 – 787.
LANGE-BERTALOT, H. 1980b. Zur taxonomischen Revision einiger ökologisch wichtiger 'Naviculae lineolatae' Cleve. *Cryptogamie: Algologie* 1: 29 – 50.
LANGE-BERTALOT, H. & BONIK, K. 1976. Massenentwicklung bisher seltener und unbekannter Diatomeen als Indikator starker Abwasserbelastung in Flüssen. *Arch. Hydrobiol.* Suppl. 49: 303 – 332.
LANGE-BERTALOT, H. & RUPPEL, M. 1980. Zur Revision taxonomisch problematischer, ökologisch jedoch wichtiger Sippen der Gattung *Achnanthes* Bory. *Arch. Hydrobiol.* Suppl. 60: 1 – 31.
LANGE-BERTALOT, H. & SIMONSEN, R. 1978. A taxonomic revision of the Nitzschiae lanceolatae Grunow. 2. European and related extra-European fresh water and brackish water taxa. *Bacillaria* 1: 11 – 111.
LE COHU, R. 1985. Ultrastructure des diatomées de Nouvelle-Calédonie. Première partie. *Annls Limnol.* 21: 3 – 12.
LE COHU, R. & MAILLARD, R. 1983. Les diatomées monoraphidées des îles Kerguelen. *Annls Limnol.* 19: 143 – 167.
LEWIS, F.W. 1863. On some new and singular intermediate forms of Diatomaceae. *Proc. Acad. nat. Sci. Philad.* 15: 336 – 346.
MAYAMA, S. & KOBAYASI, H. 1982. Diatoms from the Aono-gawa River. *Bull. Tokyo Gakugei Univ.* Sect. 4, 34: 77 – 107.
MOSS, M.O. & CARTER, J.R. 1982. The resurrection of *Achnanthes rostrata* Östrup. *Bacillaria* 5: 157 – 164.
MÜLLER, O. 1905. Bacillariaceen aus dem Nyassalande und einigen benachbarten Gebieten. Dritte Folge. *Bot. Jb. (Engler)* 36: 137 – 205.
ÖSTRUP, E. 1902(1903). Freshwater diatoms. In: Flora of Koh Chang. Contributions to the knowledge of the vegetation in the Gulf of Siam, ed. Schmidt, J. *Bot. Tidsskr.* 25: 28 – 41.
PATRICK, R. & REIMER, C.W. 1966. The diatoms of the United States exclusive of Alaska and Hawaii. Vol. 2. *Monogr. Acad. Nat. Sci. Philad.* 13: 1 – 688.
PATRICK, R. & REIMER, C.W. 1975. The diatoms of the United States exclusive of Alaska and Hawaii, Vol. 2, Part 1. *Monogr. Acad. Nat. Sci. Philad.* 13: 1 – 213.
REICHARDT, E. 1982a. Die Diatomeenflora der 'Steinernen Rinnen' in Mittelfranken. *Ber. bayer. bot. Ges.* 53: 97 – 112.
REICHARDT, E. 1982b. Diatomeen aus dem Lough Neagh. *Nova Hedwigia* 38: 401 – 420.
REICHARDT, E. 1984. Die Diatomeen der Altmühl. *Biblthca diatomol.* 6: 1 – 169.
REICHELT, H. 1904. Über Bacillariaceen der mittleren Kalahari. In: Die Kalahari, ed. Passarge, S. pp. 760 – 784. Berlin.
ROSS, R. 1963. The diatom genus *Capartogramma* and the identity of *Schizostauron*. *Bull. Br. Mus. nat. Hist.* (Bot) 3: 49 – 92.
ROSS, R., COX, E.J., KARAYEVA, N.I., MANN, D.G., PADDOCK, T.B.B., SIMONSEN, R. & SIMS, P.A. 1979. An amended terminology for the siliceous components of the diatom cell. *Nova Hedwigia* Suppl. 64: 513 – 533.
ROUND, F.E. 1984. The circumscription of *Synedra* and *Fragilaria* and their subgroupings. In: Proceedings of the seventh international diatom symposium, ed. Mann, D.G. pp. 241 – 253. Otto Koeltz, Koenigstein.
ROUND, F.E. & MANN, D.G. 1981. The diatom genus *Brachysira*. I. Typification and separation from *Anomoeoneis*. *Arch. Protistenk* 124: 221 – 231.
SCHMIDT, A. 1874 – 1959. Atlas der Diatomaceenkunde. Continued by Schmidt, M., Fricke, F., Heiden, H., Müller, O. & Hustedt, F. 480 pls. O.R. Reisland, Leipzig.
SCHOEMAN, F.R. 1969. Diatoms from the Orange Free State (South Africa) and Lesotho. No. 2. *Revta Biol.* 7: 35 – 74.
SCHOEMAN, F.R. 1970. Diatoms from the Orange Free State, South Africa, and Lesotho I. *Nova Hedwigia* Suppl. 31: 331 – 353.
SCHOEMAN, F.R. 1973. A sytematical and ecological study of the diatom flora of Lesotho with special reference to the water quality, 355 pp. and 10 pls. V. & R Printers, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1977a. The diatom flora of southern Africa. No. 2, February 1977. CSIR Special Report WAT 50. No pagination; series of plates with text, 49 pp. National Institute for Water Research, CSIR, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1977b. The diatom flora of southern Africa. No. 3, September 1977. CSIR Special Report WAT 50. No pagination; series of plates with text, 61 pp. National Institute for Water Research, CSIR, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1978. The diatom flora of southern Africa. No. 4, April 1978. CSIR Special Report WAT 50. No pagination; series of plates with text, 68 pp. National Institute for Water Research, CSIR, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1979. The diatom flora of southern Africa. No. 5, September 1979. CSIR Special Report WAT 50. No pagination; series of plates with text, 65 pp. National Institute for Water Research, CSIR, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1980. The diatom flora of southern Africa. No. 6, May 1980. CSIR Special Report WAT 50. No pagination; series of plates with text, 111 pp. National Institute for Water Research, CSIR, Pretoria.
SCHOEMAN, F.R. & ARCHIBALD, R.E.M. 1986. Observations on *Amphora* species (Bacillariophyceae) in the British Museum (Natural History). V. Some species from the subgenus *Amphora* Cleve. *S. Afr. J. Bot.* 52: 425 – 437.
SCHOEMAN, F.R., ARCHIBALD, R.E.M. & ASHTON, P.J. 1984. The diatom flora in the vicinity of the Pretoria Salt Pan, Transvaal, Republic of South Africa. Part III (final). *S. Afr. J. Bot.* 3: 191 – 207.
SCHOEMAN, F.R., ARCHIBALD, R.E.M. & BARLOW, D.J. 1976. Structural observations and notes on the freshwater diatom (Diatomeae) *Navicula pelliculosa* (Brébisson *ex* Kützing) Hilse. *Br. phycol. J.* 11: 251 – 263.
SCHOEMAN, F.R. & ASHTON, P.J. 1982. The diatom flora in the vicinity of the Pretoria Salt Pan, Transvaal, Republic of South Africa. I. *Nova Hedwigia* Suppl. 73: 21 – 54.

SCHOEMAN, F.R. & ASHTON, P.J. 1983. The diatom flora in the vicinity of the Pretoria Salt Pan, Transvaal, Republic of South Africa. Part II. *S. Afr. J. Bot.* 2: 191 – 201.

SMITH, W. 1853. A synopsis of the British Diatomaceae; with remarks on their structure, functions and distribution, Vol. 1, 89 pp. & 31 pls. John Van Voorst, London.

VAN HEURCK, H. 1880 – 83. Synopsis des diatomées de Belgique. Atlas: 132 pls. J. Ducaju & Co., Anvers.

VAN HEURCK, H. 1884 – 87. Types du synopsis des diatomées de Belgique. Série I – XXII, 123 pp. & 550 slides. Anvers.

VAN HEURCK, H. 1885. Synopsis des diatomées de Belgique. Text: 235 pp. J. Ducaju & Co., Anvers.

VANLANDINGHAM, S.L. 1967 – 79. Catalogue of the fossil and recent genera and species of diatoms and their synonyms. Parts 1 – 8, 4654 pp. J. Cramer, Lehre & Vaduz.

WALLACE, J.H. 1960. New and variable diatoms. *Notulae Naturae* No. 331: 1 – 6.

WALLACE, J.H. & PATRICK, R. 1950. A consideration of *Gomphonema parvulum* Kütz. *Butler Univ. bot. Studies* 9: 227 – 234.

WOODHEAD, N., & TWEED, R.D. 1960. Freshwater algae of Sierra Leone. 3. The algae of Rokupr and Great Scarcies River. *Revue algol.*, N.S. 5: 116 – 150.

ZANON, D.V. 1941. Diatomee dell'Africa Occidentale Francese. *Commentationes Pontificia Acad. Sci.* 5: 1 – 60.