



***Ninastrelnikovia*: A new genus of biraphid Bacillariophyceae**

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With 42 figures

Abstract: A new genus of naviculoid diatoms is proposed with *Navicula gibbosa* Hustedt as type species. Frustule and valve morphology, in particular the pattern of fine structures differs distinctly from all established genera of the *Naviculaceae*. Closely related though not congeneric are the genera *Frankophila* Lange-Bertalot 1997 and *Hygropetra* Krammer & Lange-Bertalot in Krammer 2000. *In situ* individual cells are concatenated to form chain-like colonies. As a consequence of the chain-like integration of the frustules, individual cells exhibit a peculiar polymorphism dependent on whether a frustule occurs terminally in a chain or in contact with neighbouring frustules. From a biogeographical point of view *Navicula gibbosa* is a generally rare species world-wide and its autecology is exceptional. It was found recently (in moderate abundance) in mountainous ephemeral rock-pools in Algeria and Namibia, both regions being situated in extra-tropical Africa. *N. gibbosa* is associated with numerous desiccation-tolerant diatom taxa recently described from Sardinia and other places in Algeria or still new to science.

Keywords: *Ninastrelnikovia* gen. nov., *Navicula gibbosa*, frustule morphology, disjunctive distribution, autecology, biogeography, taxonomy.

Introduction

Among the diatoms *Navicula gibbosa* Hustedt may serve as an excellent example of disjunctive occurrence in biogeography. Despite its peculiar shape it has rarely been recorded in the past. The type location is a lake of some fame in geology: Lake Toba, situated at 905 meters above sea level in northern Sumatra, Indonesia; cf. Hustedt (1937, fig. 18:10; see also Hustedt 1961–66, fig. 1337). The taxon was later reported from a few further localities. Where it occurs it seems to be mostly rare; only in a few sites *N. gibbosa* occurs in moderate abundance. Most of the records to date are from rivers in south-eastern North America (Patrick & Reimer 1966, fig. 46:16 from Savannah River, South Carolina; 19 counts to date in the geological survey of the US Academy of Natural Sciences (ANS), all in the south-east, except for one rare occurrence in a Nevada rock pool). There is only one record from South America (in the state of Paraná in south-eastern Brazil; see Leandrini et. al. 2002, fig. 15). The taxon has possibly also been found in Iran (Jaballou et al. 2006, without figure or description, i.e. not verifiable). On the African continent the only published record so far was in Maillard (1977), who reports *N. gibbosa* from the river Niger as “very rare”. Recently we found a moderately large number of individuals in samples taken from rock pools in Algeria and Namibia. So far there are neither records from Europe nor from the large regions of holarctic Asia.

As far as we know the fine structure of the frustules has never been investigated. There are only two line drawings (in Hustedt 1937 and in Reimer & Patrick 1966), the light-microscopic micrographs of the holotype in Simonsen (1987, fig. 303: 8) and another micrograph in Leandrini

et al. (2002). Hustedt's (1937) protologue gives only the basic dimensional parameters and mentions as characteristics the strong transapical inflation and the large central area. On closer inspection it quickly becomes apparent that *N. gibbosa* cannot be subsumed under *Navicula* sensu stricto. Neither, so we shall show, does the taxon belong to one of the other naviculoid genera into which *Navicula* sensu lato has been split since the 1990s. Thus we shall describe here a new genus of naviculoid diatoms, *Ninastrelnikovia*, and differentiate it from other genera to which it bears superficial resemblance.

Material and methods

Our description of the new genus is based on specimens taken from two rock pools (*gueltas*) on silicate rocks located in central Algeria, not far from the area of the Eastern Great Erg Desert on the Hamada de Tinrhert (Plateau du Tinrhert, rock desert). The water bodies are shallow pools supplied by springs and rain during the winter. One of the pools contained a considerable growth of vascular plants, whereas the other was barely colonized other than by micro-organisms. The samples were collected in September 1982. Physical and chemical data of the water quality were not available. The diatom assemblages indicate slightly alkaline freshwater of medium electrolyte content.

Samples for diatom analyses were treated using standard procedures. Samples were heated in a mixture of sulphuric and nitric acid (1:1 v/v) and afterwards repeatedly washed in distilled water. From the sediment obtained permanent slides were prepared using Naphrax mountant with a refractive index of 1.65. Light microscopic studies were carried out with a Leitz Diaplan and a Zeiss Universal, equipped with apochromatic lenses (x100) with N.A. no less than 1.3. All light-microscopic images were taken in bright field with the aperture diaphragm fully or close to fully open. For SEM observation, material was sputter-coated with gold on stubs and observed using a Hitachi S4500.

All specimens shown in the figures are from the samples described above (except, of course, for the reproductions of Hustedt's holotype and a line drawing from Patrick & Reimer, 1966).

Results

Ninastrelnikovia gen. nov.

Figs 1–41

TYPUS GENERIS: *Navicula gibbosa* Hustedt 1937 (fig. 18:10).

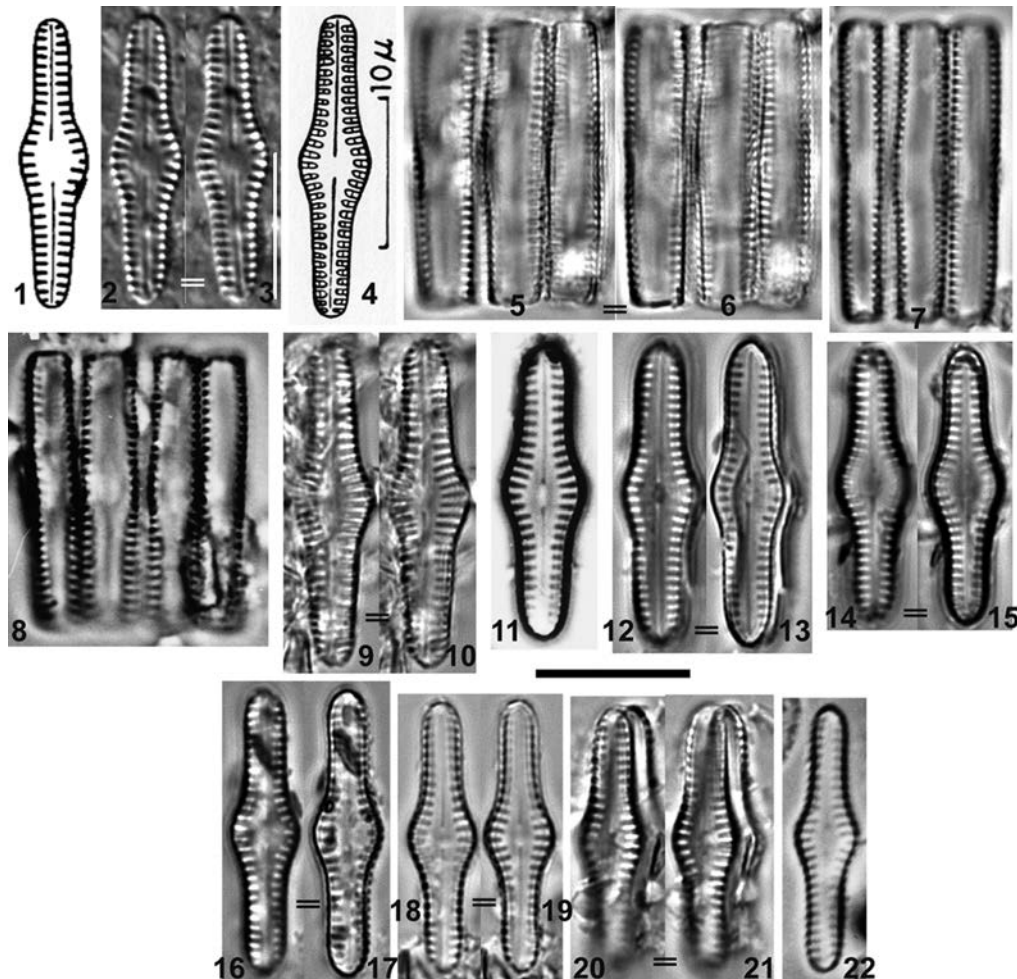
ETYMOLOGY: The new genus is named in honour of Prof. Nina Strelnikova on the occasion of her 80th birthday.

Ninastrelnikovia is as yet monospecific. It is strictly distinct from *Navicula* sensu stricto as based on the neotype species *Navicula tripunctata* (O.F. Müller) Bory 1822 syn. *Vibrio tripunctatus* O.F. Müller 1786, designated by R. Patrick 1959. A family relationship is uncertain but likely to be inappropriate with respect to Naviculaceae Kützing 1844 emend. D.G. Mann in Round et al. 1990.

Description

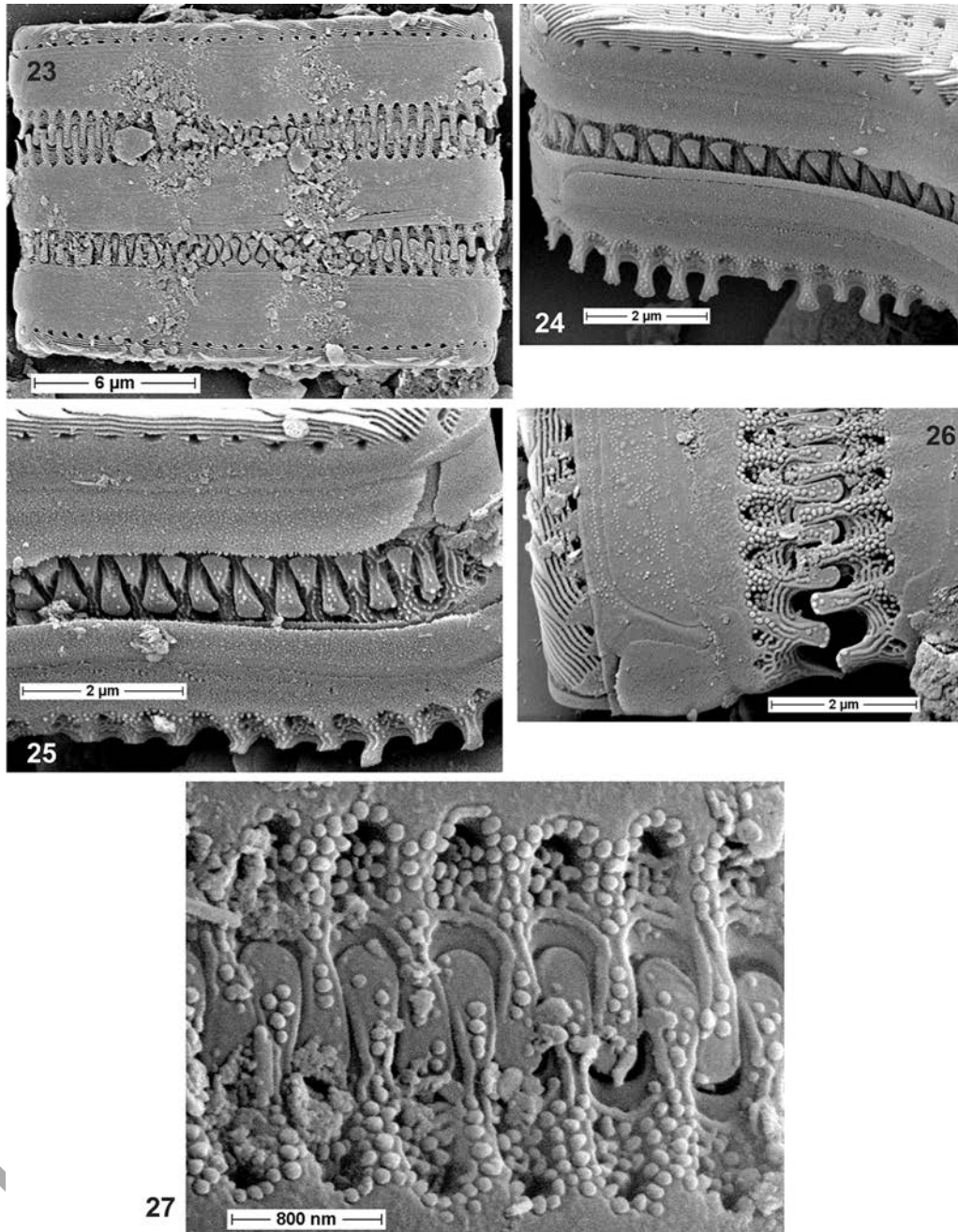
Light microscopy

Cells naviculoid in the classical sense, i.e. isovalvate and biraphid with a median raphe system. Valves symmetrical with respect to both apical and transapical axis. Protoplast with plastids not known as yet. Cells solitary or in shorter, band-like aggregations connected by their valve faces, thus lying more often in girdle rather than in valve view. Outline in girdle view rectangular, length ca. 17–21 µm, depth 2.4–4 µm, appearing indistinctly swollen in the centre when focussing. Apical margins with shorter striae on the valve mantle, resembling *Fragilaria* or *Staurosira* frustules, for which they may easily be misidentified. The cingulum appears hyaline, copulae barely resolvable. Valves in face view linear, strongly inflated in the centre, ends obtusely rounded, not protracted. Length 17–21 µm, breadth 4–5 µm in the centre, 2–3 µm distally. Raphe filiform, straight with central ends being in some valves moderately wider spaced than in others. Distal ends indistinctly deflected to the same side or appearing straight. Axial

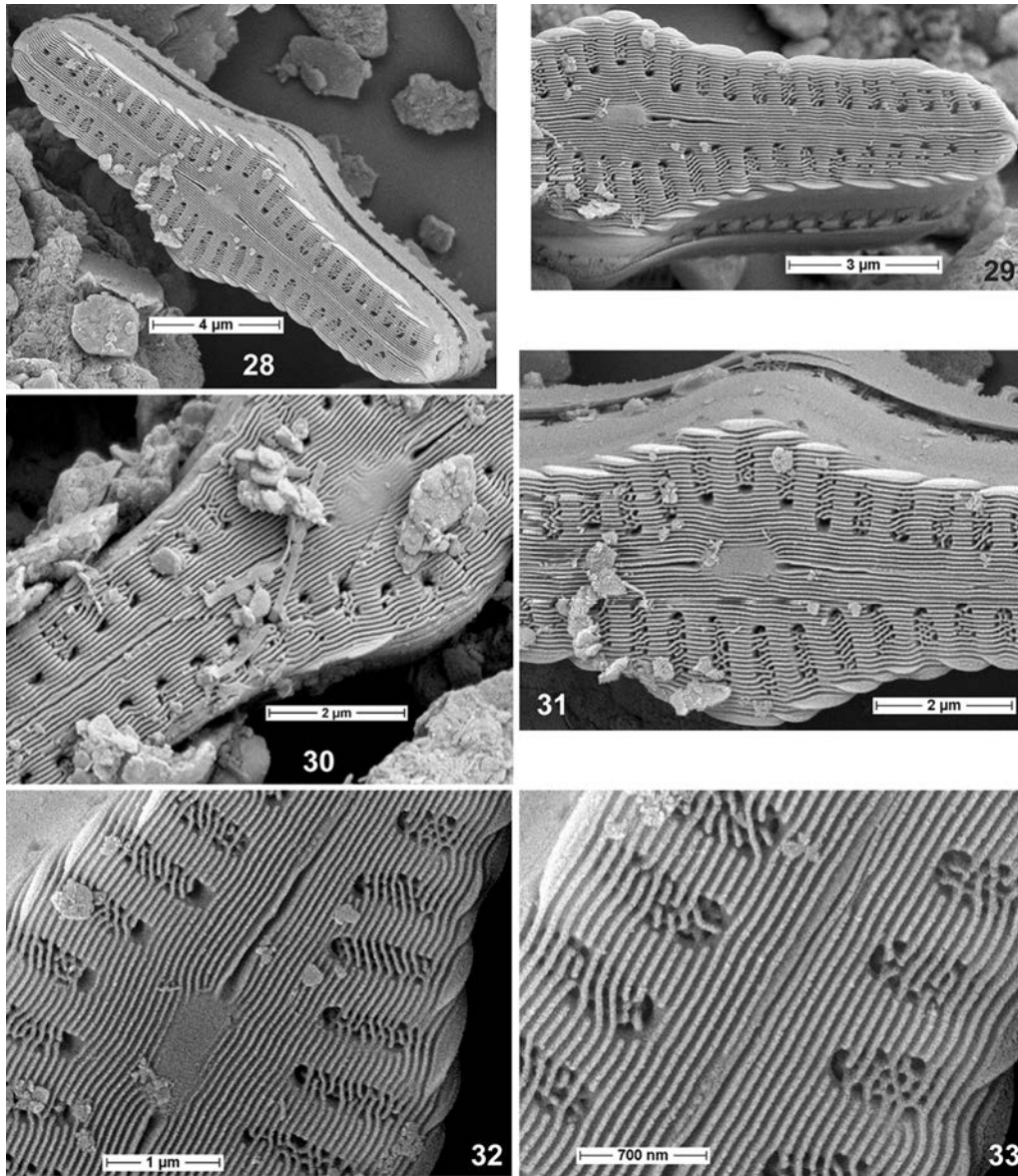


Figs 1–22. *Ninastrelnikovia gibbosa*, LM-micrographs and line drawings. 1. Hustedt's drawing of the holotype of *Navicula gibbosa*. 2–3. Photographs of the single valve representing the holotype (from the Hustedt archive). 4. Drawing from Patrick and Reimer (1966, fig. 45:16), specimen from Savannah River. 5–8. Frustules in girdle view, aggregated in short chains. 11–22. Frustules in valve view with high and low focusing. Note distinctly contoured raphe and central nodule in **Figs 11, 18–19**, independently of focus; compare indistinct, i.e. reduced raphes with wider spaced central endings in **Figs 14–15, 22**. Linking spines recognizable in **Figs 17** (right margin), **20** (left margin), **22**. (All images x2000, scale bar 10 µm.)

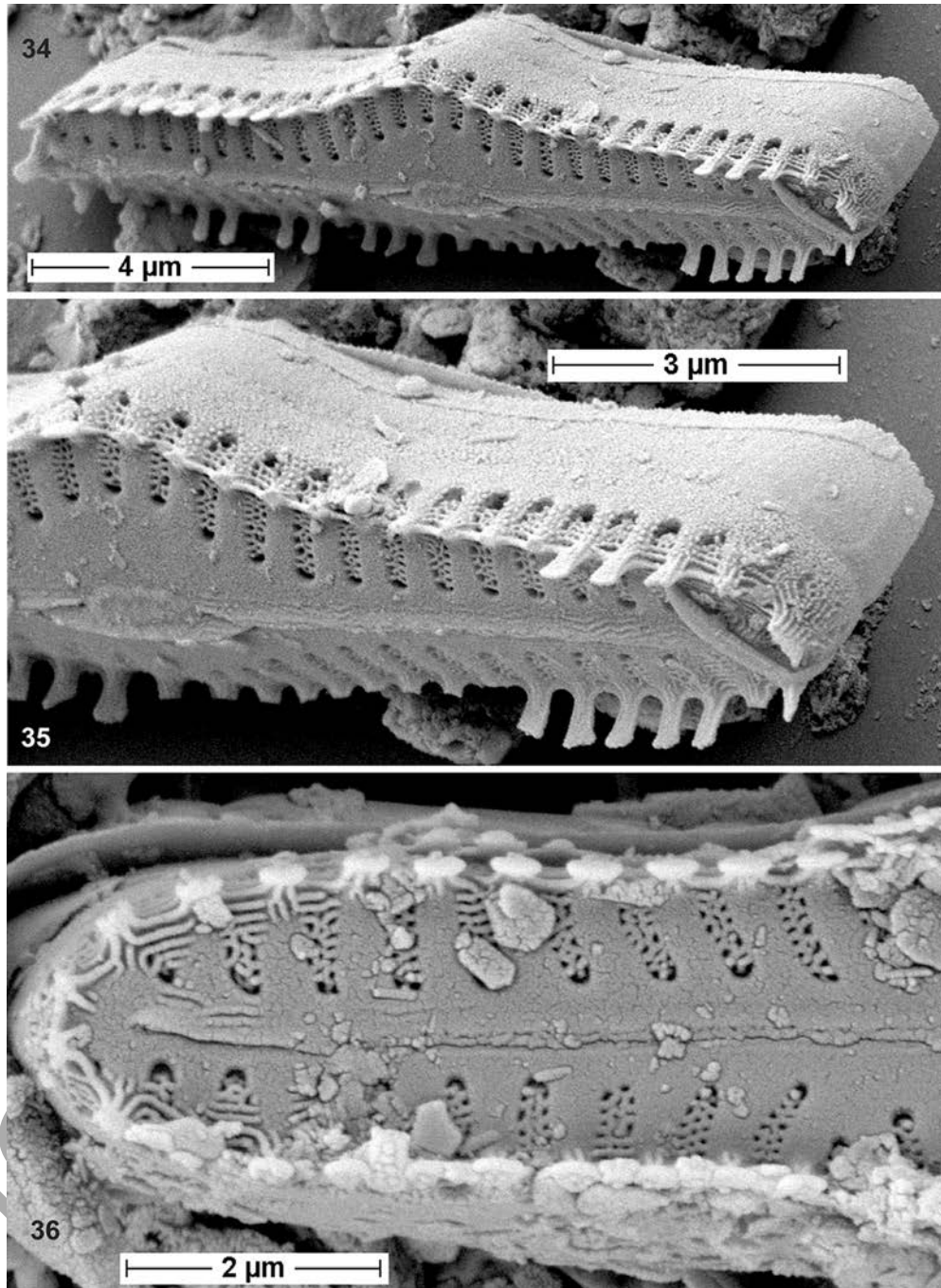
area variable from rather narrow to moderately broad, gradually widening towards an apically expanded elliptical central area. Transapical striae radiate proximally, becoming subparallel and finally slightly convergent towards the ends; 15–16 in 10 µm. Our measurements integrate specimens from various populations in Sumatra, Africa and North-America. For the Brazilian population Leandrini et al. 2002 cite: length 18–33 µm, breadth 4.6–5.6 µm, 12–14 striae in 10 µm. The only figure, however, shows a frustule that is 21 µm long, 5 µm broad and has ca. 14 striae in 10 µm – which fits well with our measurements above.



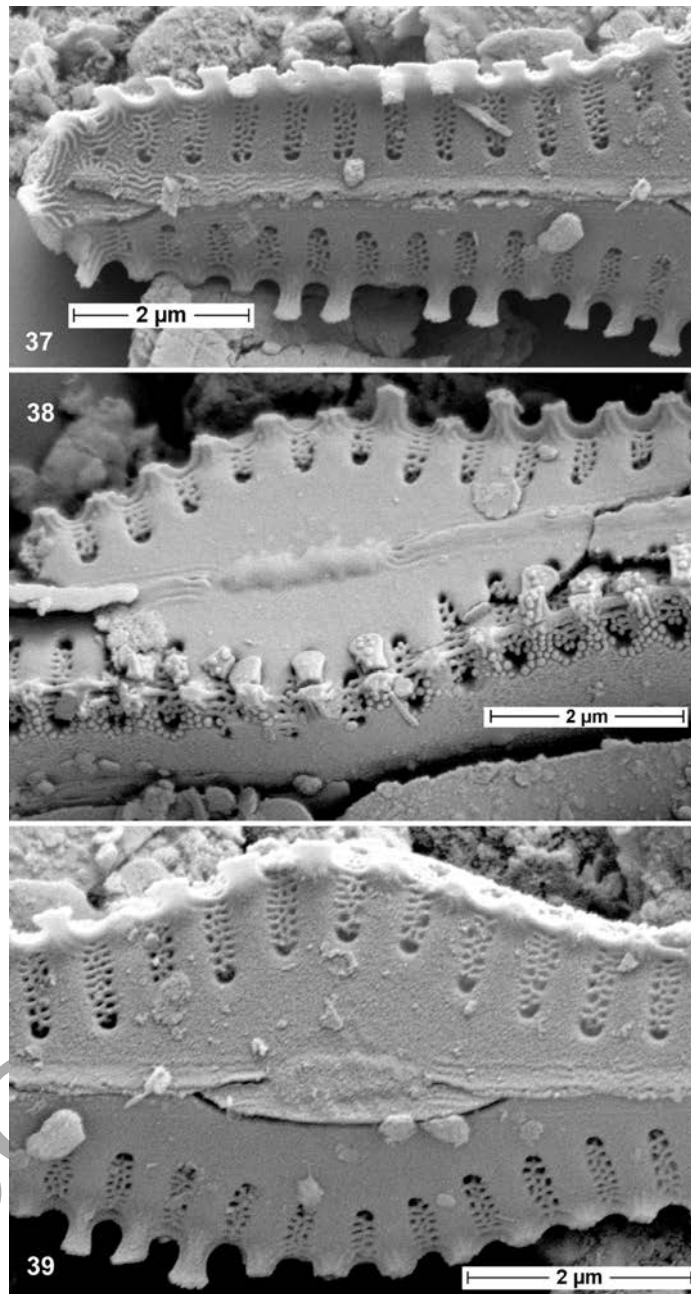
Figs 23–27. *Ninastrelnikovia gibbosa*, SEM, frustules in girdle view. **23.** Two terminal cells connected to a third in the middle by interdigitating, long spatulate spines. No such spines on the terminal (outer) valve faces. **24–27.** Terminal cell connected with an intermediate cell. Note ligula of abvalvar copula produced into the slit of the open advalvar copula (**Figs 24–26**). Granula and modified slats curve around interdigitating spines (**Figs 26–27**).



Figs 28–33. *Ninastrelnikovia gibbosa*, SEM, frustules in valve and mantle view. Terminal valve faces covered by apically orientated slats, more or less modified when crossing pluriseriate areola foramina (**Fig. 33**) and thickened at junction to valve mantle. **32.** Raphe slit with slightly expanded central endings enclosed by particular raphe ribs almost conforming to the apical slats. Central nodule free from “ornamentations”.



Figs 34–36. *Ninastrelnikovia gibbosa*, SEM. Valve faces which (in situ) connect to adjacent frustules. Linking spines present or broken. Apical slats missing, resp. only rudimentarily developed at the ends, where the contact to the neighbouring cells is loose. Pattern of bi- to irregularly tri-seriate areolae. Adaxial areolae larger and deeper depressed, often crescent-like; the same areolae pattern in striae on the mantle. Raphe only rudimentarily developed.

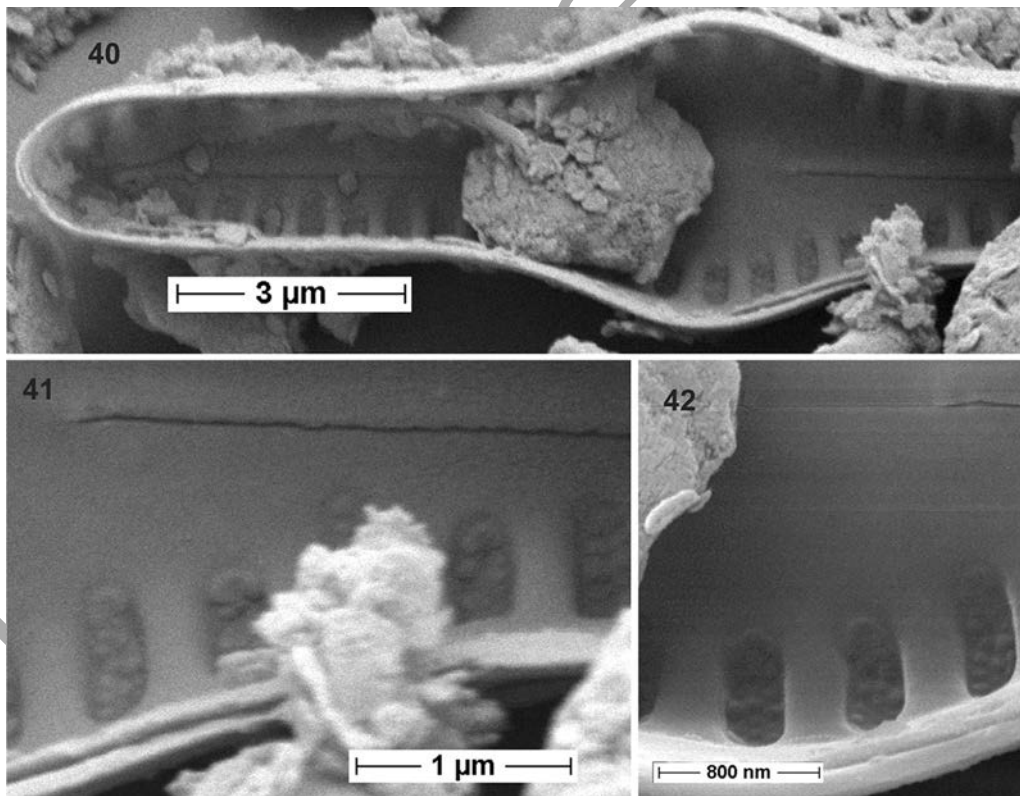


Figs 37–39. *Ninastrelnikovia gibbosa*, SEM. Detached valve faces of intermediate cells. Strongly reduced raphe, thickened central nodule with filled-in silica. Widely spaced vestiges of central raphe pores (38). See comments to **Figs 34–36**.

Scanning electron microscopy

In girdle view several cells are connected valve face to face. The connection is effected by spatulate linking spines which are produced from the virgae of the junction between face and mantle. The epicingulum is rather broad, consisting of a few unperforated open copulae. The abvalvar (distal) copula produces a ligula into the slit of the broad, open adjacent valvocopula (Figs 24–26). Pluriseriate striae are shortly prolonged onto the mantle. Interdigitating spines are partly masked by numerous siliceous granules (Fig. 27) and curving slats (Fig. 26). Valves terminating a cell colony are devoid of marginal spines (Figs 23, 28–33). Instead of spines, a system of apically orientated slats, covering the entire surface, forms “pseudo-spines”, i.e. sharply interrupted ridges at the margins (Figs 28, 31).

External view: In face view, such valves show a fully developed raphe system (Figs 28–32). The raphe branches have only slightly expanded or deflected central endings, separated by a distinct, apically elliptical central nodule (Fig. 32). Distal raphe ends are curving to the same side onto the mantle (Figs 28–29). Only raphe slits and central nodules are free of the slender siliceous slat system that runs over the valve face and is somewhat deflected over the pluriseriate areolae, its adaxial ends being somewhat deeper depressed into the valve system. Valve faces that are covered by neighbouring cells of the aggregation are distinctly different (Figs 34–39). The raphe is reduced to rudimentary vestiges while the central nodule appears elongated by filled-in silica (similar to the araphid valves of the Achnantidiaceae). A slat system is lacking and,



Figs 40–42. *Ninastrelnikovia gibbosa*, SEM. Internal views. Internal views. Note internally closed areolae (despite low contrast).

consequently, two- or more commonly tri-seriate areolae are unmasked. Spatulate interdigitating spines are free or partly broken due to mechanical impact (Fig. 37–39).

Internal view: Irregularly pluriseriate areolae, probably occluded by hymens lying in rather broad depressions (alveoli in the sense of Krammer & Lange-Bertalot 1986). There is no separation between alveoli on face and mantle. The median raphe slit with slightly deflected central ends appears rather weakly developed (probably so only in cells taken from the middle of a colony). The raphe sternum is broad and flat, lying flush with the virgae and not being differentiated between axial and central area. Fragments of a copula are visible on the valve mantle.

New combination of the *typus generis*:

Ninastrelnikovia gibbosa (Hustedt) comb. nov.

BASEONYM: *Navicula gibbosa* Hustedt 1937, Arch. Hydrobiol. Suppl. **15**, p. 253, fig. 18: 10.

Autecological comments

The diatom assemblages of the Algerian gueltas (freshwater desert pools), where *N. gibbosa* was found, are subject to extreme fluctuation of water levels, comparable to the Sardinian ephemeral rock pools (see Lange-Bertalot et al. 2003). In these gueltas cosmopolitan or holarctic species are associated with numerous taxa that can be characterized biogeographically as circum-mediterranean or have not yet been described.

The first, cosmopolitan, group includes: *Navicula cryptocephala* Kützing, *N. cryptotenella* Lange-Bertalot, *N. trivialis* Lange-Bertalot, *Gomphonema parvulum* (Kütz.) Kützing, *Encyonema minutum* (Hilse) D.G. Mann, *Hantzschia amphioxys* (Ehrenb.) Grunow, *Nitzschia linearis* (Ag.) W. Smith, *N. salinarum* Grunow, *N. desertorum* Hustedt, *N. solita* Hustedt, *Rhopalodia gibba* (Ehrenb.) O. Müller, *Simonsenia delognei* (Grun.) Lange-Bertalot, a common aerophilous taxon.

The circum-mediterranean group of taxa (all but the last described from Sardinia in Lange-Bertalot et al. 2003) includes: *Mayamaea mediterranea* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *M. crassistriata* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *Craticula fumantii* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *C. angustilancea* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *Gomphonema subangustatum* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *Sellaphora sardiniensis* Lange-Bertalot, Cavacini, Tagliaventi & Alfinito, *Cymbella kolbei* Hustedt is frequent and abundant in mediterranean regions and in non-tropical Africa.

Among the apparently endemic diatoms found in Algeria the genus *Navigiolium* Lange-Bertalot et al. 2003 is particularly remarkable, four species having been described from two Algerian gueltas in Lange-Bertalot et al. (2009). However, many more taxa from various genera are probably not yet known to science, among them three species of *Pinnularia*. An evidently new species belonging to *Lacunicula* Lange-Bertalot et al. 2003 was observed in Algerian and Namibian rock pools. Finally we note that the rarely reported *Hantzschia hermannii* (type locality an affluent (creek) to Lake Toba) could also be observed in association with *N. gibbosa* in the Algerian gueltas.

Discussion

The genus proposed here as new to science is typified by the holotype of *Navicula gibbosa* Hustedt which, however, is poorly represented by a single valve from Lake Toba in northern Sumatra (specimen marked and named on the label of the slide by Hustedt.). Hustedt (1937, p. 253) reports its rare occurrence in two samples taken from the broadest part of the lake's inundation zone. Given Hustedt's usual terminology, this may indicate observation of a single valve (not documented) from two samples or just two valves, one in each sample. Hustedt's line drawings in the Schmidt atlas (1936, figs 402: 57–58) – showing a single valve in two magnifications – without description are not a valid publication according to the rules of the

ICBN. Although Hustedt's original material will barely allow for SEM observations, there is no doubt that the holotype and the specimens from Algeria and Namibia are conspecific. The very particular combination of light-microscopic characteristics, even if only documented by way of line drawings, is sufficiently significant to make the conspecificity with the specimens from North- and South-America equally plausible. To be sure, Hustedt's line drawing is only approximately correct; compare Fig. 1 with the photographic image of the holotype in Figs 2–3. Hustedt depicts the distance between the central raphe ends somewhat too wide and he neglects the striae's tendency to become slightly convergent near the valve ends.

More to the point of introducing a new genus is the question of how *N. gibbosa* relates to other generic offsprings from *Navicula sensu lato*, i.e. *Navicula* in the historical sense until 1990. Thus we close our discussion with a differential comparison of *Ninastrelnikovia*, as represented by *N. gibbosa*, with other naviculoid genera.

A certain similarity may be found particularly with *Diadasmus* subgenus *Paradiadasmus* Lange Bertalot & Le Cohn (in Rumrich et al. 2000, p. 108). The similarity pertains to the formation of colonies, facultative linking spines, raphe reduction, general size and valve outlines. However, *Paradiadasmus* is characterised by a consistently different areola arrangement: uniseriate, never pluriseriate, and not subdivided but continuously slit-like on the valve face. Moreover, copulae are perforated by elongated slits and the details of the raphe systems differ conspicuously.

Although *Diadasmus* Kützing subgenus *Diadasmus* possesses a roughly similar dimorphism in chain-like cell aggregations, it has a fundamentally different areolation pattern as well as a different detailed raphe and spine morphology.

Another example of a somewhat pronounced similarity may be found in the genus *Frankophila* Lange-Bertalot (1997, p. 66). In particular *F. horstii* U. Rumrich & M. Rumrich (in Rumrich et al. 2000, p. 128) possesses comparable valve size dimensions, outlines, striae and areae, and forms chains by linking spines. Without exception, however, species of *Frankophila* have strictly biseriate, alternating and larger areolae as well as strongly reduced raphoid subpolar slits in both valves.

Hygropetra Krammer & Lange-Bertalot in Krammer (2000, p. 206, plates 32–35) with its elliptical, linear-elliptical or lanceolate valve shape resembles more *Frankophila* than the new genus. *Hygropetra* is hardly similar when seen in the light microscope but conforms to some extent to the new genus in virtue of its pluriseriate areolae. *Hygropetra* mainly differs by its shortened, only rudimental raphe branches; the absence of linking spines; a different areola arrangement, commonly following a hexagonal pattern; lower striae density; and septated valvocopulae. So far three species of *Hygropetra* have been described: The type species, *H. balfouriana* syn. *Pinnularia balfouriana*, is the most frequent and abundant. *H. elongata* Lange-Bertalot & Krammer 2000 (from Firehole River, Wyoming, U.S.A.) and *H. gelasina* Mayama & Idei 2000 (from Japan) seem to have a more restricted distribution.

With more than fifty taxa the genus *Nupela* Vyverman & Compère 1991 is comparatively rich in species. It includes several species with reduced raphes. But the fine structure of the areolae with their external occlusion is clearly different (Rumrich et al. 2000, pl. 32–35, Monnier et al. 2003, Kulikovskiy et al. 2009).

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