Re-Evaluation of the Diatom Species Nitzschia frustulum (Kutz.) Grun.

Charles W. Reimer

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Edited by

J. E. Potzger
The *Butler University Botanical Studies* journal was published by the Botany Department of Butler University, Indianapolis, Indiana, from 1929 to 1964. The scientific journal featured original papers primarily on plant ecology, taxonomy, and microbiology. The papers contain valuable historical studies, especially floristic surveys that document Indiana’s vegetation in past decades. Authors were Butler faculty, current and former master’s degree students and undergraduates, and other Indiana botanists. The journal was started by Stanley Cain, noted conservation biologist, and edited through most of its years of production by Ray C. Friesner, Butler’s first botanist and founder of the department in 1919. The journal was distributed to learned societies and libraries through exchange.

During the years of the journal’s publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor’s degrees and 75 master’s degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner, included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master’s students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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RE-EVALUATION OF THE DIATOM SPECIES
NITZSCHIA FRUSTULUM (KUTZ.) GRUN.¹

By Charles W. Reimer²

INTRODUCTION

As in almost every other facet of science, the diatom taxonomist is constantly faced with the problem of merging phenomena. With the introduction of "quantitative," "mass," or "population" studies on various forms of plant life, lines of distinction between closely related species and varieties have often disappeared, thus indicating a single variable taxon (9). On the other hand, such studies have upheld the individuality of two or more similar taxa (1, 3). It is now amply apparent that many of the presently accepted species of diatoms must be re-examined with such concepts in mind, for the purpose of determining, in other than a purely arbitrary fashion, the limits of specific variation. This becomes especially important in a study of diatoms because of the nature of reproduction in this group. The most common method is asexual (7) in which case the size of the frustule frequently becomes gradually smaller, until a certain size range (10) is reached. Sometimes other taxonomic features are altered as well (4). If in a single ecological habitat intergrades are found between two entities, it usually is a good indication that a genetic difference does not actually exist, and that the investigator is dealing with a single entity.

*Nitzschia frustulum* belongs to the subgenus (or group) Lanceolatae and is taxonomically quite similar to several other species of Nitzschia. Occasionally these closely related forms are found in the same collection, in which case it is most difficult to categorize each specimen. With this in mind the present investigation was undertaken on some diatom populations collected in the United States and identified as having *N. frustulum* present.

¹Presented before the American Society of Plant Taxonomists at the meeting in Gainesville, Florida, on September 6, 1954.
²Department of Limnology, Academy of Natural Sciences of Philadelphia, Philadelphia 3, Pennsylvania.

178
METHODS

Diatom material from three sources was used in this investigation: (1) Arizona, Mohave Co., river near Beaver Dam Lodge, Littlefield; (2) Texas, Calhoun Co., Mission Lake; (3) Pennsylvania, Chester Co., Ridley Creek near Chester Park. The first location can be considered as strictly fresh water, the second as brackish and the third as fresh to slightly brackish. These collections were selected for two reasons. They represent diverse habitats, and available slides from these locations had sufficient specimens for adequate measurement and comparison.

Specimens were observed under an oil immersion fluorite lens giving approximately 1,100 diameters magnification. Measurements on each specimen included length, width, striae number, keel punctae number, configuration of margins, and shape of ends. From each population, 110 specimens were observed. With each slide, specimens in the upper third of the cover slip were measured, continuous rows being observed until about one-third of the total 110 specimens had been tabulated. The slide was then shifted and the central and lower areas were scanned in turn, each area contributing another third of the total. Observations were selective only insofar as specimens of Nitzschia which obviously were out of the range of this particular group of the Lanceolatae were excluded. In counting keel punctae, the total number of punctae on one side was counted and from this data the average number in 10 µ was calculated. This differed from conventional methods of simply counting the keel punctae along a portion of the ocular micrometer. Since the spaces between keel punctae vary, it seemed that the former method represented a more constant and thus more reliable figure for comparison.

After these slides had been studied, an attempt was made to categorize the various forms observed. For comparison available slides of Van Heurck (authenticated by Grunow) were used, together with material from Rabenhorst's collection sent to the Academy through the courtesy of the Cryptogamic Herbarium of the American Museum of Natural History in New York City.

OBSERVATION AND RESULTS

The distribution of the "Nitzschia frustulum-like" specimens from Ridley Creek is shown in Fig. 1, where striae numbers are
FIG. I. DIATOM POPULATION—RIDLEY CREEK, PA.

plotted against keel punctae numbers. The range of variation is seen to be quite restricted, the striae numbering between 24 and 26 in 10 μ. Other measured data on the specimens plotted in Fig. 1 are shown in
Table 1. From this table it is seen that only 5 of the 110 specimens had both margins convex. The remaining ones varied from parallel to slightly concave. Some specimens had one parallel and one convex margin, a few had one parallel and one concave margin. The ends varied only slightly (Table 1). They were all obtuse, varying mostly in the amount of taper from the body to the tip. Also, depending on the position in which the diatom was situated, the ends appeared with a small knob-like extremity. The length varied from 13 to 42 μ; the width held rather constant from about 3 to 4.5 μ.

### TABLE 1

**Populations of Nitzschia frustulum**

<table>
<thead>
<tr>
<th>Variation</th>
<th>Penna.</th>
<th>Ariz.</th>
<th>Texas</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-10</td>
<td>0</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>10-20</td>
<td>21</td>
<td>30</td>
<td>86</td>
</tr>
<tr>
<td>20-30</td>
<td>64</td>
<td>54</td>
<td>11</td>
</tr>
<tr>
<td>30-40</td>
<td>20</td>
<td>22</td>
<td>0</td>
</tr>
<tr>
<td>Over 40</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Body Margins</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both concave</td>
<td>24</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Concave, straight</td>
<td>23</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Both straight</td>
<td>47</td>
<td>64</td>
<td>9</td>
</tr>
<tr>
<td>Convex, straight</td>
<td>11</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Both convex</td>
<td>5</td>
<td>22</td>
<td>98</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ends</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fig. 1 A and B</td>
<td>110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fig. 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type A</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type B</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type C and D</td>
<td>49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fig. 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type A</td>
<td>37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type B</td>
<td>41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type C</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type D</td>
<td>12</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIG. 2. DIATOM POPULATION—RIVER IN MOJAVE COUNTY, ARIZ.
The same plotting technique, as shown in Fig. 2, was applied to a diatom population from a river in Mojave Co., Arizona. Of the 110 specimens measured 72 were within a narrow range of 24 striae and 9 to 10 keel punctae in 10 μ. Specimens immediately adjacent to this grouping brought the total up to 100. Only 10 specimens had striae 30 in 10 μ or above, thus setting them apart from the majority of specimens measured. These 10 specimens had a tendency to divide into two groups, those with keel punctae 9 to 11 and those with keel punctae 12 to 14 in 10 μ. However, with the small number of specimens observed, it is difficult to determine if this difference be real or only apparent. Those specimens with a striae number of 30 or above had either parallel or convex margins; none had any indication of a concave margin. The larger grouping with striae from 22 to 26 varied as to body margin from concave to slightly convex. In most cases, a more definitely sub-capitate end was apparent in the group with finer striae.

In Fig. 3 are shown the ratios of striae to keel punctae as found in a population of diatoms from Mission Lake, Texas. Two groupings are apparent, the separation being mainly on the basis of striae number. Variation in number of keel punctae appears to be not too great. All specimens with finer striae (28 to 32 in 10 μ) were quite small, varying in length from 5 to 13 μ. In the grouping with coarser striae (22 to 24 in 10 μ) variation in length was from 8 to 22 μ. As in the specimens observed from Arizona, the more finely striate specimens from Mission Lake showed body margins varying from very slightly convex to strongly convex. In the coarsely striate specimens margins varied from one straight and one concave margin to those with both margins slightly convex. Neither group showed a characteristic type of end with the exception of specimens of Type C (Fig. 3) in which case the ends were slightly cuneate and sometimes had a small rounded knob-like end, not definitely capitate, however.
Although the more coarsely striate specimens shown in Fig. 3 appear to form a single entity on the basis of striae to keel punctae ratio, there was a noticeable difference in body margins and ends.
(Fig. 3, A, B, C. Table 1). All specimens of categories A and B, of which there were 63, had convex margins and attenuate narrow ends. Those of category C had concave, parallel or slightly convex margins.

A. Synedra frustulum Kütz.  
B. Nitzschia hantzschiiana Rahn.  
C. N. hantzschiiana Rahn.

D. N. frustulum var. perminuta Grün.  
E. N. frustulum var. perminuta Grün.  
F. N. frustulum var. minutula Grün.

G. N. frustulum var. subseriana Grün.  
H. N. lebethrathii Grün.  
I. N. romana Grün.

FIG. 4. FORMS PREVIOUSLY DESCRIBED
Ends were obtuse and somewhat cuneate, occasionally somewhat rounded off (Table 1). The smaller members of category C had convex margins somewhat as in category "E" but, of course, the striae number remained at 24 in 10 μ. Only those specimens below about 12 μ seemed to lose all indication of a nearly straight margin.

In an attempt to correlate the observed forms with described entities, material identified by Rabenhorst and slides authenticated by Grunow were examined. Fig. 4 shows the most common forms found on these slides.

**DISCUSSION**

The following range of variation has been given for *Nitzschia frustulum*:

<table>
<thead>
<tr>
<th>Character</th>
<th>Klitzing (6) (Fig. 4A)</th>
<th>Grunow (8)</th>
<th>Hustedt (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>20 μ</td>
<td>20-40 μ</td>
<td>20-70 μ</td>
</tr>
<tr>
<td>Width</td>
<td>?</td>
<td>4-5 μ</td>
<td>3-5 μ</td>
</tr>
<tr>
<td>Striae</td>
<td>?</td>
<td>20-22 μ</td>
<td>20-23 μ</td>
</tr>
<tr>
<td>Keel punctae</td>
<td>?</td>
<td>9-11</td>
<td>9-12</td>
</tr>
<tr>
<td>Ends</td>
<td>Cuneate-acute</td>
<td>Pointed</td>
<td>Cuneate-pointed</td>
</tr>
</tbody>
</table>

The species most closely associated with it are: *N. heufleuriana* Grun. and *N. hantzschiana* Rabh. The former is separated on the basis of its larger size (75-90 μ) and capitate ends; *N. hantzschiana* seems to overlap on all characters, but is said to differ by having coarser keel punctae (7-10 in 10 μ as opposed to 9-12 for *N. frustulum*) and mention is made of its being predominantly a montane form (5).

The majority of forms represented in Fig. 1 more closely resemble the description of *N. hantzschiana* than *N. frustulum*, in that the keel punctae number falls predominantly around 9 in 10 μ and the striae range is around 24 in 10 μ. With the method used in calculating keel punctae in 10 μ, the number would probably run one or two keel punctae higher than given in conventional descriptions. If two keel punctae per 10 μ were subtracted this would place the number within the range given for *N. hantzschiana*.

In the two remaining populations, types C and D in Fig. 2 and type C in Fig. 3 reveal a wider diversity in striae and keel punctae. Many specimens from Arizona (Fig. 2) duplicate those from Ridley Creek (Fig. 1) in general shape, ends, striae and keel punctae. The
majority of specimens of type C from Mission Lake, Texas, have a keel punctae number around 12 in 10 \( \mu \), somewhat higher than in the other two populations, yet all other characters are identical and in these specimens (type C and D, Fig. 2, type C, Fig. 3) some would fit the description of \( N. frustulum \), others would fit the descriptions for \( N. hantzschiana \).

When the specimens of Rabenhorst were examined, it was apparent that the keel punctae number, by the conventional method along the ocular micrometer scale, varied from 9-12.5 in 10 \( \mu \). The striae number remained constant at about 24 in 10 \( \mu \) (Fig. 4B, 4C). This removes the major segregating factor between the two species, provided, of course, that the Kützing type slide shows the range of keel punctae given for \( N. frustulum \).

It does not seem reasonable to separate the specimens on a striae difference of one or two striae, especially since this difference seems to disappear when several specimens are counted. Also the method of counting striae does not seem to the writer to be sufficiently accurate to permit distinction between 22, 23 or 24 striae in 10\( \mu \), especially when the specimens are small. In such a case a portion of the scale must be used and the striae count multiplied in order to get a count for 10\( \mu \). Only those counts varying more than two striae in 10\( \mu \) would appear practical for taxonomic differentiation in this group, especially in specimens with more than 20 striae in 10\( \mu \).

It is quite possible that certain selected habitats would favor the development of a clone such as \( N. hantzschiana \) over one like \( N. frustulum \). This would account for separate identifications based on these small differences. On the basis of the specimens observed, it hardly seems justifiable to keep these two species as separate entities and it is proposed that they be drawn together under the earliest epithet, \( N. frustulum \).

With the incorporation of these species it is also proposed that the lower limits of the size range be extended to forms as small as 10\( \mu \), the smallest forms of type C from Mission Lake. The upper limits may well reach to 70 \( \mu \), but in these populations only two specimens characteristic of \( N. hantzschiana \) exceeded 40\( \mu \), one being 41 and the other 51\( \mu \).
Forms A and B from Arizona (Fig. 2) probably represent the periphery of another population or populations. From their features it is possible that they represent forms of *N. palea* (Kütz.) W. Sm. although it is difficult to say without having analyzed other forms of *N. palea* which were present.

Forms D and E from Texas (Fig. 3) are very likely *N. fonticola* Grun., which has the shape of *N. romana* Grun. (Fig. 41), but has finer striae (28–30 in 10 μ).

The remaining forms from Texas, A and B, differ from type C in having a characteristic narrow attenuate end, together with a consistently convex body margin. There appeared no clear-cut series of intermediate forms between these two. Until more such populations are observed it seems prudent to exclude this from the *N. frustulum* complex and consider it a form of *N. romana* (Fig. 41) or *N. liebethruthii* Rábh. (Fig. 4H), two forms which do not differ significantly. These species are distinguished as follows:

<table>
<thead>
<tr>
<th>Species</th>
<th>Length (11–27 μ)</th>
<th>Width (2–3 μ)</th>
<th>Striae (ca. 24 in 10 μ)</th>
<th>Keel punctae (ca. 12 in 10 μ)</th>
<th>Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>N. liebethruthii</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pointed-lanceolate</td>
</tr>
<tr>
<td><em>N. romana</em></td>
<td>22–23 μ</td>
<td>4–5 μ</td>
<td>23–24 in 10 μ</td>
<td>9½–11½ in 10 μ</td>
<td>lanceolate-linear</td>
</tr>
</tbody>
</table>

Specimens observed showed no clear-cut tendency to fit either category. For example, most specimens measured between 3 and 4 μ in width and nearly all were less than 29 μ long. Keel punctae varied from 8 to 12 by usual methods of measurement. Evidence is not definite enough to categorize these specimens according to known taxa except to say that they appear closer to these two species than any other found described by the author. In the original description by Cleve and Grunow (2), it is suggested that *N. romana* may well be considered as a variety of *N. hantzschiana*. The solution to this problem must await further study and observation on specimens of *N. liebethruthii* and *N. romana*. Van Heurck (8) reports they have the same keel-punctae number and says further that the striae number varies by a single stria in 10 μ.

Diagrams of the specimens on the Van Heurck slide for *N. frustulum var. perminuta* Grun. (type locality) are given in Fig. 4D, 4E.
The striae on all specimens observed, ranged between 28 and 30 in 10 μ, indicating that the variety is distinct enough from the species as described by Grunow to be retained as a variety of the species *N. frustulum*. Specimens labelled *N. frustulum* var. *minutula* Grun. (Fig. 4F) from the Van Heurck collection all have 24 striae in 10 μ. This does not agree with the original description of Grunow (8) which gives the striae number as 30 in 10 μ. Since the Van Heurck slide was authenticated by Grunow it represents the best specimens available for this variety. Since striae number is the only distinctive character, the variety should probably be included in the species. Several such forms were observed in the three populations studied.

*N. frustulum* var. *subseriens* (Fig. 4G) agrees in all respects with the species description but appears most commonly with a conspicuously bilobate shape on the Van Heurck slide observed. Some specimens in the populations studied had a concave margin but did not show a clear indentation in the center. At present no conclusions as to the validity of this variety can be reached. If the bilobate feature appear constant a separate variety of *N. frustulum* may be retained. Otherwise it will probably be drawn into the species concept since all other features agree. It is hoped to present a second paper on this taxon including more of the named varieties and their possible position in the group. At present there is some question as to the validity of *N. inconspicua* Grun. and *N. perpusilla* both of which appear to be quite close to the *N. frustulum* taxon. In separating these various varieties earlier workers appear to have placed great emphasis on size and small variation in keel punctae number along with slight differences in striae number. Many of these differences disappear when populations such as these are observed.

SUMMARY AND CONCLUSIONS

1. Diatom collections from three locations in the U. S. A. were examined. Each collection was listed as having *N. frustulum* (Kütz.) Grun. present.

2. Populations of *N. frustulum*-like specimens were variously heterogeneous as shown in Figs. 1-3.

3. In each of the three localities studied there was present a continuous gradation of specimens ranging from those which could be
identified as *N. hantzschiana* Hantz. to those which could be identified as *N. frustulum*.

4. Since the two entities are very similar, the differences between them was further investigated. Specimens identified by Kützing as *Synedra frustulum* (original epithet for *N. frustulum*) were not available. The original description and plates of Kützing plus Grunow's and Hustedt's descriptions and plates were used as a basis of the concept of *N. frustulum*.

5. Species of *N. hantzschiana* Rabh. from the Rabenhorst collection No. 943 showed variation in number of keel punctae from 8 to about 12.5 in 10 μ. Striae number was always about 24 in 10 μ. Shape varied from slightly concave sides to somewhat convex margins in many of the smaller forms. These characters fall within the described range given for *N. frustulum*.

6. To say that *N. hantzschiana* prefers montane habitats in contrast to *N. frustulum* would not be in agreement with the findings in this investigation. Actually the species more nearly resembling the mid-range of *N. hantzschiana* were found in a stream on the Coastal Plain.

7. Since these two entities are so nearly the same in description and since good representatives of both were found in the collections studied in addition to intermediate forms, it is here proposed to unite the two under the earliest legitimate epithet, *N. frustulum* (Kütz.) Grun.

8. Other entities very closely related to this taxon were found. Their probable descriptions are discussed.

9. It is proposed that the variety *N. frustulum* var. *minutula* be included under the species *N. frustulum* and that *N. frustulum* var. *perminuta* be retained as a variety.

10. Under the epithet *N. frustulum*, the following description would apply: valves mostly linear, occasionally somewhat linear-lanceolate, with sides varying from slightly concave to slightly convex; ends obtuse, attenuate-cuneate, sometimes slightly knob-like at the very end, but never capitate as such; length 10-ca. 50 μ, width 2.5-4 μ striae 22-ca. 24 in 10 μ, keel punctae 8-13 in 10 μ.
ACKNOWLEDGMENTS

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REFERENCES


