Abstract: A new monoraphid diatom genus, Planoplatessa gen. nov., is described on the basis of a detailed morphological investigation using light and scanning electron microscopy. We transferred Achnanthes joursacensis Hébrard, a species described from fossil deposits in France, to our new genus. We investigated material from Mongolia from Recent populations. This taxon is known from fossils to Recent across the Holarctic. Achnanthes joursacensis was previously transferred to the genera Planothidium and Platessa, but the morphology of A. joursacensis does not share all morphological features with these two genera. We discuss important morphological features for the delimitation of monoraphid genera based on careful morphological and molecular investigations we presented previously. Planoplatessa gen. nov. as a genus is characterized by having uniseriate striae on both the raphe and the rapheless valves, a cavum in rapheless valves only, and straight distal raphe ends on the valve face.

Keywords: diatoms; Planoplatessa; Platessa; new genus; morphology; Mongolia; Lake Khövsgöl

1. Introduction

About 16 freshwater monoraphid diatom genera previously associated with the genus Achnanthidium J.B.M. Bory de Saint-Vincent 1822 [1] are currently recognized: Achnanthes Kützing 1844 [2], Eucocconeis P.T. Cleve 1895 [3], Psammothidium Bukhtiyarova & Round 1996 [4], Karageeva Round & Bukhtiyarova 1996 [5], Rossithidium Round & Bukhtiyarova 1996 [5], Lennicola Round & Basson 1997 [6], Crenotia Wojtal 2013 [7], Trifonovia Kulikovskiy & Lange-Bertalot 2012 [8], Gololobovia Gliviczia Kulikovskiy, Lange-Bertalot & Witkowski 2013 [9], Skabitschewskia Kulikovskiy & Lange-Bertalot 2015 [10], Platessa Lange-Bertalot 2004 [11], Planothidium Round & Bukhtiyarova 1996, Kulikovskiy, Glushchenko, Genkal & Kociolek 2020 [12], Gogorevia Kulikovskiy, Glushchenko, Maltsev & Kociolek 2020 [13], Platebaikalia Kulikovskiy, Glushchenko, Genkal & Kociolek 2020 [14], and Gomphothidium Kociolek et al. 2022 [15].

Of the above genera, only Gliviczia, Planothidium, and Skabitschewskia have a very interesting morphological feature that is visible under a light microscope known as a horseshoe-shaped area [10]. The morphology of this horseshoe-like structure as seen with scanning electron microscopy includes a rimmed depression or sinus and hood or cavum (see description in [16]). Interestingly, species that possess a sinus and cavum, and those species where these features are weakly expressed have been shown to be closely related to one another and included in the genus Planothidium [16]. According to molecular data, these species can be recognized as three distinct clades: (a) species with a sinus, (b) species with a cavum, or (c) species without these features [16]. The genus Skabitschewskia is characterized by having only a cavum on rapheless valves in all known species, but this genus differs from Planothidium by striae morphology [10]. Striae in Planothidium are multiseriate on both valves, whereas, in Skabitschewskia, striae are uniseriate on raphe valves and biseriate on rapheless valves [10]. In the genus Gliviczia, a cavum is present on both valves, and the striae are also uniseriate on both valves [9].

Planoplatessa gen. nov.—A New, Neglected Monoraphid Diatom Genus with a Cavum

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Abstract: A new monoraphid diatom genus, Planoplatessa gen. nov., is described on the basis of a detailed morphological investigation using light and scanning electron microscopy. We transferred Achnanthes joursacensis Hébrard, a species described from fossil deposits in France, to our new genus. We investigated material from Mongolia from Recent populations. This taxon is known from fossils to Recent across the Holarctic. Achnanthes joursacensis was previously transferred to the genera Planothidium and Platessa, but the morphology of A. joursacensis does not share all morphological features with these two genera. We discuss important morphological features for the delimitation of monoraphid genera based on careful morphological and molecular investigations we presented previously. Planoplatessa gen. nov. as a genus is characterized by having uniseriate striae on both the raphe and the rapheless valves, a cavum in rapheless valves only, and straight distal raphe ends on the valve face.

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Of the above genera, only Gliviczia, Planothidium, and Skabitschewskia have a very interesting morphological feature that is visible under a light microscope known as a horseshoe-shaped area [10]. The morphology of this horseshoe-like structure as seen with scanning electron microscopy includes a rimmed depression or sinus and hood or cavum (see description in [16]). Interestingly, species that possess a sinus and cavum, and those species where these features are weakly expressed have been shown to be closely related to one another and included in the genus Planothidium [16]. According to molecular data, these species can be recognized as three distinct clades: (a) species with a sinus, (b) species with a cavum, or (c) species without these features [16]. The genus Skabitschewskia is characterized by having only a cavum on rapheless valves in all known species, but this genus differs from Planothidium by striae morphology [10]. Striae in Planothidium are multiseriate on both valves, whereas, in Skabitschewskia, striae are uniseriate on raphe valves and biseriate on rapheless valves [10]. In the genus Gliviczia, a cavum is present on both valves, and the striae are also uniseriate on both valves [9].
It is evident from the data discussed above that presence and number of horseshoe-like structures and morphology of striae are important features for the delimitation of genera between freshwater monoraphid taxa. The morphology of striae between monoraphid genera was comprehensively discussed by us during the description of the new genus Platebaikalia [14]. Freshwater monoraphid genera have different combinations of striae on raphe and rapheless valves that can include the presence of uniseriate, biseriate, or multiseriate striae. On the basis of this morphological feature, we prepared a revision of the genus Platea, a genus that was described on the basis of species with biseriate striae in both valves and the absence of horseshoe-shaped structure [17]. After this description, many species were transferred to this genus, and Platea soon became a catch-all taxon [14]. We described eight groups within the genus Platea, and some of these groups have subsequently been described as new genera [14]. One of the eight groups of Platea species includes the very interesting species Platea joursacense (Héribaud) Chudaev which has uniseriate striae on both valves, but this species possesses a cavum on the rapheless valves [18].

P. joursacense was firstly described as Achnanthes joursacensis Héribaud 1903 [19] and for a long time was a neglected taxon. The generic position of this species has been interpreted differently by several authors. This species was included in the genus Planothidium as Planothidium joursacense (Héribaud) Lange-Bertalot 1999 [20] and later in Platea as Platea joursacensis (Héribaud) Chudaev [18]. The reason for this taxonomical instability is, on the one hand, the presence of cavum being a feature considered typical for Planothidium and, on the other hand, uniseriate striae in both valves not being typical for Planothidium. The presence of distal raphe ends that terminate on the valve face and straight is typical for Platea. For a long time, this species was neglected due to its rarity and limited (only Holarctic) distribution [11]. Morphology of the raphe and rapheless valves was first investigated by Chudaev et al. [18].

The aim of this publication is to provide additional morphological evidence for the monoraphid diatom, Achnanthes joursacensis Héribaud 1903 and, on the basis of the results of this study, to describe the genus Planoplasta gen. nov.

2. Results
Planoplasta Kulikovskiy, Glushchenko & Kociolek gen. nov.

Type species (designated here): Planoplasta joursacensis (Héribaud) Kulikovskiy, Glushchenko & Kociolek comb. nov.

Description

Light microscopy (LM), raphe valves (Figure 1A–I). Valves broadly elliptic with broadly rounded ends. Length 9.3–19.3 μm, width 5.5–8.4 μm. Raphe straight and filiform. Central area small and roundish. Axial area moderately narrow, almost linear. Striae 17–19 in 10 μm. Striae radiate at the center of the valve; very strongly radiate and curved toward the ends.

LM, rapheless valves (Figure 1J–R). Axial area narrowly lanceolate. Striae spaced slightly wider than in raphe valves. Visible horseshoe-shaped structure is present.

Scanning electron microscopy (SEM), raphe valves (Figure 2A–F). Striae uniseriate (Figure 2A,D, white arrows). Raphe filiform and straight (Figure 2A, black arrows). Distal raphe ends straight and present on valve face outside (Figure 2C, white arrow). Central raphe ends straight and tear-shaped outside (Figure 2B, black arrows). Mantle is short, with two small areolae present in prolongation of every striae (Figure 2A, black arrowhead). Interstriae are wider than striae inside and outside (Figure 2A,D, white arrowhead). Inside, distal raphe ends in smaller helictoglossae and curved in opposite direction (Figure 2F, black arrow). Central raphe ends are slim and curved to different sides (Figure 2E, black arrows). Distal and central raphe ends are curved opposite to another. Areolae ≈ 60 in 10 μm.
Description
Light microscopy (LM), raphe valves (Figure 1A–I). The entire valve, external view. Black arrows show the filiform and straight raphe. White arrow shows the uniseriate stria. Black arrowhead shows the valve mantle. White arrowhead shows the interstria. (B). Central area, external view. Black arrows show the central raphe ends. (C). Valve end, external view. White arrow shows the distal raphe end. (D). The whole valve, internal views. Black arrows show the filiform and straight raphe. White arrow shows the uniseriate stria. White arrowhead shows the interstria. (E). Central area, internal view. Black arrows show the deflected in opposite directions central raphe ends. (F). Valve end, internal view. Black arrow shows the helictoglossa. Scale bar (A,D) = 2 μm; (B,E) = 1 μm; (C,F) = 0.5 μm.

Figure 1. Planoplatessa joursacensis (Héribaud) Kulikovskiy, Glushchenko & Kociolek comb. nov. Slide no. 02605. Light microscopy, differential interference contrast, size diminution series. (A–I). Raphe valves. (J–R). Rapheless valves. Scale bar = 10 μm.

Figure 2. Planoplatessa joursacensis (Héribaud) Kulikovskiy, Glushchenko & Kociolek comb. nov. Scanning electron microscopy. Raphe valves. (A). The entire valve, external view. Black arrows show the filiform and straight raphe. White arrow shows the uniseriate stria. (A–I). Raphe valves (Figure 1A–I). The entire valve, external view. Black arrows show the filiform and straight raphe. White arrow shows the uniseriate stria. Black arrowhead shows the valve mantle. White arrowhead shows the interstria. (B). Central area, external view. Black arrows show the central raphe ends. (C). Valve end, external view. White arrow shows the distal raphe end. (D). The whole valve, internal views. Black arrows show the filiform and straight raphe. White arrow shows the uniseriate stria. White arrowhead shows the interstria. (E). Central area, internal view. Black arrows show the deflected in opposite directions central raphe ends. (F). Valve end, internal view. Black arrow shows the helictoglossa. Scale bar (A,D) = 2 μm; (B,E) = 1 μm; (C,F) = 0.5 μm.
SEM, rapheless valves (Figure 3A–F). Striae uniseriate (Figure 3D, black arrow). Inter-
striae are wider than striae. Areolae covered by silica membrane internally [18].

**Figure 3.** Planoplatessa joursacensis (Héribaud) Kulikovskiy, Glushchenko & Kociolek comb. nov. Scanning electron microscopy. Rapheless valves. (A). The entire valve, external view. Black arrow shows the shortened central stria. White arrow shows the central area. White arrowhead shows the interstria. (B). Central area, external view. Black arrow shows the shortened central stria. White arrow shows the central area. (C). Valve end, external view. Black arrow shows the uniseriate stria. Black (D). The whole valve, internal view. Black arrow shows the uniseriate stria, situated in deep alveola. White arrowhead shows the interstria. (E). Internal view. Black arrow shows the cavum. (F). Valve end, internal views. Black arrow shows the uniseriate stria, situated in deep alveola. Scale bar (A,D) = 2 μm; (B,E) = 1 μm; (C,F) = 0.5 μm.

Externally, central area large and flat on one side of valve (Figure 3A,B, white arrows); in another part, all striae are normally present or one central stria is slightly shorter (Figure 3A,B, black arrows). Internally, a large cavum is present (Figure 3E, black arrow). Striae are situated in deep alveoli (Figure 3D,F, black arrows).

**Etymology**
Combining epithet refers to the similarity with two monoraphid diatom genera, Platessa and Planothidium.

**New Combination**
Planoplatessa joursacensis (Héribaud) Kulikovskiy, Glushchenko & Kociolek comb. nov. Basionym: Achnanthes joursacensis Héribaud 1903, in Les Diatomées Fossiles d’Auvergne Paris: 5; pl. 11, Figures 26 and 27.
3. Discussion

*Achnanthes joursacensis* was described by Héribaud from fossil material (Upper Miocene or Pontus) near Joursac Village (currently commune) in the southern part of Central France [19]. Subsequently, this taxon was found in sediments of different Epochs of the Neogene Period, including Miocene [21] and Pliocene [22,23], as well as from the Quaternary Period, both Pleistocene [24] and Recent in Europe [25], Russia, Moscow Region [18], Russian Far East [26], Mongolia (this investigation), Japan [27], and USA [28]. The lectotype of the species was investigated and illustrated by Krammer and Lange-Bertalot, taf. 47, Figures 7–9 [29]. This taxon prefers alkaline, meso- to eutrophic lakes and lake outlets [25].

We found this taxon in weakly alkaline (pH = 8.7) Lake Khövsgöl (Mongolia) with an electrical conductivity of 236 \(\mu\)S·cm\(^{-1}\).

All findings of this species, with both LM and SEM, correspond to observations of the lectotype investigated previously. This taxon is characterized by uniseriate striae on both valves and the presence of a cavum on rapheless valves; external distal raphe ends are straight and placed on the valve face and do not extend onto the mantle [18,29]. This combination of morphological features makes this species easily recognizable. Populations of this species were found in the Holarctic, both fossil to Recent [18].

The presence of a cavum was a good reason to transfer this species to the genus *Planothidium* [20]. However, *Planothidium* as a genus is also characterized by having multiseriate striae on both valves. *Planoplatessa joursacensis* comb. nov., however, only has uniseriate striae [10]. External distal raphe ends extend onto the valve mantle in *Planothidium*; however, in *Planoplatessa joursacensis* comb. nov., they are straight and only occur on the valve face. As discussed above, *Planothidium* as a genus can be divided into three groups, one with cavum, a second with sinus, and a third without a cavum and sinus. However, all the taxa in these groups of *Planothidium* have multiseriate striae. *Skabitschewskia* is another genus with the presence of a cavum in rapheless valves. However, *Skabitschewskia* is characterized by uniseriate striae on the raphe valves and biseriate striae on the rapheless valves [10]. The genus *Gliviczia* is characterized by the presence of a cavum and uniseriate striae on both valves similar to the situation in *Planoplatessa* gen. nov. However, *Gliviczia* has a cavum on both raphe and rapheless valves, a situation that is unique among monoraphid genera.

Genera such as *Achnanthidium*, *Eucocconeis*, *Psammothidium*, *Trifonovia*, *Gololobovia*, and *Gogorevia* are characterized by having uniseriate striae on both valves [8,10,12,13]. However, these genera do not have a cavum, a feature that is typical for *Planoplatessa* gen. nov. All these genera are very easy to distinguish from *Planoplatessa* gen. nov. by a combination of morphological features such as valve shape, presence or absence of sternum and stauros internally and externally, and morphology of distal and central raphe ends (see Table 1). Combinations of stria morphology with the presence or absence of a cavum and stauros are important taxonomical features that were shown with molecular data to help diagnose freshwater monoraphid genera such as *Achnanthidium*, *Psammothidium*, *Gogorevia*, *Karayevia*, *Planothidium*, and *Lemnicola* [13,16,30–34].
Plants 2022, 11, 2314

6 of 9

Table 1. Comparison of different freshwater monoraphid diatom genera with cavum.

| Planoplatessa gen. nov. | Skaletschewskia | Planothidium | Gigliaccia |
|------------------------|----------------|-------------|------------|
| **Type species**        | Kulikovskiy, G. (Heinbald) | Kulikovskiy & Lange-Bertalot 2015 | G. lanceolatum (Kützing) Lange-Bertalot 1999 |
| **Striae in raphe valves (RV)** | Uniseriate | Uniseriate | Uniseriate |
| **Striae in raphless valves (RLV)** | Uniseriate | Biseriate | Multiseriate |
| **Interstriae in RV externally** | Flat, wider than striae | Flat, equal to striae | Flat, less than striae |
| **Interstriae in RV internally** | Very prominent on striae, broader than striae | Prominent, equal to or broader than striae | Prominent, narrower than striae |
| **Interstriae in RLV externally** | Flat, broader than striae | Very prominent (rib-like), connected with sternum, close areolae by silica layer (alveoli), narrower than striae; in some species with reduced striae the interstriae are longer and broader |
| **Interstriae in RLV internally** | Very prominent on striae, broader than striae | Evidently raised and narrower than striae | Slightly raised, narrower than striae |
| **Pore occlusions** | Silica membrane | Silica membrane | Hymenens |
| **Distal raphe ends externally** | Straight, on valve face near mantle | Straight or slightly curved on valve face or extending slightly onto valve mantle; turned in opposite directions | Smoothly curved to the same direction and extending onto valve mantle |
| **Distal raphe ends internally** | In small helictoglossae; curved in the opposite directions | In small helictoglossae; turned in different directions | In small helictoglossae; turned in different directions |
| **Central raphe ends externally** | Tear-shaped, straight | Tear-shaped, straight | Tear-shaped, turned to the same direction and opposite to distal ends |
| **Central raphe ends internally** | Linear, straight, curved in opposite directions | Straight, turned to the different direction | Straight, turned in different directions |
| **Axial area in RV, externally** | Narrow and linear, sternum | Narrow and well-developed, narrow and linear | Narrow and linear, sternum |
| **Axial area in RV, internally** | Narrow and straight, sternum evident and elevated | Narrow and linear or slightly wider to central area, in many species deep on valve face | Narrow and linear or slightly wider to central area, deep on valve face |
| **Axial area in RLV, externally** | Flat, lanceolate | Narrow lanceolate, raised on valve face in middle | Narrow lanceolate, raised on valve face in middle |
| **Axial area in RLV, internally** | Flat, lanceolate | Flat, lanceolate | Flat, lanceolate |
| **Central area in RV externally** | Small, circle | Circle or bowtie-shaped, flat or slightly raised in center | Stauros elevated, central node evidently raised |
| **Central area in RV internally** | Small, circle | Circle or bowtie-shaped, raised in center | Stauros strongly elevated with cavum on one side |
| **Central area in RLV externally** | Flat and large trapezium in one side | Flat, fascia in one cavum side of valve | Stauros elevated |
| **Central area in RLV internally** | Large cavum in one side | Cavum | Stauros strongly elevated with cavum on one side |

**References**

This investigation, [18] [10] [53] [16], own data

Planoplatessa gen. nov. as a genus is distinguished from other known monoraphid genera. Previous transfer of A. jousacensis to the genus Platessa was based on some morphological features shared between them, especially external distal raphe ends being straight and extending onto the valve face only [18]. Transfer of taxa that were divided on some morphological features between similar genera to different genera is normal practice. We discussed the same situation with the previous transfer of Achnanthes exigua Grunow 1880 to the genera Achnanthes and Lemnicola [13]. However, our molecular investigation of species from this complex showed that a new genus was required, which we described as Gogorevia. Future research combining morphological and molecular datasets will be necessary to further resolve relationship of the other freshwater monoraphid genus and help to identify features that allow us to not only recognize and distinguish the genera, but also diagnose monophyletic taxa and create a natural classification for them [35].
4. Materials and Methods

Samples from Mongolia were collected by M.S. Kulikovskiy on 21 July 2015 from the Khövsgöl Lake (50°59′22.8″ N, 100°42′30.4″ E; pH = 8.7; T = 11.5 °C; conductivity = 236 μS·cm⁻¹), directly sampling benthos and designated Mn 282.

The samples were boiled in concentrated hydrogen peroxide (≈37%) to dissolve organic matter. The samples were then washed with deionized water four times at 12 h intervals. After decanting and rinsing with up to 100 mL of deionized water, the suspension was spread onto coverslips and left to dry at room temperature. Permanent diatom slides were mounted in Naphrax®. The slide was designated no. 02605. Light microscopic (LM) observations were performed using a Zeiss Scope A1 microscope equipped with an oil immersion objective (100×, n.a. 1.4, differential interference contrast (DIC)) and Zeiss AxioCam ERc 5 s camera. For scanning electron microscopy (SEM), parts of the suspensions were fixed on aluminum stubs after air-drying. The stubs were sputter-coated with 50 nm of gold. The valve ultrastructure was examined by means of a JSM-6510LV scanning electron microscope (Institute for Biology of Inland Waters RAS, Borok, Russia).

5. Conclusions

New insights into character combinations found in freshwater monoraphid diatoms are demonstrating key features used to diagnose genera. An easily recognizable feature in both light and scanning electron microscopy is a cavum, a hollow covering found in the valve interior of certain monoraphid genera. We can now recognize four monoraphid genera that possess a cavum: Planothidium, Skabitschewskia, Gliwiczia, and Planoplatessa gen. nov. These genera are recognizable from one another on the basis of whether there is a single cavum per frustule or two (found in Gliwiczia only), multiserial versus uniserial striae, and whether the external distal raphe ends extend onto the valve mantle or are restricted to the valve face. While we expect these groups to constitute a monophyletic lineage, formal analyses based on morphology and molecules will be needed to verify taxon relationships and monophyly.

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Abbreviations

LM—light microscopy; SEM—scanning electron microscopy; RV—raphe valves; RLV—rapheless valves.
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