DIATOMS FROM THE HYPERSALINE "LA AMARGA" LAKE (LA PAMPA, ARGENTINA)

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ABSTRACT - As part of a more comprehensive study of the diatom flora from La Pampa province (Argentina), several samples collected in April 1991 and October 1992, from the hypersaline "La Amarga" lake (35°15'S, 63°05'W) were analized. Fifty three taxa were identified, from which five are new records for Argentina, two are new records for argentine inland waters and fifteen of the remaining diatoms had not been mentioned previously for the province. Ecological affinities of some taxa are discussed. Some comments about LM and SEM morphological features, taxonomy and distribution of several taxa are included.

RESUMEN - Como parte de un estudio más amplio de la flora de diatomeas de la provincia de La Pampa (Argentina), se analizaron varias muestras coleccionadas en la laguna hipersalina "La Amarga" (35°15'S, 63°05'W). Se identificaron cincuenta y tres taxa de los cuales cinco son nuevos registros para el país, dos se citan por primera vez para aguas continentales argentinas y quince de los restantes no habían sido mencionados previamente para la provincia. Se discuten las afinidades ecológicas de algunos taxa. Se presentan algunos comentarios respecto de las características morfológicas, estudiadas bajo microscopio óptico y electrónico de barrido, taxonomía y distribución de varios taxa.

INTRODUCTION

La Amarga is a hypersaline lake in La Pampa province, Argentina (35°15'S, 63°05'W) at 200 m a.s.l. (fig. 1), *ca* 900 km^2 in area and its greatest depth is 10 m. Lake vegetation surroundings is composed by xerophytic schrubs which favours the high evaporation rate and the water infiltration in the sandy soil. La Amarga lake is joined by a short river to Urre-Lauquen lake from which catches its river. Urre-Lauquen lake is essentially fed by melting waters from Los Andes Mountains, through the Chadileuvú River (Lell & Hernandes, 1982).

Diatoms in hypersaline lakes from South America have been little studied. All these studies have been realized in high altitude lakes (Hustedt, 1927; Frenguelli, 1929, 1938; Patrick, 1961; Servant-Vilary, 1983, 1984), but there is no information concerning diatoms associations from low-altitude hypersaline lakes. Diatom flora occurring in La Amarga lake was analyzed as part of a more comprehensive study of the Bacilla-

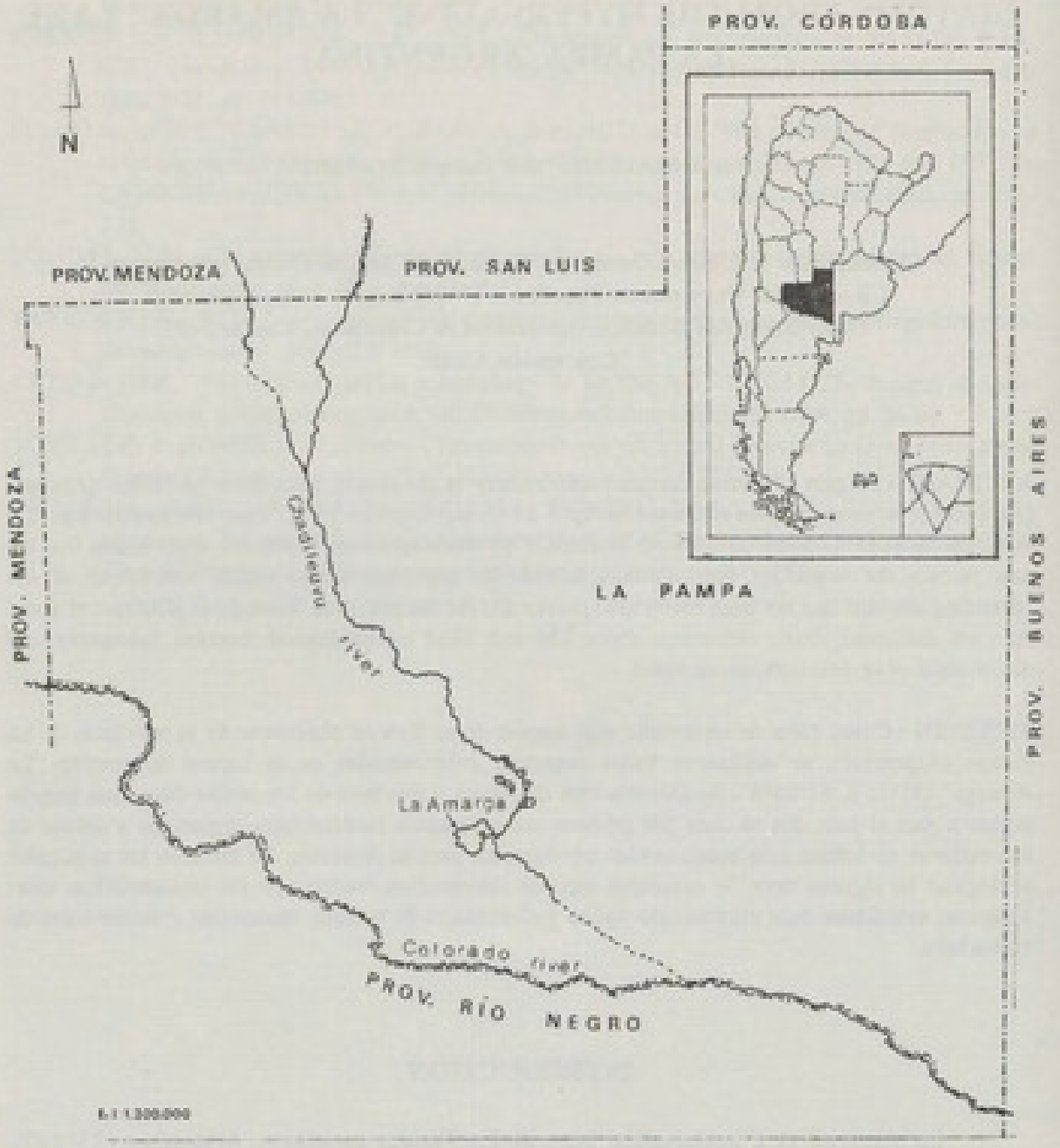

Fig. 1 - Location of La Amarga lake, La Pampa, Argentina.

riophyceae from La Pampa, begun by one of the authors (Romero, 1993 and m.s.). The objective of this paper is to provide an inventory of the diatoms present in this lake during April 1991 and October 1992.

MATERIAL AND METHODS

Samples were collected in April 1991 and October 1992. In both samplings plankton-net samples, superficial sediments and epiphytes on *Lamprothamnium haes-*

selliae Donkin and *Chara halina* Garcia (Charophyceae) (Garcia, 1993a and b) were collected. Samples fixed *in situ* with formaline 4% were deposited at the Herbarium of Facultad de Agronomia, Universidad Nacional de La Pampa as SRFA 205 (April, 1991) and SRFA 353 (October, 1992).

Standard methodology (Hasle & Fryxell, 1970) were used for the observation of frustules under light microscope (LM) and scanning electron microscope (SEM). Diatoms were examined using a Zeiss Standard 14 and a Zeiss III photomicroscopes and a SEM ETEC Autoscan U-1 (Laboratorio de Microscopía Electrónica, Universidad de Concepción, Chile) and a SEM JEOL JSM 25 S II (Servicio de Microscopía Electrónica, Facultad de Odontologia, Universidad de Buenos Aires, Argentina).

Identifications were performed according A. Schmidt *et al.* (1874-1959), Van Heurck (1880-1885), Hustedt (1930, 1959-1966) and Krammer & Lange-Bertalot (1985, 1986, 1988 and 1991 a and b) among other references.

The terminology used in text descriptions is that suggested by Ross *et al.* (1979). The catalogues of Luchini & Verona (1972), Tell (1985) and Ferrario & Galvan (1989) were consulted for previous reports and geographical distribution of taxa in Argentina.

Only description of taxa new for Argentina or those interesting because their morphology and/or taxonomy are here included. For each one the original citation, consulted references, measurements and relevant observations are given.

Table I summarizes, in alphabetical order, the list of identified taxa and the samples in which they were present. One asterisk (*) indicates new records for Argentina and two (**) the new records for La Pampa province.

Available physico-chemical data are those belonging to sample of April 1991: pH 8.33; conductivity 76.9 mm h^{-1} at 25°C; total salts 58.715 mg l^{-1}; chlorides 26.840 mg l^{-1}; sulfates 4.800 mg l^{-1}; hydrocarbons 176 mg l^{-1}; calcium 1.854 mg l^{-1}; magnesium 1.096 mg l^{-1}; sodium 15.456 mg l^{-1} and potassium 68 mg l^{-1} (Laboratorio de Química Analítica report, Facultad de Agronomía, Universidad Nacional de La Pampa, April 1991).

RESULTS AND DISCUSSION

Cyclotella **Kütz.**

Cyclotella choctawhatcheeana **A.K.S. Prasad**

Prasad *et al.* (1990): 419-426, figs. 2-26. References: Wendker (1991): 359-363; Håkansson *et al.* (1993: 337-338, figs. 1-10, table 1. - **Figs. 6, 15-20.**

Diameter 3-10 µm; 19-20 striae in 10µm; marginal fultoportulae every 3rd to 7th interstriae, 3-6 in 10 µm; 1-6 valve face fultoportulae.

Observations: In the single complete frustulum seen under SEM, epicingulum is composed by a very narrow valvocopula with one prominent antiligula filling the gap of the adjacent open copula, whereas hypocingulum presents a broad, non porous, open valvocopula with its gap filled by a prominent ligula of the narrow adjacent copula. The antiligula and ligula of epi and hypocingulum are aligned (fig. 15).

	Taxa	Samples	
		SRFA Nº 205	SRFA Nº 353
	Achnanthes delicatula (Kütz.) Grunow ssp. delicatula	x	-
	Achnanthes exigua Grunow	-	x
	Achnanthes minutissima Kütz. var. minutissima	-	x
*	Achnanthes taeniata Grunow	x	x
**	Amphipleura rutilans (Trentep.) Cleve	x	x
	Amphora coffeaeformis (C.Agardh) Kütz	x	x
**	Amphora copulata (Kütz.) Schoeman & R.E.M.Archibald	-	x
**	Amphora lineolata Ehrenb.	x	-
	Amphora veneta Kütz.	-	x
	Aulacoseira granulata (Ehrenb.) Simonsen	x	x
	Chaetoceros sp	x	x
	Cocconeis placentula var. euglypta (Ehrenb.) Grunow	x	x
**	Cyclotella choctawhatcheeana A.K.S.Prasad	x	x
	Cyclotella meneghiniana Kütz.	-	x
	Cymbella affinis Kütz.	x	-
	Cymbella pusilla Grunow	x	x
**	Diploneis boldtiana Cleve	x	x
	Fragilaria construens var. venter (Ehrenb.) Grunow	x	-
	Fragilaria fasciculata (C.Agardh) Lange-Bert.	x	x
	Fragilaria ulna (Nitzsch) Lange-Bert.	x	-
	Gomphonema parvulum (Kütz.) Kütz.	-	x
	Gyrosigma spencerii (Quekett) J.W.Griff. & Henfr.	-	x
**	Gyrosigma strigilis (W.Sm.) Cleve.	x	x
	Hantzschia amphioxys (Ehrenb.) Grunow	x	x
**	Mastogloia braunii Grunow	x	x
	Mastogloia elliptica (C.Agardh) Cleve	x	x
	Mastogloia pumila (Grunow) Cleve	x	x
	Navicula cryptocephala Kütz.	-	x
	Navicula digitoradiata (W.Greg.) Ralfs	x	x
*	Navicula flanatica Grunow	x	x
	Navicula goeppertiana (Bleisch) Grunow	x	-
	Navicula mutica Kütz.	x	x
	Navicula normaloides Cholnoky	x	x
	Navicula pygmaea Kütz.	x	x
*	Navicula salinicola Hust.	x	x
	Navicula soodensis Krasske	x	x
**	Navicula tenera Hust.	-	x
	Nitzschia amphibia Grunow	-	x
**	Nitzschia bergii A.Cleve	x	x
	Nitzschia constricta (Kütz.) Ralfs	x	x
**	Nitzschia epithemioides Grunow	-	x
	Nitzschia hustedtiana Sabh	x	x
	Nitzschia inconspicua Grunow	x	x
	Nitzschia microcephala Grunow	x	-
**	Nitzschia nana Grunow	x	-
*	Nitzschia pellucida Grunow	x	x
**	Nitzschia supralitorea Lange-Bert.	x	x
	Pinnularia borealis Ehrenb.	x	x
*	Pleurosigma amara Stidolph	x	x
	Rhopalodia brebissonii Krammer	x	x
**	Stauroneis concapta Cholnoky	x	x
**	Stauroneis salina W.Sm.	x	x
	Surirella striatula Turpin	x	x

Valve face fultoportulae, always on the uplift of the undulation along the striation (figs. 16, 17), had mostly three (fig. 18), occasionally two satellites pores (fig. 19), whereas marginal fultoportulae always showed two (fig. 20), one towards the edge of the valve and the other towards the valve face-mantle junction.

The submarginal rimoportula is placed on an interstria with an external oblong opening and the internal fissure radially oriented (fig.20).

This material is included into the group of "small-sized species" related to the *C. striata* complex, widely distributed in brackish waters (Hakansson *et al.*, 1993), mentioned under different names by different authors (i.e. *C. choctawhatcheeana* by Prasad *et al.*, 1990; *C. caspia* Grunow by Archibald, 1983 and Maidana, 1994; *C. hakanssoniae* Wendker *in* Wendker, 1991 and the "species from Baltic Sea" by Håkansson *et al.*, op. cit.).

Håkansson *et al.* (op. cit.) stated that the valid name for this small diatom is *C. choctawhatcheeana* and they include *C. hakanssoniae* Wendker and their "species from Baltic Sea" into its list of synonyms.

Our material agrees on almost every respect with Prasad's original diagnosis, except:

a - this diatom does not form chains (as *C. hakanssoniae* and the "species from Baltic Sea").

b - a siliceous rib can be seen in the mantle edge (fig. 15, see also Håkansson *et al.*, op. cit., fig. 7). This feature is absent in quaternary material from San Luis province, Argentina, studied by one of us (Maidana, 1994, fig. 19; see also Håkansson *et al.*, op. cit., fig. 8).

c - the epicingulum (not so the hypocingulum) does not coincide with Prasad's diagnosis: "valvocopula lata pleuraque angusta longiligulata ornatum" but our fig. 15 is very similar to their fig. 23.

Small siliceous grains around the margin mentioned by Prasad *et al.* (op. cit.), Wendker (op. cit.) and Håkansson *et al.* (op. cit.) were not present in our material.

Salinity measured in La Amarga lake in April 1991 (58 ‰) is higher than the recorded in the consulted literature (0-25 ‰), so its limits of tolerance for that environmental parameter must be increased.

Chaetoceros Ehrenb.

Chaetoceros sp.

References: Johansen & Rushford (1985): 437-447; Krammer & Lange-Bertalot, (1991a): 84, fig. 80: 1-2. - **Fig. 5.**

Observations: Only resting spores (7-10 µm x 5.5-8 µm) were found. The observation of vegetative cells is also needed for a correct specific identification.

Table I - Summary of identified taxa and samples where they were recognized (x: present; -: absent). One asterisk (*) indicates new records for Argentina and two (**) these that represent new recordings for La Pampa province. SRFA: Facultad de Agronomía Herbarium, Universidad Nacional de La Pampa, Santa Rosa, La Pampa, Argentina.

Achnanthes Bory

Achnanthes taeniata Grunow

Grunow, A. *in* Cleve, P. T. & Grunow A. (1880). Kongliga Svenska Vetenskaps-Akademiens Handligar, 17/2: 22, pl. 1, fig. 5. Reference: Hustedt (1962): 382, fig. 828; Krammer & Lange-Bertalot (1991 b): 52, fig. 29: 10-15. - **Figs. 2, 3.**

Valves lineal-elliptical with rounded apices. Axial area narrow and straight, central area very reduced or absent in both valves. Raphe filiform and straight. Striae parallel at the centre - more distant from each other arround the central area in the raphe-valve - and slightly radiate towards the apices.

Apical axis (Aa) 14-18 µm; transapical axis (ta) 4.5-6 µm; 20-23 striae in 10 µm.

Amphipleura Kütz.

Amphipleura rutilans (Trentep.) Cleve

Cleve, P.T. (1894). Kongliga Svenska Vetenskaps-Akadiemiens Handligar, Bd. 26: 126. = *Berkeleya rutilans* (Trentep. ex Roth) Grunow (1880). Botanische Centralblatt, 4 (47/48): 1587.

References: Cox (1975 a and b); Krammer & Lange-Bertalot (1986): 264, fig. 98: 9-11. Aa 15-24 µm; ta 2.5-3 µm; (25)-37-57 striae in 10 µm (SEM). - **Figs. 4, 21.**

Observations: In the studied diatoms the transapical axis is shorter and the striae density is higher than those mentioned by Cox (op. cit.: 4-6 µm and 27 striae in 10 µm). It is recorded for the first time in Argentine inland waters.

Gyrosigma Hassall

Gyrosigma spencerii (Quekett) Griff. & Henfr.

Griffith, J.W. & Henfrey, A. (1856). Diatomaceae *in* "The Micrographic Dictionary". John Van Voorst, Paternoster Row, London, p. 303, pl. 11, fig. 17. Reference: Krammer & Lange-Bertalot (1986): 298, fig. 115: 2. **Figs. 7a, 7b.**

Aa 104-170 µm; ta 12-17 µm; 20-21-(24-26) transversal striae and 25-(28-35) longitudinal striae in 10 µm.

Observations: some individuals, whose dimensions are in brackets, show a higher density of transversal and longitudinal striae than those mentioned by Krammer & Lange-Bertalot (op. cit.) (17-23 and 22-26 in 10 µm, respectively).

Gyrosigma strigilis (W. Sm.) Cleve

Cleve P.T. (1894). Kongliga Svenska Vetenskaps-Akadiemiens Handligar, Bd. 26: 115. References: Hustedt (1930): 224, fig. 332; Frenguelli (1945): 171, lam. 10, fig. 1. - **Fig. 8a, 8b, 22, 23.**

Aa 302-305 µm; ta 36-38.2 µm; 13-14 transversal and 14-15 longitudinal striae in 10 µm.

Observations: Under SEM, the internal valve face shows the central nodule slightly oblique to apical axis, with one elevated siliceous bar at each side and surrounded by an asymmetrical hyaline area with irregular outline. Internal proximal raphe fissures are T-shaped (fig. 22). At the apices, the raphe is very slightly deflected to-

wards the concave side of the valve. Pyramidal helictoglossa is surrounded by a hyaline area where the internal openings of areolae appear very reduced or are absent. Apical micropores (after Stidolph, 1992: 347) are arranged in two rows, one of them located just above the helictoglossa and the other, longer than former, displaced on the more convex side of the valve. A row of isolate areolae are located at the valve face-mantle junction, interrupted at the base of the helictoglossa (fig. 23).

The ultrastructure of the internal valve face resembles *F. sterrenburgii* Stidolph, *op. cit.*) in regarding the appearance of the central nodule, the occurrence of a hyaline area at the apical region, the arrangement of apical micropores in rows and the presence of a row of isolate areolae at the valve face-mantle junction. The main differences are the pyramidal elevation of the helictoglossa, two rows of micropores and noticeably marginal location of the isolate areolae.

Navicula Bory

Navicula flanatica Grun.

Grunow A. (1860). Verhandlungen der kaiserlich-königlichen, zoologisch-botanischen gessellschaft in Wien, Bd. 10: 527, 3/9. References: Cleve-Euler, 1953: 131, fig. 757 A a; Krammer & Lange-Bertalot, 1986: 109, fig. 34: 10-11. - **Figs. 9, 24-26.**

Valves narrowly lanceolate to lineal-lanceolate, rostrate to subrostrate ends with narrowly, rounded apices. Axial area almost indistinct, slightly enlarged towards the centre; central area orbicular. Raphe filiform and straight; helictoglossa not very marked. Raphe-sternum narrow with its distal ends curved at the same side of the valve. Striae slightly radiate at the centre and then convergent or parallel toward or parallel towards the apices. Areolate lineolate with rectangular internal openings (fig. 26).

Aa 23-44 µm; ta 4.5-6.5 µm; 12-15 striae in 10 µm; 20-28 areolae in 10 µm.

Navicula salinicola Hust.

Hustedt (1939): 638, fig. 61-69.

= *N. incerta* Grunow *in* Van Heurck (1880-1185), p. 107, pl. 14, fig. 43 non Ehrenb. 1837. = *N. incertata* Lange-Bert. in Krammer & Lange Bertalot (1985): 75; Krammer & Lange-Bertalot (1986): 111, fig. 35: 21-24. Reference: Krammer & Lange-Bertalot (1986): 111, fig. 35: 9-10. - **Figs. 10, 11, 27-31.**

Frustules almost rectangular in girdle view. Valves flat, concave or convex, elliptical-lanceolate to lanceolate with narrowly rounded, not protrude apices. Axial area narrow; central area very reduced and slightly asymmetrical. Raphe filiform with branches slightly curved. Striae parallel at the centre and then parallel to almost convergent towards the apices. At the secondary side of the valve, two central striae are generally divergent or more spaced than the remaining and their apices tend to be coincident with the proximal raphe fissures. Frequently, at the opposite side of the valve, one stria is oriented towards the middle of the central nodule.

Aa 7.4 µm; ta 2.4 µm; 15-20 striae in 10 µm; areolae 50-64 in 10 µm.

Observations: Under SEM, external terminal raphe fissures are sickle-shaped and are hooked towards the secondary side of the valve, ending on the mantle (figs. 28-30) whereas internal fissures end subapically in a small helictoglossa (fig. 31). External proximal raphe fissures end in a pore (figs. 29, 30). Striae lineolate with areolae enclo-

sing the terminal raphe fissures. They are elongated in the pervalval axis, perpendicular to the other areolae (fig. 28-30).

The valves are noticeably asymmetrical to the apical axis. This is evident in the external terminal raphe fissures deflection, in the arrangement of the central striae (fig. 29-30) and because when a reduction in areolae length from the margin towards the centre is recognized, it is always more evident at the secondary side of the valve (fig. 31).

N. incerta is conspecific with *N. salinicola* (Lange-Bertalot, *in lit.*) and, following the ICBN rules, the oldest correct epitheton (in this case *N. salinicola*) has priority.

Pleurosigma W. Sm.
Pleurosigma amara Stidolph
Reference: Stidolph (1992): 349, figs. 44-51, 64-76. - **Figs. 14a, 14b, 32-38.**

Valves lanceolate, sigmoid, with the valve face flat until quarter of the distance from the central area to the apices, then vaulted towards the rounded apices. Axial area narrow; central area small and orbicular. Raphe-sternum straight and median at the centre and then curved and displaced towards the convex margin near the apices in the distal one third of the valve.

Aa 250-280 µm; ta 28-30 µm; 10-13 striae in 10 µm crossed in 62-68° angles.

Observations: Under SEM, external proximal raphe fissures are wavy and closely ended (fig. 32, see also Stidolph, *op. cit.*, fig. 76 E); terminal fissures are longer than internal ones, deflected towards the concave side of the valve reaching the mantle (fig. 33). At the apices there are a series of three-four pores, parallel and beneath the external terminal fissures and, at the opposite side, one isolate pore on the centre of each apex on the valve face-mantle junction (figs. 33, 34). At the internal side of the apices a series of modified areolae surrounds the helictoglossa and sometimes they are separate off from the remaining by a hyaline area (figs. 35, 36). At the apices (fig. 35, 36) two-four isolate pores can be seen behing the helictoglossa (corresponding to the single central external pore?).

The central nodule presents a raised dome, surrounded by two bars, sometimes with transapical complex extensions (fig. 37, 38). A hyaline area is always present at each side of the central bars (fig. 37, 38; see also Stidolph, *op. cit.*, fig. 73).

Striae are built up by areolae with narrow and lineolate external openings, whereas internal ones are transapically divided by a tiny bar (fig. 32, 35, 36). Areolae close to the central area and some in the mantle are not internally bisected (figs. 35, 37).

Stauroneis Ehrenb.
Stauroneis salina Smith
Smith Wm. (1853). Synopsis of the British Diatomaceae: 60, pl. 19, fig. 188. Reference: Krammer & Lange-Bertalot (1986): 250, fig. 91: 14-15. - **Fig. 13.**

Aa 40-41 µm; ta 9.5-12 µm; 18-24 striae in 10 µm.

Observations: It is recorded for the first time in Argentine inland waters.

Nitzschia Hassal nom. cons.
Nitzschia pellucida Grunow
Grunow A. *in* Cleve P.T. & Grunow A. (1880). K. Svenska Vet. Akad. Handl., 17/2: 80, pl. 5, fig. 96. Reference: Krammer & Lange-Bertalot (1988): 63, figs. 47: 4-6; 48: 1-9. - **Figs. 12, 39, 40.**

Frustules biconstricted in girdle view. Valves narrowly lineal-lanceolate progressively narrowed towards the subrostrate to capitate ends. Raphe-keel slightly excentric with irregularly spaced, narrow and transapically elongated fibulae. Striae not evident with LM; areolae indistinct even under SEM.

Aa 38-73 µm; ta 3-4 µm; 13-15 fibulae in 10 µm; 36-40 striae in 10 µm.

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FIGURES

Fig. 2-14 - 2, 3. *Achnanthes taeniata*: 2. raphe valve; 3. rapheless valve; 4. *Amphipleura rutilans*; 5. *Chaetoceros* sp.: resting spores; 6. *Cyclotella choctawhatcheeana*; 7. *Gyrosigma spencerii* (a: valve view, b. detail of striation); 8. *G. strigilis* (a. valve view, b. detail of striation); 9. *Navicula flanatica*; 10, 11. *N. salinicola*; 12. *Nitzschia pellucida*; 13. *Stauroneis salina*; 14. *Pleurosigma amara* (a. valve view, b. detail of striation). Scale bars = 10 µm.

Fig. 15-20 (SEM) - *Cyclotella choctawhatcheeana*. 15-17. External view: 15. frustule; 16, 17. valve view; 18-20. internal view: 18. valve with three satellite pores in the central fultoportulae; 19. valve with two satellite pores in the central fultoportulae; 20. detail of the valve-mantle junction (cf. central fultoportulae in the uplift of the central undulation, mf: marginal fultoportulae in the valve face-mantle junction; rp: rimoportulae). Scale bars = 1 µm.

Figs. 21-26 (SEM) - 21. *Amphipleura rutilans*: external view; 22, 23. *Gyrosigma strigilis*, internal view: 22. central zone; 23. apical zone (arrows: rows of apical micropores; ha: hyaline areas surrounding the helictoglossa); 24-26. *Navicula flanatica*, internal view: 24. general view of the valve; 25. detail of the central zone; 26. detail of one apex. Scale bars: 21, 23, 26 = 1 µm; 22, 24, 25 = 2 µm.

Figs. 27-31 (SEM) - *Navicula salinicola*. 27-28. girdle view: 27. frustule; 28. detail of one apex. Note the placement of apical areolae (arrows); 29, 30. external valve view; 31. internal valve face view. Note the reduction in length of the areolate on the secondary side of the valve. Scale bars: 1 µm.

Figs. 32-40 (SEM) - 32-38. *Pleurosigma amara*. 32-34. external view: 32. central area; 33, 34. apices (long arrow: apical micropores, short arrow: isolate central micropore); 35-38. internal view: 35, 36. apices (arrows: rows of modified areolae; mp: micropores); 37, 38. details of central nodules: 37. with very complex surrounding bars; 38. with surrounding bars not complex; 39, 40. *Nitzschia pellucida*: valvar internal view; 39. centre; 40. general view. Scale bars: 32, 34-38 = 1 µm; 33 = 2 µm; 40 = 4 µm.