Acta Bot. Croat. 68 (2), 421–430, 2009

CODEN: ABCRA 25
ISSN 0365–0588

Variability of the pennatae diatom *Gomphonema ventricosum* Gregory from far eastern lakes

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The present study examined by light microscope the morphological variations of 625 specimens of *Gomphonema ventricosum* Gregory collected from Lake Hövsgöl (Mongolia), Lake Baikal (Russia) and Lake Kurilskoye (Kamchatka, Russia). We classified the specimens into five types with respect to valve outline; (1) type A (type form of *Gomphonema ventricosum*), (2) type B (Lake Baikal type), (3) type C (Lake Karluk type), (4) type D (*Gomphoneis septa* type) and (5) type E (*G. ventricosum* f. *curta* type). Based on the relative frequencies of these five types, specimens from Lake Baikal were shown to be different from those of the other two lakes. Specimens from Lake Baikal are remarkably smaller both in length and breadth; specimens from the other two lakes are longer than those from Lake Baikal, though specimens from Lake Kurilskoye are wider than those from Lake Hövsgöl. Thus, clear differences in morphological features are recognized between the specimens from these three lakes.

Keywords: Diatom, *Gomphonema ventricosum*, morphology, variability, Lake Hövsgol, Lake Baikal, Lake Kurilskoye, Mongolia, Russia

Introduction

Gomphonema ventricosum was first described by GREGORY (1856) from the River Sprey in Scotland. Later, KOCIOLEK and STOERMER (1987) provided a list of localities where this taxon had been reported. The distribution of this taxon is restricted to northern latitudes between 47°N and 68°N in Eurasia, essentially in a longitudinal transect from Kamchatka to the British Isles. On the North American Continent, it was observed between 36 °N and approximately 68 °N, in a longitudinal transect from Massachusetts to the Aleutian Islands (KOCIOLEK and STOERMER 1987). Thus, the geographic distribution of this taxon is limited to the northern hemisphere and has been considered a northern alpine or cold water species (HUSTEDT 1930, KRASSKE 1932, TYNNI 1978, FOGED 1981, KOCIOLEK

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and STOERMER 1987, BAHLS 2005). KOCIOLEK and STOERMER (1987) attempted to compare the type specimens with other populations from Eurasia and concluded that the specimens from Eurasia were conspecific. They also investigated specimens from the North American Continent and considered that most of the population identified as *Gomphonema ventricosum* (except for specimens from the Alaskan mainland) belonged to the genus *Gomphoneis*. Specimens from Washington are identical to those of *Gomphonema ventricosum* (BAHLS 2005), which suggests that this taxon is more widely distributed over the North American Continent. The purpose of the present study is to compare the morphological characteristics (such as length, breadth and striae density as well as valve outline) of *G. ventricosum* from three far eastern lakes in Eurasia.

Materials and methods

Attached algae were sampled in Lake Hövsgöl in August 2005, in Lake Baikal in September 2006 and Lake Kurilskoye in August 2005 (Fig. 1a). In Lake Baikal, the pH value, water temperature and electrical conductivity were 8.5, 12.0 °C and 93 μs cm^{-1}; in Lake Kurilskoye 6.9, 9.0 °C and 149 μs cm^{-1}, respectively. Physicochemical data for the samples from Lake Hövsgöl cannot be shown as they were provided by another investigator. The specimens were fixed in 10% formalin and subsequently cleaned with sulphuric acid and hydrogen peroxide, rinsed several times with distilled water and then embedded in Pleurax. Observations were made with a Carl Zeiss Axioscope differential interference contrast microscope. Diatom identification was performed using a 100 x objective and microphotographs. Microphotographs of 625 valves (Lake Hövsgöl: 145 valves, Lake Baikal: 280 valves and Lake Kurilskoye: 200 valves) were analyzed in this study.

Fig. 1. Location of sampling sites of far eastern lakes. H – Lake Hövsgöl (Mongolia), B – Lake Baikal (Russia), K – Lake Kurilskoye (Kamchatka, Russia)

Results

Type classification by valve outline

Gomphonema ventricosum was classified according to valve shape, with reference to the microphotographs as well as illustrations published by many investigators. Referring to the microphotographs of KOCIOLEK and STOERMER (1987), we classified the specimens of *G. ventricosum* into five types based on valve outline (Tab. 1), as follows:

Type A is the type form of *G. ventricosum* (Figs. 1–6). The valves are swollen in the central portion and taper gently to a broadly rounded headpole, while tapering very consid-

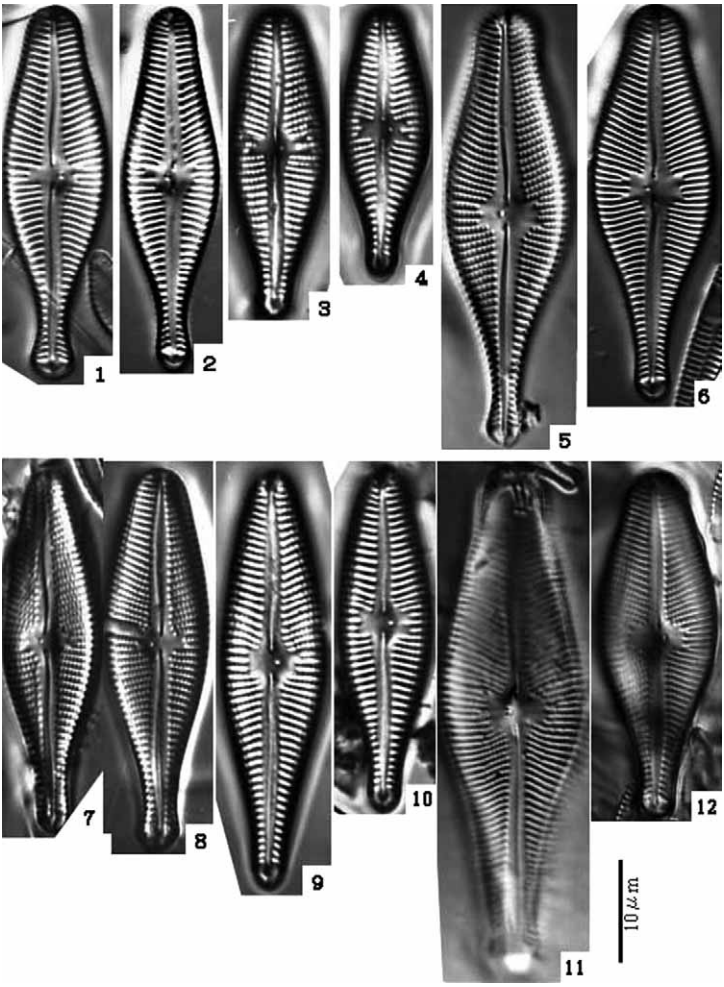

Plate 1. Light microphotographs of *Gomphonema ventricosum* Gregory. **Figs. 1, 2** – type A specimens from Lake Hövsgöl; **Figs. 3, 4** – type A specimens from Lake Baikal; **Figs. 5, 6** – type A specimens from Lake Kurilskoye; **Figs. 7, 8** – type B specimens from Lake Hövsgöl; **Figs. 9, 10** – type B specimens from Lake Baikal; **Figs. 11, 12** – type B specimens from Lake Kurilskoye.

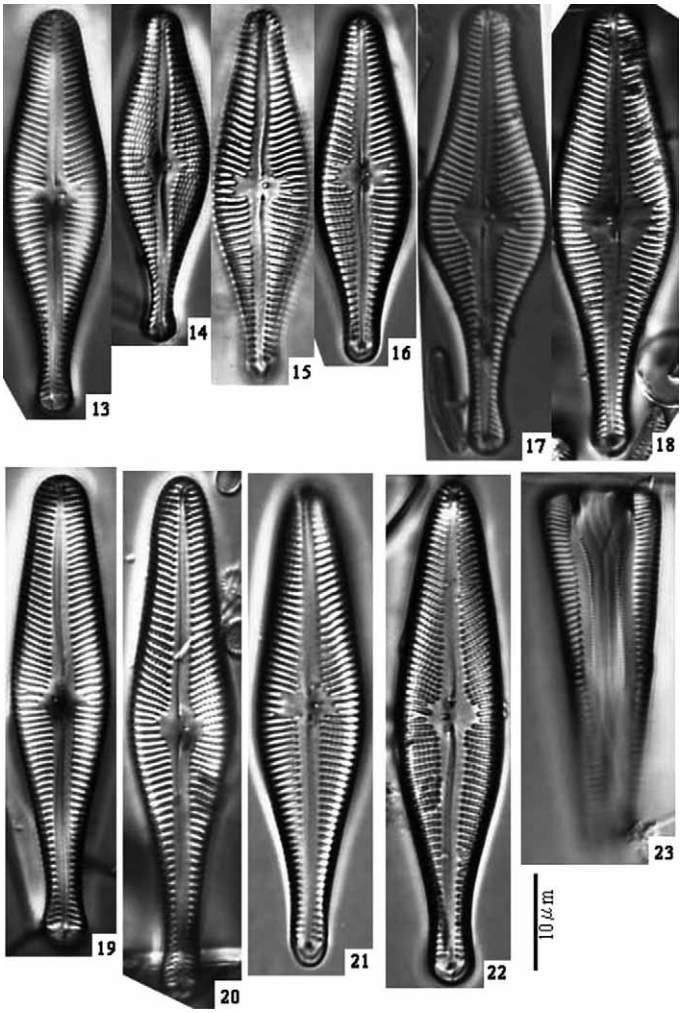

Plate 2. Light microphotographs of *Gomphonema ventricosum* Gregory. **Figs. 13, 14** – type C specimens from Lake Hövsgöl; **Figs. 15, 16** – type C specimens from Lake Baikal; **Figs. 17, 18** – type C specimens from Lake Kurilskoye; **Figs. 19, 20** – type D specimens from Lake Hövsgöl; **Figs. 21, 22** – type D specimens from Lake Baikal, **Fig. 23** – girdle view.

erably to the footpole. In our study, the samples from Lake Hövsgöl and Lake Kurilskoye contain high relative frequencies of this type (Tab. 1). Although Lake Hövsgöl is connected to Lake Baikal, the valve outlines of specimens from the two lakes are not so similar.

Type B is the Lake Baikal type (Figs. 7–12). The valves of this type lack a protracted headpole while tapering considerably towards the footpole. In Lake Baikal this type has the highest relative frequency (Tab. 1).

Type C is the Lake Karluk (Kodiak Island, North America) type (Figs. 13–18). The valve outline resembles that of specimens from Manguin's material (MANGUIN 1960). The central part of the valve is obviously tumid and steeply concave towards the headpole,

Tab. 1. Type classification by valve outline and relative frequency (%) of each type of *Gomphonema ventricosum* in the three lakes.

	Type of valve outline	Lakes		
		L. Hövsgöl	L. Baikal	L. Kurilskoye
Type A	*G. ventricosum* type form	86.7	6.2	78.1
Type B	Lake Baikal type	1.6	52.0	2.4
Type C	Lake Karluk type	8.4	16.0	19.5
Type D	*Gomphoneis septa* type	3.3	0.8	0.0
Type E	*G. ventricosum* f. *curta* type	0.0	25.0	0.0

forming a protruding round end, while the footpole tapers towards a rounded end. In Lake Kurilskoye, the relative frequency of this type is 19.5%, which is the highest among the three lakes (Tab. 1).

Type D is the *Gomphoneis septa* type (Figs. 19–22). Specimens of this type resemble *Gomphoneis septa* (Mogh.) Kociolek, Stoermer et Bahls. Valves gradually narrow to a headpole forming a broadly rounded end, and the headpole is more elongate than the footpole which abruptly tapers towards the end. Although specimens of this type rarely appear in our samples, the highest relative frequency (3.3%) of this type is found in Lake Hövsgöl. This type was rarely observed in Lake Kurilskoye (Tab. 1).

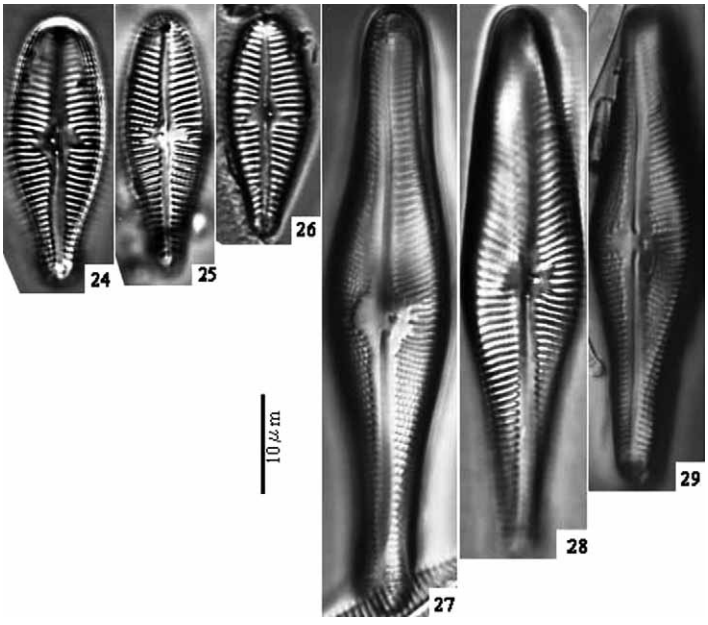

Plate 3. Light microphotographs of *Gomphonema ventricosum* Gregory. **Figs. 24–26** – type E specimens from Lake Baikal; **Figs 27–29** – initial valves of *G. ventricosum*; **Figs. 27, 28** – specimens from Lake Hövsgöl; **Fig. 29** – specimens from Lake Kurilskoye.

Type E is the *G. ventricosum* f. *curta* type (Figs. 24–26). The valve outline resembles *G. ventricosum* f. *curta* Skvortzov et K. I. Meyer. The upper half of the valve is elliptical and its lower half is wedge-shaped with a somewhat acute end. The valve length of this type is the shortest among the five types and in Lake Baikal it had a relative frequency of 25%.

Morphometric data

Morphometric characters such as length, breadth and striae density are used in this study (Tab. 2), as well as the data of KOCIOLEK and STOERMER (1987). Specimens from Lake Baikal are shorter and narrower than those from the other two lakes. Specimen lengths from Lake Hövsgöl and Lake Kurilskoye have a similar distribution of relative frequency (Fig. 30); however, specimens from Lake Kurilskoye exhibit a broader valve

Tab. 2. Measurement of parts of valve in *Gomphonema ventricosum* Gregory. Numbers in brackets refer to average values

Author	Sampling Sites	Length (μm)	Breadth (μm)	Striae Density $10\mu m^{-1}$
Kociolek & Stoermer	Type material from Scotland	28–48	10–12.5	11–12
	Eurasia	23–78	9–15	9–13
	North American Continent	25–75	9–13	9–14
This study	Lake Hövsgöl	27.5–61 (36.8)	8.5–12.5 (10.4)	13–16 (14.3)
	Lake Baikal	18.5–54.5 (32.2)	7.5–11.5 (9.3)	12–15.5 (13.9)
	Lake Kurilskoye	27–51 (37)	9.5–13.5 (11.3)	13–18 (15.2)

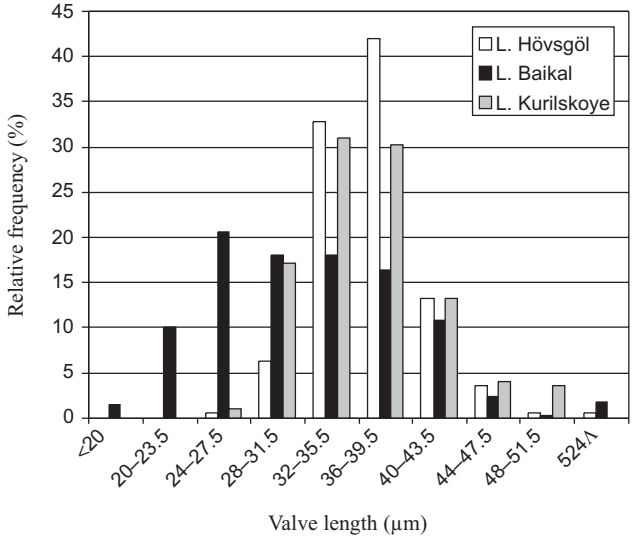

Fig. 30. Relative frequency histogram of valve length of *Gomphonema ventricosum* in the three lakes.

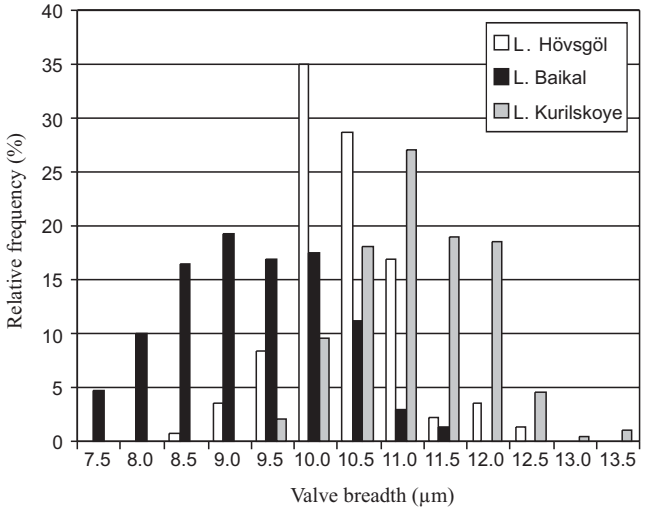

Fig. 31. Relative frequency histogram of valve breadth of *Gomphonema ventricosum* in the three lakes.

breadth than those from Lake Hövsgöl (Fig. 31). Specimens from Lake Baikal are shorter and narrower than those of the other two lakes. These tendencies are also clear from the microphotograph data (Figs. 1–18).

Initial valves of *G. ventricosum* (Figs. 27–29) were observed from Lake Hövsgöl and Lake Kurilskoye. Initial valves from these lakes are, as mentioned by Kociolek and STOERMER (1987), tumid in their central portion and taper gently towards both poles, appearing almost naviculoid in shape. Initial valves appear to be larger than valves of normal

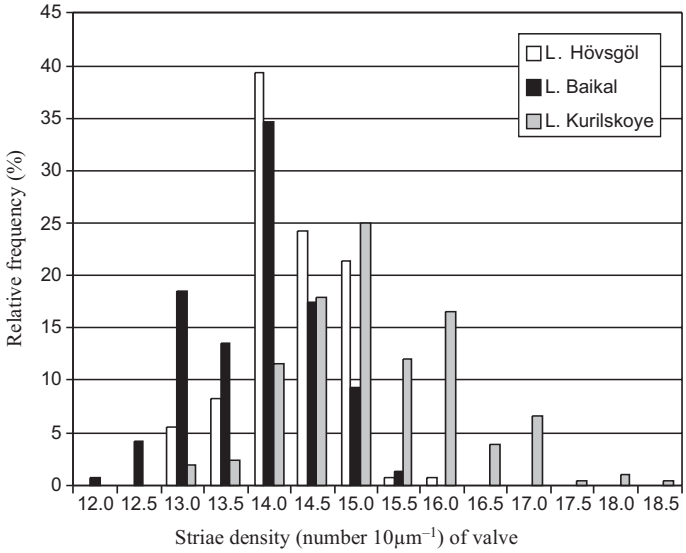

Fig. 32. Relative frequency histogram of striae density of *Gomphonema ventricosum* in the three lakes.

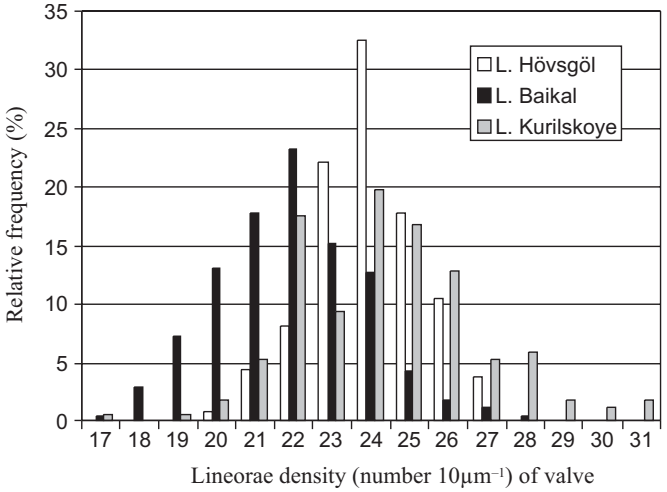

Fig. 33. Relative frequency histogram of lineolae density of *Gomphonema ventricosum* in the three lakes.

vegetative cells. Valve size is in general closely related to the frequency of auxospore formation and this coincides well with our data, in which initial valves were rarely observed in the population from Lake Baikal.

With respect to striae densities, the lowest densities of 12 striae per 10μm were recorded in specimens from Lake Baikal. Higher striae densities were observed in specimens from Lake Kurilskoye (Fig. 32) and the average density is 15.2 in 10 μm, while the densities specimens of Lake Hövsgöl and Lake Baikal are 14.2 and 13.9, respectively (Tab. 2). With regard to lineolae densities, specimens from Lake Baikal have a lower density while higher densities were recognized in specimens from Lake Kurilskoye (Fig. 33).

Discussion

Specimens of *Gomphonema ventricosum* collected from Lake Hövsgöl, Lake Baikal and Lake Kurilskoye are classified into five types based on valve outline and morphometric differences between specimens from the three lakes, including valve length, breadth, striae density and lineolae density. KOCIOLEK and STOERMER (1987) reported that illustrations of *G. ventricosum* from central Europe (HUSTEDT 1922, 1930), and those from Scandinavia (CLEVE-EULER 1955, TYNNI 1978) are very similar to type A and moreover to the type specimen of H. L. Smith (slide #670 from Christiana, Sweden). This type is common in Lake Hövsgöl and Lake Kurilskoye, representing 86.7% and 78.1% of the populations, respectively. Specimens of type B appear most frequently in the population from Lake Baikal. In specimens from Lake Baikal, valves with a weakly protruding headpole resemble the specimens in the Lake Baikal sample of KOCIOLEK and STOERMER (1987, Figs. 20–23). In their study, specimens from Lake Baikal exhibited a high degree of variability in valve shape; however, the specimens in our population show less variation. Three microphotographs from Kamchatka (SCHMIDT 1899) show a great similarity to type B. Type C was first described in Karluk Lake on Kodiak Island (MANGUIN 1960). Specimens from Karluk Lake

have a rounded central area and resemble *Gomphoneis eriense* (Grun.) Skv. et Meyer. Regarding type E, SKVORTZOW and MEYER (1928) reported specimens of this type from Lake Baikal as *G. ventricosum* f. *curta*, later SKVORTZOW (1937, Pl. 14, Fig. 22) named this type *G. ventricosum*. With respect to valve outline, specimens from Lake Hövsgöl and Lake Kurilskoye resemble the type form and those from Lake Baikal differ from those from the other two lakes. This applies also to valve length. In the Lake Hövsgöl and Lake Kurilskoye specimens, the mode of valve length appears to be longer than those from Lake Baikal (Fig. 30). Fig. 31 shows that specimens from each lake represent different ranges in valve breadth. SKVORTZOW (1937) and DAWSON (1973) indicated coarse stria densities, as few as nine striae per 10µm in specimens from Lake Baikal; however, in our study the striae densities per 10µm ranged from 12.0 to 18.5. It is clear *G. ventricosum* appears to have a wide range of striae densities.

In Lake Baikal Skvortzow and MEYER (1928) illustrated *G. ventricosum* and *G. ventricosum* f. *curta*, but SKVORTZOW (1937) later showed four illustrations including the descriptions of *G. ventricosum* from Lake Baikal. Recently, it has become difficult to find any data about *G. ventricosum* f. *curta*. Judging from his four illustrations, these specimens include types B, C and E, apart from types A and D. This is in agreement with our Lake Baikal data. Although Negoro and IKUTA (1989) showed six illustrations of *Gomphoneis* from Lake Baikal, including three specimens of *Gomphoneis eriense* var. *eriense* and three of *G. eriense* var. *rostrata*, these specimens are all considered to be *G. ventricosum* judging from the shape of the central area and location of the stigma. We classified these six specimens as types B and E. In this case, specimens of types A and D are rarely observed, as reported by SKVORTZOW (1937). A comparison of the *G. ventricosum* specimens from the three lakes indicates that differences in valve outline can be recognized between specimens from Lake Baikal and those from the other two lakes as well as valve length, breadth and striae density.

Acknowledgements

The authors are thankful to Prof. Genki Inou, DSc, (Otsuma Women's University) who collected and provided the samples from Lake Hövsgöl, and to Aleksey Maslov for helping to sample Lake Kurilskoye.

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