Communs geol. Surv. Namibia, 14 (2009), 87-93

Discovery of the first macroscopic algal assemblage in the Terminal Proterozoic of Namibia, southwest Africa

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A diverse assemblage of macroscopic algal fossils was recently discovered in the lower part of the Nama Group, Kliphoek Member of the Dabis Formation (Late Ediacaran of Namibia). This assemblage consists of three distinct taxa that have been previously reported from Neoproterozoic successions of European Russia and South China: *Glomulus filamentum* Steiner, 1994; *Eoholinia fruticulosa* A. Istchenko, 1989; *Tyrasotaenia podolica* Gnilovskaya, 1971; a fourth taxon may be related to *Kanilovia* sp., but also may have other affinities. This assemblage suggests that the best correlation of the Namibian sediments bearing this new algal assemblage would be with with the Upper Kotlin (uppermost Neoproterozoic) deposits of the Russian Platform.

Introduction

Macroscopic dark-filmed compressions are significant fossils preserved in the Ediacaran fossil assemblages associated with soft-bodied metazoans and acritarchs. The most diverse assemblages of such fossils come primarily from two regions: the Eastern European Platform (Gnilovskaya, 1971; Gnilovskaya *et al*., 1988) and southern China (Chen and Xiao, 1991; Steiner, 1994; Xiao *et al*., 2002). Assemblages from the terminal Neoproterozoic rocks of the Eastern European Platform include more than 20 species of dark-filmed compressions (Gnilovskaya *et al*., 1989; Gnilovskaya, 2003; Leonov, 2007), and more than 100 species have been described from China. However, after re-examination of these assemblages, only twenty distinct taxa could be clearly defined (Xiao *et al*., 2002). Most of these are thought to be eukaryotic algae or cyanobacterial colonies.

Systematics for dark-filmed compressions are based on formal morphologic criteria (Gnilovskaya et. al., 1989; Hoffmann, 1992, 1994). Some taxa may belong to modern phyla of algae, such as *Miaohephyton bifurcatum* (Phaeophyta, Fucales (?) (Xiao *et al*., 1998)) or *Archyfasma dimera* (Phaeophyta; Gnilovskaya, 2003).

Some macroscopic dark-filmed fossils have also been reported in the Neoproterozoic of South Africa. Dispersed fragments of thalli were described as *Vendotaenia* sp. from the lower Nama Group and also from black shales of the Owambo Formation (Mulden Group) (Germs *et al*., 1986; Germs, 1995). The newly discovered diverse assemblage described in this paper is preserved as dark films (phytoleimae, often carbonaceous) on the surface of shales. In the case of the Farm Aar sample, these films are rich in barium.

The study material is stored in the paleontological collections of the National Earth Science Museum of Namibia, Windhoek.

Geologic Setting

Algal fossils preserved as dark films have been found in some abundance within clay layers, which occur in the lower part of the Nama Group, i.e. in the Kliphoek Member of the Dabis Formation (Kuibis Subgroup) on Farm Aar, near Aus in southern Namibia (Fig. A). In this region of Namibia, the Kuibis Subgroup consists of four units, starting with the basal conglomerates/sandstones of the Kanies Member, which overlie granitic basement (Fig. B). This unit is in turn overlain by the limestone-rich Mara Member, which represents a marine transgression, followed by the quartz sandstones and siltstones of the Kliphoek Member, and finally topped by the Zaris Formation consisting of the plateau-top forming carbonates of the Mooifontein Limestone. This succession was originally interpreted by Germs (1983) as a fluvial sequence gradually giving way to open marine conditions, characterized by the dominance of thick limestones, with a number of transgressive/regressive cycles (Saylor *et al*., 1995).

At the time (older than 548 ± 1 million years - Grotzinger *et al*., 1995; Folling *et al*., 2000), that the Kuibis Subgroup sediments were being deposited, a basement arch, the Osis Arch, separated the Nama Basin into two distinct sub-basins. Sediments thin considerably across this basement high. The algal remains come from a locality (Road 2.3 Quarry) on Farm Aar in the southern basin, and occur within a predominantly quartz- and siltstone / claystone-rich sequence forming the lower part of the Upper Kliphoek Member of the Dabis Formation (Fig. C). Above this fossil-bearing locality, sediments become increasingly carbonate-rich, carbonates which thin eastward towards land. Just below the algal-bearing level are thick, well-sorted, light-coloured quartzites, which characteristically contain well-preserved *Pteridinium* and *Ernietta* and abundant evidence of microbial mats. In the upper sequence, and above the algal level, thin quartzites and shales/clays

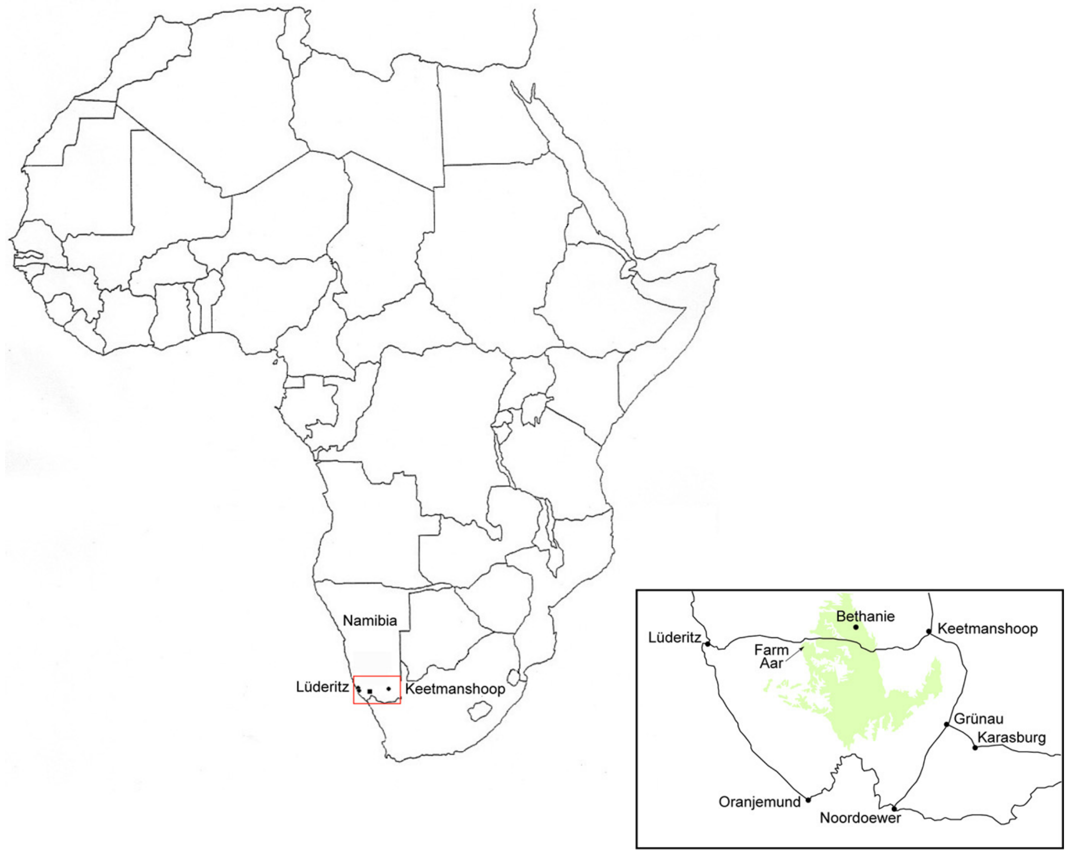

Figure A: Map of southern Namibia with Farm Aar, the region where macroscopic algal assemblages were discovered.

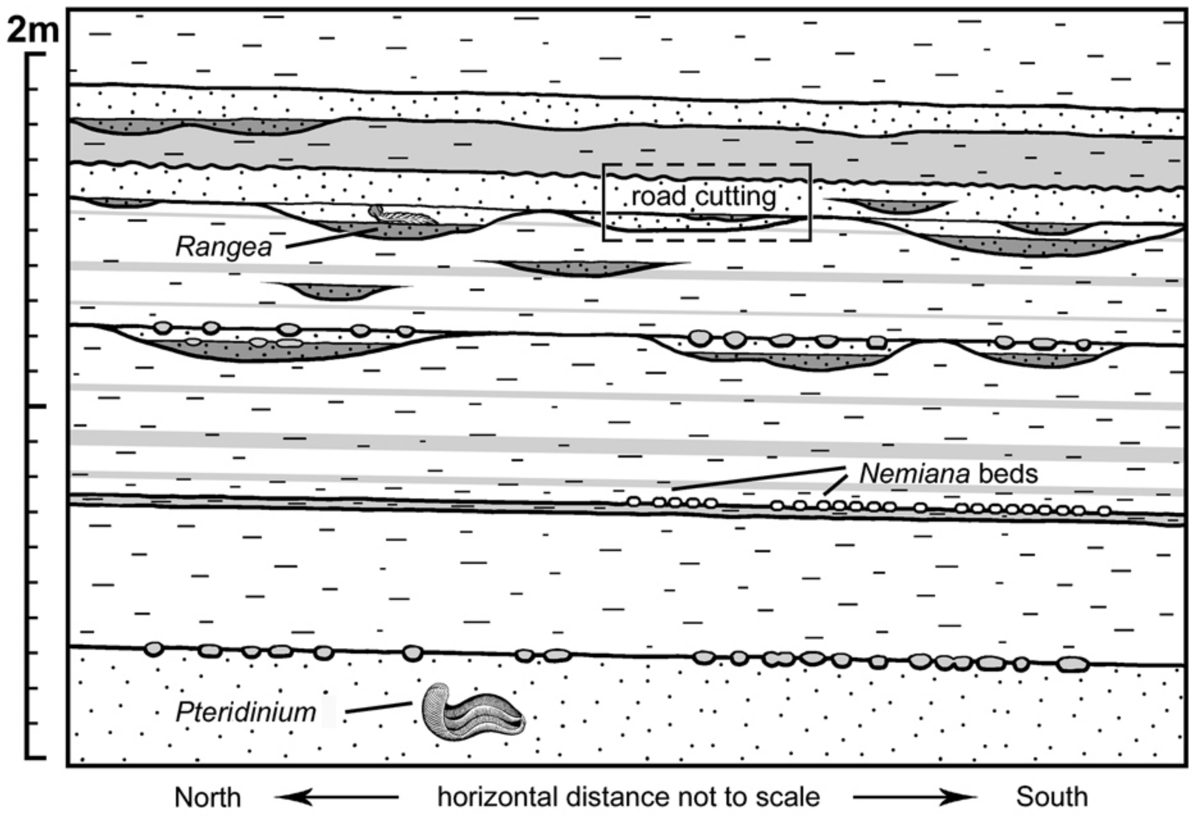

Figure B: Cross-section of the local stratigraphy of the algal concentrations in the Kliphoek Member of the Dabis Formation at Road 2.3 Quarry indicative of the changing shallow marine environments in the area on Farm Aar.

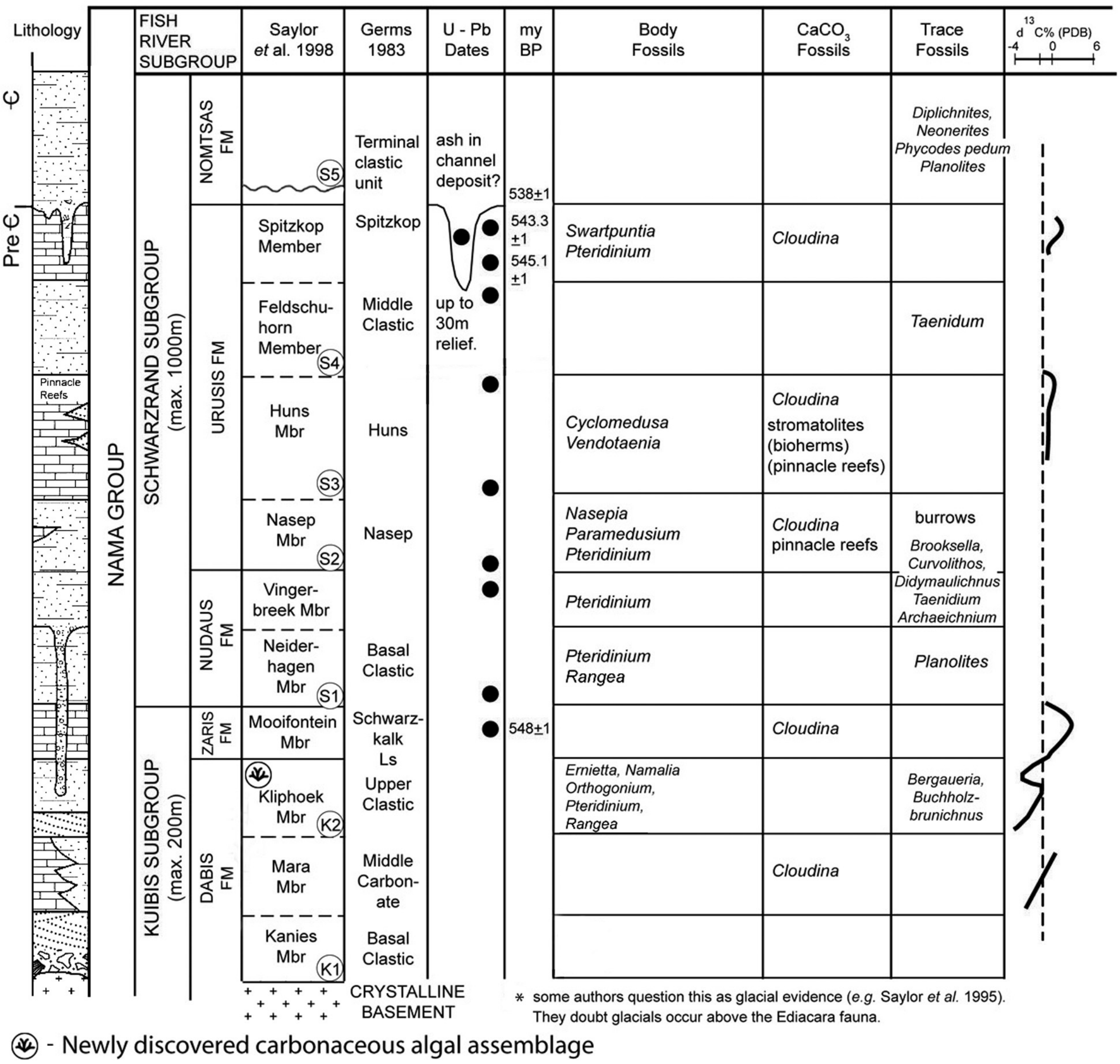

Figure C: Regional setting of the sediments including level of the macroscopic algal assemblage (after Fedonkin *et al*., 2007, with changes).

occur between at least three, possibly four, prominent, regionally extensive limestone beds. In these quartzites, which thin upwards as the carbonates become more prominent, Ediacaran fossils also occur. These quartzites represent upward shallowing sequences, which are overstepped by the transgressive limestones, the upper units of which contain organisms with carbonate-reinforced shells (*Namipoikia* in the uppermost Kliphoek and *Cloudina* in the Mooifontein Member; *Cloudina* is also known from the Mara Member of the Dabis Formation, which underlies the Kliphoek Member).

Channel sands within which *Rangea* fossils occur, lie below the clays bearing the algae, and in turn are underlain by mudstones with local concentrations of *Ernietta*. These channels within the Upper Kliphoek Member record current activity that could be associated with storm-induced, downslope movement of sediments of rather a random nature, which cut small channels as they descended, characteristic of this unit. Saylor *et al*. (1995) and Germs (1972, 1983, 1995) have interpreted the environment of deposition as shallow marine with fluviatile, tidal and storm influences. They have found no indication of subaerial exposure.

Description

The newly described assemblage consists of three distinct algal taxa: *Glomulus filamentum* Steiner, 1994, *Eoholinia fruticulosa* A. Istchenko, 1989, *Tyrasotaenia podolica* Gnilovskaya, 1971, and a fourth whose affinities are not resolved, but which shares some similarities with *Kanilovia* sp.

Glomulus filamentum **Steiner, 1994 (Fig. E, 8)**

Thallus represented by irregular aggregations consisting of numerous unbranched filaments, gathered into

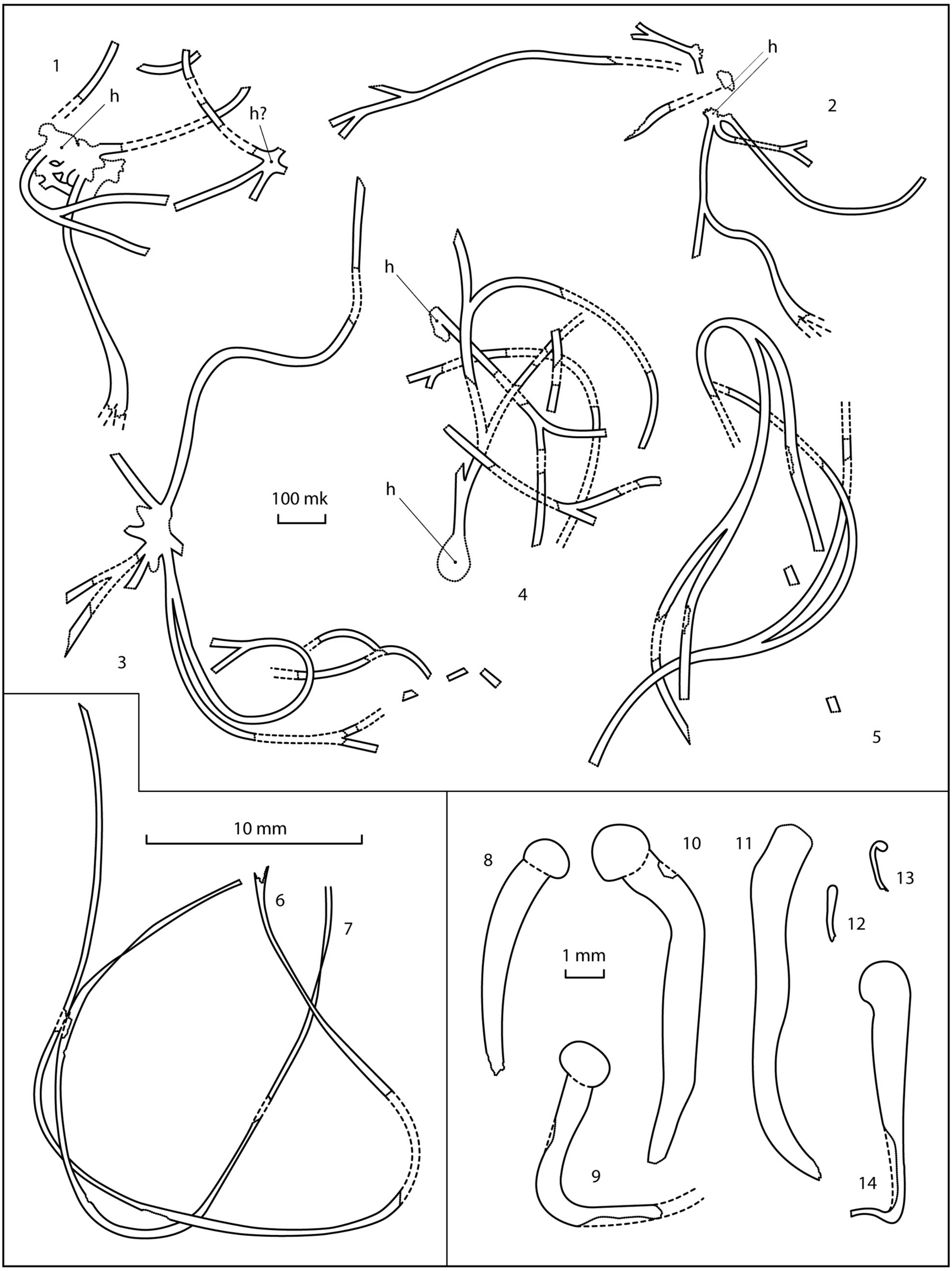

Figure D: Drawings of the general morphology of fossil algae (M. Leonov). (1-5) - *Eoholynia fruticulosa* A. Istchenko, 1989: 1 - specimen # F 663, 2 - F 662, 3 - F 657, 4 - F 658, 5 - F 661, h - holdfast. (6-7) - *Tyrasotaenia podolica* Gnilovskaya, 1971: 6 - F 651, 7 - F 650. (8-14) – cf. *Kanilovia* sp.: 8 - F 672, 9 - F 669, 10 - F 668, 11 - F 670, 12 - F 652, 13 - F 653, 14 - F 671.

multiple sinuous to folded bundles. Colony size usually less than 50 mm across; filaments 12-25 microns in diameter; bundles 150-200 microns wide.

Interpretation of this form is speculative due to its simple morphology. It may represent remains of a cyanobacterial colony with affinity to *Polytrichoides lineatus* (Xiao *et al*., 2002). However, the latter taxon is commonly associated with a thin organic biofilm. The Namibian specimens of *Glomulus filamentum* lay on the surface of clays, which do not bear traces of such a film. Another difference from *Polytrichoides* is that the curvature of the filaments of the Namibian material is different: *Polytrichoides* is characterized by smooth bends on the middle parts of bundles and sharper, sometimes broken bends on the peripheral part of bundles. Bundles of *Glomulus* are always smooth-curved and less dense.

***Eoholinia fruticulosa* A. Istchenko, 1989 (Fig. D, 1-5; Fig. E, 5, 6)**

Bush-like, small-sized algae with holdfasts of amorphous shape and numerous ribbon-like branches of constant width attached to it. Branches bifurcate several times, and form an angle of approximately 40 degrees with each other. This form is distinct in appearance from most of the Doushantuo taxa of bush-like algae, with many axes derived from one holdfast. A. Istchenko (Gnilovskaya *et al*., 1989) noted that narrow stolons connect some specimens of *Eoholynia fruticulosa*. Such stolons may be present in the Namibian material, but it is difficult to ascertain this due to the poor preservation. The size of an individual bush varies from 400 to 1500 microns; width of the axes is about 15-20 microns.

***Tyrasotaenia podolica* Gnilovskaya, 1971 (Fig. D, 6,7; Fig. E, 7)**

Thallus medium-sized (width 0.15-0.43 mm) and tubular with straight margins. Width of the thallus is about constant along each fragment, but phytoleima does not have a constant width due to twisting and curving. Surface is ornamented with thin longitudinal striations. Branching, terminations and holdfasts are not observed. Length of the fragments reaches up to 40 mm.

A form which shares some similarities with *Kanilovia* sp. (Fig. D, 8-14; Fig. E, 1-4)

Medium-sized, short, ribbon-like form without any distinct origin. Ribbons become broader towards the terminus. The terminal part is rounded and broader than the rest of the ribbon. On some specimens the latter is pinched near the terminal structure. Terminal structure is denser and darker in colour than the ribbon. The waist between the terminal structure and ribbon sometimes bears transverse striations. The ribbon itself has thin longitudinal striations. Width of thalli varies from 0.2 to 1.2 mm (values between 0.4 and 0.6 mm are most common). Length of the fragments can reach 10 mm. Two specimens, N F 652 and N F 653, are significantly smaller than all others (width of the thalli is about 0.1 mm), but their morphology is generally the same. Thus, all specimens are here referred to the same taxon, but further study and collection of a larger sample are needed to resolve the identity of this form.

Conclusions

The composition of the macroscopic algal assemblage from the Neoproterozoic of southern Namibia is mixed in biostratigraphic aspect (when compared with known data of algal distribution in the Neoproterozoic sequences of the Russian Platform). Fossils similar in morphology to *Glomulus filamentum* and *Polytrichoides lineatus*, are the most common components of many Neoproterozoic algal assemblages (Hermann, 1990; Xiao *et al*., 2002) and have wide stratigraphic ranges. Possibly these forms represent bundles of cyanobacterial sheaths. *Eoholinia fruticulosa* is a form with relatively narrow time distribution, a characteristic taxon for the lower part of the Redkino regional stage of the Eastern European Platform (Gnilovskaya *et al*., 1989; Leonov and Ragozina, in press). The two other forms, *Tyrasotaenia podolica* and perhaps *Kanilovia* sp., are typical of Kotlin-aged algal assemblages. Such a mixture of taxa is typical of the uppermost part of the Kotlin deposits, the upper part of the Kanillovka Series (Podolia, Ukraine). But joint occurrence of such typical taxa with *Eoholynia fruticulosa* in the newly discovered Namibian assemblage is not at all typical of the Kotlin assemblages of the Eastern European Platform. Nevertheless, the remaining assemblage suggests that the best stratigraphic correlation of the Namibian sediments bearing this new algal assemblage would be with the Upper Kotlin deposits of the Russian Platform. Further collection may more clearly resolve this dilemma.

Acknowledgements

Research was supported by RFBR grant N 08-05-00801-a and grant for leading science schools NSH-4156.2008.5. Field research was funded by a UNESCO grant (IGCP493) to M. A. Fedonkin, P. Vickers-Rich and J. G. Gehling and funds generated by an international exhibition on the late Neoproterozoic organized by scientists in the School of Geosciences, Monash University (Melbourne, Australia) and the Paleontological Institute, RAS, (Moscow, Russia), the Namibian Geological Survey (Windhoek, Namibia), the South Australian Museum (Adelaide, Australia) and Queens University (Ontario, Canada) together with the Monash Science Centre in Melbourne, Australia. We thank Dr Gabi Schneider for access to vehicles and support from the Geological Survey of Namibia, and Barbara Boehm-Ernie and Bruno Boehm for their hospitality and assistance on Farm Aar. Draga Gelt assisted in the graphic design, and Mary Walters is acknowledged for proof reading. K.H. Hoffmann of the Nambian Geological

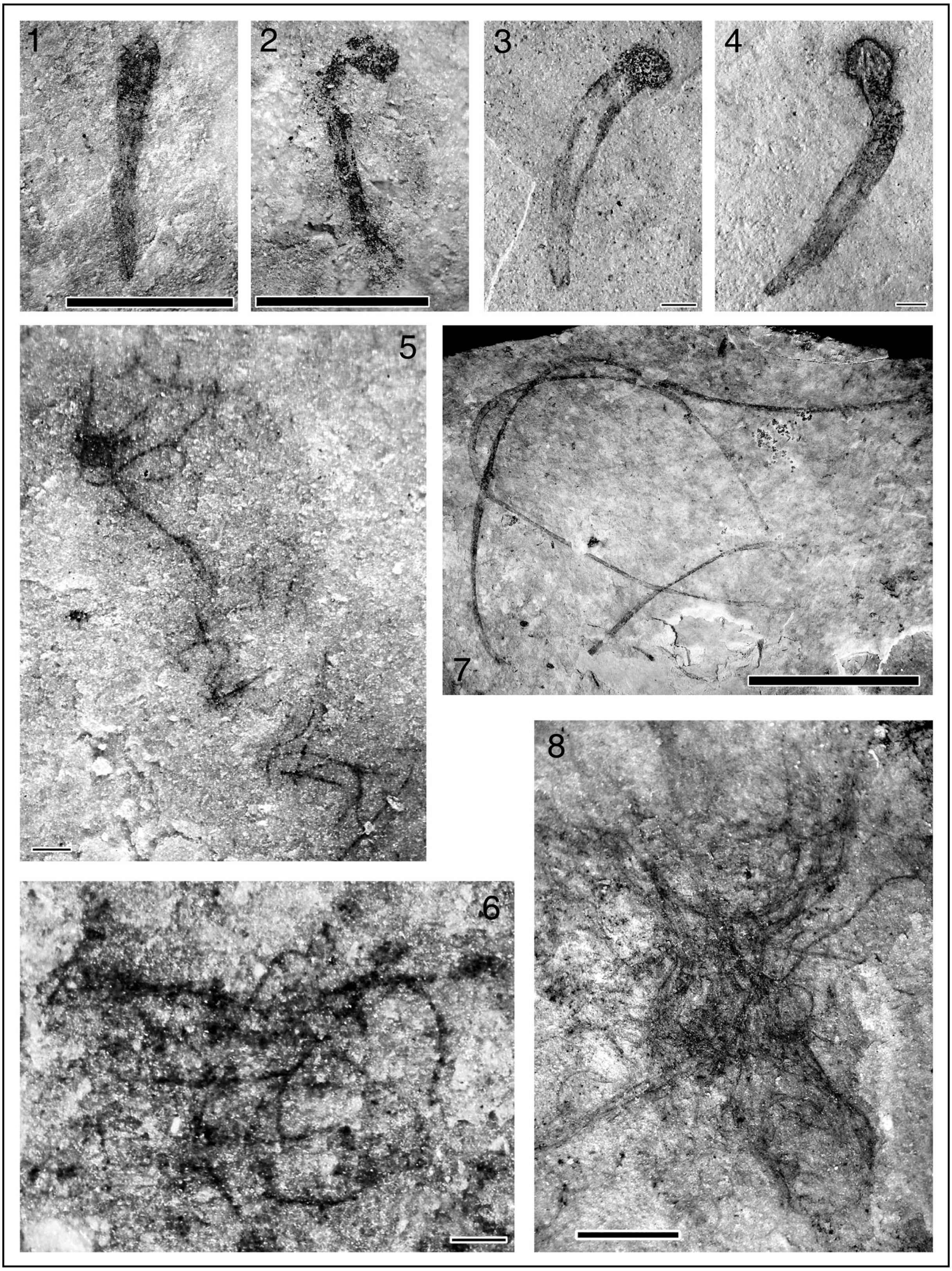

Figure E: 1-4 – cf. *Kanilovia* sp. (scale 1 mm); 1 - specimen # F 652, 2 - F 653, 3 - F 672, 4 - F 668 ; 5, 6 - *Eoholinia fruticulosa* A. Istchenko, 1989 (scale 100 mk); 5 - F 663, 6 - F 658; 7 - *Tyrasotaenia podolica* Gnilovskaya, 1971, F 650, F 651 (scale 1 cm); 8 - *Glomulus filamentum* Steiner, 1994, F 667 (scale 100 mk).

Survey provided important field support and guidance in this project.

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