The origin and ecology of Late Paleozoic *Palaeoaplysina* in Arctic Canada: an aberrant ancestral coralline algae (?) that grew at a time of high atmospheric CO_2

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Summary

Lower Permian reefs are known to form highly productive oil and gas reservoirs. On Ellesmere Island in the Canadian arctic, the organism *Palaeoaplysina* is a dominant biogenic component in carbonate mounds and lenses of Early Permian age. *Palaeoaplysina* is a large, plate-like fossil which was a major reef builder in Upper Carboniferous to Lower Permian reefs and other environments. In Russia some of the world`s most productive structures are hosted in *Palaeoaplysina* reefs with successful explorations undertaken throughout the Urals. Similar build-ups have been exploration targets in the Barents Sea and will likely form a significant part of future exploration in the Canadian Arctic. Although a great deal of research was undertaken in the 1970's and 1980's (for example: Chuvashov, 1973; Davies and Nassichuk, 1973; Beauchamp *et al.*, 1989), many fundamental questions remain unanswered about the origins and significance of *Palaeoaplysina.* The purpose of this study is to provide new insights regarding the biological affinity of the organism *Palaeoaplysina* through a detailed examination of its internal structures and palaeoenvironmental distribution.

Palaeoaplysina flourished under tropical to subtropical conditions along the north-western Pangea margin, and had a paleogeographic range which covered a broad belt from the northwest United States, to western Canada, Yukon, Alaska, Canadian Arctic (Sverdrup Basin), Barents Sea, Timan-Pechora, Ural Mountains, and to the Donets Basin. However their range was confined to this north-western margin belt, and they did not occur anywhere in the Tethys Ocean, nor in the lower latitudes along the western margin of Pangea. This dominance in shallow-water low-latitude areas ended abruptly during the Artinskian when *Palaeoaplysina* disappeared suddenly, creating a huge change in the nature of reefs thereafter. *Palaeoaplysina* is characterized by its platy calcareous skeleton, an internal canal structure, a cellular fabric, and a surface layer of mamelon-like protuberances (Fig. 1). Debate ranges as to the biological affiliation for *Palaeoaplysina* but three main schools of thought dominate; first that it may be a filter-feeding organism such as a sponge or hydrozoan based on the internal canal network and mamelon-like protuberances (Chuvashov, 1973; Davies and Nassichuk, 1973). Second, that it may be photosynthetic ancestral coralline algae as suggested by the presence of a cellular skeleton (Vachard and Kabanov, 2007). A combination of these two lines of evidence may be suggestive of an animal living as a filter-feeding organism that was later encrusted by the red algae *Archaeolithophyllum* (Mamet et al, 1987). Little is known about the biological functions of the living animal. Were the canals truly interconnected and functional? The role of the

mamelons is also still obscure, although these oddly shaped features may represent preservation of reproductive budding. Additionally, it is still unclear as to their role in the reef ecosystem. Was *Palaeoaplysina* an active participant in the reef building process as a binder, baffler or by acting as a solid pavement surface for other organisms to grow on, or were they more passive, contributing little to the erection of the reef and simply providing sediments?

To address some of the many issues surrounding *Palaeoaplysina*, its biological affinity, its ecology and its contribution to the growth of reefs along the northwestern margin of Pangea, hundreds of thin-sections from four different sections visited from 1983 to 1989 along the northern (Axel Heiberg) and southern (Raanes Peninsula) were examined to garner knowledge about the stratigraphic range and evolutionary trend of *Palaeoaplysina*. In addition, thin-sections from one exceptionally preserved occurrence of *Palaeoaplysina* from East Blind Fiord, SW Ellesmere were also examined for details about the composition and physical structure of the organism.

Particularly well preserved *Palaeoaplysina* specimens display a cellular structure that is nearly identical to that of the ancestral coralline alga *Archaeolithophyllum*, which is broadly developed in contemporaneous strata at lower paleo latitudes. The cellular network is broadly divided into a peripheral area of very small cells (10-20µm) and a larger internal area of larger cells (30-50µm) which are similar to the epithallium and hypothallium of *Archaeolithophyllum*. Furthermore, the small-celled "epithallium" area perfectly wraps around the "canals" suggesting that these are simply holes within *Palaeoaplysina* that may have played a role in increasing its surface area and allowing growth to enormous size and length. Unlike *Archaeolithophyllum*, however, *Palaeoaplysina* plates are pierced by a series of canal-like holes and "tubes" which some authors believe are indicative of a filter-feeding animal, such as a sponge or a hydrozoan. Investigations were carried out to map the connectivity of these canals in order to suggest possible functions.

Variation in size and canal morphology and complexity suggest the presence of at most three forms over the measured sections. By and large, the number, size and internal complexity of *Palaeoaplysina* increases up until the Early Sakmarian when some individual plates were observed to be nearly 1 cm thick and 0.5 m in length. These abundant, large and complex occurrences of *Palaeoaplysina* coincides with the culmination of algal growth in the Sverdrup Basin, when a plethora of small and large red, green and blue-green algae (stacheins, *Tubiphytes*, phylloid, dasycladaceans, *Nansenella*, *Ellesmerella*, etc.) developed in all shallow mid to inner shelf environments, suggesting a possible algal affinity.

It may be significant that the maximum development of *Palaeoaplysina* around NW Pangea occurs at the time of well-documented CO_2 build-up in the atmosphere and associated global warming, immediately before the demise of Gondwana glaciers. Our preliminary study, to be confirmed by further microscopic analysis and geochemistry, does suggest that *Palaeoaplysina* is indeed an ancestral coralline algae, but one of aberrant size and shape which may in part have resulted from a high atmospheric pCO_2 at the time. In that sense, our interpretation is similar to that of Vachard and Kabanov (2007) who consider that *Palaeoaplysina* was related to *Archaeolithophyllum*, and to that of G.R. Davies who evoked, more than once (e.g. Davies and Nassichuk, 1973) the possibility that *Palaeoaplysina* was an "aberrant algal form". This study

has important implications for our understanding of global climactic shifts and ocean calcium carbonate saturation levels. The unique paleobiogeographic distribution of *Palaeoaplysina*, its particular calcifying fabric and its poorly understood biological affinity may provide information with regards to the carbonate saturation along the western margin of Pangea at a time of global warming prior to a global crisis in the global production of carbonates.

Acknowledgements

This study greatly benefited from input from Steve Grasby of the GSC. Additional feedback from the members of the Center for Applied Basin Studies (CABS) was also appreciated. Funding for this project was largely supplied by NSERC and the Department of Geosciences at the University of Calgary.

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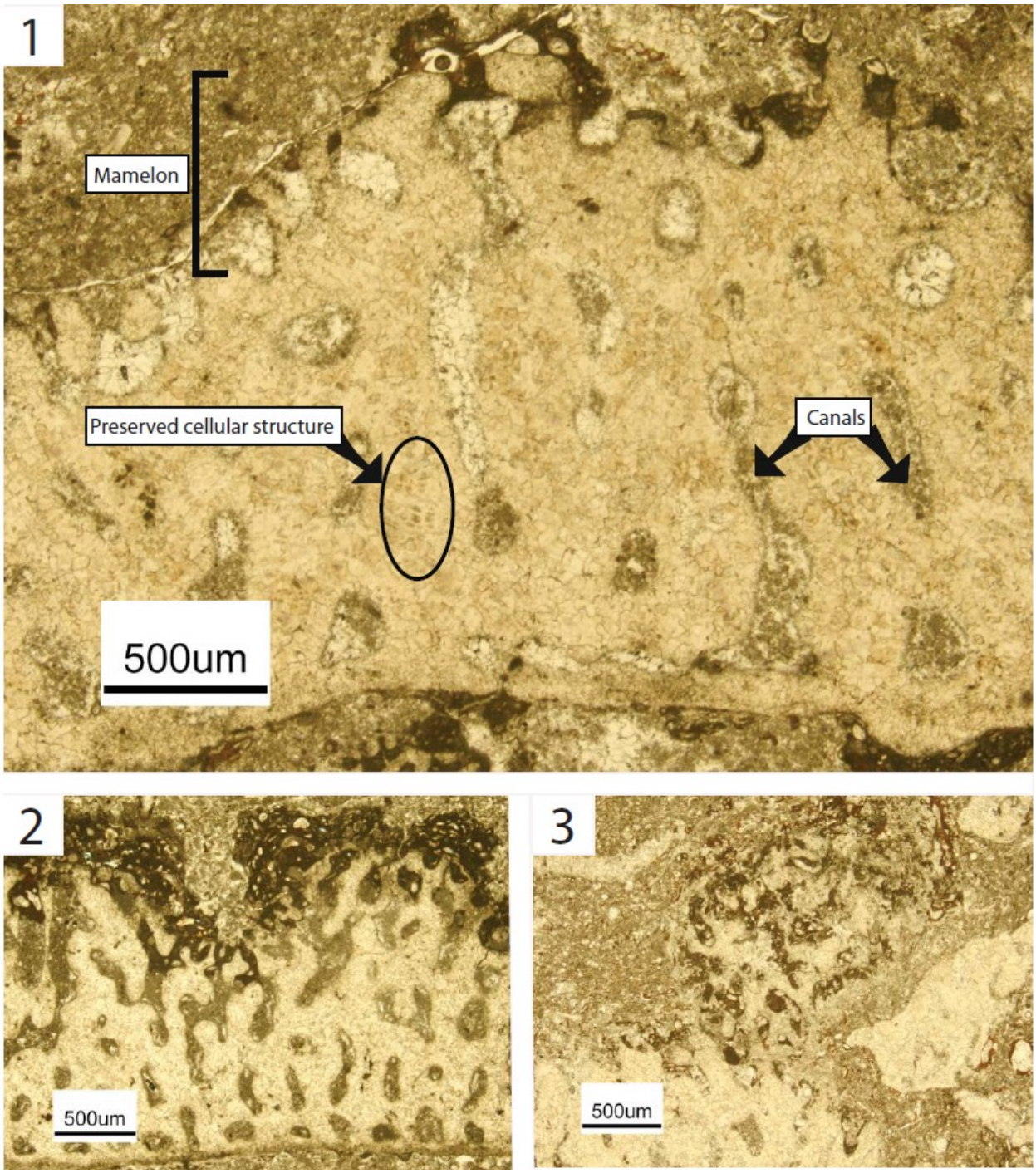

Fig. 1.- Well preserved *Palaeoaplysina* plates from East Blind Fiord, SW Ellesmere. Excellent preservation allows examination of internal structures 1) Plate displaying preserved cellular texture between canals. Canals are mostly filled by sparry cement, but may also contain some dark sediment. 2) *Palaeoaplysina* with closely spaced upper mamelons. Encrusters preferentially on top of mamelons suggest the way up. 3) *Palaeoaplysina* with elongated mamelon structure resembling a budding structure.