Field report: Expedition C-22-36, "Ecosystem change across the Devonian-Carboniferous boundary in East Greenland"

Fieldwork was carried out between 21 July and 18 August 2022, in upper Famennian (Late Devonian) and lowermost Tournaisian (Early Carboniferous) strata on the south and west faces of Celsius Bjerg, Ymer Ø, north-east Greenland (**Figure 1**). The participants were Per Ahlberg, Grzegorz Niedzwiedzki, Henning Blom and Martin Qvarnström (all Uppsala University, Sweden), John Marshall (University of Southampton, UK) and Alex Chavanne (field manager). Robert Gess (Rhodes University, South Africa) was meant to participate but had to drop out at the last moment becauseo f a medical emergency.

Background:

The overall aim of the expedition was to investigate the response of the terrestrial ecosystem, and in particular the tetrapods (land vertebrates), to the end-Devonian extinction event. This question has been a major focus of interest in the palaeontological community for several decades. Tetrapods originated during the Devonian, and the first mass extinction that they encountered was the so-called Hangenberg Crisis at the end of the Devonian. The 20 million years after the extinction event have a very sparse tetrapod fossil record, a phenomenon known as 'Romer's Gap'. It is widely believed that the evolutionary radiation of the modern tetrapod groups - amphibians and amniotes - began during Romer's Gap, but in fact the response of tetrapods to this event is far from clear. Part of the problem is that we have until now had little idea of what the tetrapod faunas of the latest Devonian were like: 'classic' Devonian tetrapods like *Acanthostega* and *Ichthyostega* date to a couple of million years before the extinction event, and are thus not necessarily informative about the kinds of tetrapod faunas that were impacted by the extinction. The purpose of our expedition was to remedy this deficiency. Greenland has one of the best terrestrial sedimentary sequences in the world crossing the Devonian-Carboniferous boundary. We intended to search the latest Devonian Stensiö Bjerg Formation for tetrapod fossils and investigate the boundary-spanning Obrutschew Bjerg Formation for evidence of the extinction event itself.

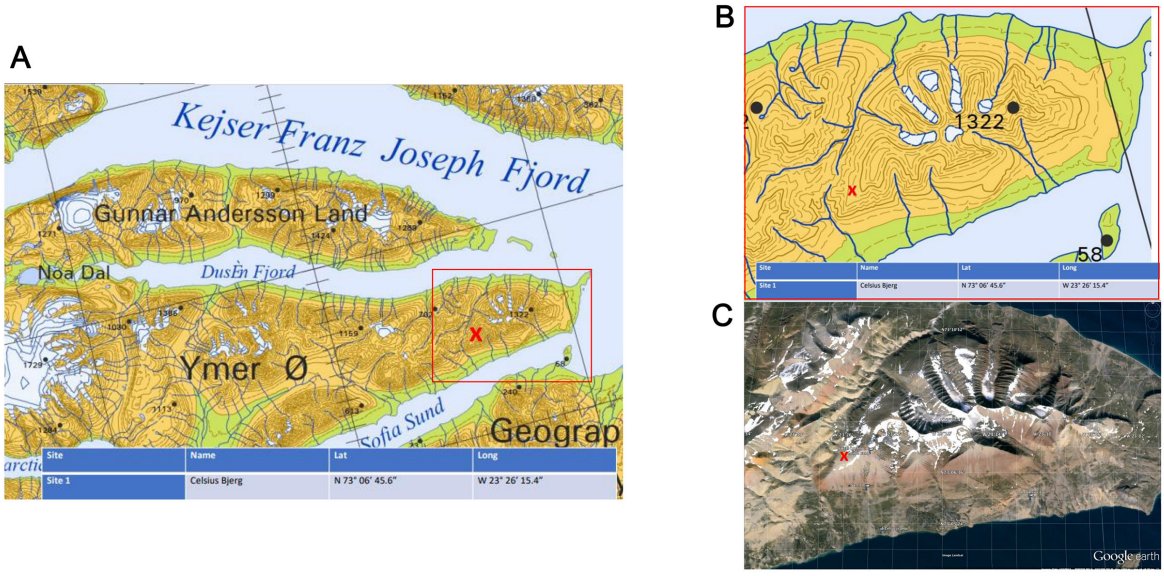

Figure 1. Map of the field area A, overview map of Ymer Ø, with red rectangle indicating the Celsius Bjerg area and red x, the camp site. B, detail image of area in rectangle. C, same in satellite view.

Results:

The two main targets were a tetrapod-bearing bone bed at the top of the Stensiö Bjerg Formation (uppermost Famennian), located at an altitude of approximately 1000m on the south-west ridge of Celsius Bjerg, and an outcrop of the overlying Obrutschew Bjerg Formation

which straddles the Devonian-Carboniferous boundary, about 20 m higher up on the same ridge (**Figure 1**). A sedimentary core was bored through the Obrutschew Bjerg Formation (which is about 1m in thick) by John Marshall, who is studying the geochemical signature of the end-Devonian extinction horizon, which lies within this formation. This core and other sedimentary samples are now in Southampton where they are being analysed. John Marshall and Per Ahlberg also made a stratigraphic log though the upper part of the Stensiö Bjerg Formation, across the Obrutschew Bjerg Formation, and up into the overlying Harder Bjerg Formation (Tournaisian), and took sediment samples for palynological analysis at intervals. These samples are being analysed in Southampton.

The tetrapod-bearing bone bed comprises a 7m thick sequence of overbank muds and fine sands, capped by a thinly bedded sandstone. Most of this is exposed as a near-horizontal and heavily weathered surface on which tetrapod fragments appear as 'float', but at the top of the sequence a well-lithified level just below the capping sandstone can be extracted in blocks. These blocks are full of tetrapod bones (**Figure 2**). We collected approximately 200kg of blocks, which are currently housed in dedicated storage at the Museum of Evolution, Uppsala University, but which will be returned to Copenhagen at the end of the project. Their contents are being studied by means of synchrotron microtomography at the European Synchrotron Radiation Facility (ESRF) in Grenoble, France; this technique is non-invasive and non-destructive, requiring no chemical or mechanical preparation of the blocks, so with very few exceptions the blocks will be returned in 'field condition' as found.

Figure 2. Left, tetrapod skull roof and braincase at the tetrapod locality, with Sofia Sund in background. Right, counterpart of same specimen.

We are only beginning to work through the data from our first scanning session at ESRF in February 2023, but it is already clear that the tetrapod bed is extraordinarily rich and will change our understanding of the end-Devonian tetrapod fauna, not just of Greenland but of the world. The past 90 years of collecting in the Famennian of Greenland has produced four valid tetrapod taxa: *Ichthyostega* (Säve-Söderbergh 1932), *Acanthostega* (Jarvik 1952), *Ymeria* (Clack et al. 2012) and *Brittagnathus* (Ahlberg & Clack 2020). We now have at least another four, and probably several more. The material includes both isolated bones and partially articulated heads and bodies. We have also found soft-tissue preservation, including the only known example of structurally preserved Devonian tetrapod skin. In summary, this is the most important Devonian tetrapod discovery in Greenland since the famous 1987 expedition led by Jennifer Clack, which discovered the *Acanthostega* mass-death deposit on Stensiö Bjerg. In addition to the tetrapod body fossils we found a number of footprints and two body impressions (the only known examples from the Devonian), which were recorded with

3D optical scanner and left in situ. Non-tetrapod discoveries from the same level include numerous lycopod tree logs and several *Stigmaria* rooting systems, which are among the earliest known. These remain in situ.

We intend to apply for permission for a follow-up expedition in July-August 2025. 2023-24 will be spent working up and describing the material from the 2022 expedition.

Per Erik Ahlberg
Uppsala, 31 May 2023