The Ellesmerian Orogeny: Fact or Fiction?

Stephen Rippington
CASP, University of Cambridge, 181a Huntingdon Road, Cambridge, UK
steve.rippington@casp.cam.ac.uk

Robert A. Scott, Helen Smyth, Olga Bogolepova, Alexander Gubanov
CASP, University of Cambridge, 181a Huntingdon Road, Cambridge, UK

Summary

Palaeogeographical reconstructions of the Arctic are impeded by uncertainties surrounding key tectonic events, of which the late Devonian to early Carboniferous Ellesmerian Orogeny is one of the most enigmatic. Despite abundant published evidence, including reports of a regional unconformity, contractional deformation belts and magmatism of late Devonian to early Carboniferous age, in regions as diverse as the north slope of Alaska, north Yukon, the Canadian Arctic Islands, north Greenland, Svalbard, Severnaya Zemlya, the New Siberian Islands, Verkhoyansk and Chukotka, there is no consensus on how these features relate to each other.

A critical appraisal of the published evidence for Ellesmerian tectonism reveals that many of these structures lack sufficient age constraints to be interpreted as unequivocally Ellesmerian. A programme of circum-Arctic literature reviews, GIS-based studies and structural fieldwork on Ellesmere Island is beginning to clarify our understanding of the tectonic evolution of the Arctic in the mid-Palaeozoic and has highlighted key areas for further study.

Introduction

Thorsteinsson and Tozer (1957) first used the term Ellesmerian Orogeny in reference to the late Devonian to early Carboniferous tectonic event which ended deposition of the Franklinian succession and preceeded initiation of Sverdrup Basin sedimentation in the Canadian Arctic. This event is expressed in folded Fammenian strata overlain by undeformed Viséan strata on central Ellesmere Island. Following this early work, accounts of contractional deformation in the Yukon (e.g. Lane 2007), the Canadian Arctic (e.g. Piepjohn et al. 2008), north Greenland (e.g. Soper & Higgins 1990) and Svalbard (e.g. Piepjohn 2000) have been attributed to the Ellesmerian Orogeny. Further afield, a regional unconformity, magmatism and contractional deformation of late Devonian to early Carboniferous age have also been reported on Severnaya Zemlya and in the New Siberian Islands (Fig. 1). Evidence for circum-Arctic tectonism in the late Devonian to early Carboniferous is abundant. However, the relationship between these structures is unclear. Consequently, the extent, timing and geodynamic cause of Ellesmerian tectonism are poorly understood.

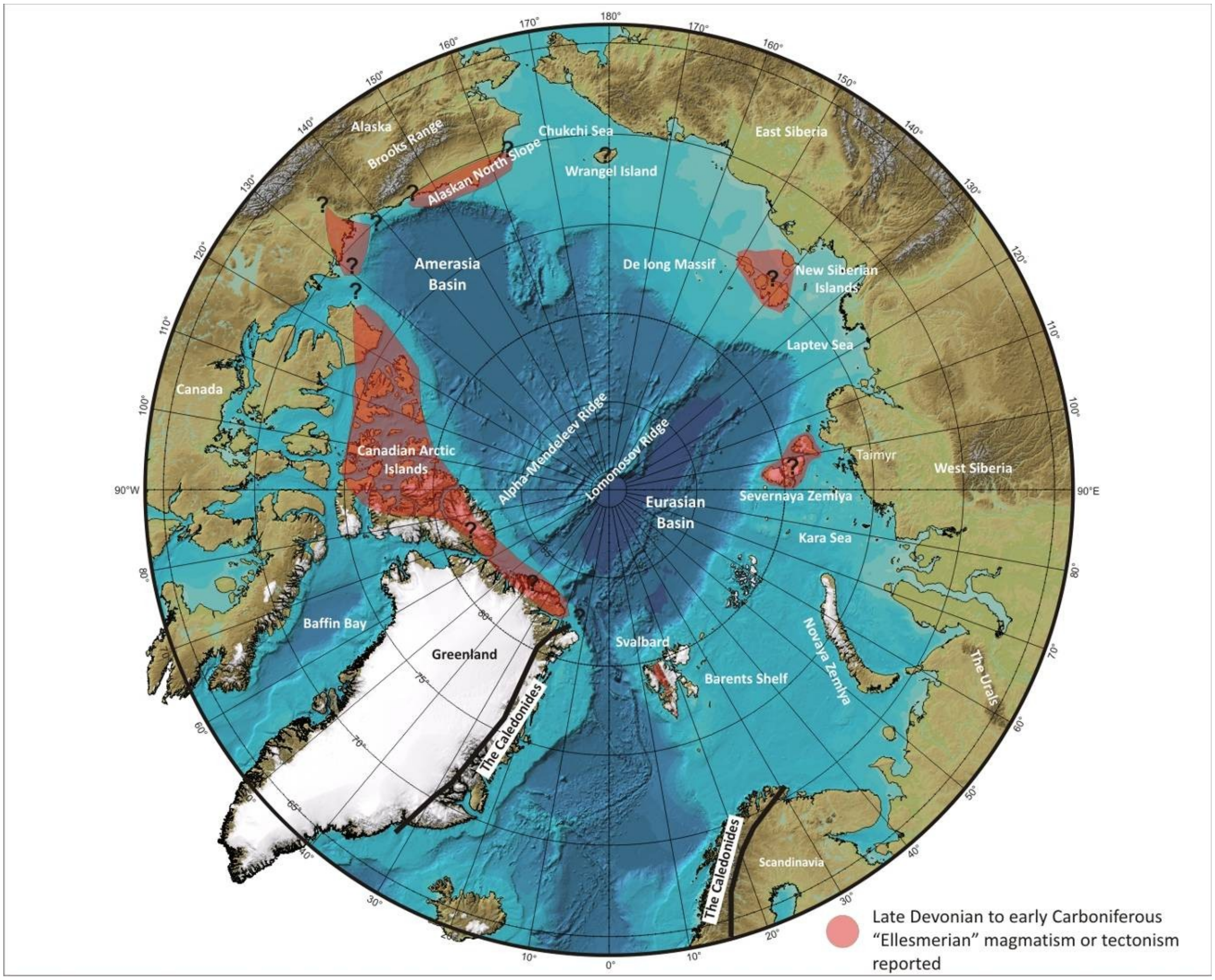

Figure 1. Map of the Arctic showing locations where evidence for Late Devonian to early Carboniferous tectonism has been cited in literature. Base map from IBCAO 2008.

Approaching the problem

A critical appraisal of geological maps and published literature suggests much of the evidence used to support an Ellesmerian origin for structures reported in the circum-Arctic is poorly constrained. To investigate the published evidence for Ellesmerian tectonism, a GIS-based structural database for key areas in the circum-Arctic is in production. The data used for this study have been obtained from published geological maps and reports based on field observations. Cross-cutting field relationships and in some cases published radiometric dates have been used to assign ages to the structures in the database, providing an interactive tool for identifying tectonically active periods. GIS databases of structures in Svalbard and north Greenland have already been completed, and work is underway on a GIS-based structural database for Ellesmere Island.

The GIS-based structural database has proved exceptionally useful for filtering out poorly constrained evidence, leaving a clearer picture of which structures can be confidently attributed to Ellesmerian tectonism. The resulting model suggests that Ellesmerian tectonism is less widespread than previously thought. In conjunction with the GIS-based review, there is an ongoing programme of fieldwork in the Canadian Arctic. In summer 2009, a team of 5 geologists from CASP completed a 7 week field season in Lake Hazen on Ellesmere Island (Fig. 2). Three detailed structural transects were carried out through the polydeformed Cambrian Grantland Formation and into the Sverdrup succession. Samples were taken for microstructural analysis and radiometric dating of cleavage-forming mica minerals. The data from this field season will give a better understanding of the potential role of Ellesmerian tectonism in the tectonic evolution of the region. Fieldwork planned for next year will focus on the late Devonian to early Carboniferous unconformity on the Raanes Peninsula, and will provide an opportunity to compare and contrast Ellesmerian and Eurekan structures on central Ellesmere Island.

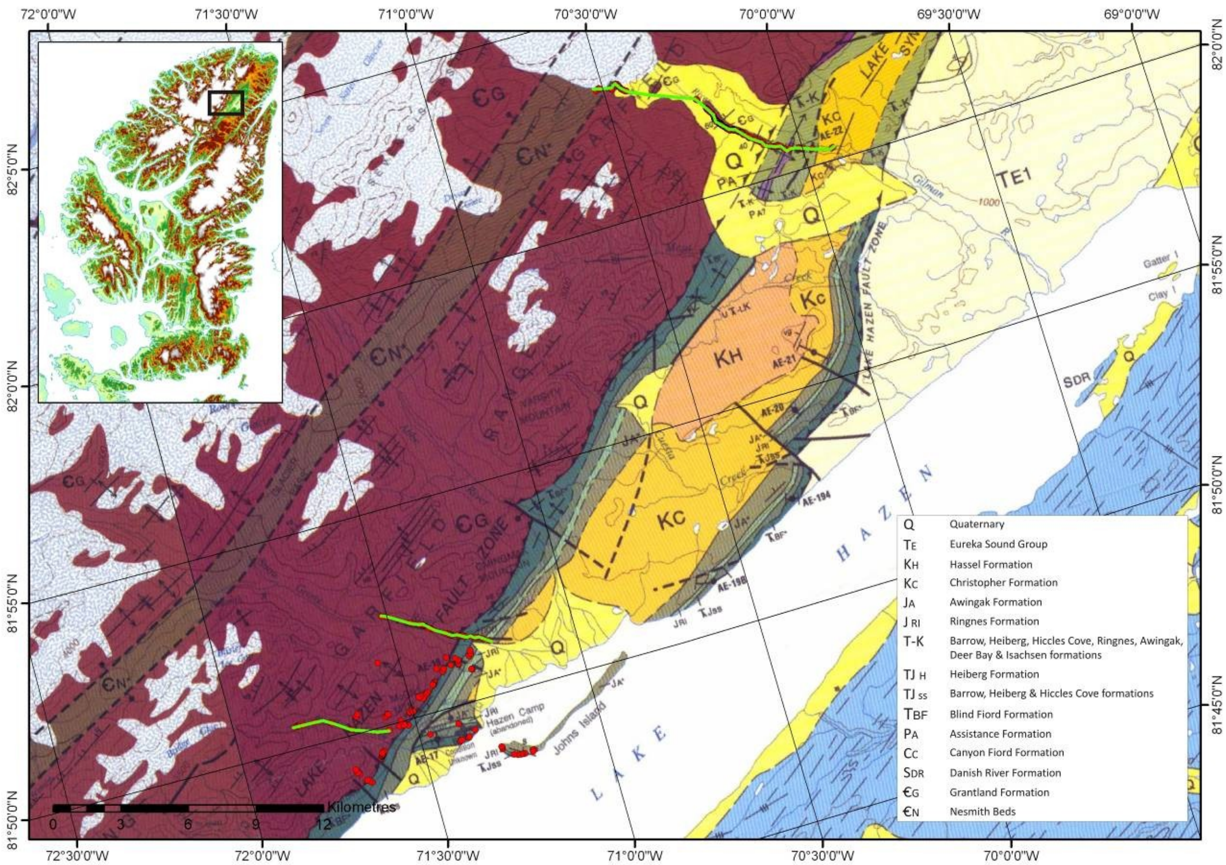

Figure 2. Geological map of Lake Hazen (after Mayr & Trettin 1996) and the location on Ellesmere Island (inset). Green lines show locations of structural transects and red dots show locations where additional structural observations were made by S.Rippington.

Initial results

A critical appraisal of structural evidence for Ellesmerian tectonism in north Greenland and Svalbard indicates that the only place where unequivocal Ellesmerian structures can be identified is Dicksonland, on central Spitsbergen. In this area, late Devonian strata are folded and cut by thrust faults, but are unconformably overlain by undeformed Viséan strata. However, in north Greenland, south-vergent folds and south-directed thrust faults cutting the Cambrian to Silurian strata are not constrained by younger strata. Therefore, it is possible that the structures in north Greenland relate to older events (i.e. Late Caledonian). Similarly, due to a lack of suitable cross-cutting field relationships, it is not possible to rule out older tectonism as the cause of contractional deformation in Cambrian to Silurian rocks in northeast Ellesmere Island.

During fieldwork at Lake Hazen in northeast Ellesmere Island, three phases of contractional deformation have been documented in the Cambrian Grantland Formation. During D1, bedding was folded into upright to southeast-vergent open folds of bedding and an S1 cleavage formed. During D2, southeast-vergent folds of cleavage and bedding were formed and some F1 folds were tightened. D1 and D2 do not affect the Permian to Cretaceous Sverdrup succession; however, there are no further age constraints. Radiometric dating of cleavage-forming micas should give constrain the timing of D1, and will help us determine whether it is Ellesmerian or older. D3 deformation locally deforms Cenozoic strata in the region along southeast-directed brittle thrust faults, and is attributed to Eurekan tectonism.

Conclusions

Current understanding of the extent, timing and geodynamic cause of Ellesmerian tectonism is hampered by regional correlation of structures where ages are poorly constrained. Many of the structures attributed to Ellesmerian tectonism in Svalbard, north Greenland and northeastern Ellesmere Island lack suitable cross-cutting field relationships with younger strata to rule out their formation during other tectonic events. It is therefore essential to appraise evidence critically for Ellesmerian tectonism elsewhere in the Arctic, and to continue to collect new evidence through an ongoing programme of fieldwork and sample analysis. Until the extent and timing of Ellesmerian tectonism are better understood, it will not be possible to determine its geodynamic cause.

Acknowledgements

We would like to extend our thanks to the Polar Continental Shelf Programme, Nunavut Research Institute and Parks Canada. We also appreciate the invaluable support offered by the Parks Canada personnel in Quttinirpaaq National Park.

References

Lane, L.S., 2007, Devonian-Carboniferous paleogeography and orogenesis, northern Yukon and adjacent Arctic Alaska: Canadian Journal of Earth Science, 44, 679-694.

Mayr, U., and Trettin, H.P., 1996, Map 1883A Geology of the Clements Markham Inlet and part of Robeson Channel, District of Franklin, Northwest Territories: Geological Survey of Canada, Ottawa.

Piepjohn, K., 2000, The Svalbardian-Ellesmerian deformation of the Old Red Sandstone and the pore-Devonian basement in NW Spitsbergen (Svalbard): in Friend, P.F., and Williams, B.P.J., New Perspectives on the Old Red Sandstone: Geological Society, London, Special Publications, 180, 585-601.

Piepjohn, K., von Gosen, W., Tessensohn, F., and Saalmann, K., 2008, Ellesmerian fold-and-thrust belt (northeast Ellesmere Island, Nunavut) and its Eurekan overprint: Geological Survey of Canada Bulletin, 592, 285-303.

Soper, N.J., and Higgins, A.K., 1990, Models for the Ellesmerian mountain front in North Greenland: a basin margin inverted by basement uplift: Journal of Structural Geology, 12(1), 83-97.

Thorsteinsson, R., and Tozer, E.T., 1957, Geological Investigations in Ellesmere and Axel Heiberg Islands, 1956: Arctic, 10, 2-31,