

# Chronostratigraphic framework and environmental setting of Upper Jurassic-Paleogene strata: a multi-national project to address large-scale integrated correlations and paleogeographic reconstructions of the Canadian Arctic

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## Introduction

Rapid climate and environmental change has created significant government and international research interest in Canada's Arctic region. The Arctic basins provide a singular record of Late Jurassic to Paleogene sedimentation and geological history in the high Boreal region. This stratigraphic record provides a unique opportunity to study ecosystems of a past geological time when predominantly greenhouse climates prevailed. Large-scale stratigraphic and sequence stratigraphic correlations require biostratigraphic and chronostratigraphic frameworks. Detailed documentation of multitaxial faunal and floral successions will provide a necessary framework to enhance our understanding of tectonism, sea-level history, and paleoceanographic changes that are recorded in the stratigraphic record of the Arctic basins. A pan-Arctic approach is needed to improve existing paleogeographic reconstructions.

## The GEM-Energy Program

The Government of Canada is investing significant resources in its Geo-mapping for Energy and Minerals (GEM) program, to provide the necessary geoscience information to guide investment decisions leading to the discovery and development of new energy and mineral resources in the Far North. GEM-Energy is the portion of the GEM program devoted to delivery of geoscience knowledge related to energy development. GEM-Energy is being delivered federally by the Geological Survey of Canada (GSC) and the Polar Continental Shelf Project (PCSP), both of Natural Resources Canada (NRCan).

Multidisciplinary biostratigraphic and chronostratigraphic research under the auspices of GEM-Energy will integrate activities of numerous national and international research organizations, as well as contributions from industry. GEM is focused on targeted geologic studies in the Arctic, where there are large areas with insufficient public geoscience information to attract and guide effective private sector investment. GEM will also emphasize the training of the next generation of Canadian geoscientists required to remedy the current and future capacity gap, and contribute to the creation and retention of prosperity and well-being in Canada's North.

GEM is supporting multidisciplinary geologic projects targeting sedimentary basins in the eastern, western, and High Arctic region. In the eastern Arctic, Cretaceous and Paleogene strata of Bylot Trough are being reviewed for hydrocarbon potential. Western Arctic studies are examining Jurassic-Cretaceous strata in the Eagle Plain as well as the Mackenzie Corridor and Delta regions of Yukon and Northwest Territories. Upper Jurassic-Cretaceous strata of the Sverdrup basin in the High Arctic are the focus of geologic mapping and structural studies. Together, these projects profit from an integrated biostratigraphic and chronostratigraphic framework based on multiple taxonomic groups.

## **CASP**

CASP (formerly known as the Cambridge Arctic Shelf Programme) is a non-profit organisation affiliated to the Department of Earth Sciences at the University of Cambridge, UK. CASP's objectives are the advancement of public education by conducting geological research and the publication of the useful results of such research. CASP undertakes field and analytical studies in diverse and remote areas, and the organization has many years of circum-Arctic experience in areas such as East Greenland, Spitsbergen, and Russia. Since 2007 CASP has been working in the eastern Sverdrup basin. Through collaboration with Canadian institutions, CASP will integrate data from sites in the eastern Sverdrup basin with the existing literature and studies undertaken under the GEM program, to further understanding of the lithostratigraphic and biostratigraphic framework of the region.

## **Chronostratigraphic Framework**

The key to an accurate biostratigraphy is an integrated biostratigraphic approach: the more taxonomic groups utilized, the better will be the constraints on age. Combine this with isotope stratigraphy, and a powerful tool is available to construct a comprehensive time framework for any regional study. To date, biostratigraphic correlations of Upper Jurassic-Paleogene strata within the Arctic basins have relied predominantly on mollusks (ammonites and bivalves; e.g. Jeletzky, 1971), foraminifera (e.g. Sliter, 1981; Wall, 1983), and palynology (e.g. Núñez-Betelu and Hills, 1994; Hills and Strong, 2007). Diatom zonation is emerging for the Upper Cretaceous interval (Tapia and Harwood, 2002). Lack of abundant carbonate in Upper Jurassic-Paleogene successions limits the use of calcareous nannofossils, although they have so far been little sought for in the Arctic basins. Distribution of these fossil groups was controlled variously by sea-level trends, active tectonism, ocean temperatures and chemistry, and each of the groups has limitations on its environmental range, utility, and applicability.

Biostratigraphic zonation established for each of the principal fossil groups employed in the Canadian Arctic basins to date contain gaps related to lack of sampling or poor return, and systematic integrated sampling for all fossil groups has not been previously undertaken. Similarly, the extent of facies control on benthic faunal successions has not been fully established. Petroleum assessment analysis and exploration modeling has recognized the value of biostratigraphic correlation frameworks, but has also demonstrated the limitations inherent in some schemes, particularly when applied to widely disparate facies, characteristic of differing depositional environments. Practical utilization of the local biostratigraphic schemes shows that they are often strongly influenced by paleoclimatic, paleoenvironmental, and paleoceanic factors, thus limiting their chronostratigraphic value.

Fortunately, many of the molluscan taxa found in the Canadian Arctic Upper Jurassic-Paleogene are broadly distributed environmentally, and also found in northern European basins, allowing important correlation ties to be made at specific stratigraphic levels and providing age constraints on associated facies-restricted faunal and floral groups. In general, molluscan taxa are short-ranging temporally and less restricted paleoenvironmentally than are benthic foraminifera, but the latter are significantly more abundant in many sedimentary sections,

enhancing their value in local correlations and small subsurface core samples. Both groups are typically constrained to marine facies, of little value in correlation of non-marine or coarse-clastic shoreface deposits. Integrated biostratigraphic analysis incorporating both these groups with palynology will help to bridge the ‘biostratigraphic gap’ in correlation between marine and non-marine environments. A comprehensive chronostratigraphic framework will reduce limitations imposed by variations in paleoenvironment, thus enhancing circum-Arctic regional and global stratigraphic correlations, and working towards a unified international standard zonation.

## Understanding Paleoclimate and Paleogeography

The Canadian Arctic basins were located at a nodal point for faunal migration between the North American Western Interior Sea to the south, the basins of northern and central Europe to the east, and the vast proto-Pacific basins to the west. Incorporating data from the Western Interior Sea, as well as Greenland to the east, the new Arctic chronostratigraphic framework will allow a comprehensive review of pan-Arctic stratigraphy and correlations. Targeted study areas in the GEM program provide key opportunities to assess the paleoceanographic and paleogeographic interplay between the Boreal Sea and the Western Interior Sea, where strong tectonic activity produced periodic uplifts and consequent rapid and substantial changes in the geometry of the seaway, with associated changes in paleocirculation, ocean geochemistry, and faunal and floral assemblages. Differential and competing sea-level trends, tectonic processes, and paleoclimatic and paleogeographic patterns produced numerous, apparently widely-developed unconformities in the Upper Jurassic-Paleogene stratigraphic record of the Arctic basins, the extent of which have yet to be fully documented. Associated research utilizing detrital zircon provenance studies will help to constrain source terrains, sediment dispersal patterns, and basin accumulation histories.

Repeated Oceanic Anoxic Events (OAEs) are globally documented for the Cretaceous Period, but their effects on the Boreal Sea are not yet understood. Detailed ocean chemistry analysis utilizing carbon isotopes tied to the chronostratigraphic framework will allow enhanced understanding of paleoclimatic and paleoceanic controls which influenced organic evolution in the Arctic region, as well as faunal migration patterns between the Boreal seas and the lower latitudes, including the Western Interior Sea. Through integration of detailed faunal and floral biostratigraphy, basin sedimentation histories, and ocean sediment geochemistry, a comprehensive understanding of the evolving late Mesozoic climate of the Arctic region will be achieved.

## Principal Objectives

Specific objectives for GEM-supported research include:

- Establishment of an Upper Jurassic-Paleogene bio- and chronostratigraphic framework for the basins of Arctic Canada, integrating macro- and microfossil faunal and floral groups
- Assessment of the potential for calcareous nannofossils within the biostratigraphic framework
- Identification of, and distinction between, facies-related microfossil zonal markers and facies-independent first and last species occurrences
- Assessment of the link between Cretaceous tectonics and basin architectures, sea-level histories, and faunal response
- Verification and correlation of widespread Cretaceous unconformities, to aid establishment of sequence stratigraphic frameworks
- Integration of stable-isotope geochemistry for carbon isotope stratigraphy and to elucidate climatic trends in the Arctic region
- Refinement of Late Jurassic-Paleogene paleogeographic and facies distribution maps of the Arctic basins

## References

- Hills, L. V., and Strong, W.,L., 2007, Multivariate analysis of Late Cretaceous Kanguk Formation (Arctic Canada) palynomorph assemblages to identify nearshore to distal marine groupings: *Bulletin of Canadian Petroleum Geology*, 55(2), 160-172.
- Jeletzky, J. A., 1971, Marine Cretaceous biotic provinces and paleogeography of western and Arctic Canada: illustrated by a detailed study of ammonites: *Geological Survey of Canada, Paper 70-22*, 92 p.
- Núñez-Betelu, L. K., and Hills, L. V., 1994, Palynological data from the uppermost Hassel and Kanguk formations and the lowermost Eureka Sound Group (uppermost Lower Cretaceous-Paleocene), Axel Heiberg and Ellesmere islands, Canadian Arctic: *Geological Survey of Canada, Open File 2489*, 192 p.
- Sliter, W. V., 1981, Albian foraminifers from the Lower Cretaceous Christopher Formation of the Canadian Arctic Islands: *Geological Survey of Canada, Bulletin 300*, 41-70.
- Tapia, P. M., and Harwood, D. M., Upper Cretaceous diatom biostratigraphy of the Arctic archipelago and northern continental margin, Canada: *Micropaleontology*, 48(4), 303-342.
- Wall, J. H., 1983, Jurassic and Cretaceous foraminiferal biostratigraphy in the eastern Sverdrup Basin, Canadian Arctic archipelago: *Bulletin of Canadian Petroleum Geology*, 31(4), 246-281, 7 pls.