A Four Billion Year Journey through the Circumpolar Region: Paleogeographic Perspectives Provided by the "Geological Map of the Arctic" Database

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Summary
Selective querying has been undertaken and step-wise graphic displays have been generated which draw on age and compositional attributes of geological map units, linear and planar structural features and selected point data that illustrate a recently completed 1:5,000,000 scale map and spatial database of bedrock geology for the northern circumpolar region. Results provide a useful overview of Arctic paleogeography through most of Earth history.

Introduction
Since 2006, the Commission for the Geological Map of the World (CGMW) have embarked on the production of an atlas of small scale thematic geoscience maps of the circumpolar Arctic region that include separate compilations of gravity, magnetics, geology, tectonic features, and mineral and energy resources. Compilation of the 1:5 million scale bedrock geology thematic layer has involved staff with the geological surveys of Russia, United States, Norway, Sweden, Denmark (for Greenland) and Canada (overall lead). Preliminary results were released in November 2008 as Geological Survey of Canada Open File 5816 ("Geological map of the Arctic"; Figure 1; Harrison et al., 2008). Objectives since that time have included upgrade mapping of the offshore parts of the map, notably in the Arctic Ocean, and preparation for formal publication, sometime late in 2010 or in 2011, of a revised map including the associated spatial data. The present paper provides a preliminary overview of the assembled spatial data with examples of how these data can be employed to better understand the paleogeographic evolution of the northern circumpolar region since the early Archean.

Method
The relational database assembled to produce the latest Geological map of the Arctic (in prep.) provides systematic descriptions of more than 1200 map units that encompass all onshore and offshore areas down to 60 degrees North latitude. Map unit description is based on 137 divisions of geologic time as derived from compilation source maps and the latest ICS time scale (Gradstein et al., 2004; with revisions as provided at: http://www.stratigraphy.org/cheu.pdf). Lithologic character is arranged into 15 igneous compositional end members (9 intrusive; 6 extrusive), eight sedimentary depositional settings, six other compositional groups, and eight degrees of metamorphism. Sets of spatial objects (i.e. polygons) are assigned to and located within various named tectonic domains or geographic regions of 11 types. Geological linear and planar features include active and extinct spreading ridges, and faults of five types. For geological point data there are young volcanic features, kimberlitic rocks, impact structures and diapirs of salt and or

shale. Database queries, augmented by recent published literature, reveal useful aspects of Arctic paleogeography through four billion years of Earth history.

Examples

The geology of the Arctic (and of the Earth in general) features land and continental shelf areas underlain by ancient rocks, dating back to the Archean and by deep offshore areas underlain by either young oceanic crust or thinned continental crust together with younger cover. A second, less known division comprises distinct hemispheres embracing the exposed and submerged Arctic continental blocks. The older continental hemisphere, which extends westwards from the Baltic Shield through Greenland and Arctic Canada to Alaska, is dominantly (but not exclusively) metamorphic and non-metamorphosed Precambrian and lower Paleozoic geology, containing large base and precious metal resources, a long history of Neogene uplift and Plio-Pleistocene glaciation, and extant large Alpine glaciers and remnant continental ice caps that reach southward into the sub-polar Arctic. The other continental hemisphere, which extends from European Russia north of St. Petersburg and eastwards to the Russian Far East, is dominated by low-grade metamorphosed or nonmetamorphic upper Paleozoic and younger rocks, vast conventional hydrocarbon and shallow-emplaced mineral resources, a history of local glaciations in the Plio-Pleistocene, subdued isostatic effects and only small ice caps located on islands in the far north.

The early evolution of the circumarctic continents is, therefore, primarily understood from the Baltic Shield of Fennoscandia and Laurentian shield of Greenland and Arctic Canada with only small exposed windows into the ancient heart of Siberia. Remnants of Eoarchean and Paleoarchean crust form nuclei for Mesoarchean crustal blocks most notably found in the Anabar shield of Siberia, northern Fennoscandia, southwest Greenland, western Baffin Island, and east of Great Bear Lake in northwestern Canada. Accretion of new crust was widespread in the Neoarchean and, by 1.8 Ga in the middle Paleoproterozoic, a reduced number of large continental blocks had combined into the earliest of the supercontinents (Nuna). Dominant features of Arctic Nuna are Archean stable blocks, notably the Slave, Karelian and Murmansk cratons in the north, and Rae, Hearne, North Atlantic and Superior cratons in the south all fused together by the Himalayan-scale Trans-Hudson Orogen, as well as by the Taltson-Thelon and Inglefield orogens in Arctic Canada and Greenland, and by the Lapland–Kola and Svecofennian orogens in Scandinavia.

Subsequent events follow a repeated pattern of supercontinent disintegration, sometimes accompanied by plume-related flood basalts and radiating dyke swarms, and of supercontinent rebuilding involving new arrangements of component continental blocks. In the Arctic, these half cycles include: 1) the break-up of Nuna after 1.8 Ga; 2) assembly of Rodinia which produced the Sveconorwegian and Grenville orogens after 1.27 Ga); 3) Rodinia disintegration prior to the beginning of the Cambrian including emplacement of the Franklin-Thule LIP (0.7 Ga) and; 4) the assembly of Pangea notably involving accretion of Baltica to Laurentia to form the East Greenland and Scandinavian Caledonides in the Silurian and of Siberia to Euramerica to form the Urals-Taymyr orogen in the late Carboniferous to early Permian. The fifth tectonic half cycle has involved the dismemberment of Pangea, a process that can be considered to have started with emplacement of the Siberian Large Igneous Province in the Early Triassic (245 Ma).

Complications are provided by microplate evolution within each of the major tectonic half cycles for which insights are provided by example successive time slice views of the North American and Russian Pacific Cordillera onwards from the lower Paleozoic. Most notable is the accretion by Early Cretaceous time of the Kolyma-Omolon composite terrane to the eastern margin of Siberia to form the Verkhoyansk foredeep and Yana-Kolyma fold thrust belt. Likewise, the development of the Arctic Ocean basin relates to the scattering of microplates that were detached from circumarctic Pangea including Arctic Alaska, Chukotka and parts of the Arctic East Siberian shelf starting probably in the mid- Early Cretaceous, and of Lomonosov Ridge in the Paleogene. Paleogeography of the Arctic Cretaceous indicates contemporaneous formation of the Amerasian Basin and Okhotsk-Chukhotsk volcanic belt during emplacement of the mid-Cretaceous High Arctic Large Igneous Province (HALIP) and, subsequently, the opening of the Labrador Sea-Baffin Bay, North Atlantic and Eurasian basins following late Paleocene-early Eocene emplacement of the North Atlantic LIP (NALIP). This process continues down to the present with Arctic Eurasia-North America plate separation focussed on active plate boundary volcanism in Iceland.

Conclusions

The evolution of Arctic paleogeography through four billion years of earth history involves the repeated building of supercontinents, their break-up (sometimes associated with the emplacement of plume-related large igneous provinces), and their eventual reassembly in new tectonic configurations. Successive time slice views of the Arctic region provide useful insight into the evolution of continents and oceans. Diversion and entertainment is provided by the continuous antics of the microplates.

Acknowledgments

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References

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Natural Resources Canada Ressources naturelles Canada

Geological Map of the Arctic

scale 1:5,000,000

Geological Survey of Canada Open File 5816

Find it on the web/trouvez la sur le Web:

http://apps1.gdr.nrcan.gc.ca/mirage/full_result_e.php?id=225705

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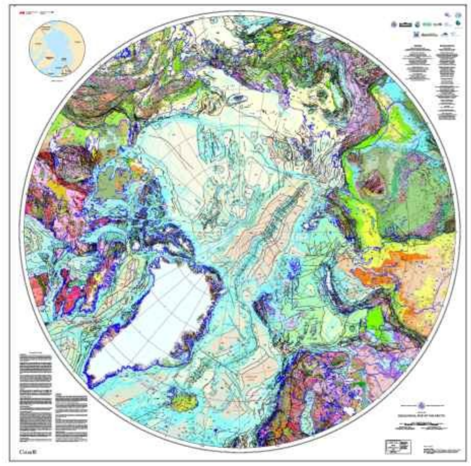

Sheet 1: Geology map, scale 1: 5,000,000 (141 x 141 cm); includes explanatory notes and list of contributors

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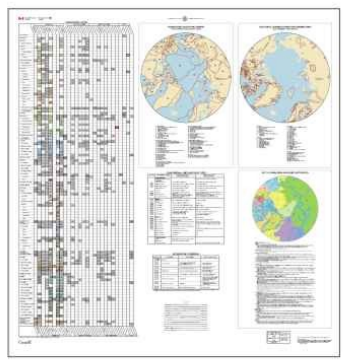
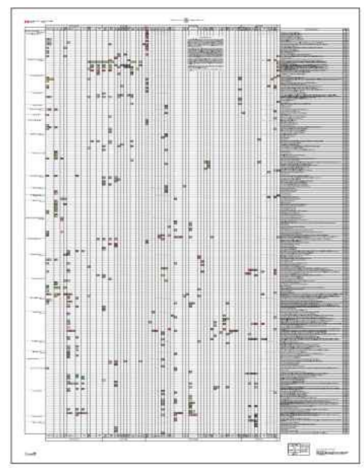
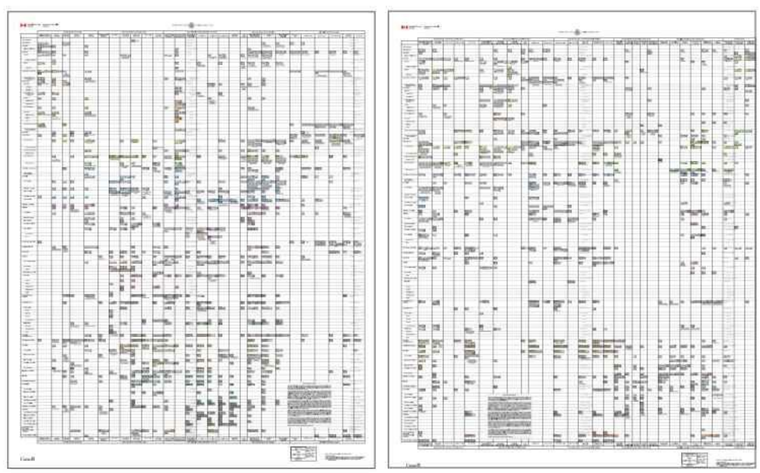


Sheet 2: Legend



Sheet 3: Precambrian correlation chart



Sheets 4,5: Phanerozoic correlation chart

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Figure 1: Thumbnail illustrations of the “Geological map of the Arctic” including sponsors and scientific and technical contributors.