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Sm-Nd Isotopic Data from the Canadian Shield north of 60 degrees latitude, northern Canada

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Contribution to the Geo-mapping for Energy and Minerals Program (GEM)

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ABSTRACT

Sm-Nd isotopic data are presented for ca. 1350 samples of Archean and Paleoproterozoic plutonic, volcanic, metamorphic, hydrothermal and sedimentary rocks of the Canadian Shield, mainly north of 60° latitude, along with ages of rock formation. Derivative data such as 'depleted mantle' model ages, as well as $Epsilon_{Nd}$ values for samples of known age are also presented. Use of the data is discussed in terms of caveats for interpreting Nd model ages and protocols for plotting equivalent data for meaningful comparison.

INTRODUCTION

This compilation comprises whole rock Sm-Nd isotopic data from Archean and Paleoproterozoic cratonic rocks and overlying cover sequences within the Canadian Shield north of 60° latitude; within the territories of the Northwest Territories and Nunavut as well as the province of Quebec. To maintain the integrity of geographical distribution, data is also presented for the regions 1° south of the 60° boundary of NWT and Nunavut within Alberta, Saskatchewan and Manitoba (Fig. 1). The database is intended to serve the mineral exploration industry by providing a guide to the age distribution of crustal lithosphere within the northern Canadian Shield and is a component of the Geoscience Knowledge Management (GKM) program (Tri-Territorial Framework - Bedrock database (TriT) project) of the Geological Survey of Canada (GSC).

The database aims to provide all whole rock Sm-Nd data within the public domain to 2010, with updates and corrections to continue after release. The analytical data is largely compiled from published sources (listed below) but includes some previously unpublished data acquired as part of GSC projects over the past two decades. The compilation builds on recent regionally-based compilations from Baffin Island (Wodicka et al. 2007a), the Trans-Hudsonian Belt of northern Quebec (Wodicka et al. 2007b) and from the Western Churchill Province (Peterson et al. 2010). A significant portion of the data was collected at the GSC Geochronology laboratories between 1988 and 2008 and was acquired using Thermal Ionization Mass Spectrometry (TIMS) analytical methods as described in Thériault (1990; GSC Paper 89-2, p. 3-6). GSC data acquired after 2005 utilized MC-ICP-MS techniques described in Whalen et al. (2010). The compilation includes data from a number of other laboratories including: University of British Columbia (UBC), University of Alberta (U of A), University of Saskatchewan (U of S), Carleton University, University of California Santa Cruz (UCSC), Arizona Research Institute, Carleton University, Massachusetts Institute of Technology (MIT), Ontario Geological Survey (OGS), Université de Québec à Montréal (UQAM) and Université de Montréal. References for the analytical methods undertaken by these laboratories can be found in the references cited per entry.

DESCRIPTION OF DATA FIELDS

The data in this file is divided into two sections and the structure is outlined as follows, with explanations for each column heading as well as principles and parameters used in calculations:

A. Sample Characterization

Lab Number: refers to GSC Geochronology Database lab number (z____). Negative numbers are for analyses entered in this database from outside publications. Not all samples have lab numbers (NA = Not Applicable).

Sample Number: Sample number as defined by primary reference.

Cratons and Orogenic Belts: Archean cratons and Paleoproterozoic orogenic belts (e.g. Slave, Bear).

Geological Locale: This heading is generally taken from the literature and is not always consistent. Entrees can be either a geological entity such as a major tectonostratigraphic assemblage (e.g. 'Hottah terrane') or a geographical identification of an area (e.g. 'Rankin Inlet')

Unit Name: Major geological unit as defined by primary reference. Geological units are not standard and do not refer to the Canadian Lexicon but are taken from the publications.

Rock type: Major rock type: Plutonic, Volcanic, Sedimentary, Metamorphic or Hydrothermal.

Rock Association: Informal term used to classify rocks according to broad tectonic association. This category is primarily used for sorting samples in order to compare and evaluate the data displayed on maps. Three categories are utilized based on their relationship to regional orogenic events. 1) Crust formation – refers to rocks that were formed or deposited during the major orogenic episode characteristic of the area. For example volcanic, plutonic and sedimentary rocks within a greenstone belt would all be classified as crust formation. 2) Intracratonic – refers to igneous rocks that were intruded into a 'stable' continent (e.g. major mafic dyke swarms). 3) Cover sequence – refers to sedimentary rocks that were deposited on stable cratonic areas (e.g. rocks of the Thelon basin deposited on the Rae province).

Rock Description: Rock lithology as defined by primary reference. Mineral abbreviations are after Kretz (1983).

Laboratory: Laboratory where Sm-Nd isotopic measurements were made.

Technique: TIMS or MC-ICP-MS.

B. Sm-Nd Isotopic Data

Data Type: Whole-rock or Mineral data.

Age (Ma): Age of rock formation.

Age Error (+/- Ma): If reported, otherwise NA.

Determination: 'Direct' if age is determined from same sample or equivalent sample in same unit; ideally by U-Pb method; 'Inferred' if age is estimate or representative of unit.

Sm (ppm): Samarium concentration in parts per million.

Nd (ppm): Neodymium concentration in parts per million.

^{147}Sm/^{144}Nd: Measured ^{147}Sm/^{144}Nd ratio.

2s: Two-sigma error. Default value of 0.5% of ^{147}Sm/^{144}Nd ratio.

Error Source: Default (see above) or Reported (from primary data source).

^{143}Nd/^{144}Nd: Measured ^{143}Nd/^{144}Nd ratio. Nd isotopic ratios were normalized to a ^{146}Nd/^{144}Nd value of 0.7219, where the value for this ratio was provided at source. Also, ^{143}Nd/^{144}Nd isotopic ratios were adjusted to a La Jolla accepted value of 0.51186, where the La Jolla value is reported at source.

2s: Two-sigma error. Default value of 0.000020.

Error Source: Default (see above) or Reported (from primary data source).

E(0): Epsilon at zero; measure of variance of current ^{143}Nd/^{144}Nd value with respect to a CHUR (chondrite uniform reservoir) value of 0.512638. E (0) = ((^{143}Nd/^{144}Nd$_{Sample}$)/(^{143}Nd/^{144}Nd$_{Chondrite}$) – 1)

2s: Two-sigma error (propagated ^{143}Nd/^{144}Nd error).

E(T): Epsilon at time or crystallization; measure of variance of ^{143}Nd/^{144}Nd value at time of crystallization with respect to CHUR value (0.512638). Time of crystallization refers to U-Pb age (as above). Epsilon values are based on chondritic ratios ^{147}Sm/^{144}Nd of 0.1967 and ^{143}Nd/^{144}Nd of 0.512638.
=(10^4*((^{143}Nd/^{144}Nd -(^{147}Sm/^{144}Nd *(EXP(0.00000000000654*Age*1000000)-1)))/(^{143}Nd/^{144}Nd$_{Chondrite}$ – ^{147}Sm/^{144}Nd$_{Chondrite}$ *(EXP(0.00000000000654*Age*1000000)-1))-1))).

2s: Two-sigma error (propagated from stated $^{147}Sm/^{144}Nd$ error and $^{143}Nd/^{144}Nd$ error). Uncertainties on $^{143}Nd/^{144}Nd$ isotopic ratios are those reported at source.

Depleted Mantle Model Age: Model age calculation from DePaolo (1981), in million years, is based on a modern CHUR value of 0.512638. Decay constant for ^{147}Sm is $6.54E^{-12}$. Nd model ages were calculated only for rocks with $^{147}Sm/^{144}Nd$ ratios less than 0.14. T_D = ((1000000 * {-(((^{147}Sm/^{144}Nd / 0.1967) - 1) * 25.09 - 3) – SQRT[(((^{147}Sm/^{144}Nd / 0.1967 - 1) * 25.09 – 3)^2 - 4 * 0.25 * (8.5 – $\varepsilon_{(0)}$))]/(2 * 0.25)} / 1000)).

$^{146}Nd/^{144}Nd$: Normalization value as reported in primary data source.

$^{143}Nd/^{144}Nd$ La Jolla: Value measured for La Jolla standard, if provided in data source.

Lat: Latitude in decimal degrees.

Long: Longitude in decimal degrees.

Zone: UTM zone.

Northing: UTM Northing (m), NAD 83.

Easting: Easting (m), NAD 83.

Authors: List of Authors of primary data source.

Year: Year of publication of primary data source.

Title: Title of primary data source.

Journal: Journal which primary data source was published in.

Volume: Volume of journal which primary data source was published in.

First Page: First page in journal which primary data source was published in.

Last Page: Last page in journal which primary data source was published in.

DEPLETED MANTLE MODEL AGES

The depleted mantle model age is the time in the past when a given sample would have had the identical Nd isotopic composition to the contemporaneous depleted mantle reservoir (DePaolo 1981, Arndt and Goldstein, 1987). In the simplest case the depleted mantle model age can be interpreted as the time of extraction and transfer of material from the depleted mantle reservoir to the continental crust. It therefore provides an indication of the relative antiquity of different continental regions. The model age is dependant on a number of parameters, the most significant of which is the isotopic evolution model selected for the depleted mantle reservoir.

In this compilation, Nd depleted mantle model ages are calculated for each entry based on parameters of DePaolo (1981). Other commonly used depleted mantle models, such as Goldstein et al (1984) and Nägler and Kramers (1998), make different assumptions about the change in mantle composition over time and therefore produce systematic differences in model ages for identical isotopic compositions. Systematic biases and inaccuracies in the model age data must be taken into account when interpreting the data set. Model ages are calculated directly from the reported $^{147}Sm/^{144}Nd$ and $^{143}Nd/^{144}Nd$ values and therefore may be different than values reported in the original publication which may have used different model parameters. As all the data have been recalculated to a single model the compilation represents an internally consistent data set. Model ages have not been calculated for rocks of mafic and ultramafic composition, with $^{147}Sm/^{144}Nd > 0.14$ as the small difference in this ratio relative to that of the depleted mantle reservoir provides a poorly defined intersection with the model depleted mantle curve and may be quite inaccurate. Model ages have, therefore, not been calculated for a significant proportion of mafic rocks.

The assumptions and the use of model age data are discussed by Arndt and Goldstein (1987). We cannot stress enough that caution is advised in uncritical interpretation of model age data. The following assumptions are implicit in the model age calculation: 1) the isotopic evolution of the sample is known; the sample attained a continent like Sm/Nd ratio (<0.14), the Sm/Nd ratio was not affected by subsequent intracrustal events, and all the material within the sample is from a single source (Arndt & Goldstein 1987). In many cases, however, model ages are the result of mixtures of material of different ages and cannot be interpreted as the age of the source. In the case of igneous rocks, partial melting and fractional crystallization may fractionate the Sm/Nd ratio relative to its crustal source changing the isotopic evolution of the sample relative to source and producing inaccurate model ages. Nd model ages should only be used, therefore, as a general indicator of average crustal residence that needs to be followed up by dating rock formation through mineral crystallization.

GROUPING AND PRESENTATION

This report does not attempt to relate Sm-Nd isotopic data to geological domains or tectonic boundaries. Such comparisons are addressed in separate, more focussed compilations (e.g. Wodicka et al., 2007a) and publications addressing regional tectonics. The data can be characterized according to Aeon (based on age), ‘Rock Association’ and ‘Rock Type’ as follows:

Archean

Crust Formation

Plutonic

Volcanic

Sedimentary

Proterozoic

Crust Formation

Plutonic

Volcanic

Sedimentary

Intracratonic

Plutonic

Volcanic

Cover Sequence

Sedimentary

These categories, which can be viewed separately or in different combinations (ArcMap, Google), allow comparison of model ages reflecting roughly equivalent provenance (Fig. 2). For example, primary igneous rocks of Archean terranes are generally formed higher in the crust than Proterozoic intrusions in cratonized Archean basement. Plutonic rocks may assimilate more upper crust than volcanics. For sedimentary rocks, provenance is the most important factor. The associations ‘Intracratonic’, for igneous rocks, and ‘Cover Sequence’, for sedimentary rocks are restricted to the Proterozoic, as they depend on the existence of older, post-Kenoran, Archean crust. Their inclusion with ‘Crust Formation’ igneous or sedimentary rocks would skew the population to deeper sources making them incomparable with Proterozoic ‘crust formation’. The Paleoprotorozoic plutonic Nueltin and Hudson granitoid suites are, however, assigned ‘Crust Formation’/Plutonic as they involved substantial crustal modification.

‘Rock Association’ provide only an arbitrary preview to how data can be projected and should be modified as appropriate by the user. For reliably dated rocks, a more quantitative indicator of crustal assimilation is Epsilon (T). For in depth data interpretation, the user should consult primary records in the references listed below.

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Figure Captions

Figure 1. Map of northern Canada showing distribution of all Sm-Nd isotopic data. The data points are superimposed onto the Canadian onshore segment of the Geologic Map of the Arctic by Harrison et al. (in press).

Figure 2. Depleted mantle model ages (DePaolo, 1981) for Sm-Nd isotopic data analyses of two rock types (Plutonic, Volcanic) and one rock association (Intracratonic); each group is further categorized into a total of six DePaolo Age intervals ranging from the Proterozoic to the Hadean. The data points are superimposed onto the Canadian onshore segment of the Geologic Map of the Arctic by Harrison et al. (in press).