GEOLOGICAL SURVEY OF CANADA
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Athabasca Basin Uranium Geochemistry Database

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Publications in this series have not been edited; they are released as submitted by the author.

1. Overview

The **A**thabasca Basin **U**ranium **G**eochemistry Database (AUG) represents the compilation of several Saskatchewan Geological Survey Data Files and drill core geochemistry extracted from Mineral Assessment reports submitted to the Saskatchewan Mineral Assessment Database for the period 2000 to 2010 for the Athabasca Basin of northern Saskatchewan and Alberta (Figure 1). The primary purpose of this compilation is to produce a dataset from which further academic, government, and industrial research related to unconformity-associated uranium deposits may proceed.

The AUG is stored in the MsAccess™ 2000 database accompanying this summary (Ath_Basin_lithgeoch2013.mdb). During compilation, the metadata associated with the data has been standardized to assist with sorting, summarizing, and querying the dataset, described in detail in the following sections four sections: 2) Original Data Sources; 3) Geographic Distribution; 4) Sample Descriptions; 5) Analytical Laboratories; and 6) Analytical Results. Two tables separate the data reported in UTM NAD83 Zone 13 coordinates from the data reported in UTM NAD83 Zone 12 coordinates. Due to the limitations of the shapefile format, the column headers have been truncated to 10 characters in the shapefiles and the included ArcMap™ 10.1 document.

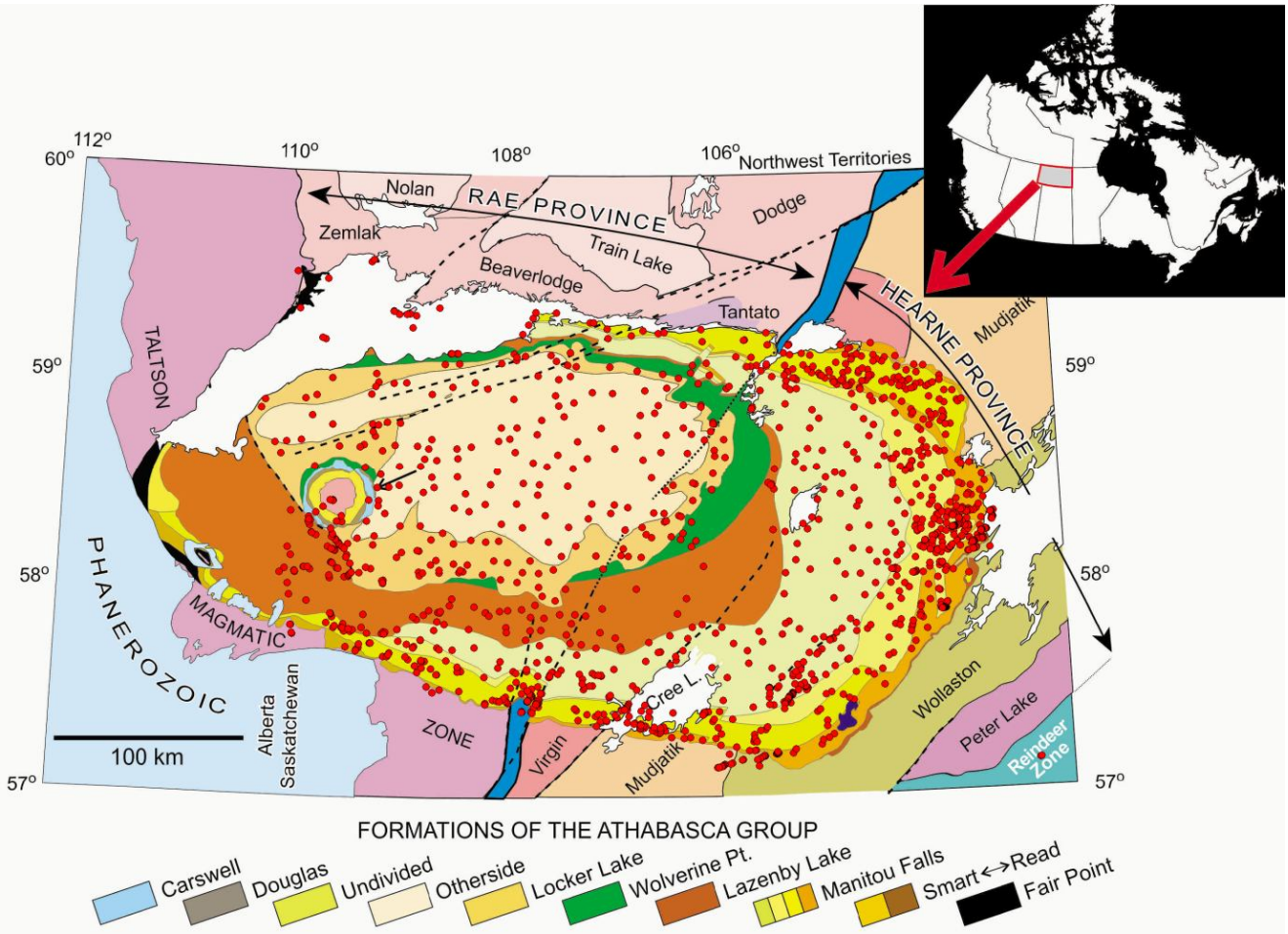

Figure 1: Location Map of the Athabasca Basin and the geographic distribution of samples (red) within the AUG database (modified after Jefferson et al., 2007)

2. Original Data Sources

Saskatchewan Geological Survey Data File publications and Mineral Assessment Reports submitted to the Saskatchewan Mineral Assessment Database (SMAD) are the primary sources of information contained within the AUG database.

Column: DATASET

- **SGS_DF#:** Five separate surface and diamond drill core geochemistry Data Files from the Athabasca Basin have been published by the Saskatchewan Geological Survey (Table 1).
- **SGS_MAD**: The Saskatchewan Mineral Assessment Database was queried to identify Mineral Assessment reports containing geochemical data submitted for uranium exploration or development within the Athabasca Basin between 2000 and 2010. This range of dates was used to encompass the adoption of multielement geochemical analysis as a common method (~2000) to the date at which the assessment reports would become public (i.e. assessment reports submitted in 2010 would be no longer confidential as of 2013). One additional assessment report was also obtained from the government of Alberta for the western Athabasca Basin and is cited as a source in Card et al., (2011).

Column: REPORT_ID

- The specific Assessment Report file number or SGS Data File Report number from which the original data were extracted.

Column: YEAR_FROM

- The year within which the work reported in the Assessment Report was started.

Column: YEAR_TO

- The year within which the work reported in the Assessment Report was completed.

Column: COMPANY

- The company primarily responsible for submitting the Assessment Report. A tabulation of the companies represented in the database is presented in Table 2.

Column: CONFIDENTIAL_DATE

- The date at which the submitted assessment report became confidential.

Column: OFF_CONFIDENTIAL_DATE

- The date at which the submitted assessment report would be no longer confidential.

Table 1: Summary of SGS Data Files included in the AUG compilation

SGS Data File	Description	Reference
Data File Report 24	Industry Drillcore Data	Uravan Minerals Inc., 2010
Data File Report 29	Geochemical Analyses: Athabasca Group Outcrops	Card et al., 2011
Data File Report 30	Geochemical Analyses: Athabasca Group Outcrops (Supplementary to DF 29)	Card and Bosman, 2012
Data File Report 31	Geochemical Analyses: Athabasca Group Drillholes (Supplementary to DF 24, 29, & 30)	Bosman and Card, 2012
Data File Report 32	Geochemical Analyses: Athabasca Group Drillholes (Supplementary to DF 24, 29, 30, & 31)	Bosman and Card, 2013

Table 2: Company representation within AUG Dataset.

Column: COMPANY	Sample Count (n)	Proportion of AUG Dataset (n = 30,256)
AREVA RESOURCES CANADA INC.	3087	10.20%
CAMECO CORP.	11137	36.81%
CANALASKA URANIUM	866	2.86%
CLARK LLOYD (OPTIONED TO NUINSCO RESOURCES)	380	1.26%
DEJOUR ENTERPRISES LTD	724	2.39%
DENISON MINES	2069	6.84%
ESO URANIUM CORP	380	1.26%
FISSION ENERGY CORP	343	1.13%
FORUM URANIUM CORP	816	2.70%
HATHOR EXPLORATION LTD.	128	0.42%
JNR RESOURCES INC.	271	0.90%
PHELPS DODGE CORPORATION - LEDERHOUSE M	25	0.08%
PITCHSTONE EXPLORATION LTD	112	0.37%
SGS	1326	4.38%
SGS-Uravan	955	3.16%
TITAN URANIUM INC.	923	3.05%
TRIEX MINERALS CORPORATION	247	0.82%
UEM INC.	2029	6.71%
UEX CORP.	4046	13.37%
URANERZ EXPLORATION AND MINING LIMITED	392	1.30%

3. Geographic Distribution

The geographic location of each sample is described in both absolute and relative terms within the AUG dataset.

3.1 Absolute Geographic Distribution

The UTM coordinates of individual samples/drillholes were extracted from each assessment report or data file, and tabulated according to datum, zone, easting and northing. To facilitate spatial modeling, the data were converted and compiled into the NAD83 datum. The following conversion parameters were followed:

- WGS84 data were copied directly to NAD83, assuming no shifts (not precisely accurate, but at the scale of the current compilation, likely acceptable)

- NAD27 data were converted to NAD83 using the NTv2 National Transformation software provided by Natural Resources Canada: (http://geoapps.nrcan.gc.ca/applications/0/NTv2%20National)

Column: E_NAD83Z13

- UTM NAD83 Zone 13 Easting value.
-

Column: N_NAD83Z13

- UTM NAD83 Zone 13 Northing value.

Column: E_NAD83Z12

- UTM NAD83 Zone 12 Easting value.

Column: N_NAD83Z12

- UTM NAD83 Zone 12 Northing value.

Column: DDH_SAMPID

- The original sample label or drillhole label with which the sample is associated.

Column: DDH_FROM

- For samples collected from drillcore, the depth within the drillhole at which the sample interval begins.

Column: DDH_TO

- For samples collected from drillcore, the depth within the drillhole at which the sample interval ends.

3.2 Relative Geographic Distribution

The spatial distribution of each sample from submitted Assessment Reports was also categorized according to their relative position within the Athabasca Basin. The individual samples within the SGS Data Files were not assigned to specific regions due to the regional nature of the dataset.

Column: GEN_AREA

- For most Assessment Report files, a general area of the Athabasca Basin was identified within the report.

Column: DEP_AREA

- For some areas, a spatial association with the sampling completed and a known deposit area or area of interest was identified (Table 3).

Column: REL_GEOG_DIST

- The spatial distribution of each sample from submitted Assessment Reports was also categorized according to their relative position within the Athabasca Basin (Table 4).

Table 3: Sampling summary statistics from known deposit areas and areas of interest.

Column: DEPOSIT_AREA	Column: COMPANY	Sample Count (n)
Cree-Ex - Millennium	CAMECO CORP.	1895
Dawn Lake - Q14A	CAMECO CORP.	222
Dawn Lake - Q8 - Tamarack	CAMECO CORP.	2239
Eagle Point Extension	CAMECO CORP.	248
Fox Lake	CAMECO CORP.	129
Key Lake	CAMECO CORP.	603
	CANALASKA URANIUM	195
McArthur River	CAMECO CORP.	481
Patterson Lake	FISSION ENERGY CORP	343
Roughrider	HATHOR EXPLORATION LTD.	128
Shea Creek	AREVA RESOURCES CANADA INC.	2107
UEX - West Bear	UEX CORP.	956
Virgin River - Centennial	CAMECO CORP.	1017
	UEM INC.	1143
	URANERZ EXPLORATION AND MINING LIMITED	184
Wheeler River	CAMECO CORP.	597
	DENISON MINES	2069

Table 4: Column: REL_GEOG_DIST Statistics

Column: REL_GEOG_DIST	Description	Sample Count (n)	Proportion of AUG Dataset (n = 30,256)
1_West	West Athabasca	4740	15.67%
2_South	South Athabasca	3926	12.98%
3_Southeast	South-East Athabasca	10151	33.55%
4_Northeast	North-East Athabasca	9158	30.27%
5_Regional	Regional	2281	7.54%

4. Sample Descriptions

Sample descriptions within the AUG dataset range from very detailed to non-existent, often without any standard format or content between or even within the same report. In an attempt at standardization, several summary columns were added to the database to facilitate rapid sorting of the data in future, summarized from the original sample descriptions.

Column: LITHOLOGY_BASIC

- Several types of description are applied to each sample, depending on their basic lithology or purpose as described within the respective source reports (Table 5). Unknown samples were most commonly those for which either a sample lithology label was not provided, or the labels provided were insufficient to accurately define the actual sample lithology.
- Samples collected for the purposes of monitoring quality control (QAQC) were not well represented in original Assessment Report files. As they represented only a very small proportion of the original sample data population, their value was considered minimal within the context of the compilation and were excluded.

Column: BASEMENT_CODES

- Of a total of 13,343 Basement samples (Table 5), 4,795 were labeled with enough information to identify the likely basement source material (Table 6).
- This column was added to facilitate the interpretation of geochemical variations relative to primary basement host rock.

Column: FORMATION

- Of a total of 13,005 Sandstone samples (Table 5), 5,962 were labeled with enough information to identify the likely stratigraphic formation from which these samples were collected (Column: Sandstone_Formation; Table 7).

Column: STRATORDER

- In addition to the basic Sandstone Formation labels, an additional column containing the formation labels with a numeric prefix is also included to assist with sorting the data based on stratigraphic order (Table 7).

Table 5: Column: LITHOLOGY_BASIC Statistics

Column: LITHOLOGY_BASIC	Sample Count (n)	Proportion of AUG Dataset (n = 30,256)
Basement	13,343	44.10%
Sandstone	13,005	42.98%
Unknown	3,908	12.92%

Table 6: Column: BASEMENT_CODES Statistics

Column: BASEMENT_CODES	Description	Sample Count (n)	Proportion of Coded Samples (n = 4,712)
PELT	Pelite	2,763	58.64%
ARKS	Arkose	829	17.59%
QZIT	Quartzite	421	8.93%
GRAN	Granite	195	4.14%
PEGM	Pegmatite	149	3.16%
CALC	Calc-Silicate	102	2.16%
PSAM	Psammite	89	1.89%
MARB	Marble	57	1.21%
MYLN	Mylonite	51	1.08%
AMPH	Amphibolite	26	0.55%
MDYK	Mafic Dyke	24	0.51%
FXPO	Feldspar Porphyry	6	0.13%

Table 7: Column: FORMATION Statistics

Column: FORMATION	Column: STRATORDER	Formation Description	Sample Count (n)	Proportion of Coded Samples (n=5,962)
O	01_O	Otherside	107	1.79%
LL	02_LL	Locker Lake (undivided)	133	2.23%
W	03_W	Wolverine Point (undivided)	129	2.16%
LZ	04_LZ	Lazenby Lake (undivided)	248	4.16%
MFd	05_MFd	Manitou Falls, Dunlop Member	1,207	20.24%
MFc	06_MFc	Manitou Falls, Collins Member	817	13.70%
MFw	07_MFw	Manitou Falls, Warnes Member	75	1.26%
MFr	08_MFr	Manitou Falls, Raibl Member	114	1.91%
MFb	09_MFb	Manitou Falls, Bird Member	1,138	19.09%
MFa/RD	10_MFa/RD/SMT	Manitou Falls, “A” Member / Read / Smart	1,989	33.36%
FP	11_FP	Fair Point	5	0.08%

5. Analytical Laboratories

Column: ANALYTICAL_LABORATORY

- Six analytical laboratories are represented in the AUG dataset, summarized in Table 8.
    - The SRC (Saskatchewan Research Council – GeoAnalytical Laboratory) is the most common commercial laboratory used for the analysis of geochemical samples from the Athabasca Basin region.

Column: PARTIAL_DIGESTION

- Partial digestion attempts to focus the digestion of the sample to the more labile components of the sample, assumed to more likely represent the proportion of the sample associated with alteration and mineralization.
- The most common partial digest analysis method employed in the Athabasca Basin is the SRC Partial digest, comprising a 9:1 mixture of HNO_3:HCl; This digest was designed to more particularly focus on uranium than the similar Aqua Regia partial digest (3:1 HCl:HNO_3). Final analysis of the digestion product is most commonly completed by ICP-OES techniques, yet ICP-MS techniques may also be used, providing lower detection limits.

Column: TOTAL_DIGESTION

- Total digestion attempts to fully digest samples, providing a relatively complete geochemical signature. Total digestion methods usually rely on a combination of three to four different acids, usually including hydrofluoric acid (HF). These techniques are typically effective, but incomplete digestion of the sample is still possible due to the presence of highly resistate minerals. In addition, elements that may volatilize during total digestion may be under-represented in the dataset, including elements such as As, Se, and Te. The most common total digest method employed in the Athabasca Basin is the three-acid digest provided by the SRC. (Table 8); The author is not aware of published comparisons of the effectiveness of this digest relative to more common four-acid digest combinations. Final analysis of the digestion product is most commonly completed by ICP-OES techniques, yet ICP-MS techniques may also be used.
- A major difference is observed in the reporting of major element data between the data provided by the SRC versus that of other laboratories: Major element data reported by the SRC and NTEL are commonly reported as oxide values, whereas other laboratories report these elements in the elemental form. This difference has not always been respected in the datasets reported to the SGS MAD. As a result, mixtures of oxide and elemental data are possible within the major element data present. All reasonable attempts have been made to respect the oxide vs. elemental reporting of the major elements in the compiled AUG dataset.

Column: BORON_DIGESTION

- A sodium peroxide fusion digest has been commonly applied to enhance the extraction of boron. Boron is of interest due to its role as a component of dravite/magnesiofoitite alteration in the sandstones of the Athabasca Basin (REFS). Analysis of the digestion product is typically by ICP-OES techniques.

Column: ALT_DIGESTION

- Prior to commercial access to ICP technology, partial digest uranium analysis was completed using fluorimetry (most commonly at the SRC). As the detection limits available via ICP-OES analysis were commonly higher than those available via fluorimetry, the use of the latter as the primary method for uranium determination was continued.

Table 8: Analytical Laboratories represented in the **AUG** dataset.

Analytical Laboratory	**Sample Count (n)**	**Proportion of AUG Dataset (n = 30,256)**	**Partial Digest**	**Total Digest**	**Additional Digests**
SRC Saskatoon, SK	27,240	90.03%	SRC Partial: 9-1 HNO_3:HCl	$HF/HNO_3/HClO_4$	B: Na_2O_2 Fusion; U(p): Fluorimetry
NTEL Darwin, NT, Australia	1,343	4.44%	2% HNO_3 or $HClO_4$	$HCl/HF/HNO_3/HClO_4$	
Loring Laboratories Calgary, AB	1,196	3.95%	Aqua Regia: 3-1 HCl/HNO_3	N/A	
ACME Laboratories Vancouver, BC	477	1.58%	Aqua Regia: 3-1 HCl/HNO_3	$HNO_3/HClO_4/HF/HCl$	B: Na_2O_2 Fusion

6. Analytical Results

The analytical results for each sample are listed in individual columns using standardized labels indicating the element determined, the digest used, and the units used to measure the element. Data below detection have been handled in a variety of ways within the various Assessment Reports reviewed, including preserving the original detection limit values (using "<" or "-" prefixes), modification of the detection limit values, or deletion. Where possible, the absolute value of the original detection limit has been preserved in the AUG dataset, identified as the negative value of the absolute value.

Column: Element_Digest_Unit

- Element Labels:
  - Trace Elements (e.g. Ag through Zr)
    - Some lead isotope data is present, with the specific isotopes identified according to their isotopic number (e.g. ^{206}Pb = Pb206)
  - Major Element Oxides (e.g. Al_2O_3 through TiO_2)
  - Major Elements (e.g. Al through Ti – not reported as Oxides)
- Digest Labels:
  - p = Partial Digest (laboratory specific)
  - t = Total Digest (laboratory specific)
    - Note: includes Boron by Na_2O_2 fusion digestion.
- Unit Labels:
  - ppm = parts per million
  - pct = Percent.
- Sample Column Header Examples:
  - Ag_p_ppm = Silver by Partial Digest, reported in parts per million.
  - Al2O3_t_pct = Aluminum Oxide by Total Digest, reported in percent.

7. Acknowledgments

The AUG database plus associated GIS files benefitted from constructive reviews and technical assistance by Leslie Chorlton and Beth Hillary of the Geological Survey of Canada.

8. References

The references for the individual assessment reports are included in the database as a separate table.

Bosman, S.A. and Card, C.D., 2012. Geochemical Analyses of Athabasca Group Drillcores in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Reports 24, 29, and 30; Saskatchewan Ministry of Energy and Resources Data File Report 31 (digital).

Bosman, S.A. and Card, C.D., 2013. Geochemical Analyses of Athabasca Group Drillcores in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Reports 24, 29, 30, and 31; Saskatchewan Ministry of Energy and Resources Data File Report 32 (digital).

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Card, C.D. and Bosman, S.A., 2012. Geochemical Analyses of Athabasca Group Outcrops in Saskatchewan (NTS 64L, 74F to 74K, and 74N to 74P) – Supplementary to Data File Report 29; Saskatchewan Ministry of Energy and Resources Data File Report 30 (digital).

Jefferson, C.W., Thomas, D.J., Gandhi, S.S., Ramaekers, P., Delaney, G., Brisbin, D., Cutts, C., Portella, P. and Olson, R.A., 2007. Unconformity-associated uranium deposits of the Athabasca basin, Saskatchewan and Alberta; in EXTECH IV: Geology and Uranium EXploration TECHnology of the Proterozoic Athabasca Basin, Saskatchewan and Alberta, (eds.) C.W. Jefferson and G. Delaney; Geological Survey of Canada Bulletin 588, p. 23-67.

Saskatchewan Mineral Assessment Database: http://economy.gov.sk.ca/smad. (94 Individual Reports listed in Open File Report)

Uravan Minerals Inc., 2010. Industry Drillcore Data – Regina Subsurface Core Facility – Uravan Minerals, Athabasca Basin (NTS 64L, 74F to 74K, and 74N to 74P); Saskatchewan Ministry of Energy and Resources Data File Report 24 (digital).

9. Appendices

Access 2010 Database: Ath_Basin_lithgeoch2013.mdb
ArcGIS ArcMap 10.1 document: AthBasin_lithogeoch_v10.mxd