

Evidence of geothermal activity near the Nazko volcanic cone, British Columbia, Canada, from ground and surface water chemistry

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Introduction

Water-rock and water-mineral interactions, aquifer geology, solution residence times, environmental factors and reaction rates are all factors that affect ground and surface water geochemistry. In areas where there is evidence of geothermal activity, variations of surface and ground water chemistry can also reflect accelerated rock weathering, changes in mineral solubility with increasing temperature and the mixing of hot and cold ground water. For example, Pasvanoğlu (2013) interpreted high dissolved CO₂, Si, Li, As, Hg and B concentrations in the thermal waters from wells in Eastern Turkey to be the result of reactions between hot water and silica-rich volcanic rocks and by mixing of hot and cold solutions during the ascent of water through rock fractures to the surface. Hence, the solubility of altera-

tion minerals in surface and ground water may be a guide to water temperature.

Here we describe evidence of geothermal activity from a study of the water chemistry in two wetlands, informally named the North and South Bogs, near the Nazko volcanic cone, British Columbia, Canada (Fig. 1). The bog water chemical data are interpreted by their comparison to other geothermal areas, from a thermodynamic simulation with the PHREEQC software (Parkhurst & Appelo 2013) and from the results of stable isotope (δD , $\delta^{18}O$, $\delta^{13}C$) analysis of bog water.

There has been past interest in the geothermal potential of the area because of the presence of scattered travertine deposits on the wetland surface, calcium carbonate-rich organic bog soil and many carbon CO₂-rich gas seepages. Although the Nazko cone last erupted in 7200 ka BP

(Souther *et al.* 1987) there is geophysical evidence of more recent seismic activity. An earthquake swarm 20 km west the Nazko cone in 2007 (Cassidy *et al.* 2011) and an interpretation of seismic data by Kim *et al.* (2014) suggested that magma, a potential geothermal heat source, has accumulated in the lower crust beneath the cone. While there is an anecdotal report that the wetlands are snow-free in winter, indicating near-surface heat, the highest bog water temperature measured by the authors is 23° C.

Background to the study

Located on the glaciated Fraser Plateau 95 km west of Quesnel, British Columbia, Canada, the Nazko cone is the youngest and most easterly of several Pleistocene-Holocene volcanoes that

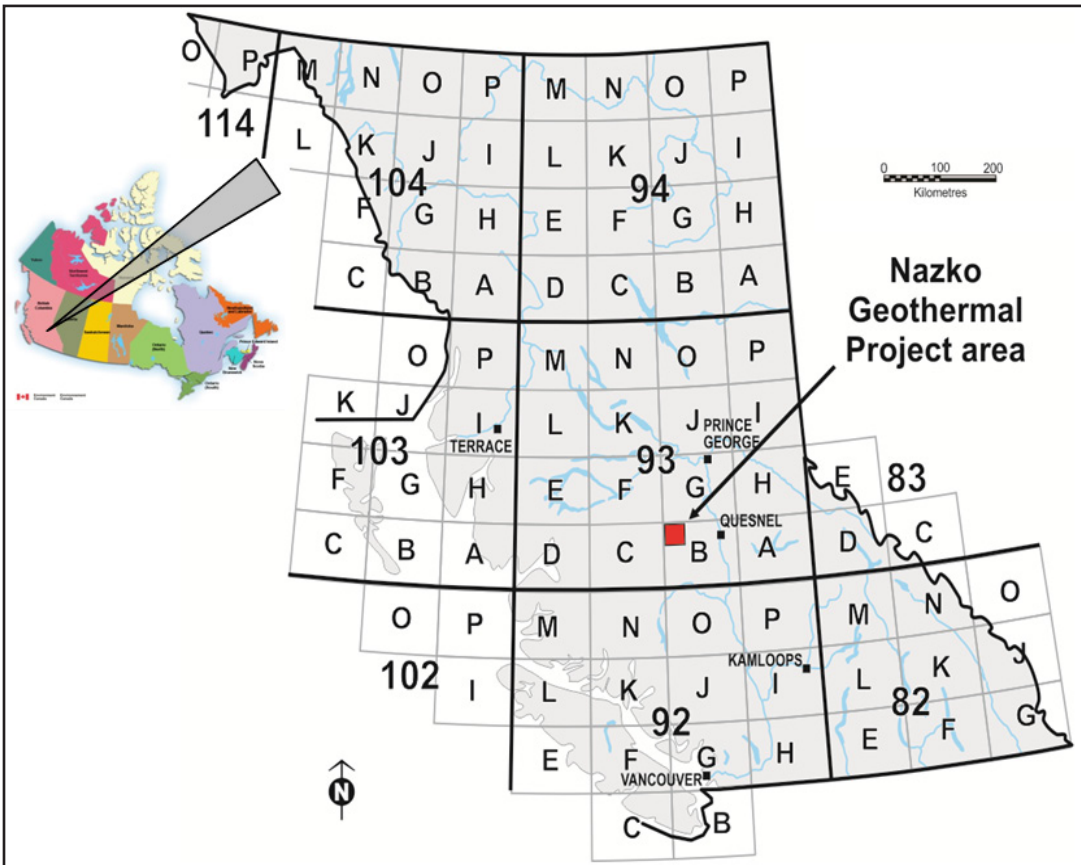


Figure 1. Geothermal project area location in western Canada.

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Information for Contributors

Manuscripts should be double-spaced and submitted in digital format using Microsoft® WORD. Do NOT embed figures or tables in the text document. Each photo and/or figure (colour or black and white) should be submitted as separate high resolution tiff, jpeg or PDF (2400 resolution or better) file. Each table should be submitted as separate digital file in Microsoft® EXCEL format. All scientific/technical articles will be reviewed. All contributions may be edited for clarity or brevity.

Formats for headings, abbreviations, scientific notations, references and figures must follow the Guide to Authors for Geochemistry: Exploration, Environment, Analysis (GEEA) that are posted on the GEEA website at: http://www.geolosc.org.uk/template.cfm?name=geea_instructions_for_authors

In addition to the technical article, authors are asked to submit a separate 250 word abstract that summarizes the content of their article. This abstract will be published in the journal ELEMENTS on the 'AAG News' page.

Submissions should be sent to the Editor of EXPLORE:

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Notes from the Editor

Welcome to the second issue of 2017. EXPLORE issue 175 includes one technical article that describes the use of ground and surface water chemistry to detect geothermal activity and was written by Ray Lett and Wayne Jackaman. EXPLORE thanks all those who contributed to the writing and/or editing of this issue: Steve Amor, Dennis Arne, Al Arseneault, Bob Garrett, Gwendy Hall, Wayne Jackaman, David Leng, Ray Lett, Matt Leybourne, Ryan Noble, and Wang Xueqiu.

Beth McClenaghan

Editor

2017 AAG Dues Reminder

Reminder that AAG membership fees
for 2017 are now due.

Membership fees can be paid on
AAG's website

www.appliedgeochemists.org



President's Message

Later this year, Exploration '17 will be convened in Toronto, Canada. This event is the sixth decennial mining exploration conference, which have been held in the seventh year of every decade since 1967. I hope to attend and am a co-author of a publication titled "Advances in Exploration Geochemistry, 2007 to 2017 and beyond." In pursuing background details for this paper, I referred to the previous decennial abstract "Major advances in exploration geochemistry", 1998-2007 by Cohen, Kelley, Anand and Coker, along with the similarly titled paper in our journal GEEA published in 2010. I also referred farther back to one of the earliest online AAG newsletter articles (No. 15, December 1975) to see what the state-of-play was during these times. In issue No.15 was an article authored by Carpenter titled "Status of exploration geochemistry in U.S. and Canadian Universities". Interestingly, the one clear common thread in all of these aforementioned articles was the lack of future geochemists coming through the tertiary education system. Exploration geochemistry courses offered were few and far between. While the early newsletter article was only referring to North America, I can safely say the same challenges exist in Australia and many other countries. Our recent AAG member survey identified this risk to a key area of our applied research and although I don't want to give too much away for the upcoming decennial paper, I think it is safe to assume that this theme continues.

"At present, most personnel training is done by geochemical departments in government organizations and industry groups. Most schools in the United States and Canada do not offer geochemical training particularly at graduate levels, due to faculty limitations, lack of budgetary support, and the erroneous impression that applied geochemistry is not sufficiently academic." Cavender, W. (1968) – a review article in Mining Engineering quoted in Carpenter's newsletter article No. 15 in 1975.

The more things change, the more things stay the same, it would seem. So while concepts, applications, technology and many other things have come a long way forward in applied geochemistry, our ability to train future geochemists has come full circle. This is not completely disheartening and should be viewed as a clear guideline. It is in fact just solid evidence to support where we as a community and the AAG need to do better. I hope if you are reading this and in academia or in a current training or mentoring role, please know you are possibly the most critical part of future geochemistry and I hope you are able to support or grow your educational offerings and continue to bring more students into our discipline.

As I stated in the last **Explore**, student awards are being updated and there will be more funding available to attend to next IAGS in Vancouver (as part of RFG 2018) and I fully anticipate the AAG will be giving as good a platform for students to present their work than ever before. So please make sure to mark it in your calendar and get prepared well in advance. More details are available at the RFG website as well as the AAG website. In addition the AAG will circulate details for abstract submission and travel awards in the near future.

An update from the most recent Council meeting shows that the AAG is managing its general business smoothly. The AAG website will be shifting to a more easily operated platform, that should make renewals and a number of other issues that members have raised, a easier to deal with. Hopefully, AAG members will not notice too much of a change from the front end. One clear point from the Council meeting was that new AAG Councillors are needed for next year (2018). If you are a Fellow and would like to be more active in the AAG, please let me know.

Finally, it is with regret that we learned of the passing of Professor Xie Xuejing. He will be missed greatly in the geochemistry community. As a young geochemist in 2007, in Oviedo, Spain, I clearly remember his speech when he received the AAG gold medal. His list of achievements was most impressive.

Kind regards,

Ryan Noble
AAG President
ryan.noble@csiro.au



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MINERALS

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together form the east-trending Anahim volcanic belt in Central British Columbia (Kuehn *et al.* 2015). The youngest rocks are the Miocene to Holocene Anahim Volcanics that form the Nazko cone. Souther *et al.* (1987) proposed that the Nazko cone formed from pyroclastic ash, lapilli and volcanic bombs ejected periodically after the Fraser Glaciation (9,000 ka BP). An ash layer deposited between 7100 and 7200 ka BP is the most recent evidence of local volcanic activity and the ash covers much of the area around the cone including the North and South bogs. Older volcanic and sedimentary rocks in the area include the Miocene to Pliocene Chilcotin Group, the Eocene Ootsa Lake Group and the Cretaceous Skeena Group. Recent geological mapping and an interpretation of airborne geophysical survey data by Angen *et al.* (2015) identified several new faults crossing the area (Fig. 2). Bedrock is largely concealed beneath Pleistocene deposits including till and glaciofluvial sediments, and there are several eskers and outwash features on the north side of the Nazko cone.

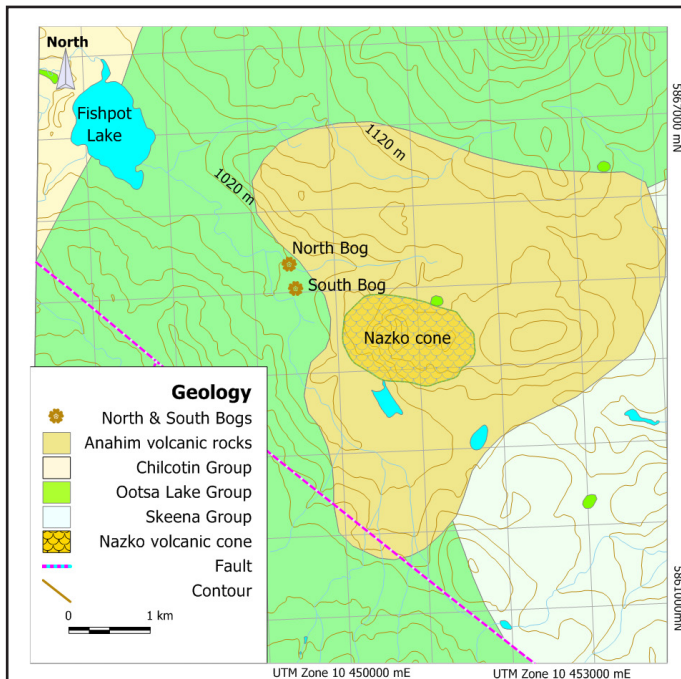


Figure 2. Bedrock geology of the area around the Nazko volcanic cone (modified from Angen *et al.* 2015).

Features typical of the North and South Bog are sedge and scattered wetland shrubs intersected by areas of calcium carbonate-rich mud, stagnant pools or slow moving streams, small, isolated areas of travertine, forest dominated bog, small ponds and meandering streams (Fig. 3). Vegetation ranges from scattered willow and spruce stands in the wetland to a second-growth lodge pole pine (*Pinus contorta*) canopy on the surrounding upland. Luvisolic and brunisolic soils have developed on glacial deposits that cover bedrock on the hill slopes surrounding the bogs, whereas gleyosic and organic soil form along the poorly drained bog margin. The wetlands contain more than 3 m of peat mixed with a calcium carbonate-rich mud. Travertine, typically a rusty to white coloured rubble, forms small, isolated mounds on the

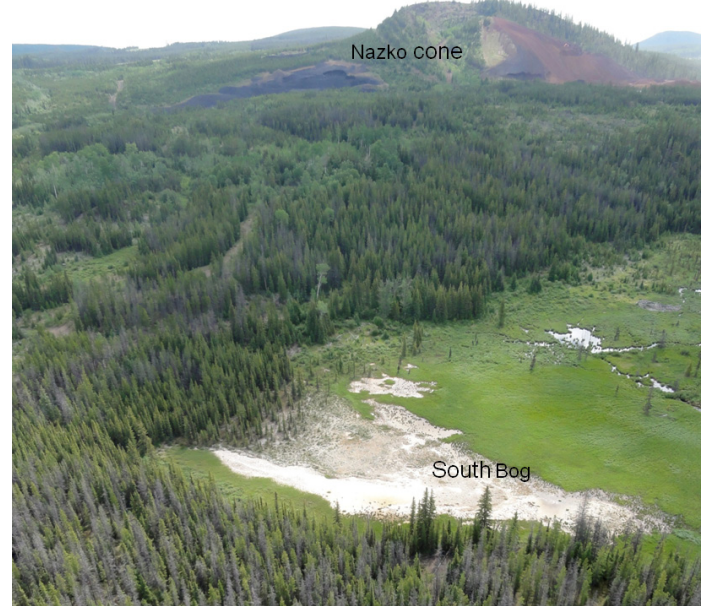


Figure 3. South view across part of the South Bog towards the Nazko volcanic cone. The white coloured surface area is carbonate mud and travertine deposits. Carbon dioxide seeps through surface water pools in this area are common.

bog surface. A small, 35 cm high cone-shaped travertine deposit on the northern edge of the North bog has a partially water-filled vent from through which there is a steady flow of CO₂-rich gas (Fig. 4).



Figure 4. Water filled travertine cone in the North Bog with associated CO₂-rich gas seepage.

Methodology

Sampling

During field visits between 2013 and 2015, 19 ground and 27 surface water samples were collected by Lett & Jackaman (2015) in the North and South Bogs from pits, pools and streams (Fig. 5). At each site the following water samples were collected: (1) filtered (0.45 μ) and acidified (HNO₃) for trace metal analysis, (2) unfiltered for laboratory

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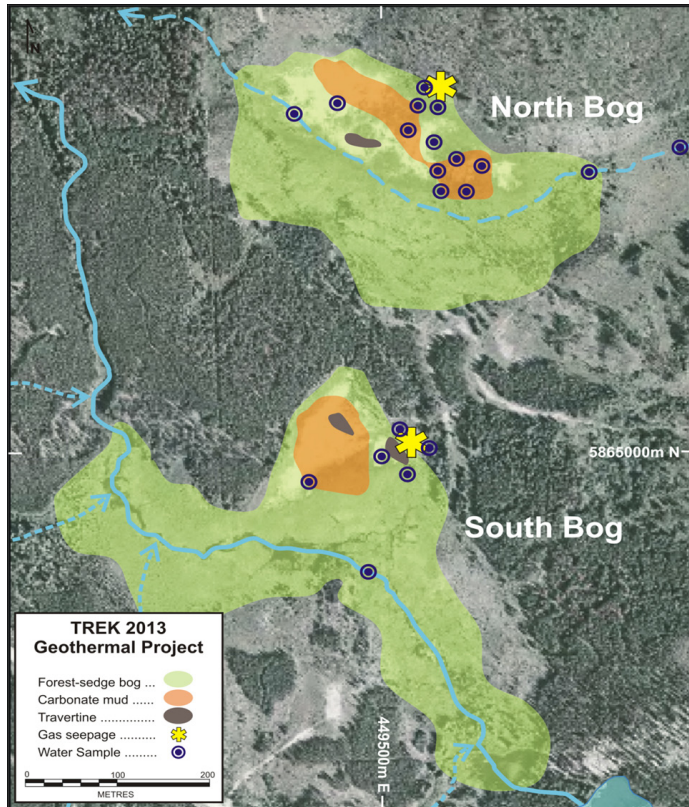


Figure 5. Location of water samples and CO₂-rich gas seepages in the North and South Bogs.

ry anion and alkalinity analysis, (3) for field determined dissolved CO₂ and alkalinity, and (at selected sites) (4) filtered, acidified (HCl) sample for dissolved Hg analysis. Water pH, conductivity, total dissolved solids and salinity were measured with an Oakton Model PCSTestr 35 meter and site characteristics recorded. Deionized water was also filtered and acidified in the field to detect contamination during sample processing. Five of the water samples collected were analysed for δD , $\delta^{18}O$ and $\delta^{13}C$.

Sample Analysis

All of the water samples were analysed by ALS Environmental, Vancouver. Filtered, acidified water samples, water blanks and the NRCC (National Research Council Canada) standard SLRS 3 were analysed for Ag, Al, As, Ag, Ba, Be, Bi, B, Cd, Ca, Cs, Cr, Co, Cu, Ga, Fe, Pb, Li, Mn, Mo, Ni, Na, P, K, Re, Rb, Sb, Se, Si Sr, Sn, Te, Tl, Ti, U, V, Y, Zn and Zr by high resolution inductively coupled plasma mass spectrometry (HR-ICP-MS). Unfiltered water samples were also analysed for hardness, total alkalinity by titration and for F⁻, Cl⁻, Br⁻, NO₃²⁻, NO₂⁻ and SO₄²⁻ by ion chromatography. Selected water samples were analysed for dissolved Hg by cold vapour-ICP-MS. Instrument detection limits for trace elements (e.g. Cu, Li, Zn) ranged from 0.05 to 1 parts per billion (ppb) and for minor elements (e.g. Ca, Mg, Na, K, Br⁻) from 1 to 0.5 parts per million (ppm). Only traces of Ca, Li and Sr (less than twice the detection limit) were detected in water blank samples. Five of the water samples from the North Bog were analysed at the University of

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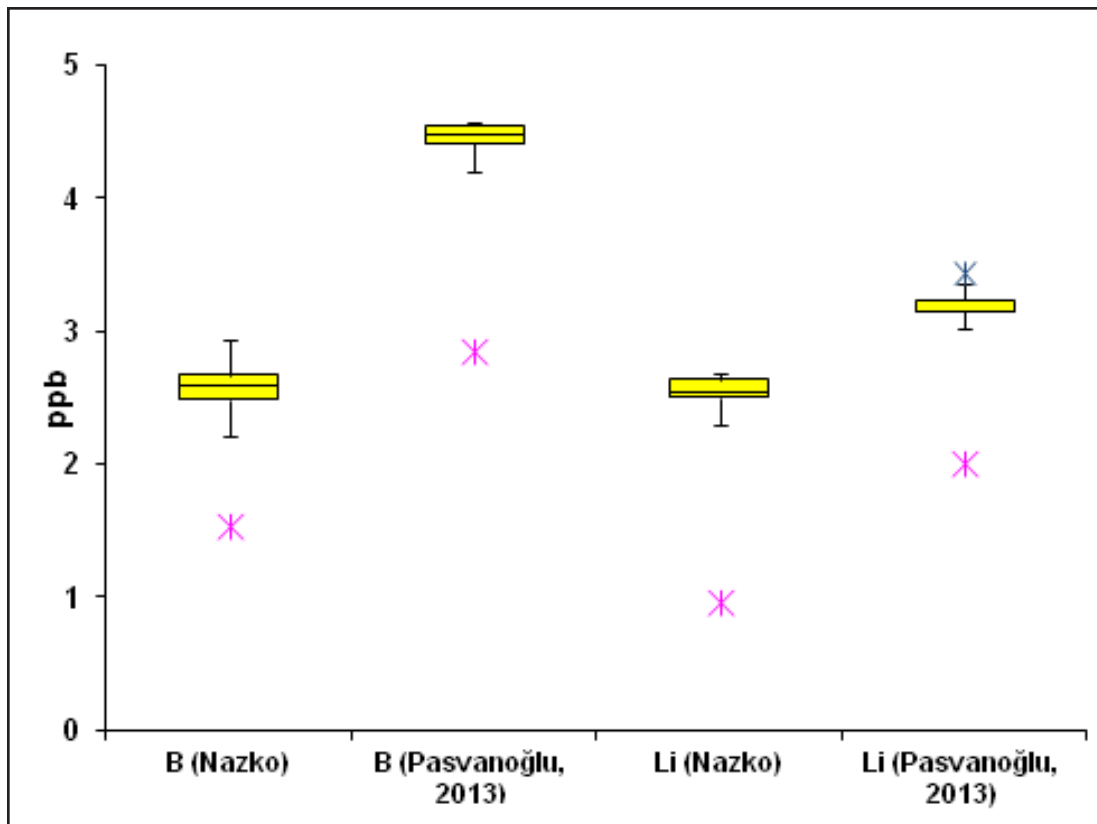


Figure 6. Lithium and B contents in Nazko (N) ground water and thermal well water (P) sampled by Pasvanoğlu (2013). Units in parts per billion (ppb).

Calgary for $\delta^{18}\text{O}$ by CF-GasBench-IRMS (Continuous Flow – Isotope Ratio Mass Spectrometry), δD by TCEA-CF-IRMS (Thermal Conversion Continuous Flow – Isotope Ratio Mass Spectrometry) and $\delta^{13}\text{C}$ and dissolved inorganic carbon (DIC) by CF-GasBench-IRMS. The Department of Earth Ocean Atmospheric Sciences, University of British Columbia, analysed the travertine samples for modal mineralogy by X-ray diffraction.

Results

Water chemistry

Lithium, B, As, Rb, Sr and Hg, are among known geochemical pathfinders for geothermal activity and may reach several hundred parts per million (ppm) in hot springs (Pasvanoğlu (2013)). For example, the thermal bore holes and

springs in Eastern Turkey sampled by Pasvanoğlu (2013) have water temperatures reaching 78°C and water that has up to 762 ppm Ca, 104 ppm Mg, 138 ppm Si, 2.7 ppm Li, 37 ppm B, 2820 ppm Sr, 5070 ppb As and 0.3 ppb Hg. By contrast, the Nazko bog waters only have up to 637 ppb B (ground water; Fig.6); 547 ppb Li (surface water; Fig 6); 2.6 ppb As (ground water); 56.1 ppb Rb and 15.9 ppm Sr (surface water), 383 ppm dissolved Ca (ground water); 850 ppm dissolved CO_2 (surface water) and up to 18.7 ppm Si (Table 1).

The highest Ni (44 ppb), As (2.4 ppb) and Fe (3920 ppb) concentrations are found in the water from the small travertine cone - CO_2 -rich gas vent on the edge of the North Bog. No Hg or Cl was detected in this water and the highest temperature measured was 5.9°C. The travertine cone - CO_2 -rich vent water was sampled several times in 2013, 2014 and 2015 to monitor seasonal changes in the water geochemistry and the results indicate that water temperature, pH, and most element concentrations (except Fe) are very similar from year to year and from month to month.

Sympathetic geochemical associations in ground water may reflect a common source for the elements. Major to trace element ratios can compensate for spurious fluctuations in water chemistry such as those caused by seasonal variations. For example, the ratio of Li to Ca vs. Ca to Mg



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Evidence of geothermal activity near the Nazko volcanic cone... continued from page 8

Table 1. Median and range for analytes in ground water (GW) and surface water (SW) samples from the North and South Bogs and surrounding area.

Analyte	Median GW	Median SW	Range GW	Range SW
pH	6.53	7.76	5.85 - 7.03	6.58 - 9.06
Temp °C	13.5	14.5	5.9 - 15.3	7.2 - 23.0
Alk. ppm	2200	140	55 - 3000	60 - 3000
TDS	2490	205	285 - 3380	2 - 3080
CO ₂ ppm	300	40	150 - 750	3 - 850
Al ppb	1	3	0.5 - 14.2	0.5 - 49.3
As ppb	0.25	0.49	0.05 - 2.56	0.05 - 0.85
B ppb	343	13	12 - 637	5.4 - 430
Ca ppm	218	34	43 - 383	6 - 358
Co ppb	0.134	0.07	0.05 - 6.73	0.05 - 0.44
Fe ppb	106	65	30 - 5240	30 - 1290
Li ppb	327	7.7	3 - 475	0.2 - 547
Mg ppm	239	18	23 - 393	5 - 390
Na ppm	250	10.4	6 - 412	6.2 - 311
Ni ppb	0.8	0.3	0.4 - 44.0	0.24 - 6.73
Rb ppb	39.6	4.2	2.8 - 52.4	1.4 - 56.1
Si ppm	13.7	13.4	6.89 - 18.7	6.58 - 18.5
Sr ppm	7.53	0.41	0.24 - 15	0.05 - 15.9

(Fig. 7) reveals that the ground and surface water chemistry is similar and a cluster of North Bog samples, including the travertine cone - CO₂ - rich vent water, plot on a common trend suggesting a similar source for the Li and major elements. The Li to major element ratios also display two diverging geochemical trends for the stream water and a different composition to the North Bog ground and surface water (Fig. 7). The Li to Ca versus Li to Rb plots (Fig 8) shows a similar difference between the stream and the surface-ground water chemistry.

Mineral solubility

Table 2 lists pH, temperature, bicarbonate alkalinity, SO₄ and element concentrations in the water sampled at six North Bog locations labelled on Figure 9. The sample sites are from the stream flowing into the bog, the stream leaving

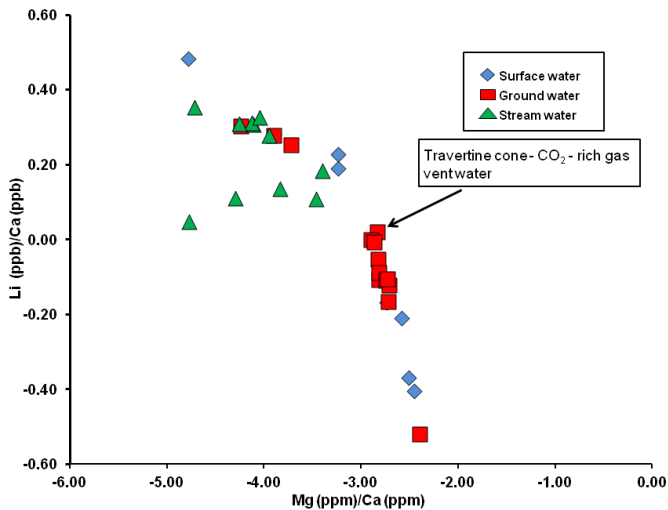


Figure 7. Lithium/Ca versus Mg/Ca in water samples collected in this study.

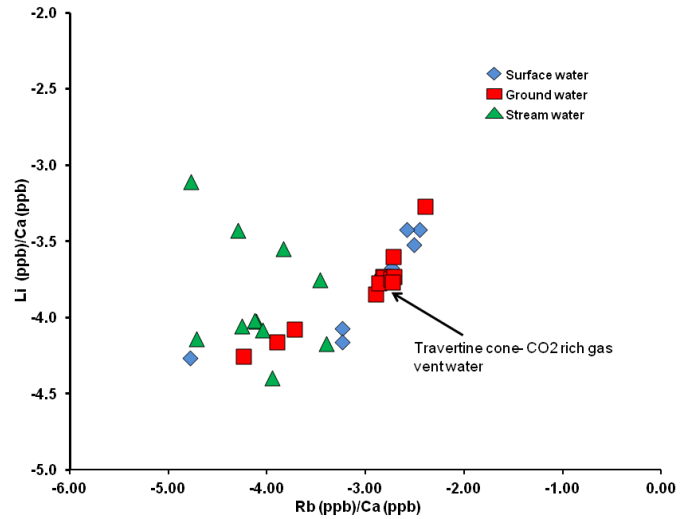


Figure 8. Lithium/Ca versus Rb/Ca in water samples collected in this study.

Table 2. Chemistry and mineral saturation indices for ground, surface pool and stream water sites in the North Bog. Ground* indicates the chemistry of the travertine cone-CO₂ vent water. HCO₃⁻ ppm = ppm CaCO₃. Temp. °C** is calculated for chalcedony equilibrium by Log SiO₂ = 4.69-(1.32/t°C +273.15) (Pasvanoğlu 2013).

Analyte	142006	132009	142002	142004	142003	142007
Type	Stream	Pool	Ground	Ground*	Ground	Stream
pH	7.14	7.8	6.5	6.37	5.76	8.12
Temp. °C	14.3	19.3	5.8	5.9	11.26	11.2
Temp. °C**	67.6	35.2	30.6	27.5	66.9	47.6
HCO ₃ ⁻ ppm	375	1590	2670	2410	249	123
Al ppb	8.5	0.5	1.1	0.5	30.7	2.12
Ca ppm	65.1	90.8	231	235	47.1	25.2
Mg ppm	42.6	213	306	239	26.3	11.9
Fe ppb	6390	65	1750	3920	15	15
Ni ppb	2.62	0.34	37.3	44	12	0.26
B ppb	44	234	429	343	34	21
Li ppb	26.4	283	450	323	9	2.27
Si ppm	21.6	10.4	9.26	9.63	21.3	14
Sr ppm	1.05	3.6	8.05	9.37	0.278	0.149
SO ₄ ppm	1	1	19	18	10.3	4
Aragonite	-0.27	1.02	0.42	0.04	-1.97	-0.15
Calcite	-0.12	1.17	0.57	0.18	-1.82	0.01
Chalcedony	0.24	-0.14	-0.12	-0.04	0.27	0.08
Dolomite	-0.23	2.99	1.19	0.49	-0.45	-0.17

the bog, the travertine cone - CO₂ - rich vent water, a typical bog surface pool, and ground water sampled in two pits adjacent to the travertine cone - CO₂ vent. Minerals that could be expected to precipitate or dissolve in the water and their saturation indices calculated from the water data with a PHREEQC thermodynamic simulation are listed with the chemistry in Table 2. There is an increase in the pH and in the concentrations of Ca, Mg, B, Li, Fe, Ni, HCO₃⁻ and SO₄⁻ from the ground water sampled upslope from the bog (sample 142003) to the travertine cone - CO₂ - rich vent water (sample 142004) and the water sampled closer to the

Evidence of geothermal activity near the Nazko volcanic cone... *continued from page 11*

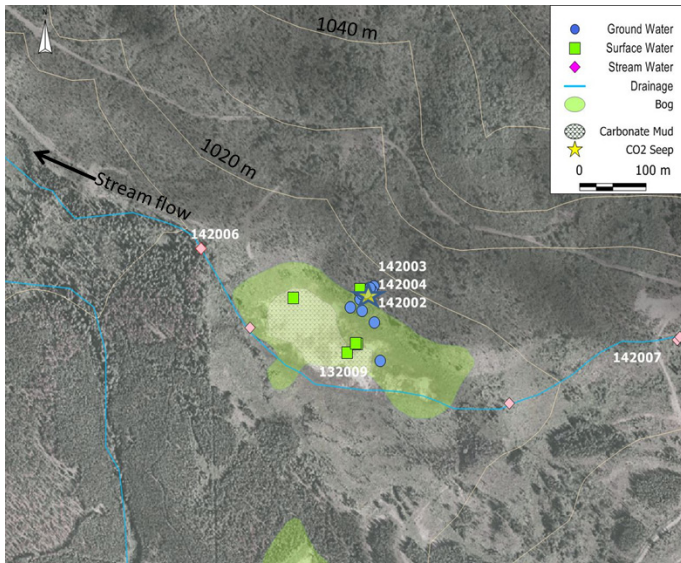


Figure 9. Location of North Bog water sample sites with geochemical data used for PHREEQC mineral solubility modelling.

bog center (samples 14002 and 13009). Stream water pH decreases whereas most element concentrations increase from the North Bog inflow (sample 142007) to the stream outflow (sample 142006).

Positive saturation indices predict that aragonite, calcite, magnesite and dolomite should precipitate from the North Bog surface and the travertine cone-CO₂-rich vent ground water, but not from the stream water and from the ground water upslope from the bog. Conversely, the saturation indices predict that chalcedony and illite should precipitate from the stream water and in the upslope ground water reflecting higher dissolved silica. Oversaturation of Fe (OH)₃ predicted for several water samples explains the visible iron oxide deposits around several of the seeps including the travertine cone-CO₂-rich vent.

Stable isotope chemistry

The δD vs. $\delta^{18}O$ in water from five North Bog sites and in the thermal water at five sites sampled by Pasvanoğlu (2013) are compared in Figure 10. The ratios are also compared to the meteoric water line plotted from a relationship $\delta D = 8 * \delta^{18}O + 10$ (Faure 1998). Depending on the sample latitude, $\delta^{18}O$ values of meteoric water range from -20‰ to -25‰ whereas isotopic values of around 0‰ for geothermal water are closer to those of sea water. Because the water samples from the Nazko North Bog have $\delta^{18}O$ values ranging from -17.8‰ to -19.8‰ with a mean of -18.62‰ and a standard deviation of -0.77‰ it is likely the water is meteoric rather than from a deeper ground water source. The DIC $\delta^{13}C$ values in the five North Bog water samples range from -1.6 to -7.1‰ with a mean of -4.6‰ and a standard deviation of -2.2‰.

Discussion

Variations in the Nazko ground and surface water chemistry could reflect (1) cold water flowing into the bogs from the surrounding uplands, (2) thermal water upwelling

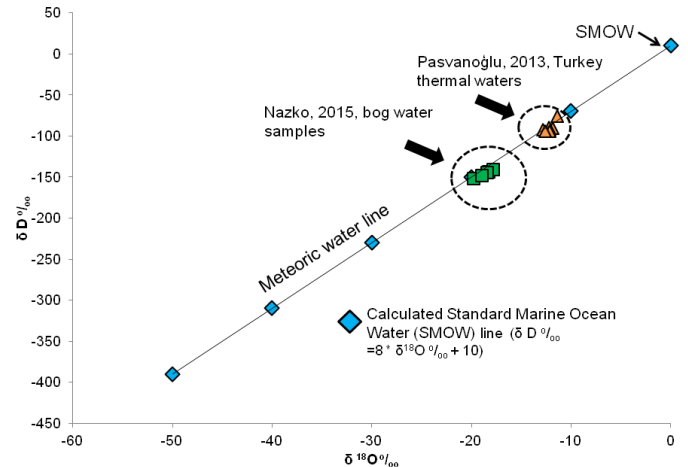


Figure 10. δD and $\delta^{18}O$ values for North Bog water samples (green square) compared to δD and $\delta^{18}O$ values for thermal waters samples reported by Pasvanoğlu (2013) (orange triangle). The sigma error for the North and South Bog water sample δD determinations is 1 and the sigma error for $\delta^{18}O$ determinations is 0.1.

from bedrock, and (3) mixing of hot and cold water in bedrock and overburden aquifers. The low temperature of the water in the travertine cone-CO₂-rich vent on the edge of the North Bog compared to surface and other ground water temperatures indicates an absence of hot water. However, the net enthalpy for the formation of carbonic acid from CO₂ and water is +1.76 kcal mol⁻¹ (Faure 1998) predicting that the reaction is endothermic. Consequently, bubbling CO₂ through the water could absorb heat and lower the water temperature. Alternatively, water upwelling from depth could dissipate heat to cooler aquifer rocks along the flow path to the surface. While Li, B and Sr concentrations measured in the North Bog ground water are lower than levels reported by Pasvanoğlu (2013) they are higher than those detected in stream water. The Li, Sr, and Si may therefore be the soluble products of volcanic rock - ground water and/or overburden - ground water reactions whereas higher B could be the product of diluting a concentrated solution of this element in upwelling thermal water.

Mineral solubility predictions can help with the interpretation of water chemistry, but the results of the PHREEQC simulation need to be applied with caution because computer thermodynamic modelling can oversimplify the complexity of natural water systems (Leybourne & Cameron 2010). The abundant mineral carbonate mud and travertine in the North and South Bogs are predicted by oversaturation of calcite and aragonite carbonate. These minerals precipitate when the CO₂ seeping from beneath the bogs reacts with dissolved Ca and Mg weathered from vesicular basalt outcropping near streams flowing into the wetlands. While saturation indices suggest calcite forms in preference to aragonite, X-ray diffraction analysis of rock from the wall of the travertine cone -CO₂-rich vent reveal that the mineral is predominately aragonite (> 80 percent).

Evidence of geothermal activity near the Nazko volcanic cone... continued from page 12

A higher temperature and a faster carbonate precipitation rate will favour formation of aragonite rather than calcite (Faure 1998).

Thermal water temperature can be predicted from the degree of silica saturation assuming that SiO₂ is in equilibrium with the water. A PHREEQC simulation predicts that chalcedony would, ideally, precipitate from the North Bog ground water and Pasvanoğlu (2013) has proposed an equation for predicting temperature from chalcedony equilibrium. The equation is:

$$\text{Log SiO}_2 = 4.69 - (1.32/t \text{ } ^\circ\text{C} + 273.15)$$

The SiO₂ geo-thermometer temperatures listed in Table 2 are clearly much higher than those actually measured in the water and are likely unrealistic since only trace amounts of quartz were detected in travertine samples by X-ray diffraction analysis. However, the predominance of aragonite in the travertine and the higher Si content of the water suggest that higher water temperatures may have existed in the past.

Probable sources for the North Bog ground water and the CO₂ are suggested by results of the stable isotope analyses. The North Bog δ¹⁸O‰ and δ D‰ values fall close to the meteoric water line and are more negative than the values reported for thermal water by Pasvanoğlu (2013). Hence, the North Bog ground water is unlikely to have upwelled from a thermal source and are likely meteoric in origin. Minissale et al. (2013) interpreted the δ¹³C values between -7‰ to +3‰ in central Yemen thermal well water to be the result of CO₂ from either magmatic source or from limestone dissolution. Because the North Bog δ¹³C values range from -1.6 to -7.1‰ the CO₂ could have been generated from a mantle magma.

Conclusions

Higher Li, B, Sr in bog waters and an existence of CO₂ seeps may be surface geochemical indicators for deeper geothermal activity although the trace element concentrations are lower than usually found in thermal springs. The North Bog water chemistry may be a product of bedrock-ground water reactions and mixing at depth of cool and warm waters. Stable isotope analyses suggest a meteoric source for the ground water and a magmatic source for the CO₂. Travertine and calcium carbonate organic mud deposits form where high concentrations of dissolved Ca and Mg in bog waters reacts with CO₂. The travertine in the Nazko bogs is predominantly aragonite suggesting that the carbonate was deposited from warm water. A SiO₂ geo-thermometer based on chalcedony solubility suggests that in the past bog water temperatures could have been higher than those at present.

Acknowledgments

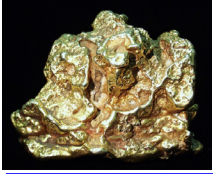
Geoscience BC funded this study as part of the 2013 TREK (Transferring Resources through Exploration and Knowledge) Project and their financial support was very much appreciated by the authors. We are grateful for field work assistance in 2013 and 2014 from J. Constable, H. Paul, T. Clement, D. Sacco, and F. Bertoia. N. Vigouroux

(Douglas College, North Vancouver, BC), Dr. G. Williams-Jones, (Simon Fraser University, Burnaby, BC), and Dr. C. Hickson, (Dajin Resources, Vancouver, BC), generously provided background information about the Nazko bogs. Dr. A. Rukhlov, (British Columbia Ministry of Energy and Mines, Geological Survey, Victoria, BC) is thanked for loaning water analysis equipment. Constructive and helpful reviews of the paper by Dr. R. Garrett, Geological Survey of Canada Emeritus Scientist, Ottawa and Dr. M. Leybourne, Department of Earth Sciences Laurentian University, Sudbury, are very much appreciated by the authors.

References

- ANGEN, J.J., WESTBERG, E., HART, C.J.R., KIM R. & RAHAMI, M., 2015. Preliminary Geological Map of the TREK Project Area, Central British Columbia; *Geoscience BC Report* 2015-10.
- CASSIDY, J.F., BALFOUR, N., HICKSON, C., KAO, H., WHITE, R., CAPLAN-AUERBACH, J., MAZZOTTI, S., ROGERS, G.C., AL-KHOUBBI, I., BIRD, A. L., ESTEBAN, L., KELMAN, M., HUTCHINSON, J., & McCORMACK, D., 2011. The 2007 Nazko, British Columbia, Earthquake Sequence: Injection of Magma Deep in the Crust beneath the Anahim Volcanic Belt. *Bulletin of the Seismological Society of America*, **101**(4): 732–1741.
- FAURE, G., 1998. Principles and applications of geochemistry, *Prentice Hall*, 600 p.
- KIM, H.S., CASSIDY, S.E., DOSSO, S.E., & KAO, H., 2014. Mapping crustal structure of the Nechako–Chilcotin plateau using teleseismic receiver function analysis; *Canadian Journal of Earth Sciences*, **51**, 407-417.
- KUEHN, C., GUEST, B., RUSSELL, J.K., & BENOWITZ, J.A., 2015. The Satah Mountain and Baldface Mountain volcanic fields: Pleistocene hot spot volcanism in the Anahim Volcanic Belt, west-central British Columbia, Canada. *Bulletin of Volcanology*, **77** (19), 4-27.
- LETT, R.E. & JACKAMAN, W., 2015. Tracing the source of anomalous geochemical patterns in soil, water and seepage gas near the Nazko volcanic cone, British Columbia, Canada, NTS 93B/13. *Geoscience BC Report*, 2015-16, 75 p.
- LEYBOURNE, M.I & CAMERON, E.M., 2010. Groundwater in geochemical exploration.. *Geochemistry: Exploration, Environment, Analysis*, **10**, 99-118.
- MINISSALE, A., VASELLI, O., MATTASH, M., MONTEGROSSI, G., TASSI, F., AD-DUKHAIN, A., KALBERKAMP, U., AL-SABRI, A. & AL-KOHLANI, T., 2013. Geothermal prospecting by geochemical methods in the Quaternary volcanic province of Dhamar (central Yemen). *Journal of Volcanology and Geothermal Research*, **249**, 95–108
- PARKHUST, D.L. & ALLEPO, C.A.J., 2013. Description of input and examples for PHREEQC version 3—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations: *United States Geological Survey Techniques and Methods*, Book 6, Chap. A43, 497 p.
- PASVANOĞLU, S., 2013. Hydrogeochemistry of thermal and mineralized water in the Diyadin (Agri) area, Eastern Turkey, *Applied Geochemistry*, **38**, 70-81.
- SOUTHER, J.S, CLAGUE, J.J., & MATHEWS, R.E., 1987. The Nazko cone: a Quaternary volcano in eastern Anahim Belt; *Canadian Journal of Earth Sciences*, **24**, 2477-2485.





Geochemical Nuggets

Coarse Sample Preparation Blanks

One of the most effective ways to monitor possible cross contamination between rock samples during sampling preparation is the inclusion of coarse blank material in the sample stream, particularly for projects involving coarse gold mineralisation. Ideally, this material would be of a similar nature and hardness to the typical run of lab sample, and its levels or the absence of the element(s) of interest should have previously been established. It's desirable that unmineralised core be used for drilling projects so that the presence of the coarse blank is not immediately evident to laboratory personnel, but logistical constraints often dictate the material used. Collars that have been cemented to stabilise them and then re-drilled can provide a ready supply of blank core. Garden centres often run a nice line of decorative stone useful for this purpose as well.

The usefulness of this approach is illustrated using two examples from 2016 in which significant cross contamination of gold was indicated in coarse blank material submitted after high grade gold samples in two different laboratories (Table 1).

Table 1. Analysis of coarse blank material from two different laboratories

Sequence	Au_ppm	Ag_ppm	Type
Case #1 - 1	202	198	Core
Case #1 - 2	13.9	10.6	Blank
Case #2 - 1	368	30.7	Core
Case #2 - 2	0.13	0.55	Core
Case #2 - 3	3.35	0.08	Blank

In case #1, the coarse blank was contaminated at the crushing stage, as re-assay of the coarse reject material also indicated the presence of ore-grade gold levels in the coarse blank. It was therefore necessary to re-sample the core for the entire submission.

In case #2, it was the blank situated two samples downstream of the high-grade gold sample that was contaminated. This reflected the use of two pulverising bowls at the work station between which the technician alternated samples for pulverising (e.g. Figure 1). It therefore required strategic placement of the blanks in the sample stream to detect the cross contamination. Note however that the amount of cross contamination in case #2, sample 3, while disconcerting, is just under 1% carry-over from the high-grade sample and that some cross contamination is inevitable when dealing with high-grade gold sample preparation. In both cases it was possible to confirm the identity of the coarse blanks from their multi-element geochemical fingerprint, which was distinctively different from the normal run of lab samples. Coarse blanks can therefore also be useful for identifying sample labelling issues as they are usually

readily identifiable in the sample stream, particularly where multi-element data are also being obtained.

These two recent examples of cross contamination highlight the importance of using coarse blank material to monitor sample preparation, particularly in projects requiring assaying of material containing high-grade gold. There are a number of important lessons to be gleaned from these two case studies:

1. It is necessary to place blanks directly after high grade gold samples in the sample stream; random placement of blanks may not identify problems.
2. Familiarity with the laboratory work flow is required to implement an effective quality assurance program (e.g. do the technicians alternate between pulverisers?).
3. Ideally, a single high-grade gold sample would be followed by two coarse blanks where two pulverising bowls are used – the first would detect contamination during crushing, and the second would detect contamination during pulverisation.
4. Cross contamination issues can be prevented by adopting the use of blank quartz washes between samples; multiple washes may be required in the case of high-grade gold material.

In both instances presented here the coarse blanks represent a small percentage of the samples in the batch. They therefore probably only reflect the tip of the iceberg with respect to the amount of cross contamination that has occurred. Failure of coarse blanks therefore brings the quality of the entire sample batch into question. Requesting the use of quartz washes between samples during all stage of sample preparation will reduce the potential for cross contamination, but should still be monitored using “blind” coarse blanks strategically placed into the sample stream. High-grade gold samples may require two quartz washes to remove all traces of gold from the pulverising bowl.



Figure 1. Example of the use of two pulverisers in the sample preparation stream.



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Archive samples used to test new scientific equipment

Geological Survey of Canada (GSC) scientists recently used samples from their archive collection to test the new portable near-infrared spectrometer mineral analyzer, the TerraSpec Halo. This new spectrometer, overseen by GSC mineralogist Jeanne Percival, provides instant and efficient mineral identification in rock and soil samples. GSC scientists Jan Peter and Beth McClenaghan working with Dan Layton-Matthews of Queen's University, used the Halo to identify jarosite, a secondary sulphate mineral that forms in ore deposits by the oxidation of iron sulphide. The jarosite is present in several archived gossan samples that were collected in the Bathurst (New Brunswick) base metal mining camp in 1965 by R.W. Boyle. Subsamples of these archived samples were taken for more rigorous scientific testing as part of the GSC's TGI-5 indicator mineral studies. Gossans in the Bathurst Mining Camp are an important source of gold and silver. Results from this study will help in the understanding of how the gossans formed and how to explore for them.

Beth McClenaghan



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Obituary



Xie Xuejing (1923-2017)

On Friday February 24, 2017 we lost an outstanding geochemist, the Chinese “father of exploration geochemistry”, and one of the pioneers of global geochemical mapping: Professor Xie Xuejing. He peacefully passed away accompanied by his children, his

students and colleagues at a hospital in Beijing, China.

Professor Xie was born on May 21, 1923 in Beijing, China. From August 1941 to July 1945, he studied in the Physics Department and then transferred to the Chemistry Department of Zhejiang University. From August 1945 to July 1946, his university education was stopped for one year and he worked at Xiaolongkan Oil Factory of Chongqing. From August 1946, he continued his study at university and graduated from the Chemistry Department in July 1947. From August 1947 to October 1949, he worked as an analyst at Nanjing Yongli Chemical Factory. In 1949 he married Li Meisheng, and together they had 5 children, Xie Yuanhong, Xie Yuanru, Xie Yuanpei, Xie Yuanjie and Xie Yuanquan.

From November of 1949 to January of 1953, he worked as a geoanalyst in the Chemical Laboratory of Nanjing Mineral Exploration Bureau. From February of 1953 to January of 1957, he served as a junior researcher at the Geochemical Prospecting Division of Ministry of Geology. From February 1957 to now, he worked as a geochemist, senior geochemist, director of the Exploration Geochemistry Division, vice director the Institute of Geophysical and Geochemical Exploration (IGGE), Chinese Academy of Geological Sciences. He was elected as an academician of the Chinese Academy of Sciences in 1980 and served as the Honorable Director of the IGGE since 1983. He was a member of the Association of Applied Geochemists and chairperson of Chinese Association of Exploration Geochemistry.

Professor Xie was the founder of exploration geochemistry in China. He conducted the first geochemical exploration activity in China in Anhui Province with the systematic sampling and chemical analysis of rocks, soils, stream sediments, and plants in the search for copper deposits in 1951. In the late 1950s, he studied element zonation in primary halos during which he developed methods that were widely applied in geochemical exploration for mineral deposits in China. In the 1970s, Professor Xie initiated and designed the China Regional Geochemistry - National Reconnaissance (RGNR) Project, also known as the China National Geochemical

Mapping Project. Over the past nearly 40 years, the project has covered more than seven million square kilometers. This project has led to China having the most remarkable national geochemical database in the world and led to discoveries of about 2500 mineral ore deposits up to now. The most exciting of these is its contribution to discovery of the total reserve of 4000 tons of gold.

Professor Xie devoted his research to the systematics of geochemical mapping, including the studies of cell sampling methodology, reference materials, laboratory chemical analysis and quality control etc. This research has made great contribution to China's high-quality geochemical data and atlas based on the 30-year sampling campaign and more than 30 laboratories' sample analyses.

Professor Xie was one of the pioneers of global geochemical mapping. He was one of the initiators for IGCP 259 and IGCP 360. Prof. Xie played an important role in designing the protocols for international geochemical mapping as a member of the steering committee for IGCP 259 and IGCP 360. He conducted the Environmental Geochemical Monitoring Network (EGMON) project in China as a pilot study of the Global Geochemical Mapping Project from 1993 to 1996. His idea of floodplain sediment sampling was put forward in this project. A total of 520 floodplain sediment samples were used to cover most of China with the similar general geochemical overview compared based on the high density stream sediment sampling data of the RGNR. In order to meet the chemical analytical requirements of IGCP 259/360 recommendations, Professor Xie proposed to composite samples from the RGNR samples (25 samples covering 100 km² were composited into 1 sample) for chemical analysis of 76 elements (71 elements as recommended by IGCP 259 plus Os, Ir, Ru, Rh and Re) in 2000. This project has promoted the development of a 76-element laboratory analytical technology. This project has produced 76-element geochemical atlas covering 2.5 million square kilometers of southwest and southern China from 2000 to 2010.

Professor Xie was a strategic scientist. In the late 1990s, he put forward the nation-wide Geological Survey Program which integrated investigation work and scientific study, and the Multi-purpose and Multi-scale Geochemical Mapping Project etc.

Professor Xie, as an international geochemist, initiated the establishment of international research centre on global geochemical mapping. With his active promotion, the UNESCO International Centre on Global-scale Geochemistry was officially established with the approval by the UNESCO and Chinese Government in May 2016.

Professor Xie was a fine teacher. He, as a supervisor of the Chinese Academy of Geological Sciences and an emeritus professor at Changchun College of Geology (Jilin University), China University of Geosciences (Beijing), mentored twenty MSc and PhD students who are currently taking on leadership roles in geochemical exploration,

Obituary... *continued from page 18*

environmental, and agricultural geochemical mapping and global geochemical baselines studies. He had 180 publications both in Chinese and in English.

Professor Xie received the China Science Conference Prize in 1978, the China State Science and Technology Progress Prize in 2008, and the Gold Medal Award of Association of Applied Geochemists (AAG) in 2007 for his remarkable achievements in the field of applied geochemistry. For more information about his AAG Gold medal see

this web link <https://www.appliedgeochemists.org/index.php/awards/2-uncategorised/74-gold-medal-2007>

Professor Xie, we will miss you enormously and we are so grateful for your long lasting legacy in exploration geochemistry and geochemical mapping.

Wang Xueqiu

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**Recently Published in Elements**

Volume 13, nos. 1 and 2

Volume 13, no. 1, Volcanoes: From Mantle to Surface

The February edition of Elements has a volcanic theme. Topics range from where magmas are stored and why they erupt, to what we know we still don't know about volcanoes. I was surprised by how little we understand about magma storage and eruption in spite of decades of research. The AAG news in this issue includes an abstract for the Explore article in issue 173 and a listing of sessions proposed by the AAG for the RFG2018 in Vancouver.

**Volume 13, no. 2, Sulfides**

The April edition of Elements is focused on sulfides; from mineralogy to mineral deposits. This issue should be of particular interest to those of us with an interest in finding mineral deposits, as well as in developing them in an environmentally sustainable way. The AAG news includes a message from our illustrious President and introduces another three of our regional councillors to the broader scientific community.

Dennis Arne

**Geochemistry: Exploration, Environment, Analysis**

Contents February 2017, v. 17, no. 1

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Geochemical and mineralogical controls on metal(loid) mobility in the oxide zone of the Prairie Creek Deposit, NWT

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Hydrogeochemical assessment of groundwater quality in the Soutpansberg Basin around Tshikondeni, Limpopo Province, South Africa

N. Malaza p. 35-41

The Blackwater gold-spessartine-pyrolusite glacial dispersal train, British Columbia, Canada: Influence of sampling depth on indicator mineralogy and geochemistry

S.A. Averill p. 43-60



Hydrothermal Ore Deposits Course

The Departments of Earth Sciences at the University of Ottawa, Ottawa, Canada and Laurentian University, Sudbury, Canada are pleased to announce the 2017 Joint Modular Course in **HYDROTHERMAL ORE DEPOSITS**, which will be held at the University of Ottawa October 21-28, 2017.

The course will feature 4 two-day modules to be presented by Dr. Mark Hannington (University of Ottawa), Dr. Daniel Kontak (Laurentian University), Dr. Matthew Leybourne (Laurentian University), Dr. Richard Goldfarb (Consultant), Dr. Jeremy Richards (Laurentian University), Dr. David Burrows (Vale), Dr. J. Bruce Gemmill (CODES), Dr. Steve Piercey (Memorial University) and Dr. Robert Seal (USGS).

Oct 21 & 22 A Practical Guide to the Ore Elements, Minerals and Fluids
Oct 23 & 24 Orogenic Gold Deposits and Porphyry-Related Systems
Oct 25 & 26 Epithermal Systems and Iron Oxide-Copper-Gold Deposits
Oct 27 & 28 Volcanogenic Massive Sulfides and Ores in Surficial Environments

The course is open to graduate students from any university as well as professionals in industry. Graduate students registered in the course may be eligible for credit toward their degree programs. Industry participants may receive credit toward professional training requirements.

More information is available at https://science.uottawa.ca/earth/short_course

Exploration '17

October 21 to 25, 2017, Toronto, Canada

Exploration '17 is the sixth of the very successful series of DMEC decennial mining exploration conferences, which have been held in the seventh year of every decade starting in 1967. The theme of the Exploration '17 conference is "Integrating the Geosciences: The Challenge of Discovery", featuring a multi-national, multi-disciplinary technical programme, exhibition, workshops and field schools.

www.exploration17.com/About.aspx

Program Schedule

Oral presentations are by invitation only
<http://www.exploration17.com/Program-Schedule.aspx>

UNIVERSITY OF NIGERIA, NSUKKA (UNN)
Department of Geology

REQUEST TO THE ASSOCIATION OF APPLIED GEOCHEMISTS

We are looking to refurbish and upgrade analytical facilities at the Geochemical Laboratory of the Geology Department, University of Nigeria, Nsukka. The aim is to develop the Laboratory to a level where it could serve as a regional centre for training a critical mass of young analytical geochemists in the southeastern region of Nigeria to complete mapping of the remaining GRN cells in Nigeria in connection with the Africa Geochemical Database Project.

In this pursuit, we have secured a suitable space for pertinent geochemical hardware, laboratory accessories and geochemistry teaching resources that may be surplus to your requirements. Geochemical hardware may include, among others: portable analytical equipment, water distillation plant, deionizer, very high temperature furnace for dry-ashing, oven, magnetic stirrers, Teflon beakers, platinum crucibles, sand baths, common reagents, standards and georeference materials (for environmental samples - soil, natural waters, vegetation) for ICP-MS and XRF analyses.

Back issues of our key journals such as GEEA and ELEMENTS, and teaching and learning resources in geochemistry may also prove very useful.

At the moment, we are trying to establish the extent to which the University (UNN) would be able to contribute towards the cost of shipment.

If you have suitable materials to gift to the UNN please contact Theo Davies
(details below).

In addition the Department is interested in employing a highly reputable analytical geochemist/technician for 3 to 6 months on an internationally competitive, as well as negotiable remuneration package. Details will be added the AAG website regarding this position at a later time.

With highest regards,

Prof. T.C. Davies
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CALL FOR SESSIONS

GET RESOURCEFUL - EMPOWER A GENERATION

A call for sessions under the technical and non-technical themes and sub-themes making up the below matrix is now open. Proposals will be accepted until late fall 2016. Session ideas that depart from these themes, provided that they are relevant to the conference, will be considered.

Session proposals must include:

Proponents | Session title | Short summary | Relationship to conference partners | Expected participation

Energy	Minerals	Water	The Earth	Resources and Society
Conventional	Major minerals	Sub-surface water	Earth Evolution	Resources and indigenous people
Unconventional	Minor - critical minerals	Surface water	Earth Processes	Role of Geological Surveys
Sedimentary Basins	Technology and metals	Water - Minerals	Earth Systems	Resource frontiers - Arctic, Oceans
Geothermal - renewable	New sources	Water - Energy	GAC-MAC	Sustainability and climate
				Knowledge and education
				Geoethics
				Young leaders

Organizers

Canadian Institute of
Mining, Metallurgy
and Petroleum



Institut canadien des
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Partners

AAG	Association of Applied Geochemists
BCGS	British Columbia Geological Survey
CFES	Canadian Federation of Earth Sciences
CGEN	Canadian Geoscience Education Network
CGS	Canadian Geotechnical Society
CIM	Canadian Institute of Mining, Metallurgy and Petroleum
CSEG	Canadian Society of Exploration Geophysicists
CSPG	Canadian Society of Petroleum Geologists
GAC	Geological Association of Canada Geoscientists Canada
GSC	Geological Survey of Canada

IAH-CNCO	International Association of Hydrogeologists - Canadian National Chapter
IAMG	International Association for Mathematical Geology
IAPG	International Association for Promoting GeoEthics
IUGG	International Union of Geodesy and Geophysics
IUGS	International Union of Geological Sciences
MAC	Mineralogical Association of Canada

Submit your session proposal at: RFG2018.org

RFG 2018

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CALENDAR OF EVENTS

International, national, and regional meetings of interest to colleagues working in exploration, environmental and other areas of applied geochemistry. These events also appear on the AAG web page at: www.appliedgeochemists.org.

2017

- 12-14 JUNE 14th Australasian Environmental Isotope Conference. Wellington New Zealand. Website: tinyurl.com/juoqtqy
- 13-15 JUNE PEG2017 – 8th International Symposium on Granitic Pegmatites. Kristiansand Norway. Website: tinyurl.com/h8hwo9g
- 23-28 JUNE Tourmaline 2017. Nové Město na Moravě Czech Republic. Website: tourmaline2017.cz
- 25-30 JUNE Catchment Science: Interactions of Hydrology, Biology & Geochemistry. Lewiston ME USA. Website: tinyurl.com/zst629v
- 26–30 JUNE 14th International Conference on Sustainable Use and Management of Soil, Sediment and Water Resources – AquaConSoil 2017. Lyon France. Website: www.aquaconsoil.org
- 30 JUNE-4 JULY 33rd International conference of the Society for Environmental Geochemistry and Health. Guangzhou China. Website: segh2017.csp.escience.cn
- 4-8 JULY 32nd International conference of Society for Environmental Geochemistry and Health. Brussels Belgium. Website: segh-brussels.sciencesconf.org/
- 16-20 JULY International Conference on the Biogeochemistry of Trace Elements. Zurich Switzerland. Website: icobte2017.ch/
- 16-21 JULY 13th International Conference on Mercury as a Global Pollutant Providence RI USA. Website: mercury2017.org/initial/index.php
- 23-28 JULY 80th Annual Meeting of the Meteoritical Society. Santa Fe NM USA. Website: metsoc2017-santafe.com
- 23-28 JULY Chemical Oceanography (Gordon Research Conference). New London NH USA. Website: www.grc.org/programs.aspx?id=11096
- 30 JULY-4 AUG Atmospheric Chemistry (Gordon Research Conference). Newry, ME USA. Website: www.grc.org/programs.aspx?id=10916
- 4-9 AUGUST Magmatism of the Earth and related strategic metal deposits. Miass Russia. Website: magmas-and-metals.ru
- 6-10 AUGUST Microscopy & Microanalysis 2017. St Louis MO USA. Website: microscopy.org/MandM/2017
- 12-17 AUGUST 21st World Congress of Soil Science. Rio de Janeiro Brazil. Website: 21wcss.org/
- 13-17 AUGUST 11th International Symposium on Selenium in Biology and Medicine. Stockholm, Sweden. Website: se2017.se
- 13-18 AUGUST Goldschmidt 2017. Paris France. Website: goldschmidt.info/2017
- 20-23 AUGUST 14th Biennial SGA Meeting. Quebec City QC Canada. Website: sga2017.ca/
- 20-29 AUGUST 12th International Eclogite Conference. Åre Sweden. Website: www.geology.lu.se/IEC12
- 28 AUGUST- 7th International Conference on Medical
1 SEPTEMBER Geology. Moscow Russia. Website: www.medgeo2017.org
- 2-9 SEPTEMBER 18th Annual Conference of International Association for Mathematical Geosciences. Fremantle WA Australia. Website: iamg2017.com
- 6-8 SEPTEMBER Discoveries in the Tasmanides, a Mines and Wines conference. Orange NSW Australia. Website: www.minesandwines.com.au
- 11-14 SEPTEMBER SIAM Conference Mathematical and Computational Issues in the Geosciences. Erlangen Germany. Website: www.siam.org/meetings/gsl7
- 17-20 SEPTEMBER SEG 2017. Beijing China. Website: www.seg2017.org/
- 17-22 SEPTEMBER 28th International Meeting on Organic Geochemistry. Florence Italy. Website: www.houseofgeoscience.org/imog/
- 17-22 SEPTEMBER Applied Isotope Geochemistry 12. Copper Mountain Resort CA USA. Website: www.iage-society.org/AIG.html
- 18-19 SEPTEMBER 19th International Conference on Gas Geochemistry. Rome Italy. Website: www.waset.org/conference/2017/09/rome/ICGG
- 18-22 SEPTEMBER 11th International Kimberlite Conference. Gaborone Botswana. Website: www.11ikc.com
- 25-29 SEPTEMBER 23rd International Symposium on Environmental Biogeochemistry. Palm Cove QLD Australia. Website: www.iseb23.info
- 9- 10 OCTOBER Annual International Conference on Geological & Earth Sciences. Singapore. Website: www.geearth.org
- 9-13 OCTOBER 14th International Symposium on Biomineralization. Tsukuba Japan. Website: www.biomin14.jp
- 21-25 OCTOBER Exploration '17. Toronto ON Canada. Website: www.exploration17.com
- 22-25 OCTOBER GSA Annual Meeting. Seattle WA USA. Website: www.geosociety.org/meetings/2017/
- 31 OCTOBER- 10th Fennoscandian Exploration and
2 NOVEMBER Mining. Levi Finland. Website: fem.lappi.fi/en
- 23-26 NOVEMBER International Conference on Computational Chemistry and Toxicology in Environmental Science. Taichung, Taiwan. Website: theochem.wikispaces.com
- 3-8 DECEMBER American Exploration and Mining Association Annual Meeting. Sparks/Reno NV USA. Website: tinyurl.com/m99kskj

Please let us know of your events by sending details to:

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P.O. Box 8700, St. John's, NL, Canada, A1B 4J6

Email: StephenAmor@gov.nl.ca Tel: +1-709-729-1161



CALENDAR OF EVENTS

continued from page 23

7-8 DECEMBER 19th International Conference on Nuclear and Environmental Radiochemical Analysis. Sydney NSW Australia.
Website: tinyurl.com/jsh9gsu

2018

8-13 JANUARY 2018 Winter Conference on Plasma Spectrochemistry. Amelia Island FL USA.
Website: tinyurl.com/mrvbqwa

18-21 FEBRUARY Australian Exploration Geoscience Conference. Sydney NSW Australia.
Website: www.aegc2018.com.au

4-7 MARCH Prospectors and Developers Association of Canada Annual Convention. Toronto ON Canada. Website: www.pdac.ca/convention

16-21 JUNE 28th International Applied Geochemistry Symposium. Vancouver BC Canada.
Website: rfg2018.org

8-13 JULY Geoanalysis 2018. Sydney NSW Australia.
Website: 2018.geoanalysis.info



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