INTRODUCTION TO TRADITIONAL KNOWLEDGE STUDIES IN SUPPORT OF GEOSCIENCE TOOLS FOR ASSESSMENT OF METAL MINING IN NORTHERN CANADA

Jennifer M. Galloway[1 *] and R. Timothy Patterson[2]

[1] *Geological Survey of Canada Calgary / Commission géologique du Canada, Calgary, Alberta, Canada*

[2] *Department of Earth Sciences and Ottawa-Carleton Geoscience Centre, Carleton University, Ottawa, Ontario, Canada*

* *Jennifer.Galloway@canada.ca*

The Geoscience Tools for Environmental Assessment Project is being co-led by the Geological Survey of Canada and Carleton University, in collaboration with the Government of the Northwest Territories Cumulative Impact Monitoring Program, the Northwest Territories Geological Survey, Crown-Indigenous Relations and Northern Affairs Canada, Environment and Climate Change Canada, the Canadian Museum of Nature, Queen's University, the University of Leeds, Seabridge Gold, TerraX Minerals Ltd., the Yellowknives Dene First Nation, the North Slave Métis Alliance, the Tłı̨chǫ Government, the Tłı̨chǫ Research and Training Institute, and Hadlari Consulting Ltd. The study area is the Slave Geological Province, with a focus on the areas around Yellowknife and Courageous Lake, Northwest Territories.

Abstract

We applied a multidisciplinary research methodology to reconstruct variations in climate, geochemistry, permafrost, and ecology over the past 1,000 years along a north-south transect in the Slave Geological Province in order to assess the cumulative effects of natural and human-driven change on the transport and fate of metals/metalloids and on the health of regional ecosystems in areas of high resource potential in northern Canada. The study focussed on Yellowknife and Courageous Lake, two areas with known gold resources and contamination from historical mining. Through collection and analyses of cores from lake sediments and permafrost peatlands, combined with spatial data, Traditional Knowledge, and Inuit Qaujimajatuqangit, the impact of climate change and land disturbance on metal/metalloid flux into aquatic systems was assessed. This contribution serves as an introduction to the project, with a focus on the traditional knowledge developed as part of this research. Traditional knowledge studies were conducted by several project partners: the North Slave Métis Alliance, the Yellowknives Dene First Nation, the Tłı̨chǫ Research and Training Institute, and Hadlari Consulting Ltd., an Inuit-owned-and-operated business. The studies provide insight into past climate and land-use changes not discernible from paleoecological records alone. Specific information on seasonality, ice quality, lake water levels, pre-industrial environmental conditions, traditional land use, spatial extent of contamination associated with legacy mining, and impact of climate change on cultural land use are some examples of the kinds of information derived from the traditional knowledge studies. The integrated, multidisciplinary approach employed in this research project highlights the utility of combining different ways of knowing to generate a knowledge assemblage that incorporates human contextual information and develops a deeper understanding of the cumulative impacts of legacy mining and climate change in northern Canada.

Suggested citation:

Galloway, J.M. and Patterson, R.T. 2018. Introduction to traditional knowledge studies in support of geoscience tools for assessment of metal mining in northern Canada. Polar Knowledge: Aqhaliat 2018, *Polar Knowledge Canada, p. 92–98. DOI: 10.35298/pkc.2018.12*

Résumé

Nous avons appliqué une méthodologie de recherche multidisciplinaire pour reconstituer les variations du climat, de la géochimie, du pergélisol et de l'écologie au cours des 1 000 dernières années le long d'un transect nord-sud dans la province géologique Slave afin d'évaluer les effets cumulatifs des changements naturels et anthropiques sur le transport et le devenir des métaux et des métalloïdes et sur la santé des écosystèmes régionaux dans les régions présentant un grand potentiel de ressources dans le nord du Canada. L'étude s'est concentrée sur Yellowknife et Courageous Lake, deux régions qui ont des ressources aurifères connues et qui sont contaminées par l'exploitation minière passée. Grâce à la collecte et à l'analyse de carottes de sédiments lacustres et de tourbières pergélisolées, combinées à des données spatiales, à des connaissances traditionnelles et à l'Inuit Qaujimajatuqangit, les répercussions des changements climatiques et de la perturbation des sols sur le flux des métaux et des métalloïdes dans les systèmes aquatiques ont été évaluées. Cette contribution sert d'introduction au projet, en mettant l'accent sur les connaissances traditionnelles développées dans le cadre de cette recherche. Plusieurs partenaires du projet ont mené des études sur les connaissances traditionnelles, notamment l'Alliance des Métis de North Slave, la Première Nation des Dénés Couteaux-Jaunes, le Tłı̨chǫ Research and Training Institute et Hadlari Consulting Ltd., une entreprise appartenant aux Inuits et exploitée par eux. Les études fournissent un aperçu des changements climatiques et de l'utilisation des terres du passé qui ne sont pas discernables uniquement à partir des archives paléoécologiques. Des renseignements précis sur la saisonnalité, la qualité de la glace, les niveaux d'eau des lacs, les conditions environnementales préindustrielles, l'utilisation traditionnelle des terres, l'étendue spatiale de la contamination associée à l'exploitation minière passée et les répercussions des changements climatiques sur l'utilisation des terres culturelles sont quelques exemples des types de renseignements tirés des études sur les connaissances traditionnelles. L'approche multidisciplinaire intégrée utilisée dans ce projet de recherche met en évidence l'utilité de combiner différents systèmes de connaissances pour générer un assemblage de connaissances qui intègre l'information contextuelle humaine et permet de mieux comprendre les effets cumulatifs de l'exploitation minière et des changements climatiques passés dans le Nord canadien.

Introduction

Geoscience Tools for Environmental Risk Assessment of Metal Mining was a three-year (2015–2018) project undertaken by the Geological Survey of Canada (GSC) and Carleton University, and funded by Polar Knowledge Canada (Project #1516-149) and the GSC. The project, co-led by Jennifer Galloway (GSC) and Timothy Patterson (Carleton University), was a collaborative effort to study the impact of climate change on the transport and fate of arsenic at two sites contaminated by legacy mining and mineral processing: Giant Mine, Yellowknife, and Tundra Mine in the Courageous Lake area(Fig. 1; Galloway et al. 2012, 2015, 2017; Palmer et al. 2015). This information may be used to assess the efficacy of remediation and establish benchmarks against which potential impacts of future resource development, land use, and climate change can be determined and regulated as necessary.

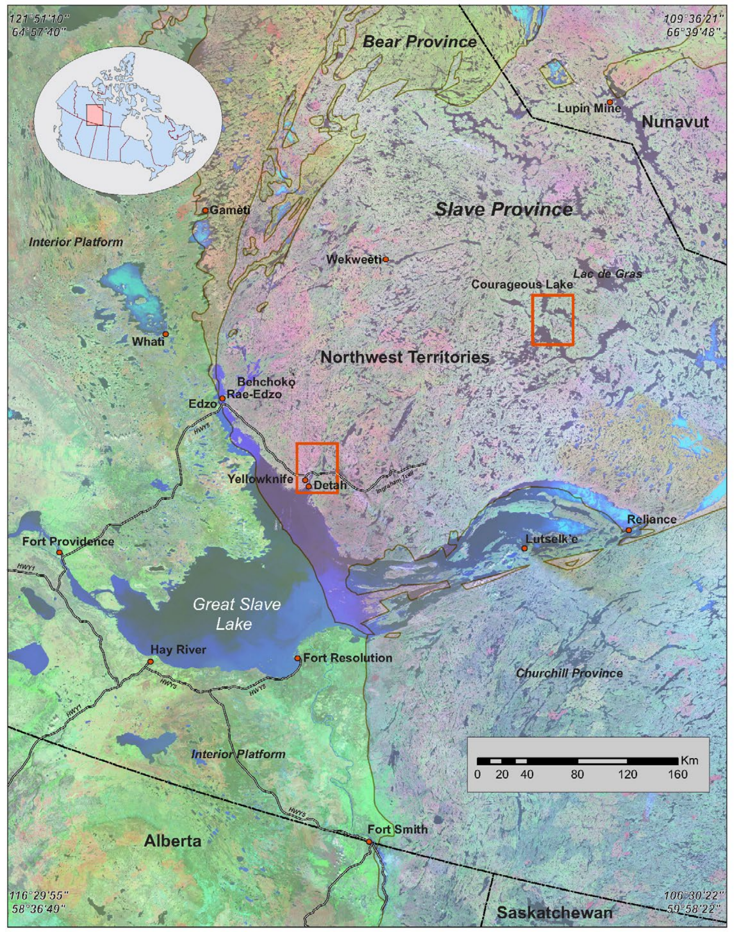

Figure 1: Map of the central Northwest Territories showing the location of the study areas.

Regional pre-mining background and baseline levels of arsenic were determined through analyses of lake sediment-water interface samples and surfacewater

Table 1: Some characteristics of traditional knowledge and western science knowledge systems (after Berneshawi 1997; Moller et al. 2004).

	Traditional Knowledge	Western Scientific Knowledge
Dominant mode of thinking	Intuitive, holistic, "interpretation of how the World works from a particular cultural perspective"[a]	Analytical, segmented, specialized, compartmentalized
Communication and learning	Oral in some cases[b,c] observational, story-telling[c-f]	Literate, experimental
Time scale	Synchronic; tends to be long time periods in a specific area; offers depth of experience in a local, culture-specific context[g]	Diachronic; tends to be short-term data over large areas; offers broad context beyond local level[g]
Characteristics	Subjective, spiritual, ethical, moral in some cases	Reductionist, objective,
Skewness	Focus on extremes[h]	Focus on averages
Data creation and transmission	Inclusive, generational, "transferred from generation to generation through daily social and cultural events"[i]	Selective
Prediction abilities	Qualitative	Quantitative, in some cases
Type of explanation	Spiritual in some cases, analogy[d]	Hypotheses, theories, laws
Knowledge management systems	Long-term, decentralized, consensus-based	Centralized, regulated
Assessment of uncertainty	Not explicit[h]	Emphasized
Assessment of authority	Reliability or credibility of knowledge holder determined based on life experience and reputation for holding sound knowledge about a topic by community members; community review	Peer review and associated metrics, determined by scientific community
Similarities	Both improve our understanding of the World and are based on repeated processes of observation, inference, verification, and prediction[j,k]	
	Both are dynamic; new knowledge is incorporated and integrated with information that cannot necessarily be understood in isolation[j]	

[a]Snively and Corsiglia (2000, p. 3); [b]Aronowitz, 1998; [c]Ignas, 2004; [d]MacLean and Wason-Ellam, 2006; [e]Mitchell et al., 2008; [f]Sutherland, 2002; [g]Becker and Ghimire (2003); [h]Huntington et al. (2004); [i]Ogawa (1997, p. 586); [j]Menzies and Bulter (2006); [k]Hoaglund (2017)

samples from 100 lakes in the Yellowknife area (Galloway et al. 2012, 2017; Palmer et al. 2015) and an additional ~100 lakes spanning a latitudinal gradient from Hay River to Lac de Gras (Fig. 1; Galloway et al. 2015). The second phase of the research, which is ongoing, is focussed on mechanisms involved in the transport and fate of arsenic in aquatic environments (alloway et al. 2017) and proxy-based reconstruction of climate over the past ~1,000 years through analyses of lake sediment and peat cores. This hind-casting approach offers the opportunity to further evaluate the hypothesis that climate mediates chemical change, using studies of past periods of warmth (e.g., the Holocene Hypsithermal and the Medieval Warm Period) as analogues for the twenty-first century and future warming.

Traditional Knowledge (TK) and Inuit Quajimajatuqangit (IQ) represent important sources of information on past climate and pre-industrial environments of the study regions. In collaboration with project partners, the North Slave Métis Alliance (NSMA), the Tłı̨chǫ Research and Training Institute (TRTI), the Yellowknives Dene First Nation (YKDFN), and Hadlari Consulting Ltd., specific insight on past climate changes is expected to provide a more comprehensive understanding of past environmental conditions than could be derived by using western science alone. The study generated by the NSMA is included as part of this volume; the other reports may be published elsewhere in the future.

Traditional knowledge

Traditional knowledge (TK) can be described as culturally relevant information passed from generation to generation, which forms part of a people's cultural identity. A commonly used definition of traditional ecological knowledge (TEK), a subset of TK, is "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, and [it is] about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999). Traditional Knowledge or IQ, comprises holistic knowledge systems; knowledge cannot be compartmentalized or separated from the people who hold it, and in this aspect, TK differs markedly from the western scientific knowledge system. TK systems are, in general, abstract, qualitative, inclusive, intuitive, diachronic, and formed from communal knowledge gained over time through practice and application (Table 1).

There has been growing acknowledgement of the value of inclusion of TK in understanding climate change, natural resource management, environmental assessment, and remediation and reclamation of industrial sites (Usher 2000; Alexander et al. 2011; Sandlos and Keeling 2016; Hoaglund 2017). TK is well suited to be included in land-use planning strategies, as these knowledge systems address needs for holistic and adaptive management of multiple resources and ecosystems (Berkes et al. 2000). TK also offers the potential to identify and monitor cumulative impacts of climate and land-use change by providing long-term descriptions of climate variability and its effects on ecosystems, as well as human contextual information, which fill knowledge and understanding gaps that western science cannot address (Johannes 1998; Usher 2000; Huntington et al. 2004; Baker and Mutitjulu Community 2009). TK and paleoecological studies are particularly well suited for integration, as knowledge gained from both approaches is typically local to regional in spatial scale but covers a great deal of time (decades to millennia).

An understanding of the differences and similarities of TK and western science knowledge is required for knowledge integration (Bohensky and Maru 2011; Table 1). The means to address the limitations of direct comparison exist. These include weight of evidence for quantitative and qualitative information (Good 1991; Chapman 2007; Suter and Cormier 2011) and Bayesian statistically-based metrics (Good 1991).

Results and discussion

TK studies to address the research theme and knowledge gaps identified by each community were developed and led by project partners, the NSMA, TRTI, YKDFN, and Hadlari Consulting Ltd. A brief summary of the report generated by the NSMA and the TRTI is provided here.

North Slave Métis Alliance

Continual Change and Gradual Warming: A Summary of the North Slave Métis Alliance's Recorded Cultural Knowledge on Climate and Environmental Change

North Slave Métis Alliance members are keepers of detailed, quantitative information on past climate, and this community reviewed publicly available and culturally relevant literature, which included Hudson's Bay Company journals (e.g., journals from Old Fort Rae covering 1888 to 1912), Warburton Pike's account of travels to the Barren Grounds (published in 1892), John Franklin's expedition documents (including meteorological journals covering 1825 to 1827), and Meteorological Council of Great Britain documents (including temperatures recorded by John Rae at Fort Confidence from 1850 to 1851 and W.J.S. Pullen at Fort Simpson from 1849 to 1851). This literature review was combined with a review of numerous secondary sources held within the NSMA's database, NSMA interview transcripts, and NSMA member journals. The report summarizes quantitative information on climate over the past ~200 years and provides specific insight on changes in seasonality, wind strength and direction, water levels, and snow pack, as well as the impact of climate change on land use by NSMA members.

Tłı̨chǫ Research and Training Institute

Everything Seems to Have Changed

TRTI undertook interviews of TK holders in a community-based setting in order to compile information on past climate and document some of the ways that recent climate warming has impacted traditional lake use. Insight into seasonality and hydrology was of particular interest from a paleoclimate perspective, as these important aspects of the climate system are difficult to reconstruct using proxy-based paleoecological study. Tłı̨chǫ TK holders reported an approximate two-week delay in freeze-up of lakes from early / mid-October to early November. In addition, they reported that the duration of freeze-up is no longer abrupt, and now includes several freeze-thaw events that affect the quality of the ice. TK holders also reported precipitation falling as rain prior to ground freeze-up in the fall, which affects spring melt, and more intense and frequent wildfires during the summer season, which are related to rapidly reduced snowpack in the spring. The report also includes some of the cultural implications of twenty-first-century climate change.

Integration of traditional knowledge and western scientific knowledge

The purpose of the larger study, Geoscience Tools for Environmental Risk Assessment of Metal Mining, is to determine if, and how, climate change has, and may, impact the transport and fate of metal/metalloids. This is highly relevant at contaminated sites in northern Canada, where twenty-first-century climate change is expected to profoundly alter biogeochemical cycling. Acquisition of western scientific knowledge through combined micropaleontological and geochemical study of paleoecological archives is ongoing. Paleoclimatological perspectives offered by TK studies will be compared with western science knowledge to produce a knowledge assemblage. It is expected that each way of knowing will provide unique insight into past climate and environmental change, which can be used to better predict future chemical change.

Conclusions

A collaborative research design that included knowledge holders from First Nation, Métis, and Inuit communities; government; industry; and academia demonstrates that complementary ways of knowing can generate insight into climate change, weather, environmental variability, cumulative effects, land-use change, contamination, changes in seasonality, ice quality, wildfires, and spatial extent of contamination. With this approach, new insight in the areas of interest in the Northwest Territories is produced.

Acknowledgements

Funding for this project was provided by the Geological Survey of Canada (Environmental Geoscience Program), Polar Knowledge Canada (Project #1516-149), the Government of the Northwest Territories Cumulative Impact Monitoring Program, and the Northwest Territories Geological Survey (NTGS). The project would not have been possible without substantial in-kind support from Crown-Indigenous Relations and Northern Affairs Canada, Environment and Climate Change Canada, the Canadian Museum of Nature, Queen's University, the University of Leeds, Seabridge Gold, TerraX Minerals Ltd., the Yellowknives Dene First Nation, the North Slave Métis Alliance, the Tłı̨chǫ Government, the Tłı̨chǫ Research and Training Institute, and Hadlari Consulting, Ltd. We thank Douglas Lemay (GSC) for his drafting assistance in the production of Figure 1. We are grateful to Scott Cairns (NTGS) and Keith Dewing (GSC) for their constructive and helpful comments, which greatly improved the manuscript. This article represents Natural Resources Canada (NRCan-RNCan) Contribution Number: 20180128.

References

Aronowitz, S. 1988. Preface to Science as power: Discourse and ideology in modern society. University of Minnesota Press, Minneapolis, MN.

Baker, L.M. and Mutijulu Community. 1992. Comparing two views of the landscape: Aboriginal traditional ecological knowledge and modern scientific knowledge. *Rangeland Journal* 14: 174–187. doi.org./10.1071RJ9920174.

Becker, C.D. and Ghimire, K., 2003. Synergy between traditional ecological knowledge and conservation science supports forest preservation in Ecuador [online]. *Conservation Ecology* 8 (2):1. Available from http://www.consecol.org/vol8/iss1/art1.

Berkes, F. 1999. Scared ecology: Traditional ecological knowledge and resource management. Taylor and Francis Publishing Company, Philadelphia, PA.

Berkes, F., Colding, J., and Folke, C. 2000. Rediscovery of traditional ecological knowledge as adaptive management. *Ecological Applications* 10:1251–1262.

Berneswahi, S. 1997. Resource management and the Mik'maq nation. *Canadian Journal of Native Studies* 17:115–148.

Bohensky, E.L. and Maru, Y. 2011. Indigenous knowledge, science, and resilience: What have we learned from a decade of international literature on integration? *Ecology and Society* 16:6. doi.org/10.5751/ES-04342-160406.

Chapman P.M. 2007. Traditional ecological knowledge (TEK) and scientific weight of evidence determination. *Marine Pollution Bulletin* 54:1839–40.

Galloway, J.M., Macumber, A., Patterson, R.T., Falck, H., Hadlari, T., and Madsen, E. 2010. Paleoclimatological assessment of the southern Northwest Territories and implications for the long-term viability of the Tibbitt to Contwoyto winter road: Part 1 - core collection. Northwest Territories Geoscience Office, NWT. Open Report 2010-002, 21 pp.

Galloway, J.M., Palmer, M., Jamieson, H.E., Patterson, R.T., Nasser, N.A., Falck, H., Macumber, A.L., Goldsmith, S.A., Sanei, H., Normandeau, P., Hadlari, T., Roe, H.M., Neville, L.A., and Lemay, D. 2015. Geochemistry of lakes across ecozones in the Northwest Territories and implications for the distribution of arsenic in the Yellowknife region: Part 1 - sediments. Geological Survey of Canada. Open File 7908, 50 pp. + appendix, 1.zip file. doi:10.4095/296954.

Galloway, J.M., Swindles, G.T., Jamieson, H.E., Palmer, M., Parsons, M.B., Sanei, H., Macumber, A.L., Patterson, R.T., and Falck, H. 2017. Organic matter control on the distribution of arsenic in lake sediments impacted by ~65 years of gold ore processing in Subarctic Canada. *Science of the Total Environment* 622–623:1668–1679. doi.org/10.1016/j.scitotenv.2017.10.048.

Good I.J. 1991. Weight of evidence and the Bayesian likelihood ratio. *In* The use of statistics in forensics science, Aitken, C.G.G. and Stoney, D. (eds.), CRC Press, Boca Raton, FL. pp. 85–106.

Huntington, H.P. 2000. Using traditional ecological knowledge in science: Methods and applications. *Ecological Applications* 5:1270–1274.

Ignas, V. 2004. Opening doors to the future: Applying local knowledge in curriculum development. *Canadian Journal of Native Education* 28:49–60.

Johannes, R.E. 1998. The case for data-less marine resource management: Examples form tropical nearshore fisheries. *Trends in Ecology and Evolution* v13:243–246. doi.org./10.1016/SO169-5347(98)01384-6.

MacLean, M. and Wason-Ellam, L. 2006. When Aboriginal and Métis teachers use storytelling as an instructional practice. Available from http://www.education.gov.sk.ca/Storytelling [accessed 1 May 2011].

Menzies, C. and Butler, C. 2006. Introduction: Understanding ecological knowledge. *In* Traditional ecological knowledge and natural resources management, Menzies, C. (ed). p. 127.

Mitchell, H., Vizinia, Y., Augustus, C., and Sawyer, J. 2008. Learning Indigenous science from place. University of Saskatchewan, Aboriginal Education Research Centre, Saskatoon, SK.

Moller, H., Berkes, F., Lyver, P.O., and Kislalioglu, M. 2004. Combining science and traditional ecological knowledge: Monitoring populations for co-management [online]. *Ecology and Society* 9:2 Available from http://www.ecologyandsociety.org/vol9/iss3/art2.

North Slave Métis Alliance community members Shiga, S., Evans, P., King, D., and Keats, B. 2017. Continual change and gradual warming: A summary of the North Slave Métis Alliance's recorded cultural knowledge on climate and environmental change. Report prepared for the Geological Survey of Canada's Geoscience Tools for Environmental Assessment of Metal Mining, compiled by Galloway, J.M. and Patterson, R. T. Project Number #1519-149. *Polar Knowledge: Aqhaliat 2018*, Polar Knowledge Canada, p. ##–## [this volume].

Ogawa, M. 1995. Science education in a multiscience perspective. *Science Education* 79:583–593. doi: 10.1002/sce.3730790507.

Palmer, M., Galloway, J.M., Jamieson, H.E., Patterson, R.T., Falck, H., and Kokelj, S.V. 2015. The concentration of arsenic in lake waters of the Yellowknife area 15 years after the end of gold ore processing. Northwest Territories Geological Survey. Open File 2015–16, 29 pp. doi: 10.13140/RG.2.1.2582.5041.

Snively, G. and Corsiglia, J. 1998. Discovering Indigenous science: Implications for science education. *Science Education.* Retrieved October 2010. ERIC database.

Suter, G.W. and Cormier, S.M. 2011. Why and how to combine evidence in environmental assessments: Weighing evidence and building cases. *Science of the Total Environment* 409:1406–1417.

Sutherland, D. 2002. Exploring culture, language, and the perception of the nature of

science. *International Journal of Science Education* 24:1–25. doi:10.1080/09500690110067011.

Usher, P.J. 2000. Traditional ecological knowledge in environmental assessment and management. *Arctic* 53:183–193.