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SPECIAL ISSUE

Geology and mineralogy of the Meguma Group and their importance to environmental problems in Nova Scotia

Foreword

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(Guest Editors)

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The readers of this issue of *Atlantic Geology* may be surprised by the titles and content of the six papers included, and may wonder what some of them have to do with "environment"; hence the rationale for this introduction. Over the last few years the geological community at large has tended to compartmentalise, and somehow isolate, a discipline designated "Environmental Geology", to encompass geology as it relates directly to human activities. In the process the practice of this discipline has been delegated to geoscientists concerned with groundwater, Quaternary geology, and perhaps volcanology, seismicity and engineering geology, to geographers, and to biologists. Here, we attempt to show how the integration of traditional hard-rock geological information (including mineralogy, litho-geochemistry, structure, metamorphism, and some aspects of geophysics), and an understanding of sampling and analytical limitations, are not only useful, but essential, if we are to understand, and eventually prevent, some of the serious environmental problems that threaten society.

Environmental problems inherent to the Meguma Group

Land subsidence related to former mining in the Goldenville district as described by Hill *et al.* (*this issue*) is only one example of the environmental problems inherent to mineral wealth in the bedrock. The metasedimentary rocks of the Meguma Group that underlie approximately 125,000 km² of southern Nova Scotia, are Cambrian to Ordovician in age, and belong to the Meguma terrane, an exotic tectonic province of the Appalachian orogen of Atlantic Canada. The Meguma terrane is host to about 50 gold mining districts that have seen production for over 100 years that owe their metal enrichment to a particular set of sedimentary and diagenetic conditions (e.g., Graves and Zentilli, 1988b; Sangster, 1990; Waldron, 1992), as well as structural and metamorphic conditions during their history (e.g., Graves, 1976; Sangster, 1990). This geologic history makes the Meguma Group stand out as a gold metallotect in the Appalachian orogen, and also led to the formation of deposits of lead-zinc, tungsten, arsenic, tin, and manganese. But the 19th century Nova Scotia gold rush (Malcolm, 1929), and land subsidence and acid drainage related to mining do not constitute the sole nor the most important relationship between humans and geology in the region. In southern Nova Scotia, the most serious concern is that of acid rock drainage (ARD), a problem that

is not limited to mining areas, but which extends to much more widespread activities such as highway and airport construction, and the digging of foundations and trenches for municipal services and pipelines (e.g., Pettipas, 1979). The use of slate for construction and the lining of wells, and the lowering of the water table in large regions due to water withdrawal or quarrying are other aspects of the same problem.

A world-class example of ARD is provided by the Halifax International Airport. The airport was built between 1955 and 1960, and to circumvent the fog, at the highest point in the region (145 m), hence in the divide between several drainage basins. The construction of the runways and taxiways disrupted and exposed to oxidation large volumes of sulphide-rich slate (Worgan, 1987). During the Fall following some years of heavy construction, severe fish kills occurred in the Shubenacadie River. It is now believed that sulphuric acid produced from sulphide oxidation was released into the watersheds surrounding the airport during heavy rainfalls, in general following prolonged dry spells. This acidic drainage had very low pH and increased levels of metals toxic to wildlife (e.g., Guilcher, 1987; Albright, 1987; Hennigar and Gibb, 1987; King and Hart, 1987; Lund, 1987; Lund *et al.*, 1987). Initial remedial costs during the 1980s were in excess of two million dollars, with substantial yearly costs since that time. Mitigating measures have included capping the waste rock pile with clay and topsoil, a lime treatment plant, the use of cellulose channels, bacteria and artificial wetlands, as well as experimental techniques such as electrochemical treatment (S. Hicks, Transport Canada, personal communication, 1996). And yet, to this day the airport and associated sites continue to discharge, sporadically, toxic, acidic drainage to brooks.

Several other dramatic cases of ARD and deterioration of water supplies have come to light in southern Nova Scotia. The paper by Fox *et al.* (*this issue*) describes similar ARD problems associated with highway roadcuts and quarries in southern Nova Scotia. A related and common problem in many localities is that of unsuitable, discolouring, iron-rich water from wells drilled into sulphidic slates, which requires expensive and persistent treatment for household or industrial use.

Although sulphides occur in all the known bedrock gold districts and throughout the stratigraphy of the Meguma Group, many of the more serious examples of ARD in southern Nova

Scotia seem to have a common denominator: they are underlain by the transition zone encompassing the uppermost Goldenville and lowermost Halifax Formations of the Meguma Group, often loosely referred to as the "GHT" (Zentilli *et al.*, 1984). The lower Meguma Group contains a thick package of dominantly sandy metawacke and grey to black metasiltstone (the Goldenville Formation) which is overlain by a thick sequence of black, dominantly silty metaturbidites and slates of the Halifax Formation (Schenk, 1983). The GHT was first described sedimentologically and stratigraphically in a type locality in southwestern Nova Scotia, where sandy and slaty facies alternate through a thickness of about 1 km (O'Brien, 1986; Waldron and Graves, 1987). Folding of the strata has caused the outcrop patterns of any sulphide-rich strata to be very complex and irregular.

The anomalous enrichment of sulphides and heavy metals (to several percent) in the GHT was documented at the mineral prospect near Eastville (Jenner, 1982; MacInnis, 1986; Binney *et al.*, 1986) and later lithochemically elsewhere in the Meguma terrane (Zentilli *et al.*, 1986; Graves and Zentilli, 1988a, 1988b). The GHT has anomalous and variable concentrations of manganese, arsenic, lead, zinc, copper, chromium and other toxic elements, and as could be expected, some of these elements are highly enriched in soils (>2000 ppm Pb at Eastville; Binney *et al.*, 1986), and ARD is derived from the anomalous bedrock. The paper by Feetham *et al.* (*this issue*) illustrates and updates the variable composition of the metalliferous metasedimentary rocks in a well studied locality of the GHT northeast of Halifax.

Sulphides are an important component of many of these strata, and when these sulphides oxidize, heavy metals are released in the ARD. But not all toxic elements are contained in sulphides. For example, manganese is accommodated in relatively soluble manganese carbonates, but also in silicates, such as spessartine garnets (Cameron, 1985; Hingston, 1985) and in manganese-rich ilmenite (MacInnis, 1986). As described in the paper by Cameron and Zentilli (*this issue*) zinc is also partitioned into silicates, depending on the regional and metamorphic history of each site. Therefore, a bulk chemical analysis is not sufficient to predict the potential toxicity of leachates derived from a rock, and the partition of zinc in metasedimentary rocks is influenced by contact metamorphism.

And yet the ARD problem at the Halifax International Airport is most definitely related to sulphides. Until recently the offending rocks have been described as "pyritiferous slates" (Nova Scotia Department of the Environment and Environment Canada joint "Guidelines for Development on Slates in Nova Scotia", April, 1991). Pyrite is in fact a mineral phase present in the GHT, but for some time hard-rock geoscientists have been aware of the fact that the prevalent sulphide in the sulphidic slates of the Meguma Group is not pyrite, but pyrrhotite (e.g., Jenner, 1982; Cameron, 1985; Hingston, 1985; MacInnis, 1986; Binney *et al.*, 1986; Pasava *et al.*, 1995; Knee, 1995). Pyrrhotite is responsible for a strong magnetic signature at Eastville (Burke, 1985) and competes with that induced by magnetite elsewhere (McGrath, 1970; Schwarz and McGrath, 1974; Schwarz and Broome, 1994).

This point in particular is well documented in the paper by King (*this issue*) where the magnetic signature of the sulphidic strata is used for stratigraphic mapping in an area north of Halifax. Pyrrhotite may be more susceptible to rapid oxidation than pyrite (e.g., MacInnis *et al.*, 1994), both in inorganic reactions and with the involvement of bacteria (e.g., Jones, 1997; Jones and Fox, 1997). The paper by Fox *et al.* (*this issue*) discusses the specific problems related to oxidation of pyrrhotite, and emphasizes that in order to be able to predict the risk of ARD, it may be essential to know the spatial distribution of sulphides (e.g., in veins, in the cleavage, in stratiform lenses), their grain sizes, detailed mineral compositions, textures, and mineral associations. As an example, Haysom *et al.* (*this issue*) present the results of a study on mineralogy and its relationship to structural geology in the Rawdon-Beaverbank area.

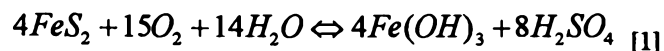
As indicated above, sulphide occurrence and ARD risk in the Meguma Group are not restricted to the GHT zone, as its gold districts also contain pyrrhotite, pyrite, arsenopyrite, galena, spahlerite, and locally stibnite, and a wide range of associated trace elements. For descriptions of different aspects of the mineralogy of sulphides and geochemistry of gold deposits hosted by the Meguma Group, the reader is referred to papers by Graves and Zentilli (1982), Smith and Kontak (1990), and references therein.

Acid Rock Drainage (ARD)

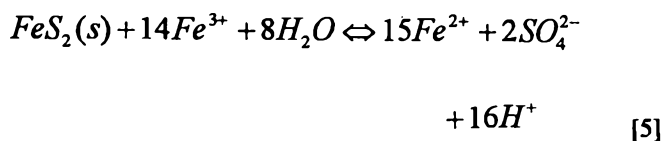
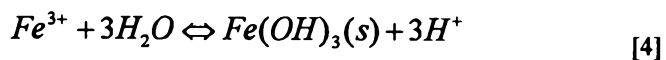
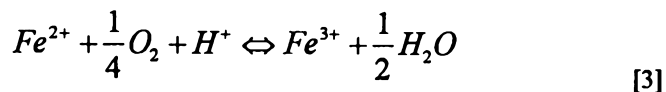
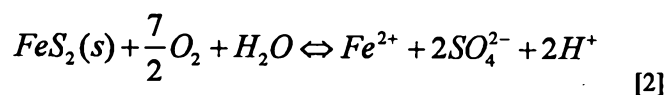
ARD develops when water flows through areas where sulphide minerals are oxidizing. The resulting leachate typically has a low pH (between 2 and 4) and high concentration of metals (such as Al, Mn, and Fe), and trace elements (such as Cu, Ni, and Co). As an example, the characteristics of ARD leachate from a waste rock pile at the airport site are shown in Table 1.

Table 1 shows that ARD leachate can have 4 to 5 orders of magnitude more the acceptable concentration of some elements such as aluminum. Fish are respectively adversely affected at pH less than approximately 5.0 (Canadian Water Quality Guidelines, 1987), and metals, in particular aluminum, clog their gills to such an extent that they die of asphyxiation (Fromm, 1980).

As an example of the development of ARD, sulphuric acid is generated when pyrite (FeS₂) is exposed to oxygen and water. The overall process may be described by equation [1] (Bruynesteyn and Duncan, 1979),



which shows that one mole of pyrite (120 grams) will produce two moles (196 grams) of sulphuric acid. In nature, the chemical oxidation of pyrite is more complex than represented by equation [1] and can be described as a multi-staged process by the reactions below (Stumm and Morgan, 1981). These reactions remind us that oxidation is only an exchange of electrons, and does not require free oxygen to proceed:



Equation [2] shows that the oxidation of sulphide to sulphate releases dissolved ferrous iron (Fe^{2+}) and hydrogen ions (H^+) into solution, thus lowering the pH. Dissolved ferrous iron is oxidized to ferric iron (Fe^{3+} , equation [3]). Ferric iron hydrolyzes to form insoluble "ferric hydroxide", releasing more hydrogen ions into solution (equation [4]). Ferric iron can also be reduced by pyrite (equation [5]), where sulphide is again oxidized to sulphate and hydrogen ions are released along with additional ferrous iron. The cycle continues through equation [3] where ferrous iron is oxidized to ferric iron and is therefore self-sustaining, even in some environments devoid of oxygen, such as in some groundwaters.

Even after the generation of sulphuric acid, ARD will actually develop only if the minerals in the rock are unable to neutralize it. Many minerals such as calcium- and magnesium-bearing carbonates and silicates, and aluminum, calcium, and magnesium oxide and hydroxide minerals, have at least some ability to neutralize acid produced from the oxidation of sulphide minerals (Sherlock *et al.*, 1995). The net result between acid-producing and acid-consuming reactions will determine the overall quality of the leachate. Recently, Kwong and Ferguson (1997) have made some important observations regarding the short-term acid consuming ability of major rock-forming minerals: calcite and dolomite are the most efficient acid-neutralizing minerals, but silicates such as biotite, chlorite, and amphibole are also effective acid-neutralizers in the short-term (24 to 48 hours). Kwong and Ferguson (1997) also emphasized that acid-consuming ability depends on the variable chemical composition of these minerals, and the need for detailed mineralogical (and microprobe) data before ARD risk can be ascertained.

Conclusion

To be consistent with the goals of attaining a measure of sustainable development, defined by Bruntland (1987) as "development which meets the needs of the present without

Table 1. Characteristics of ARD leachate compared to tolerance levels for aquatic life in freshwater (data from Canadian Water Quality Guidelines, 1987; Lund, 1987).

Airport waste rock pile leachate	Limits for freshwater aquatic life
Fe = 3800 mg/L	Fe = 0.3 mg/L
Al = 3247 mg/L	Al = 0.005 - 0.1 mg/L
SO ₄ = 27000 mg/L	SO ₄ = none
pH = 2.4 - 3.2	pH = 6.5 - 9.0

compromising the ability of future generations to meet their own needs", the geoscientific community needs to focus on prevention of environmental accidents rather than reacting to them after they occur. The requirement of a precautionary or anticipatory approach (Precautionary Principle) is explicitly mentioned in the Nova Scotia Environment Act (SNS, 1994-95, c.1; Brown and Fox, 1997). Prevention will only be possible once the processes responsible for environmental degradation are fully understood. We consider that the geological studies presented in this issue are mere steps toward the understanding of environmental problems associated with the Meguma Group and similar geological areas elsewhere.

- ALBRIGHT, R. 1987. Prediction of acid drainage in Meguma slates. Proceedings, Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March 23-26, 1987. Environment Canada, pp. 245-261.
- BINNEY, W.R., JENNER, K.A., SANGSTER, A.L., and ZENTILLI, M. 1986. A stratabound zinc-lead deposit in Meguma Group metasediments at Eastville, Nova Scotia. *Maritime Sediments and Atlantic Geology*, 22, pp. 65-88.
- BROWN, J.C.S. and FOX, D. 1997. Sustainable development and the Precautionary Principle: implications for acid rock drainage regulations in Nova Scotia. *Atlantic Geology*, 33, p. 76.
- BRUNTLAND, G.H. 1987. *Our Common Future: Report of the World Commission on Environment and Development*. Oxford University Press, Oxford, 400 p.
- BRUYNSTEYN, A. and DUNCAN, D.W. 1979. Determination of acid production potential of waste materials. *Metallurgical Society, AIME*, Paper A-79-29, 10 p.
- BURKE, W.E.F. 1985. Geophysical analysis of field and laboratory measurements at the Eastville lead-zinc deposit Colchester County, Nova Scotia. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 37 p.
- CAMERON, B. 1985. The contact metamorphic effects of a granitoid pluton on lead-zinc mineralization in the manganese metasediments of the Meguma Group, Eastville, Colchester County, Nova Scotia. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 104 p.

- CANADIAN WATER QUALITY GUIDELINES. 1987. Task Force on Water Quality Guidelines of the Canadian Council of Resource and Environment Ministers, March, 1987.
- FROMM, P.O. 1980. A review of some physiological and toxicological responses of freshwater fish to acid stress. *Environmental Biology of Fishes*, 5(1), pp. 79-93.
- GRAVES, M.C. 1976. The formation of gold-bearing quartz veins in Nova Scotia: hydraulic fracturing under conditions of greenschist regional metamorphism during early stages of deformation. M.Sc. thesis, Dalhousie University, Halifax, Nova Scotia, 166 p.
- GRAVES, M.C. and ZENTILLI, M. 1982. A review of the geology of gold in Nova Scotia. *In* Geology of Canadian Gold Deposits. Canadian Institute of Mining and Metallurgy, Special Paper 23, pp. 233-242.
- 1988a. Geological Survey of Canada, Open File Report, 1829, 110 p.
- 1988b. The lithochemistry of metal-enriched cotecules in the Goldenville-Halifax transition zone of the Meguma Group, Nova Scotia. Current Research, Part B, Geological Survey of Canada, Paper 88-1B, pp. 251-261.
- GUILCHER, M. 1987. Acid mine drainage in reactive slates "the Halifax Airport case". Proceedings, Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March 23-26, 1987. Environment Canada, pp. 117-125.
- HENNIGAR, T.W. and GIBB, J.E. 1987. Surface and groundwater impacts of acid mine drainage from the Meguma slates of Nova Scotia. Proceedings, Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March 23-26, 1987. Environment Canada, pp. 165-187.
- HINGSTON, R.W. 1985. The manganiferous slates of the Cambro-Ordovician Meguma Group at Lake Charlotte, Halifax County, Nova Scotia. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 67 p.
- JENNER, K. 1982. A study of sulphide mineralization in Gold Brook, Colchester County, Nova Scotia. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 60 p.
- JONES, R.A. 1997. Relative chemical and biological oxidation of sulphides in the Meguma Supergroup, Nova Scotia: the role of mineralogy, texture and composition. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 103 p.
- JONES, R.A. and FOX, D. 1997. Relative chemical and biological oxidation of sulphides in the Meguma Supergroup, Nova Scotia: the role of mineralogy, texture and composition. *Atlantic Geology*, 33, p. 64.
- KING, M. and HART, W. 1987. Contribution of acidity and heavy metals to surface and groundwater by pyritiferous slates in the vicinity of the Halifax Airport. Prepared for Environment Canada under Department of Supply and Services Contract: KE201-6-0103/01-SC, March, 1987, 98 p.
- KNEE, K. 1995. Magnetic susceptibility of Halifax Formation Slates at the Halifax International Airport: correlation with potential for acid drainage. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 45 p.
- KWONG, Y.T.J. and FERGUSON, K.D. 1997. Mineralogical changes during NP determinations and their implications. Proceedings of the Fourth International Conference on Acid Rock Drainage, Vancouver, British Columbia, Canada, May 31-June 6, 1997, pp. 435-447.
- LUND, O.P. 1987. Acid drainage from mineralized slate at the Halifax International Airport. Proceedings, Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March 23-26, 1987. Environment Canada, pp. 137-165.
- LUND, O.P., VAUGHAN, J., and THIRUMURTHI, D. 1987. Impact of acid drainage pollution from mineralized slate at Halifax airport. *Water Pollution Resources Journal of Canada*, 2(2), pp. 308-325.
- MACINNIS, I.N. 1986. Lithogeochemistry of the Goldenville-Halifax transition (GHT) of the Meguma Group in the manganiferous zinc-lead deposit at Eastville, Nova Scotia. B.Sc. Honours thesis, Dalhousie University, Halifax, Nova Scotia, 138 p.
- MACINNIS, I.N., SILVER, S.R., PASAVA, J., GRAVES, M.C., and ZENTILLI, M. 1994. Experimental evaluation of the relative acid drainage potential of pyrite and pyrrhotite. *Atlantic Geology*, 30, p. 75.
- MALCOLM, W. 1929. Gold fields of Nova Scotia. Geological Survey of Canada, Memoir No. 156, 253 p.
- MCGRATH, P.H. 1970. Aeromagnetic interpretation Appalachia, New Brunswick and Nova Scotia (11D, E, F, K; 20 O, P; 21 A, G, H, J). *In* Report of Activities, Part A, Geological Survey of Canada, Paper 70-1A, pp. 79-82.
- NOVA SCOTIA ENVIRONMENT ACT S.N.S. 1994-95, c.1, section 66. Order in Council 95-296 (April 11, 1995), N.S. Reg. 57/95, 7 p.
- O'BRIEN, B.H. 1986. Preliminary report on the geology of the Mahone Bay area, Nova Scotia. *In* Current Research, Part A, Geological Survey of Canada, Paper 86-1A, pp. 439-444.
- PASAVA, J., GRAVES, M.C., MACINNIS, I.N., and ZENTILLI, M. 1995. Black slates - A source of acid drainage at the Halifax International Airport, Nova Scotia, Canada. *In* Mineral Deposits: From their origin to their environmental impacts. Proceedings of the Third Biennial SGA Meeting, Prague, Czech Republic, August 28-31, 1995, pp. 785-788.
- PETTIPAS, B. 1979. A statistical evaluation of the effect of acid leachate on water quality, in Union Square, Lunenburg County. Nova Scotia Department of the Environment Report, June, 1979, 56 p.
- SANGSTER, A.L. 1990. Metallogeny of the Meguma Terrane, Nova Scotia. *In* Mineral Deposit Studies in Nova Scotia, Volume 1. Edited by A.L. Sangster. Geological Survey of Canada, Paper 90-8, pp. 115-162.
- SCHENK, P.E. 1983. The Meguma Terrane of Nova Scotia - an aid to trans-Atlantic correlation. *In* Regional trends in the geology of the Appalachian-Caledonian-Hercynian-Mauritanide orogeny. Edited by P.E. Schenk. NATO ASI Series C, 116, pp. 121-130.
- SCHWARZ, E.J. and BROOME, J. 1994. Magnetic Anomalies due to pyrrhotite in Paleozoic metasediments in Nova Scotia, Eastern Canada. *Journal of Applied Geophysics*, 32, pp. 1-10.
- SCHWARZ, E.J. and MCGRATH, P.H. 1974. Aeromagnetic anomalies related to pyrrhotite occurrences in the Canadian Appalachian region. *In* Current Research, Part B, Geological Survey of Canada, Paper 74-1, pp. 107-108.
- SHERLOCK, E.J., LAWRENCE, R.W., and POULIN, R. 1995. On the neutralization of acid rock drainage by carbonate and silicate minerals. *Environmental Geology*, 25, pp. 43-54.
- SMITH, P.K. and KONTAK, D. 1990. Nova Scotia Gold. *The Northern Miner Magazine*, March, 1990, pp. 21-28.
- STUMM, W. and MORGAN, J.J. 1981. *Aquatic Chemistry*. Wiley-Interscience, New York, Second Edition, 780 p.
- WALDRON, J.W.F. 1992. The Goldenville-Halifax transition, Mahone Bay, Nova Scotia: relative sea-level rise in the Meguma source terrane. *Canadian Journal of Earth Sciences*, 29, pp. 1091-1105.
- WALDRON, J.W.F. and GRAVES, M. 1987. Preliminary report on sedimentology of sandstones, slates, and bioclastic carbon-

- ate material in the Meguma Group, Mahone Bay, N.S. *In* Current Research, Part A, Geological Survey of Canada, Paper 87-1A, pp. 409-414.
- WORGAN, J. 1987. Acid mine drainage in reactive slates, "The Halifax International Airport Case" Transport Canada perspective. *In* Proceedings, Acid Mine Drainage Seminar/Workshop, Halifax, Nova Scotia, March 23-26, 1987. Environment Canada, pp. 127-135.
- ZENTILLI, M., WOLFSON, I., SHAW, W., and GRAVE, M.C. 1984. The Goldenville-Halifax transition of the Meguma Group as a control for metallic mineralization. GSA Abstract, 16, p. 73.
- ZENTILLI, M., GRAVES, M.C., MULJA, T., and MACINNIS, I. 1986. Geochemical characterization of the Goldenville-Halifax transition of the Meguma Group of Nova Scotia: preliminary report. Current Research, Part A. Geological Survey of Canada, Paper 86-1A, pp. 423-428.

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