

**THE HAWLEY MEDAL FOR 2004  
TO  
JAMES E. MUNGALL  
AND JAMES M. BRENNAN**



The Hawley medalists for 2004 are James E. Mungall and James M. Brennan. Their paper “Experimental evidence for the chalcophile behavior of the halogens” was selected as the best paper published in *The Canadian Mineralogist* in 2003. It appeared in Volume 41, Part 1, pages 207-220. Drs. Mungall and Brennan are professors in the Department of Geology at the University of Toronto.

The paper is based on the observation that “unusual abundances of halogen-rich minerals are found in close spatial association with base-metal and precious-metal sulfide mineralization cogenetic with igneous rocks in several localities worldwide.” Their investigation of the partitioning of fluorine, chlorine, bromine and iodine between coexisting silicate and sulfide liquids established that chlorine, bromine and iodine have significant solubilities in sulfide liquids, but that fluorine does not. In associated experiments on chlorine in Fe–Cu sulfide melts, they found that chlorine substantially lowers the melting point of monosulfide solid-solution, is moderately incompatible in monosulfide solid-solution, and thus is enriched in the residual melt. These results lead to the conclusions that “... sulfide melts are capable of dissolving and transporting significant concentrations of halogens in the absence of an aqueous fluid” and “...that observed enrichments in halogens in some mineralized environments are consistent with ore deposition by purely magmatic processes.” These are major changes in our understanding and interpretation of base-metal and precious-metal sulfide mineralization.

Although the authors pointed out that this is a reconnaissance study, the preliminary results lead to implications and speculations in a number of areas. The previously observed elevated ratio of Cl/Br in alteration halos around sulfide orebodies in the Sudbury igneous complex can be explained with the results in this paper, thus confirming that high Cl:Br ratios are a useful exploration guide. The presence of lawrencite [(Fe,Ni)Cl<sub>2</sub>] in grains of Fe–Ni alloy in lunar basalts and iron–nickel meteorites now can be explained. The possibility that halogens may have been preferentially differentiated into the core and removed from the silicate part of the early Earth has implications for dating events in the formation of the Earth.

The results presented in this paper will have a profound impact on research in many areas of the Earth sciences. Mungall’s and Brennan’s findings on the solubilities of halogens in sulfide melts are factors that must be considered in any research program on sulfides.

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Ladies and gentlemen,

It was a pleasant and wholly unexpected treat to hear that we had been awarded the Hawley Medal for our paper describing the partitioning of halogens between sulfide liquid, silicate melt, and monosulfide solid-solution. It is a rare moment when one learns that others have read and enjoyed something one has worked so

hard on; thus we are touched and honored by this award. I have been delegated to provide the response today, as Jim is hiding out somewhere in the bush north of Sudbury with a group of U of T geology undergrads and a bottle of Irish aquavit for sanity.

Like many other interesting scientific observations, the results of our study came about through a combination of serendipity and inspired guesswork. Jim first suggested to me in 2000 that halogens might be concentrated by sulfide liquids coexisting with silicate magmas, but he didn't pursue the idea for a long time. The idea he wanted to test was that when sulfide liquids separate from silicate magmas, they might sequester the halogens, leading eventually to the formation of massive sulfide deposits accompanied by halos enriched in these elements, as has been thoroughly described in the footwall of the Sudbury Igneous Complex. We discussed it a few times over the following year, but he always seemed to have something else to work on, which drove me nuts, until one day I came into his office and told him I had already begun synthesizing starting materials. That was enough to overcome the activation energy of getting him out of his chair and join me in my lab for a series of experiments that we shared.

The results at first seemed disappointing. Whereas initially we had hoped to see that chlorine was highly compatible in sulfide melt coexisting with silicate melt, we actually saw weak incompatibility. A separate and initially equally disappointing discovery was Jacob Hanley's observation that the halogen-enriched halo surrounding massive sulfide veins in the footwall of the SIC seemed easily explained by crystallization of halogen-bearing hydrous minerals in local hydrothermal systems centered on the veins; the halogens themselves appeared to have come from the local groundwater rather than the veins themselves.

It wasn't until we had had some time to think about our results that we realized that it would have been much harder to explain highly compatible behavior than the mildly incompatible behavior we saw. If halogens were highly compatible, as we had initially supposed, then there would have been gobs of salt in magmatic sulfides, much more than is really observed. In reality, our disappointing observation of weakly incompatible behav-

ior was the only one that could have been supported by the observations of natural sulfide magmas, even though it was not the one we thought we wanted to see. Furthermore, Jacob went on to discover a generation of halide melt inclusions hosted by sulfide veins and their immediate host-rocks that had previously escaped attention, lending support to the idea that at least some of the salt in and around the veins did originate from within the sulfide magma.

In the end, the combination of field evidence for coexistence of late sulfide magmas with halide melts and our experimental results have us convinced of the viability of our model: small but significant amounts of the halogens do indeed enter sulfide liquids coexisting with silicate melts, they are concentrated in the residual sulfide liquid during its cooling and crystallization, and the final stage of crystallization is accompanied by the expulsion of halide melts into the wall rocks. What is as interesting as the finding itself, is that we came to this conclusion by testing and disproving two initially incorrect hypotheses. I guess that all of us have been moved to suggest something that in retrospect we can see was quite silly, but which nevertheless led us down a path toward a truly valuable result.

The moral of the story is that the most interesting results often arise in unexpected ways, and that a research program geared toward cookbook, low-risk scientific endeavor will miss out on many potentially valuable avenues of advance. In the current climate of increasingly focused research funding, it is important to not lose sight of the value of curiosity-driven research. In other words, there is merit in sometimes just letting us toss stuff into the furnace to see what happens.

In summary, we are grateful to NSERC and the University of Toronto for creating the climate in which work like ours can be done without the requirement that we predict our results before beginning the experiments, and we are deeply grateful to the MAC for choosing to recognize our work from among the many fascinating articles published last year in *The Canadian Mineralogist*.

James M. Brenan  
and James E. Mungall