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Pyrrhotite Victims Aid Coalition

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1. The Problem

In the realm of Metal Leaching and Acid Rock Drainage (ML-ARD) from sulphide-mineral oxidation (Price, 2009), environmental impacts can be found naturally and at mining operations, proposed and existing highways, airport runways, pipeline alignments, railroads, etc. (e.g., Morin, 2018; Morin and Hutt 1997, 2001, and 2007; Morin et al., 2003; Hicks, 2003; Lombard et al., 2020). Significant effects on human health and safety, and on human fatalities, associated with sulphide oxidation and ML-ARD are rare (e.g., Hockley et al., 2009).

Nevertheless, sulphide oxidation can "strike closer to home", where it can affect houses and civic structures and it can be a factor in suicides. In Canada, the Pyrrhotite Victims Aid Coalition (in French: La coalition d'aide aux victimes de la pyrrhotite, or CAVP) has been an active and vocal advocate for improved monitoring of pyrrhotite within aggregate used for concrete (CAVP, 2023). Through personal experiences and financial losses, CAVP (https://www.cavp.info/) has found that pyrrhotite can seriously degrade building foundations over periods of years. They apparently do not have personal experience with pyrite to know that pyrite can also cause such problems.

When pyrrhotite and some other sulphide minerals are exposed to oxygen and moisture, we know from hundreds of years of experience with mining and smelting that acidity, metals, sulphate, and heat are released. This is accompanied by:

- the dissolution of surrounding minerals (and of cement when present),
- the volume expansion due to the uptake of oxygen and moisture into solid-phase minerals and compounds,
- the coating of minerals surfaces with secondary minerals, and
- the degradation of other compounds in concrete unless sulphate-resistant cement was used.

In concrete, this leads to expansion cracks and loss of cohesion. In a mining context, these issues are rarely considered except to show that the shrinking-core model does not apply and that large-scale impermeable hardpans cannot be formed.

Sadly, in Trois Rivières, Quebec, Canada, more than one thousand basements and foundations had to be replaced due to pyrrhotite oxidation, at costs of many hundreds of millions of Canadian dollars (CAVP, 2023). Other affected local buildings include civic, commercial, university, court, and a sports arena. At least four class-action lawsuits were underway or have been settled.

There are also reports that tens of thousands of buildings, in addition to dams and bridges, have been

affected by sulphide-mineral oxidation in the United States of America, Spain, and Ireland (CAVP, 2023). Studies are ongoing to understand and to predict how pyrrhotite can damage concrete, with possible future standards developed through the international CSA Group.

Current predictive techniques for concrete degradation by sulphide oxidation apparently lag behind those for mining, highways, and pipelines, such as those discussed in the Canadian federal Prediction Manual (Price, 2009). For example, initial work for concrete indicates a solid-phase pyrrhotite level below 0.23% is in a "grey zone" that may or may not become acceptable (CAVP, 2020):

> *"En fonction des informations connues à ce jour et les résultats du premier procès (Vague-1), si la teneur en pyrrhotite est de 0.23% et plus il est généralement recommandé de refaire les éléments de béton concernés. Si le dosage est de 0.22% et moins, la propriété est mise en ''zone grise'' en attendant les résultats de la chaire de recherche qui a débuté ses travaux au début 2020. Les résultats pourraient prendre quelques années."*

Some problems with this interim value of 0.23% pyrrhotite are:

- it is not clear if the value is weight-percent as sulphur (e.g., Leco or ICP-MS analysis) or volume-percent as pyrrhotite (e.g., XRD or QEMSCAN), which is significant because of the relatively high densities of pyrrhotite and pyrite;
- measurements of individual sulphide minerals are prone to substantial errors and thus total sulphur should be used instead (e.g., Morin, 2021);
- even total-sulphur values of 0.01%S, which is the typical detection limit, can still lead to problems (Morin and Hutt, 2006); and
- the Province of Quebec recently lowered the no-concern level in mine wastes from 0.30%S to below 0.1%S, due to some mines in the province with <0.1%S already having ARD.

This effect on building foundations is a notably different, yet a still severe, consequence of sulphide oxidation that we do not regularly consider with ML-ARD.

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