SULPHUR ISOTOPE ABUNDANCE RATIOS FOR THE SULPHIDES IN THE COBALT - GOWGANDA ORES

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ABSTRACT

Sulphur isotope abundance ratios were determined for the sulphides in 17 representative samples of the Cobalt-Gowganda ores. The samples were taken from ore veins, late veins, wall rock and mineralized Keewatin interflow rocks. Sulphides in the ore veins have $\delta^{34}S$ values that range from + 2.33 to + 3.11, and those in samples from late veins have $\delta^{34}S$ values of + 6.89 and + 9.22. The difference in sulphur isotope ratios between the ore vein and late vein sulphides could have resulted from fractionation of sulphur 32 and sulphur 34 in the source material. The sulphides in wall rock adjacent to ore veins have $\delta^{34}S$ values similar to those for the ore vein sulphides. The sulphides in mineralized Keewatin interflow rocks have specific $\delta^{34}S$ values for each interflow band, but the values vary from band to band. These values are in the range + 3.78 to + 6.22.

INTRODUCTION

During the course of a mineralogical investigation of the Cobalt-Gowganda ores it was found that the sulphide minerals occur in mineralized Keewatin interflow rocks, in ore veins, in late veins, and in the wall rock. In an attempt to correlate the sulphides from the various occurrences, the author arranged with Dr. R. K. Wanless, head of the Geochronology Laboratories, Geological Survey of Canada, to have the sulphur isotope abundance ratios determined for sulphide concentrates obtained from 17 representative samples. The concentrates were prepared by crushing the samples to − 100 + 275 mesh, separating them with heavy liquids and treating the sink fraction (S.G.> 3.70) with a dilute solution of cold HCl to dissolve the carbonates. The mineral contents of the concentrates were determined by grain counts on polished sections.

Dr. Wanless reported that the sulphur isotope ratios were determined by (1) converting the sulphur in the mineral concentrates to sulphur dioxide in a stream of oxygen as described in Wanless, Boyle & Lowdon (1960), (2) undertaking duplicate mass spectrometric analyses, and (3) calculating the average $\delta^{34}S$ value and arithmetic mean for each determination. The standard used in the analyses was a pyrite whose $\delta^{34}S$ value is + 1.33 ± 0.20 with respect to meteoritic troilite.

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The sulphur isotope abundance ratio is expressed as per mil difference in isotope ratios between the sample and standard according to the formula

$$\delta^{34}S = \left(\frac{(^{34}S/^{32}S)\ \text{sample}}{(^{34}S/^{32}S)\ \text{standard}} - 1 \right) \times 1,000$$

Results and Interpretations

Sulphur isotope abundance ratios were determined for the sulphides in 7 samples of mineralized Keewatin interflow rocks, 6 samples of ore veins, 2 samples of a late calcite vein, and 2 samples of wall rock. The samples of mineralized Keewatin interflow rocks were taken from three interflow bands at different distances from ore veins, and they contained different minerals.

The results of the analyses of the interflow samples, given in Table 105, show that the sulphur isotope abundance ratios for the sulphides in these samples vary from + 3.78 to + 6.22. Table 105 also shows that the sulphides in all samples from the same interflow band have nearly identical sulphur isotope ratios regardless of distance from an ore vein or of minera-

Table 105. Sulphur Isotope Ratios for Sulphides in Mineralized Keewatin Interflow Bands.

Sample	Mine	Occurrence of samples	Mineralogy of sample	$\delta^{34}S(\%)$
1140	Deer Horn (Vein 1140	Sphalerite layer adjacent to Vein 1140	sl 90%, po, ga and cp 10%	$+5.89 \pm 0.33$
	interflow band)	Chalcopyrite 1 inch from Vein 1140	cp 40%, po 40%, sl 10% and ga 10%	$+6.11 \pm 0.33$
		Massive pyrrhotite 4 inches from Vein 1140	po 65%, cp 25%, sl 10%	$+6.22 \pm 0.22$
		Massive pyrite 3 feet from Vein 1140	py 90%, mar, cp, po and sl 10%	$+6.11 \pm 0.33$
480	Hi-Ho (Vein 18	Massive chalcopyrite 4 inches from Vein 18	cp 90%, asp, py and ga 10%	$+5.11 \pm 0.00$
	interflow band)	Massive arsenopyrite 4 inches from Vein 18	asp 80%, sl and ga 20%	$+4.90 \pm 0.22$
697	Glen Lake (Big Pete Vein inter flow band)	Disseminated sphalerite from Big Pete Vein	sl 85%, ga 10%, py 5%	$+3.78 \pm 0.00$

Po = pyrrhotite, py = pyrite, mar = marcasite, cp = chalcopyrite, ga = galena, sl = sphalerite.

logical composition, whereas sulphides from different interflow bands have different sulphur isotope ratios. Different sulphur isotope ratios for each interflow band could have resulted by fractionation of sulphur in the source material during the time interval between the deposition of successive bands. The uniform sulphur isotope ratio within each band suggests the absence of fractionation during the deposition of an individual flow band. It is also noted that the arsenopyrite in the interflow band adjacent to Vein 18 in the Hi-Ho mine (sample 480) has a sulphur isotope abundance ratio that falls within the range for sulphides in interflow rocks, which suggests that the arsenopyrite in this interflow band has an interflow rather than a vein origin.

Sulphur isotope abundance ratios for sulphides in the ore veins were studied by analysing six samples taken from four veins in different localities. The veins occurred in different host rocks including both poorly- and well-mineralized Keewatin interflow rocks. The results, given in Table 106, show that sulphides from veins in poorly- and non-mineralized host rocks have fairly similar sulphur isotope abundance ratios, varying between $\delta^{34}S$ of +2.33 and +3.11 (Samples 480, 793 and 111), whereas sulphides from a vein that intersects a well-mineralized Keewatin interflow rock have different sulphur isotope abundance ratios. One of the sulphide samples from a vein that intersects a well-mineralized interflow rock (Sample 1140 cp) has a $\delta^{34}S$ value that falls within the range of values for the well-mineralized host interflow rock (Table 105, Sample 1140).

TABLE 106. SULPHUR ISOTOPE RATIOS FOR SULPHIDES IN THE ORE VEINS.

Sample	Mine	Area	Host rock of vein	Minerals	$\delta^{34}S$(%)
1140 cp	Deer Horn	Cobalt	Keewatin interflow (large, well-mineralized)	cp 50%, sl 30% po 10%, ga 10%	$+6.11\pm0.11$
1140 asp	Deer Horn	Cobalt	Keewatin interflow (large, well-mineralized)	asp 95%, cp 5%	$+5.00\pm0.1$
1140 ga	Deer Horn	Cobalt	Keewatin interflow (large, well-mineralized)	ga 95%, cp 4%	$+4.00\pm0.22$
480	Hi-Ho	Cobalt	Keewatin interflow (small, poorly-mineralized)	asp 65%, ga 35%	$+2.33\pm0.11$
793	Siscoe	Gow-ganda	Diabase	cp 100%	$+2.78\pm0.11$
111	Chris-topher	Cobalt	Lamprophyre	tet 100%	$+3.11\pm0.00$

Asp = arsenopyrite, ga = galena, cp = chalcopyrite, tet = tetrahedrite, sl = sphalerite, po = pyrrhotite, py = pyrite.

This suggests that the sulphide sample represents a recrystallized inclusion of interflow sulphides. Two other sulphide grains from the same vein (Samples 1140 asp and 1140 ga) have $\delta^{34}S$ values that fall between the values for vein sulphides and interflow sulphides. This suggests that the sulphides in these grains contain some vein sulphur intermixed with sulphur from the sulphides in the host Keewatin interflow rocks.

Sulphur isotope abundance ratios for the sulphides in some other occurrences are given in Table 107.

The fault vein and late calcite vein respectively offset and cut the ore veins hence they were introduced later than the ore veins and the sulphides contained in them are post-ore sulphides. The $\delta^{34}S$ values for these sulphides are higher than the values for the ore vein sulphides and the Keewatin interflow sulphides. This shows that later sulphides in the Cobalt ores are enriched in $\delta^{34}S$.

A sulphide pebble in Huronian conglomerate (Sample 781) was analysed for sulphur isotopes to determine the source of the sulphides in the pebble. This pebble consists of sulphides which replace rock-forming minerals. The sulphur isotope abundance ratio for the sulphides in this pebble are similar to the sulphur isotope abundance ratios for uncontamined ore vein sulphides (+ 2.33 to + 3.11) which indicates a common source.

Disseminated sulphides in a bedded slate were analyzed for sulphur isotopes in an attempt to determine the source of the sulphides. The mineralized bedded slate occurs 5 feet from an ore vein, and is 5 feet

TABLE 107. SULPHUR ISOTOPE ABUNDANCE RATIOS FOR SOME SULPHIDES IN THE COBALT AREA.

Sample	Mine	Mode of occurrence	Minerals	$\delta^{34}S(\%)$
168	Silverfields	Fault vein	sl 50%, ga 35%, mar + py 10% tet 5%	$+6.89 \pm 0.22$
6	Hi-Ho	Calcite veinlet	ga 60%, sl 30%, others 10%	$+9.22 \pm 0.11$
781	Silverfields	Pebble in conglomerate	cp 80%, po 10%, ga 5%, sl 5%	$+2.56 \pm 0.12$
763	Silverfields	Sulphides in slate	ga 90%, sl 5%, cp 5%	$+0.73 \pm 0.12$

above the contact between Huronian sediments and underlying Keewatin rocks. The sulphides are present as minute grains of galena in quartz near the tops of the beds, and of sphalerite and chalcopyrite in quartz and chlorite near the bottoms of the beds and are considered to be reworked Keewatin interflow sulphides. The $\delta^{34}S$ value for these sulphides is lower than was found for any other sulphides in the area. This anomalous $\delta^{34}S$ value, combined with the mode occurrence, suggests that the sulphides in this slate bed may be part of the original sediment.

Conclusions

Sulphides occurring differently appear to have different sulphur isotope abundance ratios, and these differences may provide some information on the origin of the ores. Sulphides in late veins have higher $\delta^{34}S$ values than those in ore veins, which indicates that different amounts of sulphur 32 and sulphur 34 were present in the two source materials. Such differences could have resulted either by deposition from two different sources, or by fractionation of sulphur from the same source material. The high $\delta^{34}S$ content in the late sulphides indicates that if fractionation occurred, it concentrated sulphur 34.

Some of the sulphides in Huronian sediments have $\delta^{34}S$ values similar to those for the ore vein sulphides, and some have lower values. The sulphides with similar $\delta^{34}S$ values to the ore vein sulphides likely have a common origin to the ore vein sulphides. The sulphides with low $\delta^{34}S$ values occur only locally along a few bedding planes and probably have a different origin.

The sulphides in Keewatin interflow rocks have specific sulphur isotope abundance ratios for the sulphides in each band, but the ratios differ from band to band. It is interpreted that the sulphides in these bands are interflow sulphides deposited with the volcanics. No correlation can be made between the interflow sulphides and those in the ore veins on the basis of this study.

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