



**RECONNAISSANCE STUDY OF  $\delta^{34}\text{S}$  VALUES OF SULPHIDES  
FROM MESOTHERMAL GOLD DEPOSITS OF THE  
EASTERN CANADIAN CORDILLERA**

**By Bruce E. Nesbitt  
Department of Geology,  
University of Alberta**

**KEYWORDS:** Sulphur isotopes, Cordilleran mesothermal gold deposits, genetic models, exploration geochemistry.

**INTRODUCTION**

Studies incorporating  $\delta^{34}\text{S}$  analyses of sulphides have been conducted on a variety of gold deposits ranging from Tertiary epithermal deposits of the western United States to Archean deposits of Canada and Australia (Kerrick, 1987; Field and Fifarek, 1986). However, to the best of our knowledge, there are no published data on results of  $\delta^{34}\text{S}$  studies of sulphides from similar gold deposits in the Canadian Cordillera. The results of a preliminary reconnaissance survey of  $\delta^{34}\text{S}$  variations in sulphides from gold deposits of the eastern Canadian Cordillera are reported here. The objectives of this study are: to better define similarities and differences between various types of gold deposits in the Canadian Cordillera; to provide additional constraints on genetic models for these deposits; and to investigate the potential for using sulphur isotope analyses as an aid to exploration. Even though the actual number of analyses in the study was limited due to financial constraints, the results of this study provide important information related to these objectives.

All three districts studied, Cassiar, Cariboo and Sheep Creek, are situated in allochthonous or suspect terranes, which adjoin autochthonous units of the North American craton (Monger *et al.*, 1982). The deposits are characterized by large, continuous quartz veins which contain variable amounts of carbonate, pyrite, arsenopyrite, graphite and scheelite. Host units for the deposits are carbonate-altered basalts at Cassiar, quartzites and marbles at Cariboo and quartzites at Sheep Creek.

**EXPERIMENTAL TECHNIQUES**

Preparation of sulphide separates was accomplished by standard magnetic, heavy liquid and hand-picking techniques.  $\delta^{34}\text{S}$  analyses were performed by the Sulphur Isotope Unit of the Department of Chemistry, McMaster University. The results are reported in the standard ‰ notation, relative to the Canon Diablo meteorite (Ohmoto and Rye, 1979).

**RESULTS**

The results of analyses of samples from the gold deposits of the Cassiar district can be divided into two categories: samples from ore-grade veins and samples from low-grade

veins. The two samples from ore-grade veins are quite close in value,  $\delta^{34}\text{S} = +13.2$  and  $+13.7\text{‰}$  (Table 5-13-1), even though they are from veins which are approximately 6 kilometres apart. The two samples from low-grade veins have an average  $\delta^{34}\text{S}$  value of  $+10.7\text{‰}$ , which is distinctly lower than the  $13.5\text{‰}$  average for the ore-grade veins. With the limited number of analyses available at this time, it is not possible to discern if this difference in  $\delta^{34}\text{S}$  values is a reproducible feature. Additional analyses are needed to test the possibility of distinguishing ore-grade from low-grade veins using sulphur isotope analyses.

The results of  $\delta^{34}\text{S}$  analyses of two pyrite samples from the Mosquito Creek mine in the Cariboo district average  $+9.2\text{‰}$  (Table 5-13-1). One  $\delta^{34}\text{S}$  analysis of an arsenopyrite from the ores yielded  $+8.8\text{‰}$ . Though the fractionation of sulphur isotopes between pyrite and arsenopyrite has not been calibrated, the close correspondence of the results for the two sulphides suggests that equilibrium was attained. One analysis of a pyrite separate from Sheep Creek ore yielded a value of  $+12.7\text{‰}$ .

**TABLE 5-13-1**

Sample Location	Mineral	$\delta^{34}\text{S}_{\text{Py}}$	$\delta^{34}\text{S}_{\text{H}_2\text{S}}$
<b>Cassiar</b>			
Ore-grade vein, Maura .....	Py	+13.2	+12.0
Ore-grade vein, Taurus .....	Py	+13.7	+12.5
Low-grade vein .....	Py	+11.7	+10.5
Low-grade vein .....	Py	+9.6	+8.4
<b>Cariboo</b>			
Ore-grade vein .....	Py	+10.1	+8.9
Ore-grade vein .....	Py	+9.1	+7.9
Ore-grade vein .....	AsPy	+8.8	+7.6
<b>Sheep Creek</b>			
Ore-grade vein .....	Py	+12.7	+11.5

**DISCUSSION**

It has been shown in various studies that, if the oxidation state of the ore-forming fluid is low, most of the sulphur is in  $\text{S}^{2-}$  state. In such a situation, the  $\delta^{34}\text{S}$  values of sulphides can be used to estimate the  $\delta^{34}\text{S}$  values of the ore-forming fluids (Ohmoto and Rye, 1979). Low oxidation states for the ore-forming fluids are indicated for all three districts examined, since iron oxides are rare to absent and carbonaceous material is common in the veins. Calculations using the

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

sulphur isotope fractionation equation for pyrite-H<sub>2</sub>S from Ohmoto and Rye (1979) and a temperature of 300°C indicate that the δ<sup>34</sup>S values for the ore-forming fluids were +12.3‰ at Cassiar, +8.4‰ at Cariboo and +11.5‰ at Sheep Creek.

The use of δ<sup>34</sup>S values as indicators of the source of ore-forming components is complicated by the effects of oxidation-reduction reactions on the fractionation of sulphur isotopes (Ohmoto and Rye, 1979). However, given the reducing nature of these fluids, the δ<sup>34</sup>S values of the fluids are most likely indicative of the δ<sup>34</sup>S values of sulphides in the source area. Magmatic sulphides typically have δ<sup>34</sup>S values within 3‰ of 0‰. Due to various oxidation-reduction processes, sedimentary sulphides possess a wide variation in δ<sup>34</sup>S values within ± 20‰ of 0‰ (Ohmoto and Rye, 1979). Given the range of +8.4‰ to +12.3‰ for the δ<sup>34</sup>S values of the ore-forming fluids in the deposits studied, it is probable that the sulphur in the fluids was derived from fluid interactions with sedimentary units. This interpretation is consistent with recent results from investigations involving radiogenic isotopes and other stable isotopes at Cassiar (Nesbitt *et al.*, in preparation). Studies of δ<sup>34</sup>S values of sedimentary sulphides in the vicinity of all three deposits, as well as additional analyses of sulphides from the deposits, are required to confirm these preliminary conclusions.

The small variation in δ<sup>34</sup>S values between districts may result from the limited number of analyses. Alternatively, if the differences are real, they probably indicate either minor differences in the δ<sup>34</sup>S values of sulphides in the sedimentary source-units or variations in chemical parameters in the ore-forming fluids.

Comparison of the δ<sup>34</sup>S values for pyrite from this study with values for pyrite from other gold deposits indicates that the results from the Canadian Cordilleran deposits are similar to slightly heavier than results from most other gold deposits. The geologically and geochemically similar Mother Lode deposits of California have δ<sup>34</sup>S values for pyrite of 0 to +5‰ (Figure 5-13-1; Taylor, 1986) which are somewhat depleted in δ<sup>34</sup>S relative to the Canadian Cordilleran deposits. The range of values observed in the Mother Lode district is believed to reflect derivation of the sulphur from meta-igneous rocks (Taylor, 1986). East of the Mother Lode district, in the sediment-hosted Carlin deposit, δ<sup>34</sup>S values for pyrite range between +4 and +16‰. This range in values is similar to that observed in the eastern Canadian Cordilleran deposits and is also believed to indicate a sedimentary source for the sulphur (Radke *et al.*, 1980). In Archean gold deposits the general range for δ<sup>34</sup>S in pyrite is +1 to +6‰ which, as with the results from the Mother Lode district, is probably a reflection of the greater abundance of meta-igneous rocks in the associated units (Kerrich, 1987).

In conclusion, the data from this investigation of δ<sup>34</sup>S values from sulphides in mesothermal deposits of the eastern Canadian Cordillera indicate: relatively uniform, δ<sup>34</sup>S-enriched values for δ<sup>34</sup>S; probable derivation of the sulphur from a sedimentary source; and a possible difference between high and low-grade veins at Cassiar of roughly 2‰.

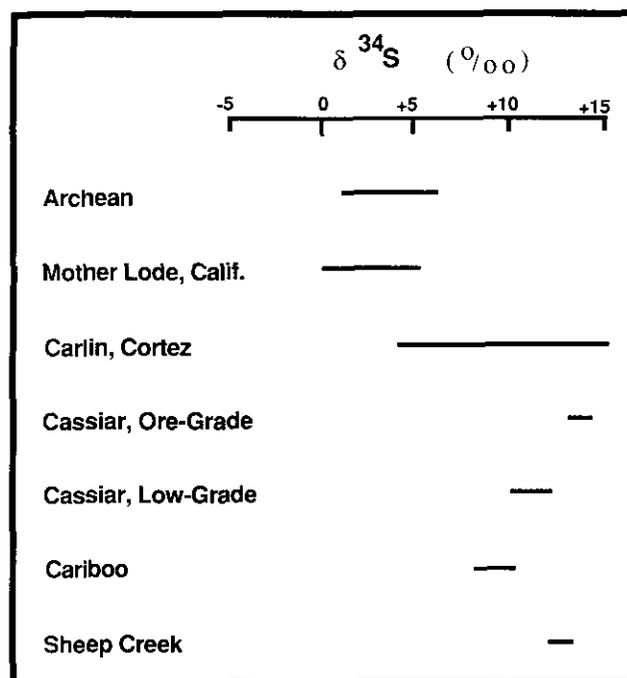


Figure 5-13-1. Results of δ<sup>34</sup>S analyses from eastern Canadian Cordilleran gold deposits in comparison to results from Archean, Mother Lode and Carlin deposits (Kerrich, 1987; Taylor, 1986; Radtke *et al.*, 1980).

## ACKNOWLEDGMENTS

I would like to acknowledge discussions with K. Muehlenbachs in interpreting the results. Funding for the project was supplied by British Columbia Research Grant RG87-09.

## REFERENCES

- Field, C.W. and Fifarek, R.H. (1985): Light-Stable Isotope Systematics in the Epithermal Environment, in *Geology and Geochemistry of Epithermal Systems*, Reviews in Economic Geology, B.R. Berger and P.M. Bethke, Editors, *Society of Economic Geologists*, Volume 2, pages 99-128.
- Kerrich, R. (1987): The Stable Isotope Geochemistry of Au-Ag Vein Deposits in Metamorphic Rocks, in *Stable Isotope Geochemistry of Low Temperature Fluids*, T.K. Kyser, Editor, *Mineralogical Association of Canada, Short Course Handbook*, Volume 13, pages 287-336.
- Monger, J.W.H., Price, R.A. and Tempelman-Kluit, D.J. (1982): Tectonic Accretion and the Origin of the Two Major Metamorphic and Plutonic Belts in the Canadian Cordillera; *Geology*, Volume 10, pages 70-75.
- Nesbitt, B.E., Cavell, P.A. and Muehlenbachs, K. (1987): Stable Isotopic Results from McDame Deposits, Cassiar District, in preparation.
- Ohmoto, H. and Rye, R.O. (1979): Isotopes of Sulfur and Carbon, in *Geochemistry of Hydrothermal Ore Deposits*, Second Edition, H.L. Barnes, Editor, *John Wiley and Sons*, New York, pages 509-567.

Radtke, A.S., Rye, R.O. and Dickson, R.W. (1980):  
Geology and Stable Isotope Studies of the Carlin Gold  
Deposit, Nevada, *Economic Geology*, Volume 75,  
pages 641-672.

Taylor, B.E. (1986): Origins and Isotopic Characteristics of  
Mother Lode Hydrothermal Fluids and Gold Deposits  
with Comparison to Archean Analogues, A.M. Chater,  
Editor, *Abstracts with Programs of Gold '86*, pages  
148-150.