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TRACE-ELEMENT GEOCHEMISTRY OF ORE-MINERAL SEPARATES FROM SELECTED CANADIAN BASE-METAL DEPOSITS

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BACKGROUND

This Open File contains geochemical data collected on ore mineral separates from more than 300 Canadian base metal sulphide deposits and mineral occurrences (Table 1). Samples were collected and processed over a period of more than 50 years, from 1952 to 2002. Most of the samples were analyzed during a 7-year period between 1994 and 2002. This is the first time that the data have been compiled in a single digital database, which accompanies the report.

The aim of the database is to provide an overview of the abundance and distribution of minor and trace elements in different ore minerals of Canadian base metal sulphide deposits. This includes volcanogenic massive sulphide deposits (VMS), sedimentary exhalative massive sulphide deposits (SEDEX), Mississippi Valley-type carbonate-hosted Pb-Zn deposits (MVT), vein deposits, magmatic deposits, manto-style deposits, skarn-type deposits, and porphyry-style deposits. Descriptions of each of the different deposit types can be found in Eckstrand et al. (1995) and Goodfellow (2007). See also Franklin et al. (1981, 2005) and Galley et al. (2007) for detailed descriptions of the VMS class.

The mineral separates were obtained from an extensive collection of sulphide ore samples archived at the Geological Survey of Canada (GSC). More than 2600 mineral separates were prepared, mainly for isotopic studies over the years, and they have now been analyzed by a number of techniques for 63 different elements. The trace element signatures provide an important geochemical "fingerprint" of the different deposits, thereby assisting regional metallogenic correlations (e.g. Jonasson and Sangster, 1975a,b; Jonasson et al., 2002, 2009). The samples encompass a wide range of mineralogy and trace element geochemistry reflecting the different ages, tectonic settings, host rocks, and conditions of mineralization of the deposits. They also record the original complex metal zoning of the deposits, as well as the effects of deformation and metamorphic recrystallization. The data have important applications in mineral exploration. In particular, different suites of trace elements in sulphides (e.g. As, Sb, Ag, Hg, Sn and Au) are often more effective than bulk Cu and Zn assays as pathfinders for favourable stratigraphy in base metal exploration, and some elements are important indicators of paleoenvironmental conditions favourable for base metal deposition (e.g. the redox-sensitive elements, Ni, Co, Se, and Mo: Hannington et al., 2012). Furthermore, some metals common in VMS and other sulphide deposits are considered as “critical metals” and the data presented in this contribution may provide useful in appraisals of possible critical metal resources.

SAMPLING AND METHODOLOGY

The original samples were collected by different researchers at the GSC and subsequently archived in Ottawa. They included mainly bulk ore samples in the form of hand specimens from active and inactive mine sites, including underground mines and mine dumps from past-producing deposits, as well as drill core from exploration projects. A few samples are concentrates and tailings from milling operations. Many samples were collected and prepared for regional studies of sulphur and lead isotopes, available in other databases (e.g. Sangster, 1972; Franklin et al., 1983; Thorpe, 1999, 2008, and references therein). Some of the historical samples (pre-1950s) are from the National Mineral Collection (NMC). After 1963, extensive sample collections were made by S.M. Roscoe, D.F. Sangster, R.I. Thorpe, J.F. Franklin, and I.R. Jonasson.

Details of the samples are provided in the accompanying database, including sample number, the year collected (where known), the location (depname) and type of deposit, together with additional comments on the conditions of the samples and the types of material collected. Sample numbers designated with the prefix SP were collected by D.F. Sangster (1960 and 70s); other samples were collected by R.W. Boyle (BH), A. Soregaroli (SVA), K.M. Dawson (DY), W. Morgan (MZK), H.G. Ansell (AO), R.V. Kirkham (KQ), A.P. Sabina (SS), J.M. Franklin (FR), A.G. Galley (GIA), I.R. Jonasson (JH), M.D. Hannington (MDH), D.E. Ames (AV), and J. Peter (POA). These sample numbers can be cross-referenced to the previously published sulphur and lead isotope databases (e.g. Thorpe, 2008, and references therein).

Sample preparation and analysis was carried out in the laboratories of the GSC. In most cases, up to 500-gram samples were crushed, pulverized, sieved, and panned to separate the sulphide fractions. The following procedures were employed:

(1) crushing and pulverizing by hand and in a steel shatterbox
(2) selection of a sieved fraction between -100 and +150 mesh
(3) superpanning of the sieved fraction to concentrate the sulphides
(4) cleaning with a Frantz magnetic separator.

Yields of different minerals ranged from <100 milligrams up to 5 grams. Subsamples for analysis were pulverized to -200 mesh prior to multi-acid dissolution. All analyses were performed at the Geological Survey of Canada in Ottawa (ICP-OES and ICP-MS) and at Activation Laboratories Ltd., Ancaster, Ontario (INAA: Table 2). The complete data set was acquired in 41 different submissions from 1994 to 2002. The year of analysis is indicated in the label for the source files listed in the compilation. Analyses at the GSC Laboratories were performed in 1994, 1996, 1997, and 2000. Analyses at Actlabs were performed in 1999 and 2002.

Results are reported for the following elements: SiO_2, TiO_2, Al_2O_3, Fe2O3, MgO, CaO, Na_2O, K_2O, MnO, P_2O_5, S_T, Ag, As, Au, Ba, Be, Bi, Br, Cd, Co, Cr, Cs, Cu, Ga, Hf, Hg, In, Ir, Mo, Nb, Ni, Pb, Rb, Sb, Sc, Se, Sn, Sr, Ta, Te, Th, Tl, U, V, W, Y, Zn, Zr, La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu. The major elements were analyzed mostly by multi-element ICP-OES; minor and trace elements were determined by a combination of ICP-MS and INAA (Table 2). Certain elements of interest in modern metallogenic studies (e.g. Ge, Re, Os, platinum-group elements) were not analyzed owing to difficulties requiring hydride generation, volatility of the elements, unresolved isotopic interferences, or elements requiring individual analytical techniques. Because many of the samples were pulverized in a steel mill, data for certain elements, such as Cr, should be considered with caution. Some samples might have been pulverized in W-carbide. Also, because many samples are mixtures of more than one sulphide species or contaminated by silicate and other gangue minerals, care is needed in interpreting the results in terms of individual mineral compositions. Some elements that are common in heavy minerals, such as the rare-earth elements, U, Th, Y, P and V, were also found in some sulphide fractions. Of the 2662 separate analyses, 442 were by INAA only (duplicate samples or splits of samples also analyzed by ICP), and the data show generally good agreement between the elements that were determined by both methods.

RESULTS

The data are provided as a single Excel® table sorted by deposit type, province, or territory, and alphabetically by deposit name (depname: Table 3). Table 3 contains analyses of mineral separates from 308 different mines and occurrences. These include, in order of importance, samples from volcanogenic Cu-Zn-Pb massive sulphide deposits (VMS), Mississippi Valley-type carbonate-hosted Pb-Zn deposits (MVT), clastic sediment-hosted Zn-Pb massive sulphide deposits (SEDEX), and magmatic deposits (e.g. veins, mantos, skarns, and porphyry-style). Subsets of the data for individual districts also have been published (e.g. Flin Flon and Sherridon: Jonasson et al., 2002, 2009; Noranda district: Sharman et al., 2015).

The majority of the mineral separates are pyrite (PY), pyrrhotite (PO), chalcopyrite (CP), sphalerite (SP) and galena (GN). Where mixtures were clearly identified, they are designated as mineral pairs (e.g. PY/SP, indicating subequal amounts of pyrite and sphalerite). Other minor and trace minerals may be included in the samples, including alphabetically: arsenopyrite (ASP), barite (BA), bornite (BN), gahnite (GAH), magnetite (MT), dolomite (DOL), and siderite (SID).

An average of 14 mineral separates were analyzed for each deposit or occurrence, ranging from 1 to 66. These include 1993 separates from 141 VMS, 284 separates from 72 MVT deposits, 129 separates from 25 SEDEX deposits, 131 separates from 40 vein deposits, and 73 separates from 15 magmatic deposits. 52 mineral separates were analyzed from 3 manto deposits (20 analyses), 4 skarn deposits (17 analyses), and 8 porphyry-style deposits (15 analyses).

Pyrite (523), pyrrhotite (155), chalcopyrite (387), sphalerite (597), and galena (187) separates account for 70% of the data (n = 1849). An additional 813 samples are mixtures, including 536 mineral pairs (24 pyrrhotite + chalcopyrite, 39 pyrrhotite + sphalerite, 50 pyrite + chalcopyrite, 70 pyrite + galena, 112 pyrite + sphalerite, 49 sphalerite + chalcopyrite, 102 sphalerite + galena, 90 sphalerite + pyrite). An additional 36 samples are Cu, Zn, Pb, and tailings concentrates from mills.

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