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Distribution of the main ore elements in the Tumurtijn-ovoo Fe–Mn–Zn skarn deposit, Mongolia

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ABSTRACT

The submarine hydrothermal Tumurtijn-ovoo skarn deposit contains large concentrations of Zn related to sphalerite, Mn predominantly hosted in jacobsite and bustamite, and Fe mainly fixed in jacobsite, magnetite, and andradite. The quantitative distribution of these ore elements was studied with special emphasis on the Zn-bearing Mn-rich upper part of the skarnbody. Here, Zn is negatively correlated with Fe, but positively with Mn. The Mn/Fe ratio of the main skarn type reflects whether sphalerite is associated either with jacobsite or magnetite. In vertical direction, Zn shows minima–maxima distributions that imply stratiform mineralization. This genetic concept is in agreement with the sedimentary characteristics of the deposit as deduced from conformable marble–skarn alternations in the transitional zone between marble and skarn and from internal laminations within the skarn. In the Zn-rich skarn sections lateral differentiations have been recognized. Highest values of Zn content and the Mn/Fe ratio are spatially correlated and are interpreted to represent ore centres. Large ore centres show elongated contours and are suggested to be formed along synsedimentary faults. Analogically, the lateral differentiations within the Zn-free, Mn-poor, and quartz-rich lower part of the skarnbody have been studied using the Fe content and the Mn/Fe ratio. It could be ascertained that the position of the ore centres changed with time from the lower to the upper skarn.

1. Introduction

The origin of skarn ore is one of the most intricate problems of ore formation. The term skarn itself is fraught with problems due to the change of its meaning during the history of petrological investigations. Originally, the term skarn was used as a descriptive term for the host rocks of distinct groups of ores in Sweden. These host rocks are composed of specific CaMgFeMnAl-silicate minerals. Later, the genetic sense of epigenetic metasomatism related to granite magmatism was added (see Magnusson, 1970; Einaudi et al., 1981). Afterwards, the knowledge on ore genesis deepened and various deposits initially named skarn-ore deposits were identified to be of syngenetic submarine hydrothermal origin. This particularly applied to most of the Swedish skarn-ore deposits (Boström et al., 1979; Frietsch, 1982; Frietsch and Papunen, 1986; Hedström, 1984; Hedström et al., 1989; Baker et al., 1988; Sundblad, 1994), but also to others (Gemmel et al., 1992). In this paper the term skarn is used in its original sense without any genetic constraints that means synonymous with CaMgFeMnAl-silicate rock.

The genesis of skarn ores can only be resolved by jointly considering geological, mineralogical, and chemical features based on a large number of samples. However, in many deposits the access to the orebody is restricted and, thus, the number of samples available for laboratory investigations is limited. In contrast, the situation at the Tumurtijn-ovoo deposit permits conclusions based on chemical data of almost the whole volume of the zinc-bearing part of the skarnbody. This skarn deposit is located in a Devonian block of sediments within the Barun-urt granite massif situated in the eastern part of Mongolia. It was explored by about one hundred boreholes (Kampe and Kraft, 1993). These boreholes provided drill cores, which were systematically analyzed for the main ore elements Zn, Fe, and Mn. The data allow to study the distribution of these elements within the skarnbody. The aim of this paper is to report the vertical and lateral variations of the ore elements as a contribution to the discussion on the genesis of this deposit. In previous papers, geological, mineralogical, and chemical arguments have been published in favour of a sedimentary submarine hydrothermal formation of the deposit. These arguments included the lithostratigraphic subdivision of the skarnbody, laminated textures in the skarn ores, and the Zn/Cd ratio of the ores (Gottesmann and Kampe, 1993, 2007; Gottesmann et al., 2009).

2. Structure of the deposit

The skarnbody is lithostratigraphically underlain by a compact metatuffite (footwall hornfels) and overlain by a banded

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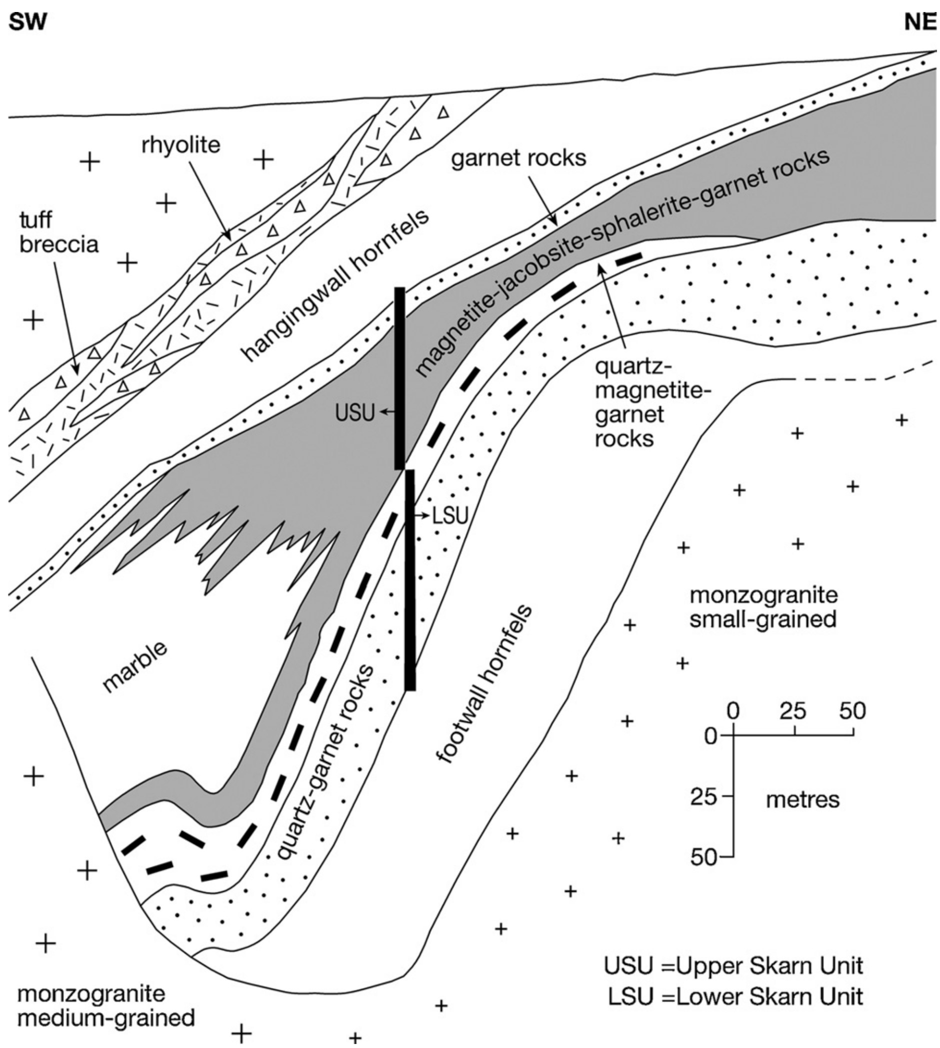

Fig. 1. Cross section through the marble–skarn–hornfels block of the Tumurtijn-ovoo deposit (Gottesmann and Kampe, 1993, modified).

metatuffite (hangingwall hornfels). Its southern part is covered by the hangingwall hornfels and overthrusted granite. Its northern part is outcropping. In the east, it is cut off by a young porphyry. The dipping of the sedimentary bedding varies from 20° in the north to 60° in the south (Fig. 1). The skarn is subdivided into an upper part (Upper Skarn Unit, USU), characterized by rich sphalerite ore, the occurrence of Mn-rich spinels, and low contents of quartz, and a lower part (Lower Skarn Unit, LSU), characterized by the lack of sphalerite and Mn-rich spinel and higher contents of quartz. The Upper Skarn Unit hosting the Mn–Zn mineralization laterally borders on barren marble with an interdigitation zone, where skarn and marble beds are conformably interlayered (Fig. 1). A sketch map of the Upper Skarn Unit is given in Fig. 2, which shows the positions of the drilling profiles discussed in detail below.

3. Minerals of the deposit

High contents of sphalerite classify Tumurtijn-ovoo as a Zn deposit. However, large contents of minerals of the jacobsite-magnetite series (here collectively named MnFe-spinel, or spinel for short) demand that Mn and Fe are also to be considered in the classification. At some sites, minor galenite has been recognized. The silicates are dominated by members of the grossularite–andradite series (here collectively referred to as garnets), with andradite being by far the most widespread. Second in order are minerals of the wollastonite–bustamite–rhodonite series, which mainly occur in the transition zone between marble and skarn, but also disseminated in the massive skarn. Third in order are quartz and calcite, which fill interstices between the main minerals. Quartz also forms separate layers in the Lower Skarn Unit. Other minerals are of subordinate quantity or of restricted occurrence. Three main skarn types have been distinguished: garnet–spinel skarn, garnet skarn, and garnet–bustamite skarn.

4. Sampling and analyzing

The results of wet-chemical analyzes on Fe, Mn, and Zn of the ores and their host rocks performed during the exploration phase are the basis of the present study. These analyzes were initially conducted to economically evaluate the deposit. Sampling was done in the following way. Drill cores were cut in halves. One half of about 1 m in length was analyzed for Zn. Powders of mostly 3–5 of such half-core samples were unified and analyzed for Fe and Mn. Exceptions of this procedure were made due to lithological borders and to the original conception that only spinel-bearing sections would be of economic interest with respect to Fe and Mn. Thus, garnet skarns and garnet–bustamite skarns were only poorly analyzed for Fe and Mn. Other reasons for incomplete datasets along drilling profiles comprise the technical loss of drill core and the strongly veined structure of the rocks. Recently, electron microprobe analyzes have