Magnetite spherules in pyroclastic iron ore at El Laco, Chile

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ABSTRACT

The El Laco iron deposits in northern Chile consist of magnetite (or martite) and minor hematite, pyroxene, and apatite. The orebodies are situated on a volcanic complex and resemble lavas and pyroclastic deposits, but a magmatic origin is rejected by some geologists who regard the ores as products of hydrothermal replacement of volcanic rocks. This study describes spherules of magnetite in the ore at Laco Sur and outlines a previously unrecognized crystallization process for the formation of spherical magnetite crystal aggregates during volcanic eruption.

 Mining at Laco Sur, the second largest deposit at El Laco, shows that most of the ore is friable and resembles pyroclastic material; hard ore with vesicle-like cavities occurs subordinately. The friable ore is a porous aggregate of 0.01–0.2 mm magnetite octahedra with only a local stratification defined by millimeter-thin strata of apatite. Films of iron phosphate are common on magnetite crystals, and vertical pipes called gas escape tubes are abundant in the ore. A SEM study reveals that magnetite spherules in the range 0.05–0.2 mm occur in most samples of friable ore from the central-lower part of the deposit. The proportion of spherules in a sample varies from high to nil, but overall the spherule content is low in the ore. The spherules are aggregates of octahedral crystals, or single octahedra, that have been rounded by stepwise, subparallel growth of magnetite with a systematic slight shift in orientation of successive steps. The shape of the spherules demonstrates that they formed unattached to any surface. Growth from hot magmatic gas saturated in iron in a volcanic plume and deposition as ash fall can account for the features of the spherule-bearing friable ore.

Keywords: Crystal growth, Fe, eruption, magmatic gas, plume, volcanic ash

INTRODUCTION

The El Laco deposits are the best preserved examples of apatite iron ore of Kiruna type in the world. They occur on the flanks of a Plio-Pleistocene volcanic complex of andesitic to dacitic composition in the High Andes of northern Chile. There are seven deposits of high-grade iron ore within an area of 30 km², with total resources exceeding 500 million tons (Fig. 1). The orebodies are composed of magnetite (or martite), and minor amounts of apatite, pyroxene, and hematite.

The first published report of the El Laco deposits (Park 1961) described the orebodies as magnetite lavas due to their morphological similarity to flows of vesicular basalt. Exploration trenching and mining subsequently revealed that much of the ore below the surface is friable and resembles pyroclastic material (Henríquez and Martin 1978; Nyström and Henríquez 1994; Naslund et al. 2002; Henríquez et al. 2003; Nyström et al. 2008). According to these authors the El Laco deposits formed from volatile-rich iron-oxide magmas that intruded the andesitic to dacitic volcanic structure at shallow depth and locally erupted to the surface.

This magmatic interpretation has been questioned but the similarity in appearance of the ore to silicate lavas and pyroclastic material is not in dispute. Some authors believe that the El Laco deposits formed from iron-rich hydrothermal fluids that completely replaced silicate rocks whose volcanic structures and textures were inherited (Rhodes and Oreskes 1999; Rhodes et al. 1999; Sillitoe and Burrows 2002). Here we report new information that is inconsistent with a replacement origin.

A SEM study of friable ore of pyroclastic appearance from one of the major orebodies, Laco Sur, reveals that ca. 0.1 mm diameter spherules of magnetite occur in most of the investigated samples. Such spherules have to the best of our knowledge not been reported before from iron deposits in the literature. The purpose of this paper is to describe these spherules and to show that they formed by rapid crystal growth in a volcanic plume during eruption of iron-oxide melt.

THE FRIABLE ORE

Laco Sur is the second largest deposit at El Laco (Fig. 1) and the only deposit that has been exploited. Mining has taken place intermittently, leaving a ca. 150 m long open pit (Fig. 2). The pit wall is ca. 25 m high in the central part of the section, where it consists of four benches, and lower at the sides. The appearance and physical character of the exposed ore varies...