Chapter 22

Skarn, Porphyry, Vein, and Replacement Mineralization in the Toqui District, Southern Chile

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Abstract

The Toqui district is located in southern Chile, 1,350 km south of Santiago. The total geological resource for the district is 20 million tonnes (Mt) grading 8.2 percent Zn and 1.5 g/t Au, with zones of significantly higher Au grades. All orebodies in the district are being developed by the Toqui mine, an underground room and pillar operation that has an average annual production of 500,000 t per year.

The Toqui district contains a series of skarn and replacement orebodies within a 24 km² area. Oldest rocks include Jurassic andesite and Cretaceous volcanic sandstone and tuff of the Toqui Formation, with a basal 5- to 30-m-thick limestone unit, rich in oyster fossils and forming the main ore host. Above these units is 800 m of black shale of the Katterfeld Formation, overlain by andesite of the Cretaceous lower Divisadero Group, which is then overlain unconformably by rhyolite ignimbrite of the upper Divisadero Group. Intrusive rocks include rhyolite, dacite, and andesite sills emplaced into all the Cretaceous rock units. Multiple periods of magmatic and hydrothermal activity have been documented from 120 to 105 Ma.

At district scale, Fe, As, Au, Bi, and Co are highest in the southeast, associated with garnet, pyroxene, and amphibole alteration, whereas Pb and Ag are highest in the northwest, associated with chlorite and sericite. Zinc grades are fairly uniform across the district, but sphalerite is zoned from high Fe in the southeast to low Fe in the northwest. Econometrically significant gold mineralization was superimposed on earlier base metal-rich skarn in the southeastern part of the district. Late hydrothermal fluids entered the skarn system along preexisting northwest-trending structures. Gold occurs as electrum associated with native bismuth, cobaltite, and a variety of sulfosalts. Gold-rich ore generally contains abundant arsenopyrite, but arsenopyrite-rich ores are not necessarily gold rich. Gold and cobaltite deposition was accompanied by extensive retrograde amphibole formation, with clay minerals more abundant at the periphery of the gold zones. Deep drilling has encountered two areas of subeconomic pyrite-chalcopyrite-molybdenite stockworks. One is beneath the skarn orebodies in the southeastern part of the district and the other is beneath mineralization in the northwestern part. The emerging picture is one of a large porphyry-skarn district with multiple pulses of intrusion and alteration, resulting in multiple orebodies and mineralization styles.

Introduction

The Toqui Zn-Au district is located in Region XI, southern Chile, approximately 1,350 km south of Santiago (Fig. 1A). It is situated along the eastern flank of the southern Andes Mountains within the Toqui River valley and between 620 and 1,650 m elevation. Within the district, Breakwater Resources Ltd. owns and operates the Toqui mine through its wholly owned Chilean subsidiary, Sociedad Contractual Minera El Toqui. By road, the mine site is approximately 120 km north of the regional capital, Coyhaique, and an equal distance northeast of the port of Chacabuco (Fig. 1B).

The district covers a 24-km² area and consists of 11 orebodies that have been or will be developed by the Toqui mine. Two of the orebodies, Antolín and Zúñiga, were discovered and developed early in the history of the district and are no longer accessible. They are described in Wellmer et al. (1983) as discordant veins of sphalerite and galena with minor amounts of pyrite and chalcopyrite in a gangue of quartz and calcite. We refer to them as the Antolín and Zúñiga Zn-Pb-Ag veins. They have not been a focus of recent exploration and are not discussed in detail in this report. Of the remaining orebodies, two are replacement deposits and seven are skarns. Skarn and replacement mineralization is hosted principally in a 5- to 30-m-thick limestone bed at the base of the Cretaceous Toqui Formation, although minor amounts of the mineralization are also hosted in other units. Historically important areas of mineralization include the Doña Rosa Zn-Au orebody; San Antonio, Mallín-Mónica, and Estatutas Zn orebodies; Concordia Zn-Pb-Ag orebody; and the previously mentioned Antolín and Zúñiga Zn-Pb-Ag orebodies. More recently, the Porvenir Zn orebody was discovered in 2006, and of particular importance, the Au-Co-Zn Aserradero and Mina Profunda orebodies were discovered in 2002 and 2007, respectively.

The Toqui mine has been in continuous production since 1983, except for during 1986 and a brief period in 1998. Between 1998 and 2008, exploration doubled the size of the known resource from 10 to 20 million tonnes (Mt). At the end of 2008, the total geological resource for the district was 20 Mt grading 8.2 percent Zn and 1.5 g/t Au. This reported...