Prediction of the environmental impact of modern slags: A petrological and chemical comparative study with Roman age slags

ANTONIO M. ÁLVAREZ-VALERO,1,2,* RAFAEL PÉREZ-LÓPEZ,2,3 AND JOSÉ M. NIETO2

1Andalusian Institute of Earth Sciences (IACT), CSIC-University of Granada, Campus Fuentenueva, Faculty of Sciences, 18002 Granada, Spain
2Department of Geology, Faculty of Experimental Sciences, University of Huelva, Campus El Carmen, 21071 Huelva, Spain
3Institute of Environmental Assessment and Water Research, IDAEA-CSIC, Jordi Girona 18, 08034 Barcelona, Spain

ABSTRACT

This work presents a comparative study of Roman and modern slags, which represent the same type of mining waste but which were produced at vastly different times. The natural laboratory in which both materials are found is São Domingos, one of the most emblematic of Portuguese mining districts in the Iberian Pyrite Belt (IPB). The methodology included: (1) detailed studies of the mineralogy and geochemistry of both materials with a reflected-light optical microscope, scanning electron microscope (SEM), electron microprobe analyses (EMPA), and bulk-rock analyses; (2) MELTS thermodynamic software to quantitatively test fractional crystallization of both glassy matrix types; (3) TWQ-v. 2.32 software for performing internally consistent thermometric calculations; and (4) a modified Community Bureau of Reference (BCR)-sequential extraction procedure applied to the chemical speciation of potentially toxic elements.

The combination of petrologic studies and sequential extraction leaching may be used to evaluate and predict pollution impact on the environment. We conclude that a 2000 year time gap has not produced an important modification to the base-metal extraction system as reflected by the petrologic similarity of both slags and that, considering the total mass of modern slags, the transfer rate of metals to the environment over the next 2000 years will be ~6.7 t/year of Fe, 1 t/year of S, 81.1 kg/year of Zn, 55.5 kg/year of Pb, 6.5 kg/year of Cu, 0.7 kg/year of As, 31.2 g/year of Sb, and 18.3 g/year of Cr. The results demonstrate the pollutant potential of the slags within this IPB mining district as revealed by the spoiled state of the fluvial courses in the region.

Keywords: Environmental impact, petrogenesis, prediction, slag, sequential extraction

INTRODUCTION

The exploitation of mineral resources has been an essential activity for the development of humanity. However, human intrusion in the environment can have adverse consequences. A clear example of this can be found in the Iberian Pyrite Belt (IPB), located in the southwest part of the Iberian Peninsula. It is one of the largest metallogenic provinces of massive sulfides in the world with original reserves of over 1700 Mt (Sáez et al. 1999). The mining-metallurgical wealth of the region provided the economic support of numerous civilizations from prehistoric times to the present. The commencement of mining activity in the region dates back to the third millennium BC (Sáez et al. 2003; Nocete et al. 2008), and became important during Phoenician and Carthaginian times (first millennium BC; Kassianidou 1993) and especially during Roman times (from 800 BC to 410 AD; Rothenberg and Blanco Freijero 1981; Pérez Macías 2007). Later, mining activities were either discontinuous or non-existent until the final resurgence in the mid-nineteenth century (Checkland 1967; Poss 1978; Salkfield 1987; Morral 1990).

The archaeological record of civilizations in the vicinity of the IPB is mainly recognized by the study of their best preserved mine residue. Slags are a type of waste resulting from the fusion of primary and secondary sources to obtain Cu concentrates. Pre-Roman mining activities are sporadic and are recognized by small slag volumes (<1 ton). However, mining activities during the Roman period brusquely increased, resulting in the formation of more than 20 million tons of metallurgical slags (Rothenberg and Blanco Freijero 1981). Environmental impacts including soil degradation, water and atmospheric pollution, and a decrease in biodiversity have been recognized as a consequence of leaching of waste piles and sulfides exposed at the surface. Weathering produces highly acidic drainage with high concentrations of potentially toxic metals and metalloids in solution, known as acid mine drainage (AMD). Hereafter, the term metal includes metals and metalloids (i.e., As and Sb).

Historical evidence of ore materials from adjacent localities mined by the Romans and contemporaries clearly show that the raw materials were of similar provenance (Webb 1958; Vara 1963; Carvalho 1971; Pérez Macías 1995, 2007). Furthermore, Roman and modern slags, though separated in time by ca. 2000 years, were produced by similar smelting processes. The sporadic pre-Roman age slags in the area were produced by different metallurgical processes, which resulted in a different type of slag (Kassianidou 1993; Saez et al. 2003).

This work investigates Roman and modern age slags from the Portuguese São Domingos district that were produced before...