Mine wastes at the polymetallic deposit of Fenice Capanne (southern Tuscany, Italy). Mineralogy, geochemistry, and environmental impact

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Abstract The polymetallic (Zn, Cu, Pb, Fe, Ag) sulfide deposit of Fenice Capanne, southern Tuscany (Italy), was mined at least 6–7th centuries B.C. until 1985. Mine wastes include dumps of roasting products and excavation wastes, mainly dating back to the 19th century, and flotation tailings produced during the period 1950–1984. The mine wastes show significant contents of polluting elements [maximum values (mg/kg) in flotation tailings and roasting As: 1,100; Cu: 7,500; Pb:10,100; Zn: 13,600]. Tailing piles show more intense leaching and acidification compared with later basin filling tailings. The greater effective porosity, as a result of coarser grain size, and the unsaturated conditions that occur in the tailing piles have enhanced sulfide weathering, compared with the fine grained and nearly saturated flotation material present in the settling basins. However, flotation tailing samples show overall negative values of net neutralization potential (NRP), as determined by a standard Sobek test. This emphasizes the importance of maintaining the present hydraulic conditions within the basins to prevent the generation of acid drainage in future. The alteration of mine waste materials have produced pollution in surficial waters and sediments.

The pollutant transport in surficial waters occurs mainly as suspended fine-grained sediments containing traces of heavy metals. A possible remediation plan could include building a settling pond for drainage waters, and moving the polluted sediments and unconfined tailing materials into the basins.

Keywords Abandoned mine wastes · Heavy metal pollution · Stream water and sediments · Tuscany

Introduction

Since 1992, studies are under way in our Department to investigate environmental effects in abandoned mining areas of Tuscany (Benvenuti and others 1997, 1999a). This study concerns mine wastes produced by exploitation and processing of the polymetallic (Zn, Cu, Pb, Fe, Ag) sulfide deposit of Fenice Capanne, southern Tuscany (Italy). The deposit has been mined at least from Etruscan times (6–7th century B.C., Benvenuti and others 1999b) until 1985. The main exploitation occurred in the medieval age and during the 19–20th centuries. Total production is estimated in the order of some thousand tonnes of Cu, Pb, Zn and some tonnes of Ag (cf. Lotti 1893; Burtet Fabris and Omenetto 1971; Capperi and Nannoni 1997). The mine wastes include huge dumps of roasting products (roastings) and excavation wastes, mainly dating back to the 19th century, and flotation tailings produced during the period 1950–1984. In this study, we investigated the mineralogy and the chemistry of flotation tailings and of the roastings. In order to examine the potential of the flotation tailings for acid generation, and for the conceptual development of a possible remediation strategy, the net neutralization potential (NRP) was determined using a typical Sobek static test. An estimate of present impact was obtained by reconnaissance analyses of stream sediments and stream waters in the area.
Background information

Geological, physiographical, climatic and hydrogeological features

A geological map of the mining area of Fenice Capanne, with sampling sites for waters and stream sediments is shown in Fig. 1. According to Elter and others (1994), the various lithologies present in the Fenice Capanne area may be grouped into four main units:

Monticiano-Roccasbrada Unit:
- anhydrites, phyllites and siliciclastic formation of Triassic–Palaeozoic age, here only recognized underground.

Tuscan Nappe Unit:
- anhydrites, limestones and marly limestones (Upper Triassic), here only recognized underground.

Ophiolitic Unit:
- carbonaticphyllitic and ±arenaceous flyschs (“Argille con Calcri a Palombini” formation – Lower Cretaceous).

Neautochthonous Unit and Recent Alluvium:
- continental lacustrine and marine sediments of Mio-Pliocene age, and Holocene sediments.

The whole area is characterized by a number of Mio-Pliocene extensional faults, trending NW–SE, bounding the Serrabottini horst. The Fenice Capanne sulphide deposit is mainly constituted by two polynmetallic [Cu, Pb, Zn (Ag)] vein bodies, linked to principal tectonic dislocations in the east side of the horst. The mineral association is characterized, in the central and northern portions, by the presence of predominant chalcopyrite (Cu: 2.5–11 wt%) and, in the southern part, by predominant Zn and Pb sulphides (Pb: 1–3.5; Zn: 4.5–16 wt%; Burtet Fabris and Omenetto 1971). The ore body originated from hydrothermal processes associated with late Apenninic magmatism (Corsini and others 1975; Tanelli 1983). The hydrothermal fluids also caused alteration and replacement phenomena that affected the host rocks, with the formation of skarn silicates (mainly pyroxenes, epidotes and ilvaite), pyrite, chalcedony, and of minor masses of kaolinite and alunite (Lotti 1893; Burtet Fabris and Omenetto 1971). The Fenice Capanne area is characterized by hills (300 to 460 m a.s.l.) mainly covered by woods (Falsini 1999). The Fosso dei Noni Creek, a tributary of the Bruna River, is the main water body of this area. It is almost 20 km long, with a catchment basin of about 35 km² and a mean slope of 3.6%. Upstream from the mine wastes, the creek shows greater slopes than downstream from the mine wastes, where the river bed is nearly flat. The Fosso dei Noni Creek presents a torrential and pluvial character, with a mean concentration time (i.e. time required for water to travel from the most remote portion of a river basin to basin outlet) of about 150 min (Menduni and

![Map of Fenice Capanne area](image-url)