



The impact of mining activities on the environment reflected by pollen, charcoal and geochemical analyses

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ABSTRACT

This article presents results of a multi-proxy study of a fen deposit in the former mining district of Falkenstein near Schwaz in the Tyrol, Austria. The aim of the study in the framework of the special research program HiMAT (The History of Mining Activities in the Tyrol and Adjacent Areas – Impact on Environment & Human Societies) was to disclose the ecological impact of mining in pollen and heavy metal diagrams and to create a model combining the changes in palaeoecological proxies with historical evidences for mining. The application of this palaeoecological–historical model to prehistoric times allowed us to reconstruct the impact of mining and metallurgic activities in the surroundings of the fen during the last millennia. The results of stratigraphy, radiocarbon dating, LOI, pollen and micro-charcoal analyses as well as geochemical analyses of scandium, lead and lead isotopes validated by historical and archaeological data are hereby presented.

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1. Introduction

Human impact on the environment is mainly expressed by settlement activities and agriculture, but also mining – encompassing ore exploitation and processing – has significant ecological consequences. Mires as archives of vegetation history, anthropogenic activities and atmospheric metal deposition are predestinated to reconstruct the impact of mining on the environment. The palaeoenvironmental data of pollen, micro-charcoal and geochemical analyses are useful to explain human–environment interactions in the mining landscape (Mighall et al., 2002a).

Geochemical analyses of the last decades disclose peat deposits as archives for both palaeobotanical purposes and as a source of information about past atmospheric pollution (Shotyk, 1996a; and Martínez-Cortizas et al., 2002b). Beside studies about the reconstruction of atmospheric pollution in peat and lake deposits across Europe (Bränvall et al., 1997; Martínez-Cortizas et al., 1997; Shotyk, 2002; De Vleeschouwer et al., 2007) and the impact of mining on

regional and local scales (Bränvall et al., 1999; Mighall et al., 2002b, 2009; Le Roux et al., 2004; Cloy et al., 2005), the multi-proxy research on the environmental impact of palaeometallurgy by pollen and geochemical analyses (Monna et al., 2004a,b; Baron et al., 2005; Jouffroy-Bapicot et al., 2007) seems to reveal the past more clearly.

In the majority of the recent palaeoecological studies in former mining areas, lead is used to detect mining phases in pollen diagrams in order to recognise mining-induced changes in the vegetation. In ombrotrophic peat bogs lead is effectively immobilized (Vile et al., 1995, 1999; Shotyk et al., 1997; MacKenzie et al., 1997; Weiss et al., 1999a,b), allowing them to be used as archives for the reconstruction of atmospheric Pb deposition (Bränvall et al., 1997; Cortizas et al., 1997; Farmer et al., 1997; Shotyk et al., 1998, 2002). Although bogs are thought to provide better geochemical data, it has recently been shown that fens, too, are suitable to record atmospheric deposition without significant distortion. The lead concentration profiles in minerogenic peat deposits suggest that atmospheric sources of lead are quantitatively more important than Pb supplied by groundwater (Shotyk et al., 2000). Additionally, West et al. (1997) showed that the variations in lead concentrations might not be the result of inputs from weathering of local soils and

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rocks as well as changes in the mineral fraction sedimentation, if the atmospheric deposition appears more important. Thus, the isotopic ratio of lead $^{206}\text{Pb}/^{207}\text{Pb}$ could be helpful in distinguishing between these two sources.

Here we present a pollen, micro-charcoal and geochemical study of a minerotrophic peat core sampled in the former prominent mining area of Schwaz in the Tyrol. The objective is to analyse the palaeoenvironmental impact since the beginning of mining activities in this area. Geochemical analyses of the peat disclose mining activities, whereas parallel pollen studies reveal the impact of mining and settlement activities on the local vegetation. Additionally, historical and archaeological data available for the last 4000 years validate the pollen data. This approach should enable the separation of the signals of mining and settlement in the pollen data and to create a palaeoecological model for mining, applicable to other mining regions.

2. Context, sampling site and study location

The Eastern Alps contain a big amount of profitable ore deposits, thus being a region with a long tradition of mining (Eibner, 1992; Höppner et al., 2005). One of the most prominent mining areas beside the Mitterberg region near Salzburg and the Kelchthal near Kitzbühel is the region between Schwaz and Brixlegg in the Tyrolean Inn-valley. In this area man has been extracting copper ores from the bedrock since at least the Early to Middle Bronze Age (Goldenberg, 1998; Goldenberg and Rieser, 2004) and the local use of copper for creating artefacts is already documented for the

beginning of the fourth millennium BC (Matuschik, 1997; Huijsmans et al., 2004). Archaeological findings and historical references confirm metallurgic activities concerning copper and silver production in the mining district of Falkenstein near Schwaz in Prehistoric and Post-Roman Times (Bartels et al., 2006). In such a situation of successive periods of mining activity, the reconstruction of the mining history of the site may be envisaged through the combination of pollen and geochemical analyses of mires (Monna et al., 2004a).

The investigation area in the lower Inn-valley (Tyrol – Austria) is located nearby Schwaz at the orographically right side to the river Inn at the north-western slope of the Mehrerkopf (Fig. 1). The northern Austroalpine Greywacke Zone around the former mining centre Schwaz consists of dolomites, schists and porphyric gneisses. The ore deposits situated in the Devonian Schwaz Dolomite are thought to be the result of hydrothermal metal transport in the lower Devonian sedimentation environment. This mineral deposit exploited at the Falkenstein mining district contains mainly fahlore of the tennantite–tetrahedrite series ($\text{Cu}_{12}\text{As}_4\text{S}_{13}$ – $\text{Cu}_{12}\text{Sb}_4\text{S}_{13}$) (Gstrein, 1988). Copper, antimony, arsenic and sulphur are the main components as indicated by the formula. Minor components are silver, mercury, iron, zinc and bismuth which substitute copper in the fahlore crystals. Chalcopyrite and galena are also present in the ore, but scarce. Therefore the lead concentration in the ore is low and ranges between 2 and 180 $\mu\text{g/g}$ in some of the chemically analyzed samples. In the Bronze Age, the ores were mined for copper, whereas silver was the main target in medieval and (early) modern times. Due to low lead concentrations

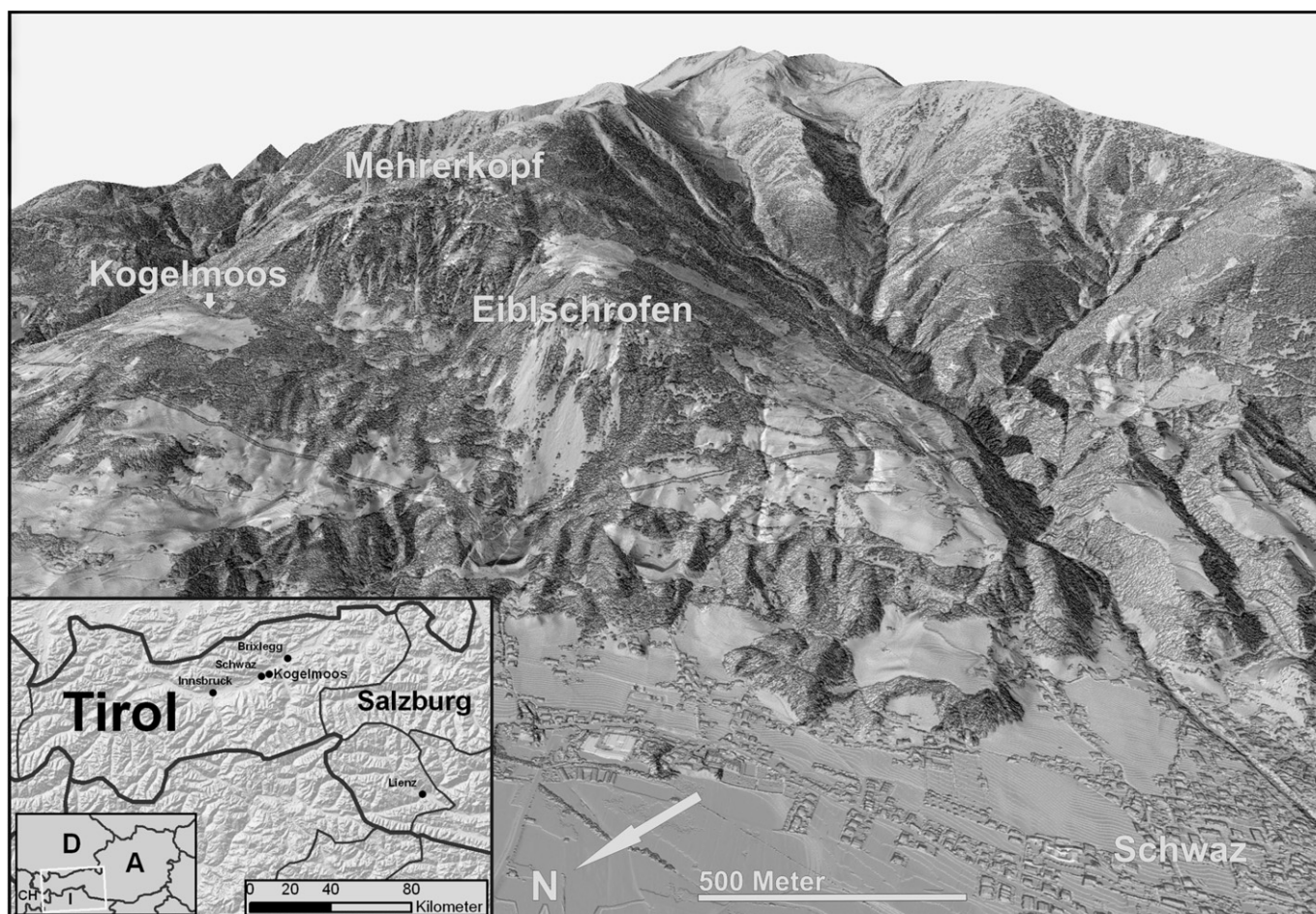


Fig. 1. General map of the former mining district Falkenstein on the north-western slope of the Mehrerkopf (©Land Tirol).

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