Ore Geology Reviews 79 (2016) 535–543

Contents lists available at ScienceDirect

Ore Geology Reviews

journal homepage: www.elsevier.com/locate/oregeorev

A multistage origin for Kupferschiefer mineralization

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ARTICLE INFO

Article history:
Received 23 November 2015
Accepted 9 May 2016
Available online 15 May 2016

Keywords:
Kupferschiefer
Red bed copper
Re–Os dating
Poland
Southern Permian Basin

ABSTRACT

New Re–Os age determinations on mineralized material from the Polish Kupferschiefer elucidate the timing of mineralization and thus the likely mechanisms of ore deposition. Three mineralization parageneses were analysed: (a) chalcocite as pore space filling in sandstone, (b) disseminated Cu–Mo mineralization in shale, and (c) massive, bedded copper sulphides. The resulting ages fall into two ranges: 245.2 (±1.6)–264.7 (±1.8) Ma and 162.3 (±0.8)–184.3 (±2.2) Ma. These results substantiate previous age determinations, although no Upper Triassic ages were found in this study. Some of the younger ages for the mineralization could represent alteration and recrystallization of existing sulphides. The results confirm that mineralization took place in several stages, from soon after Kupferschiefer sediment deposition in the Upper Permian and for at least 100 m.y. after, until at least the Cretaceous. The genesis of the mineralization can be explained by the episodic release of hydrothermal fluids from the subsiding adjacent Southern Permian sedimentary basin, although the relative importance of each successive mineralizing 'event' for introducing additional metals is as yet unknown.

1. Introduction

The world-class Kupferschiefer mineralization of northern Europe has been the focus of many detailed geological, mineralogical, and geochemical studies, yet some aspects of the mineralization remain poorly understood. This is particularly true of the timing of the mineralization, which is a key component of any theory seeking to explain the deposit genesis. During the last two decades, there have been several attempts, using a variety of methods, to determine the age of Kupferschiefer mineralization. However, the results of these studies differ significantly and are somewhat contradictory (see Table 1). In this paper, we present the results of new Re–Os age determinations on mineralized material from the Polish Kupferschiefer, and combine these results with existing age information in order to elucidate the timing of mineralization, and thus the likely mechanisms of ore deposition.

2. Kupferschiefer mineralization

The Kupferschiefer mineralization continues to be an important global producer of copper and silver. Although the stratigraphic units which host this mineralization extend for large distances over much of northern Europe (>600,000 km^2 in areal extent; 1500 km from western Russia in the east to Northern Ireland in the west), the historically economic portions are restricted to the southern margins of the Permian Basin, in southwest Poland and central Germany (Fig. 1). The deposits in Germany have been subjected to a long history of mining (ca. 800 years), but these deposits are presently uneconomic and current production is restricted to southwest Poland (Lower Silesia-Dolny Slask). However, a recent probabilistic statistical analysis (Zientek et al., 2015) suggests that undiscovered resources of >100 Mt of Cu metal could be present in Germany and Poland. Active exploration has continued in regions of both former and current mining operations, and in completely new areas (e.g. the Spremberg region of eastern Germany).

In southwest Poland the horizons mined for copper extend laterally for ca. 600 km^2 and vary in thickness from 0.4 to several tens of metres. During the last 25 years, annual production of ore has amounted to about 30 Mt, from three principal mines: Rudna, Polkowice-Sieroszowice, and Lubin (USGS, 2015). Copper production has been steadily rising during this time period with resources currently estimated at about 1700 Mt of ore containing 3.3 Mt of copper and 102,000 t of Ag. Ore grades typically average ca. 2% Cu and 50 ppm Ag. There are, in addition, important byproducts, including Pb, Zn, Au, Ni, Pt–Pd, Re, and Se.

3. Geological overview

The geological and mineralogical characteristics of the Kupferschiefer have been extensively studied and thorough descriptions of the geology are to be found in Vaughan, Sweeney, Friedrich,

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http://dx.doi.org/10.1016/j.oregeorev.2016.05.007
0169-1368/

Table 1
Published age determinations for Kupferschiefer mineralization and associated recrystallization events. Ages in brackets are the age uncertainty.

Age (Ma)	Method	Phase/unit	Location	Source
250–255	Palaeomagnetism	Rote Fäule (hematite)	North Sudetic Trough mines	Jowett, Pearce, and Rydzewski (1987), Nawrocki (1997, 2000), Torsvik et al. (2001)
240 (3.8)	Re–Os	Sulphide-rich shales	Lubin	Pašava, Vymazalová, Qu, et al. (2007)
212 (7)	Re–Os	Bornite and chalcopyrite veinlets	Lubin and Polkowice	Mikulski and Stein (2012)
204.3 (0.5)	Re–Os	Sediments and sulphides	Mansfeld	Patzold et al. (2002)
190–216	K–Ar	Illite	SW Poland	Bechtel et al. (1999)
175–180	U–Pb	Thucholite	Lubin district	Kucha and Przybylowicz (1999)
149 (3)	Palaeomagnetism	Kupferschiefer (sulphide-rich)	Sangerhausen	Symons et al. (2011)
114–187	K–Ar	Illite in Rotliegend sandstone	Western Poland	Maliszewska and Kuberska (2009)
130	U–Pb	Huttonite - monazite	Lubin	Kucha (unpublished results)
83–96	K–Ar	Illite in mineralized Weissliegend sandstone	North Sudetic Trough	Michalik (1997)
159–186			Fore Sudetic monocline	
?53 (3)	Palaeomagnetism	Kupferschiefer (sulphide-rich)	Sangerhausen	Symons et al. (2011)

Diedel, and Haranczyk (1989), Oszczepalski (1989, 1999), Kucha (2003), Borg et al. (2012), and Zientek et al. (2015).

The Kupferschiefer mineralization in Poland is located in the southwestern margin of the Polish Basin which constitutes part of the larger Central European (Southern Permian) Basin. This basin formed after the Variscan orogeny by crustal thinning, extension, basin fill, and magmatism. Mining has taken place on either side of the Fore-Sudetic Block - the eastern North Sudetic trough to the south and the Fore-Sudetic monocline to the north (Fig. 1), although production is now restricted to an area located 75 km NW of Wroclaw in the Fore-Sudetic monocline.

The Kupferschiefer (ss) is a ca. 0.5 m-thick unit consisting of pyrite-, and carbonate-bearing, organic-rich shale. It occurs at the contact between uppermost Lower Permian (Rotliegend and Weissliegend) strata composed of terrestrial, fluvial-lacustrine red bed sediments and bimodal volcanic rocks, and unconformably overlying Upper Permian (Zechstein) transgressive continental and shallow-marine sediments (evaporites, carbonates, shales, and siliciclastics). The Cu–Ag mineralization transgresses these lithological boundaries and occurs in units both above and below the Kupferschiefer shale (Fig. 2). Notably, current production in Poland includes only 12% derived from the Kupferschiefer (ss), with the majority mined from the Rotliegend, and lesser amounts

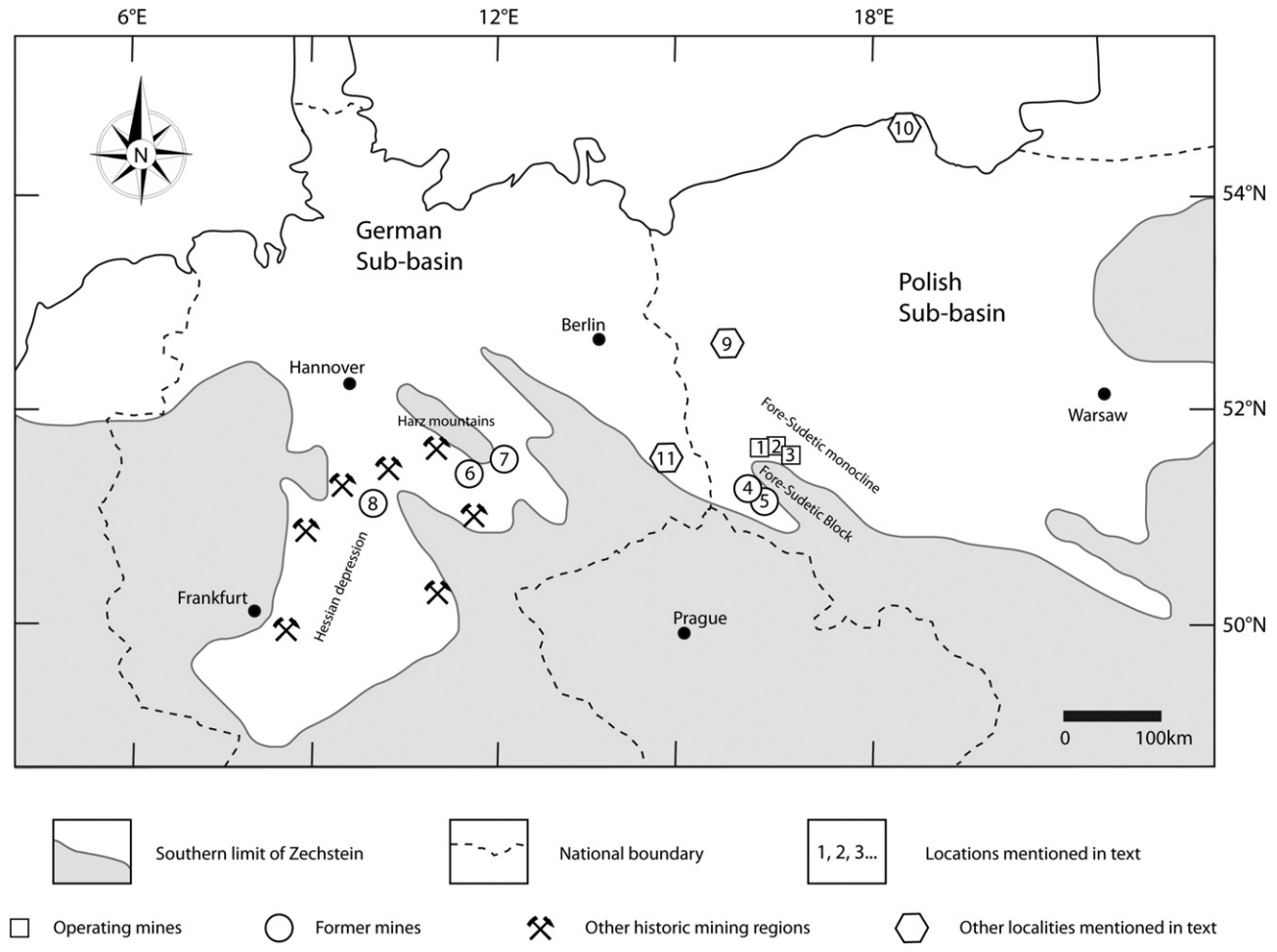

Fig. 1. Locations of the Kupferschiefer mines and other studies mentioned in the text. After Borg et al. (2012); Oszczepalski (1989) and Zientek et al. (2015). Locations: 1: Polkowice; 2: Rudna; 3: Lubin; 4: Konrad; 5: Lena; 6: Sangerhausen; 7: Mansfeld; 8: Richelsdorf; 9: Miedzychod; 10: Zdrada; 11: Spremberg.