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PB- AND SR-ISOTOPES – INDICATORS FOR MIXING PROCESSES IN MINE WATERS OF THE «HIMMELFAHRT FUNDGRUBE»

Lead and Strontium isotope ratios in mine waters were investigated to pinpoint Pb and Sr sources and mixing processes of waters in the abandoned mine «Himmelfahrt Fundgrube» (Freiberg, Germany). Both Pb- and Sr-isotope compositions have shown the important role of gangue carbonates as an element source that could not be revealed by former oxygen and sulphur isotope studies.

Соотношение изотопов свинца и стронция в рудничных водах было изучено с целью выявления источников свинца и стронция и процессов перемешивания вод в выработанной шахте «Himmelfahrt Fundgrube» (г. Фрайберг, Германия). Составы как изотопов свинца, так и изотопов стронция продемонстрировали важную роль карбонатов вмещающих пород как источника химических веществ, который не мог быть выявлен проводившимися до этого определениями изотопов кислорода и серы.

Introduction.

The polymetallic sulphide ore mine «Himmelfahrt Fundgrube» in Freiberg was closed in 1969 and flooded to the level of the deepest drainage gallery (230 m below surface). Today, continuous water and oxygen supply lead to the oxidation of remaining ores and form acid and trace-metal bearing mine waters that drain via culverts into rivers and pollute them. Oxygen and sulphur isotope studies in this mine have shown that sulphate in mine waters results from two major sources: weathered sulphide ores and seepage water. We used Pb and Sr isotopes to reveal further information about element sources and mixing processes.

Sampling points and isotope analyses.

The four major mine water types were sampled at six sampling points several times between December 2005 and March 2006. «Pool water» (PW1, PW2) was sampled on level 2 (149 m below surface). It is formed by dripping pore waters resulting from the oxidation of remaining ores from the dominating Late Variscan mineralisation. On its way towards the drainage galleries, seepage water mixes with pore waters in «flowing mine waters» that were sampled on two levels: 105 m below surface (FMW1) and 149 m below surface (FMW2). At some sites flow rates are so slow that seepage water only drips from the top. Such a «drip water» (DW) was sampled at level 2. Mineralised seepage water drains down towards the flooded area, where it mixes with groundwater. This «flooding water» (FW) was sampled 230 m below surface, where it raises up in the shaft «Reiche Zeche» until it leaves the mine via the deepest drainage gallery into the river Triebisch. Galena (PbS) from the Late Variscan (GAL-LVM) and from the Post Variscan mineralisation (GAL-PVM) were analysed to characterise ore Pb isotope composition. Isotope ratios were measured with the thermal ionisation mass spectrometer Finnigan MAT 262. Relative errors ($2\sigma_M$) were 0.01…0.34 % for $^{206}Pb/^{204}Pb$, 0.01…0.33 % for $^{208}Pb/^{204}Pb$, and 0.003…0.03 % for $^{87}Sr/^{86}Sr$.

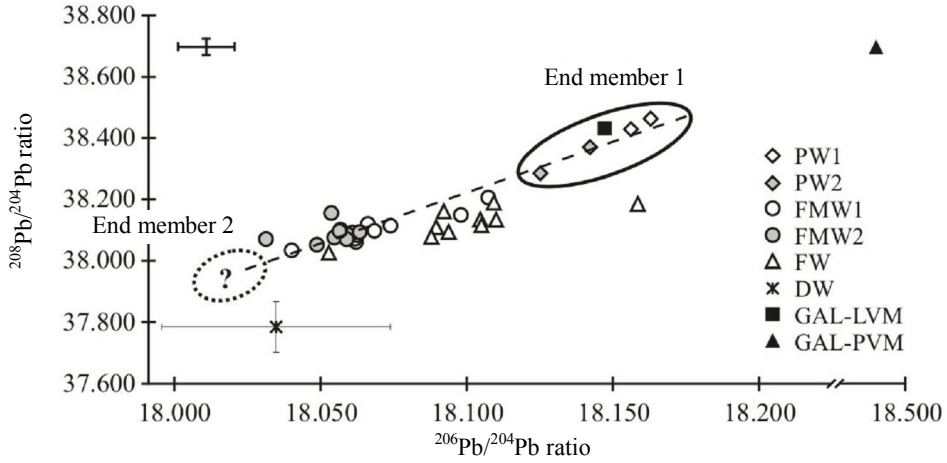


Fig.1. $^{208}Pb/^{204}Pb$ ratios vs. $^{206}Pb/^{204}Pb$ ratios

Results and discussion.

Fig.1 shows a mixing line with end member 1 consisting of pool water ($^{206}Pb/^{204}Pb$ = = 18.156…18.163, $^{208}Pb/^{204}Pb$ = 38.432…38.465 for PW1, $^{206}Pb/^{204}Pb$ = 18.125…18.142, $^{208}Pb/^{204}Pb$ = 38.286…38.370 for PW2) and galena from the Late Variscan mineralisation ($^{206}Pb/^{204}Pb$ = 18.147, $^{208}Pb/^{204}Pb$ = 38.433) as the only Pb source. The proposed end member 2 has isotope ratios similar to those from drip water ($^{206}Pb/^{204}Pb$ = 18.035, $^{208}Pb/^{204}Pb$ = = 37.786), although the large measurement errors of DW do not allow a clear definition of this end member. But low Pb concentrations (3 µg/l) indicate that Pb in drip water originates mainly from seepage water. The Pb isotope composition of flowing mine water ($^{206}Pb/^{204}Pb$ = 18.041…18.107, $^{208}Pb/^{204}Pb$ = = 38.036…38.179 for FMW1, $^{206}Pb/^{204}Pb$ = = 18.032…18.064, $^{208}Pb/^{204}Pb$ = 38.055…38.157 for FMW2) and flooding water ($^{206}Pb/^{204}Pb$ = = 18.053…18.158, $^{208}Pb/^{204}Pb$ = 38.028…38.190) is controlled by at least two Pb sources: galena from residual ores, and seepage water. Flooding water has higher $^{206}Pb/^{204}Pb$ ratios than would be expected by mixing between end member 1 and 2. Therefore, Pb in flooding water originates not only from pore water and seepage water, but maybe from weathered gangue carbonates.

Fig.2 shows at least three mine water groups resulting from different Sr sources. $^{87}Sr/^{86}Sr$ ratios of pool water have shown an increase from 0.72244 to 0.72378 (PW1) and from 0.72224 to 0.72364 (PW2) within two months. The Sr isotope composition lies within that of Grey Gneisses and identifies these host rocks as the main Sr source of pool water. Sr ratios of flowing mine water from different levels ($^{87}Sr/^{86}Sr$ = 0.71829…0.71938 for FMW1, $^{87}Sr/^{86}Sr$ = 0.71852…0.71895 for FMW2) are lower than those of pool water, although the Sr concentrations are almost equal (about 120 µg/l). Thus, Sr in flowing mine water originates mainly from seepage water. Because of lower ratios ($^{87}Sr/^{86}Sr$ = = 0.71692…0.71757 for FW and $^{87}Sr/^{86}Sr$ = = 0.71708 for DW) and higher Sr concentrations (660 µg/l in FW and 220 µg/l in DW), flooding water and drip water must be influenced by an additional Sr source. (Almost) neutral pH values point to the presence of carbonates, able to buffer the pH values. Sr in DW can be interpreted as a mix of Sr from gangue carbonates and anthropogenic Sr.

Conclusions.

The isotope Pb composition of the four major mine water types in the sulphide ore mine Freiberg can be interpreted as resulting from two major Pb sources: a) oxidation of remaining sulphide ores (mainly galena), b) anthropogenic sources (seepage water). Contrary to former oxygen and sulphur isotope studies, there are indications for a further element source: gangue carbonates. Sr isotopes indicate at least three different Sr sources in mine waters: a) weathering of Grey Gneisses in sites of low pH values, b) anthropogenic sources (seepage water), and c) gangue carbonates.

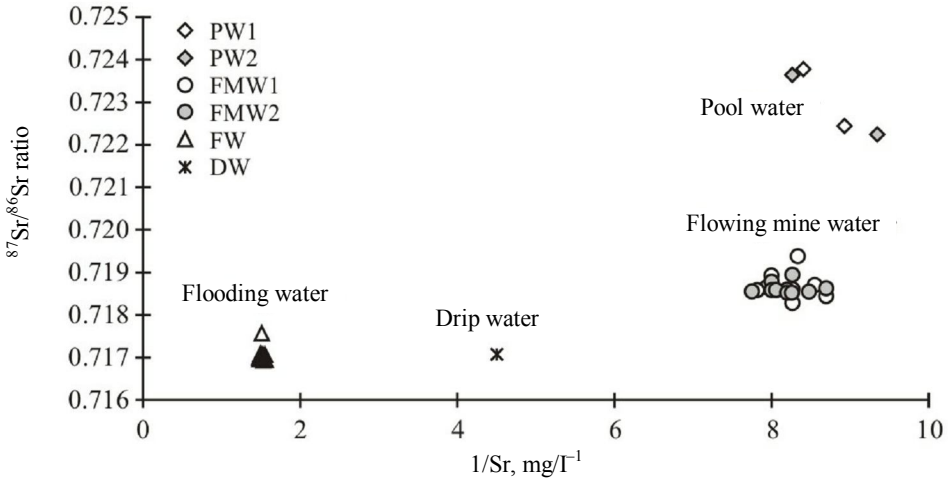


Fig.2. $^{87}Sr/^{86}Sr$ vs. reciprocal Sr concentration of mine waters

The application of isotopes Pb and Sr on mine waters has shown the important role of gangue carbonates as an element source and revealed additional mixing processes which could not be identified by sulphur and oxygen isotopes alone.