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Hydrogeochemical investigations of acid drainage water from the Emirli antimony mine, Western Turkey

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ABSTRACT

To investigate the chemical evolution of acid mine drainage water from the Emirli antimony mine, the rock-forming elements and ore metals were measured from the mine's mouth of adit, the seepage of a waste dip and a creek down stream a distance of 600 m. The oxidation of the sulfide minerals decreases the pH values to 2.4. High contents of ore metals such a Sb up to 1 ppm, are released from the host rock and waste dip. Due to the low pH values Fe^{3+} and Al^{3+} are dissolved in high concentrations. The pH values increase slightly, the Eh, Oxygen, and Mn concentrations increase as Fe concentrations decrease. Water-rock interactions and clay mineral alteration are indicated by a sharp decrease of Sr and Li concentrations.

1 INTRODUCTION

The Emirli antimony mine is one of the two biggest deposit in Turkey with 450,000 metric tons of ore grading up to l0%. Etibank (Turkish State Mining Company) obtained the mine concession for the area in l979 and the mine has been in operation since then. In the area, the antimony ore is mined by driving an adit. Acid drainage waters from this mine cause several problems with regard to the surface water quality around the village of Emirli.

The aim of this paper is to describe the behavior of the selected elements under low pH conditions. In 1994 water samples were taken from the drainage within the adit. at the mouth of the drift, and from the seepage of a waste dip. The chemical evolution was studied by following the run of a creek, originating from the drift. flowing through the waste dip, and downstream 600 meters. Rocks and precipitate samples were collected and analyzed mineralogically and geochemically for comparison.

2 GEOLOGIC SETTING

The investigated area is located at the SE margin of the Kücük Menderes rift zone (Fig. 1) within the Menderes Massif of western Anatolia, Turkey. The geological setting is controlled mainly by NW -SE and NE-SW faults, formed during the development of an E-W rift zone. The antimony mineralization of Emirli is hosted by metamorphic units of Paleozoic age which consit of mica schist, quartz schist and metaquartzite. The hydrothermal alteration of the host rocks can be recognized by a distinct colour change at the surface of the field and is distinguished by phyllic, argillic, and silicic zones.

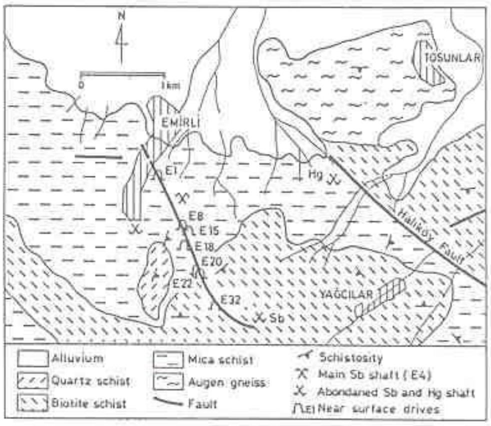

Figure 1. Geological map of the investigated area.

The antimony ore is mainly associated with the NE-SW and NW -SE faults and occurs in veins and veinlets. The ore mineral assemblage consists of stibnite, pyrite, arsenopyrite, sphalerite, chalcopyrite, tetrahedrite, marcasite, cinnabar, orpiment, realger, iron hydroxide, and native gold. The source of ore metals can be attributed to the host rocks, which were leached by water-rock interaction during the hydrothermal circulation of fluids in the system and transported to the surface

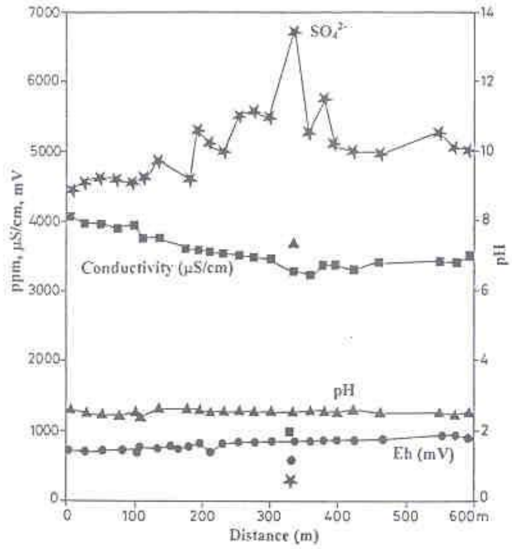

Figure 2. Plot of pH, Eh, SO_4^{2-}, and electrical conductivity versus distance. Groundwater for pH (▲), Eh (● **),** electrical conductivity (■), and SO_4^{2-} (***),**

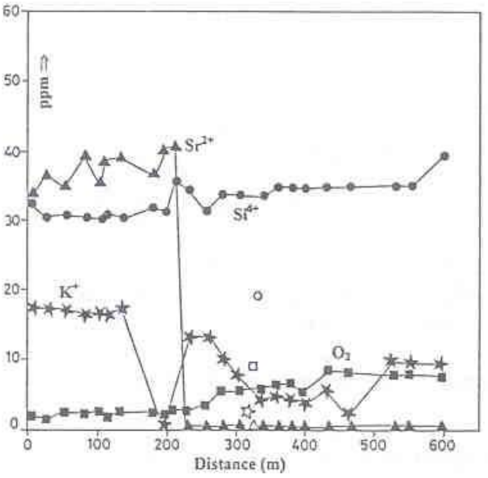

Figure 3. Plot of Sr^{2+} Si^{4+}, O_2, and K^+ versus distance. Groundwater for Sr^{2-} (▲**),** Si^{4+} (●**),** O_2 (■),and K^+ (*).

as bisulfide complexes. The solubility and transport of base and precious metals took place as Cl and HS-(H_2S) complexes (Seward 1973, 1990). Investigations of fluid inclusions in various generations of quartz indicated a homogenization temperature in a range from 100 to 300 °C (Karaoglu 1993). Therefore, the antimony ore deposit of Emirli can be considered as an extinct equivalent of active geothermal systems, which are still present in the region.

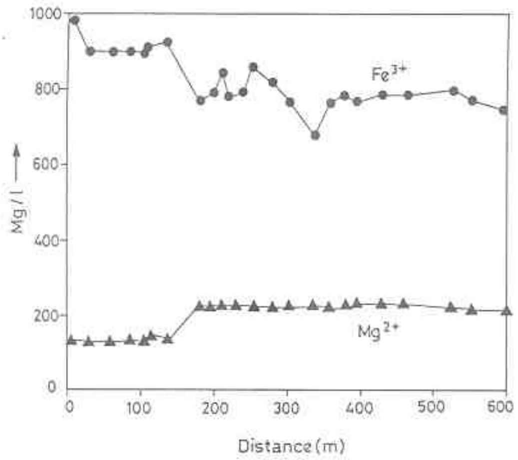

Figure 4. Plot of Fe^{3+} and Mg^{2+} versus distance.

3 PRELIMINARY RESULTS

25 surface water samples were analyzed for anions, cations, and some trace elements, In addition a groundwater sample from the host rock was analyzed.

The oxidation of the sulfide minerals decreases the pH values down to 2.4 (Fig. 2). In a distance of 120 m below the waste dip the pH values begin to increase up to 2.8. In the adjacent groundwater pH values of 7,4 were measured. Due to intake of oxygen, oxygen values increased from 2.0 to 8.5 mg/l (Fig. 3), and the sulfate from 4500 mg/l to 7000 mg/l, producing sulfuric acid (Fig. 2), Very high Eh values from 720 to 920 mV were measured, Clay mineral alteration and ion-exchange is indicated approximately 200m downstream from the dip by changing pH values and concentrations of some elements. An increase in Si values is accompanied by higher Mg and Li concentrations (Fig. 4 and 5) and a sharp decrease in Sr and K concentrations (Fig. 3).

Very high iron concentrations up to 920 mg/1 were measured in the creek whereas in the groundwater iron concentrations were below detection limit (Fig. 4). Under the existing pH/Eh values Fe^{3+} is soluble. At 200 m downstream, where the pH values increase, the Fe^{3+} concentrations decrease, slightly and reach a mean value of 800 mg/l Although ndersaturation was calculated by the SOLMINEQ program (Kharaka et al. 1988), red colored precipitations were observed. It can be

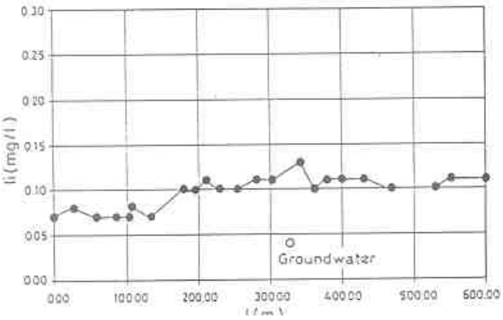

Figure 5. Plot of Li versus distance.

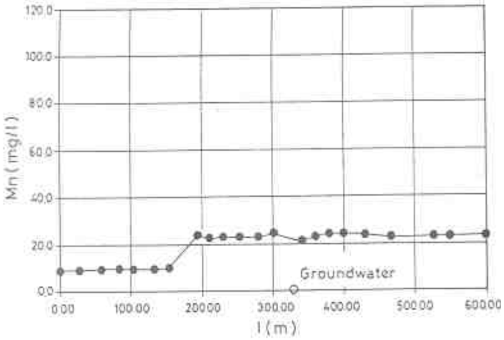

Figure 6. Plot of Mn versus distance.

assumed that either the saturation with respect to iron hydroxides vary during seasons or microbial enhancement of iron precipitation takes place. An increase in Mn concentration can be observed simultaneously with the decrease iron concentrations (Fig. 4 and 6).

A distinct increase in ore metals can be observed in the creek compared with the groundwater sample. In groundwater the concentrations of Cu, Zn, Pb and Cd lie below detection limit. The main ore forming metal, Sb, is about 1ppm and As is 40 ppm. In the-creek- the concentrations increase to 220 ppb Cu, 3000 ppb Zn, 2 ppb Pb, and 400 ppb Cd. Especially Sb (940 ppb) and As (39 ppm) are present in very high concentrations. There is no great change in the concentrations downstream 600m to below waste dip. According to calculations 4 with SOLMINEQ, the water is undersaturated with respect too the main minerals containing the above mentioned elements.

CONCLUSIONS

Due to oxidation of sulfide minerals an extreme pH decrease is observed. There is hardly any pH buffering because of the mineralogy of the host rocks as mica schists and quartzite. pH increases from only 2.4 to 2.8. There are indications that alteration of clay minerals causes this slight increase. High iron and manganese concentrations can be observed. Due to the low pH values, Fe^{3+} and Mn^{4+} stay in solution as well as other ore forming elements, especially Sb and As. Although precipitations in the creek bed could be observed, the water was undersaturated with respect to main mineral phases of the investigated elements. Seasonal changes and microbial effects can be expected. The groundwater contamination was not yet observed.

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