The mining impact on the environment at Segura, Central Portugal

I.M.H.R.Antunes
Polytechnic Institute of Castelo Branco, 6000 Castelo Branco, Portugal
A.M.R.Neiva & M.M.V.G.Silva
Department of Earth Sciences, University of Coimbra, 3000 Coimbra, Portugal

ABSTRACT: At Segura, two-mica granite, muscovite granite and granodiorite veins intruded the schist-metagraywacke complex. Aplite and stanniferous pegmatite veins cut granites and country rock. Subhorizontal Sn-W quartz veins and Ba-Pb-Zn quartz veins intruded the country rock and granites. The abandoned mining area was exploited for Sn, W, Ba and Pb until 1953. In soils and stream sediments, there are anomalies of Sn, W, B, As and Cu related to Sn-W quartz veins, whereas Ba, Pb and Zn anomalies are associated with the Ba-Pb-Zn quartz veins. Soils are contaminated in As, Sn, B and Ba, and should not be used for agriculture and residences. The highest As contamination is associated with Sn-W quartz veins. The soils contaminated in As must not be used for commerce and industry. The spring and stream waters are contaminated in As, Fe and Mn. These waters are not drinkable and they may not be used for agriculture.

1 INTRODUCTION

Mining activities affect relatively small areas, but can have a large local impact on the environment. The activities of mining exploration with mineral extraction and processing, especially metal mining, produces crushed and milled waste, which cause a potential danger to the environment. Sulphide mineralization is notorious for producing acid waters that leach heavy metals after mining exploitations had ceased. High amounts of metals, added to natural environment, in soils, stream sediments and waters are related to the occurrence of polymetallic mineralization in mining areas (Marszalek, 2000). However, the contents of elements in the environment also depend on their mobility and solubility from rocks, stream sediments and waters. The abandoned mining sites are frequently located close to occupied rural areas. Consequently surface waters contaminated by acid mine drainage has the potential to contaminate subsurface water wells and irrigation water supplies (Allen et al., 1996). At Segura, central Portugal, there are Sn-W deposits and Ba-Pb-Zn deposits, which were exploited in the past. The extractions ceased in the 1953 and there has been no significant development work in the area. The aim of this paper is to evaluate the geochemical environment impact of these deposits from Segura in related stream sediments, soils and waters.

2 GEOLOGICAL SETTING

At Segura, central Portugal, Hercynian two-mica granite and muscovite granite and granodiorite porphyry intruded the Cambrian schist-metagraywacke complex (metapelites intercalated with metagraywackes). The granites produced a contact metamorphic aureole up to 500 m thick, with hornefels up to 20 m thick (Fig. 1). NW/SE to WNW/ESE granitic aplite and NE/SW granitic pegmatite veins with lepidolite and cassiterite cut the granites and country rock. Subhorizontal quartz veins with cassiterite and wolframite and ENE/WSW to NNE/SSW quartz veins with barite, galena and sphalerite intersect mainly the schist-metagraywacke complex, but the latter also intruded the muscovite granite. The quartz veins with cassiterite and wolframite contain abundant sulphides such as monoclinic pyrrhotite, arsenopyrite, pyrite, sphalerite and chalcopyrite, and the sulfosalts - matildite and schapbachite (Antunes, 1999). These veins were exploited for Sn and W. Cobaltite, pyrite and chalcopyrite occur in these quartz veins with barite, galena and sphalerite, which also contain anglesite, mimetite and kintoreite due to alteration of galena (Antunes, 1999). These veins were exploited for Ba and Pb.

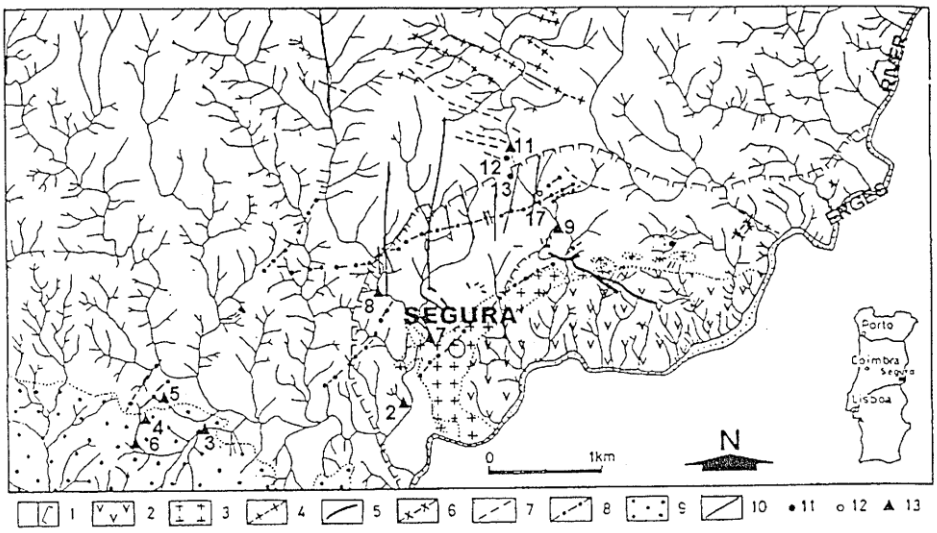

Figure 1. Geological map of Segura, central Portugal. 1. Schist-metagraywacke complex, contact metamorphic aureole; 2. medium- to coarse-grained two-mica granite; 3. medium- to fine-grained muscovite granite; 4. granodiorite porphyry veins; 5. granitic aplite vein; 6. Sn-bearing granitic pegmatite; 7. Sn-W quartz veins; 8. Ba-Pb-Zn quartz veins; 9. arkoses; 10. faults. Location of water samples : 11. springs; 12. wells; 13. streams and small retentions.

3 RESULTS AND DISCUSSION

717 samples of stream sediments on schists and granites were collected from selected locations between 50 m upstream and 100 m downstream the confluence of streams in an area of 190 km^2. They were analyzed for As, B, Cu, Ba, Pb and Zn by DCP-AES, and Sn and W were determined by XRF, all with a precision of 10% (IGM, 1988). Based on that data, 1008 samples of soils derived from schists were collected up to a depth of 30 cm in an area of 3.8 km^2, at north of Segura. They were analyzed with the same analytical techniques used for stream sediments (IGM, 1988).

The area has a dry climate and at summer only a few streams, springs and wells contain water. A total of twelve stations close to the abandoned old mine workings were selected to collect water at the end of the summer (October 1996), at the middle of the raining winter (December 1996), at the middle of raining spring (March 1997) and at the beginning of the dry summer (July 1997) making a total of 48 water samples, which were analyzed. Temperature, pH, Eh and dissolved oxygen were determined in situ.

The waters were acidified and kept at 4°C. Sn, W, B and Ba were analyzed with a spectrometer PU 7000 ICP and As, Cu, Pb and Zn were determined by atomic absorption with a Perkin Elmer 303 and all with a precision of $\pm$ 5%.

The stream sediments close to the mineralized veins have high Sn, W, B, As, Cu, Ba, Pb and Zn contents (Table 1), which are higher in the stream sediments collected on schist than in those collected on granites. Anomalies on Sn, W and B were found in soils related to quartz veins containing cassiterite and wolframite, whereas As and Cu anomalies are related to the same veins, because they also have arsenopyrite and chalcopyrite. The anomalies on Sn and B in stream sediments and soils may also be associated with the stanniferous pegmatite veins. Ba, Pb and Zn anomalies in soils are related to quartz veins with barite, galena and sphalerite. The soils are contaminated in Sn, B, As and Ba and must not be used for agriculture and human residences (Table 1). The contamination in As is the highest and consequently these soils should not be used even for commerce and industry (Table 1).

The highest values of As in waters are from samples 12, 13 and 17 (Fig. 2), which were collected close to Sn-W quartz veins (Fig. 1) and they are related to the As anomalies in soils. There is decrease in As content of water from springs to streams. The richest waters in As also have high Fe and Mn values (Fig. 2; samples 12, 13 and 17). However the highest Fe and Mn contents were found in waters associated with barite, galena, sphalerite quartz veins (Fig. 2; samples 2, 3, 6 and 7). A poor correlation be-

Table 1. Trace element concentrations for stream sediments and soils from Segura compared with recommended maximum concentrations.

	Stream sediments (ppm)		soils (ppm)				
	schists	granites	minimum	maximum	1	2	3
Sn	>20	>12.5	<4	>75	5	50	300
W	>50	>70	<10	>45	-	-	-
B	>175	>60	<55	>300	2	-	-
As	>175	>45	<20	>375	20	30	50
Cu	>60	>50	<40	>100	150	100	500
Ba	>1100	>840	<675	>1500	750	500	2000
Pb	>75	>75	<20	>120	375	500	1000
Zn	>225	>165	<125	>290	600	500	1500
N	671	46		1008			

Recommended maximum values for: 1 - agricultural soil; 2 – human residence soil; 3 – commerce and industry soil (Canadian Council of Ministers of the Environment, 1991). N – number of samples.

tween Fe and As in waters was also found by Nickson et al. (2000).

Ba content in waters is low due to the low solubility of barite at normal pH conditions. The highest Ba content (1.6 mg/l) was found in water samples 4 and 5, which are close to a quartz vein with barite, galena and sphalerite cutting the schist-metagraywacke complex. These two water samples have the lowest pH (5.2), specific conductance, dry residue and contents of most ions. pH of the other analyzed waters ranges between 5.2 and 7. Therefore there is no significant acid drainage in the area. Sn, B, Pb and Cu were not detected in waters (Antunes, 1999).

Waters from spring, well and some streams close to the abandoned mine workings are contaminated in As, Fe and Mn. They are not drinkable and most of them may also not be used for agriculture according to Portuguese Decree n° 236/98, due to high values of As and Mn (Fig. 2). As causes adverse health effects (Williams et al., 1996) because of its high toxicity.

Stream and well waters are more contaminated in summer, while waters from springs are more contaminated in winter (Fig. 2), which is attributed to more reducing conditions in spring waters during winter and causing dissolution of Fe oxyhydroxide and release of its sorbed As (Nickson et al., 2000).

In general, mines associated with sulphide-rich ores have high surface water degradation, but at Segura most of the abandoned mines consist of small quartz veins with some sulphides. Therefore the contamination in heavy metals is relatively low as found in others (Rahn et al., 1996).

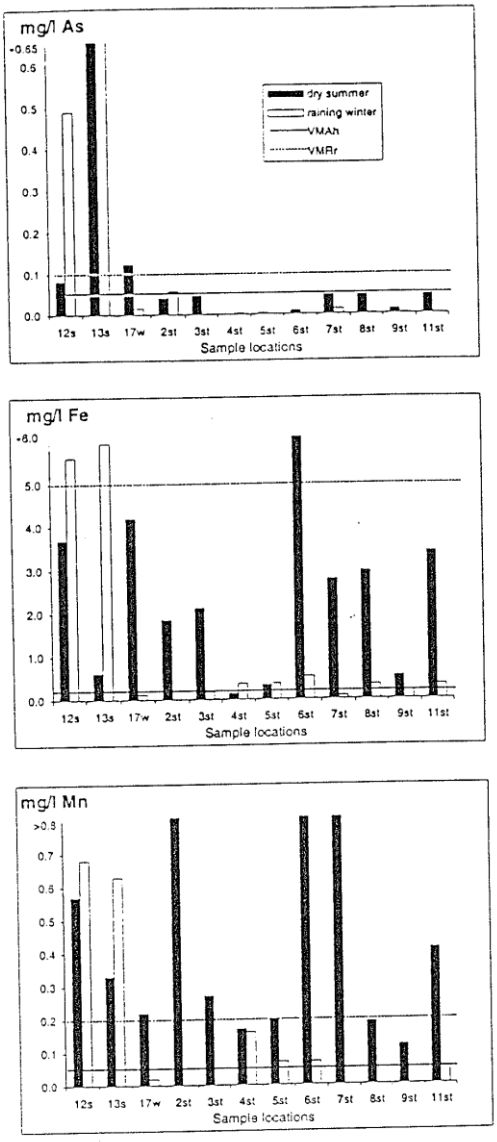

Figure 2. Trace element contents in waters from Segura. s – springs; w – wells; st – streams and small retentions. VMAh – maximum human potable water; VMRr – recommended agriculture value (Portuguese decree n° 236/98).

4 CONCLUSIONS

- In Segura, there are stanniferous pegmatite veins, quartz veins with cassiterite and wolframite and quartz veins with barite, galena and sphalerite.
- The Sn, W, B, As and Cu anomalies in stream sediments and soils are related to the Sn-W mineralizations and old mining activity.
- The Ba, Pb and Zn anomalies in stream sediments and soils are associated with barite, galena and sphalerite mineralizations and the old mining activity.
- Soils may not be used for agriculture or human residences, because they are contaminated in As, Sn, B and Ba.
- Soils contaminated in As may not also be used for commerce and industry.
- Some spring and stream waters are contaminated in As, Fe and Mn. These waters are not drinkable and they may not be used for agriculture.
- The old mine workings on the Sn-W quartz veins produced the highest contamination in As in soil or water.

ACKNOWLEDGEMENTS

We are grateful to Prof. B. J. Wood for the EUGF – Bristol facility contract ERBFMGECT 980128 to use the electron-microprobe at the Department of Earth Sciences, University of Bristol, U.K. and to IGM for the use of data on stream sediments and soils.

REFERENCES

Allen, S.K., Allen, J.M. & Lucas, S. 1996. Concentrations of contaminants in surface water samples collected in west-central Indiana impacted by acidic mine drainage. *Environmental Geology* 27: 34-37.

Antunes, I.M.H.R. 1999. *The impact of abandoned mines on the environment at Segura (Central Portugal).* MSc thesis in Geosciences. Department of Earth Sciences, University of Coimbra, Portugal, 162 pp.

Canadian Council of Ministers of the Environment 1991. *Interim Canadian environmental quality criteria for contaminated sites.* CCME EPC – CS34: 1-20, Manitoba.

Decree nº 236/98. *Portuguese Legislation on water quality.* I-A: 980-1024, Portugal.

IGM – Geological and Mining Institute 1988 – *Reports from a Prospecting project for tungsten, tin and associated minerals from Góis-Segura.* Metalic Mineral Prospecting Section. Oporto. Portugal, 10 pp.

Marszalek, H. & Wasik, M. 2000. Influence of arsenic-bearing gold deposits on water quality in Zloty Stok mining area (SW Poland). *Environmental Geology* 39: 888-892.

Nickson, R.T., McArthur, J.M., Ravenscroft, P., Burgess, W.G. & Ahmed, K.M. (2000). Mechanism of arsenic release to groundwater, Bangladesh and West Bengal. *Applied Geochemistry* 15: 403-413.

Rahn, P.H., Davis, A.D., Webb, C.J. & Nichols, A.D. 1996. Water quality impacts from mining in the Black Hills, South Dakota, USA. *Environmental Geology* 27: 38-53.

Williams, M., Fordyce, F., Paijitprapapon, A. & Charoenchaisri, P. 1996. Arsenic contamination in surface drainage and groundwater in part of the southeast Asian tin belt, Nakhon Si Thammarat Province, southern Thailand. *Environmental Geology* 27: 16-33.