Impact of mineral springs on soil chemistry and mineralogy: field evidence from the Massif Central (France)

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The fractured bedrock in the Cezallier region of the Massif Central (France) gives rise to numerous mineral springs containing carbo-gaseous and trace-element-rich water (Fouillac, 1983). Arriving at the surface, these waters precipitate oxyhydroxides and calcite (Bodenan *et al.*, 1998). The impact of this precipitation on the soil chemistry and mineralogy were studied at three neighbouring springs lying about 100 m apart along a toposequence, the highest being spring 1.

Material and methods

The spring waters were sampled throughout the year and analysed for major and trace elements.

Soil and sediment profiles were sampled along transepts. Major- and trace-element analysis and mineral determination by X-ray diffraction spectroscopy was realised for all the samples.

A principal component analysis was applied to the soil/sediment chemistry and mineralogy in order to discriminate spring impact on soil quality from the bedrock influence.

Water-mineral equilibria were modelled using EQ3NR (Wolery, 1992) software.

Water composition and thermodynamic equilibrium

Concentrations in Ca, Mg, K, Si and Fe decreased from spring 1 to 3.

For calcite and aragonite, the water samples from springs 1 and 2 were in equilibrium, while those from spring 3 were oversaturated.

For iron oxyhydroxides, the water samples from spring 1 were oversaturated, those from spring 2 were in equilibrium, while those from spring 3 showed no systematic saturation.

Soils and sediments

The soils and sediments in the vicinity of the three springs all showed subsurface enrichment in Fe and Ca, which decreased a) with increasing distance from each spring, and b) from spring 1 to 3.

The principal component analysis showed that around 70% of the variance was explained by the 2 first factors. This enabled three element groups to be identified (Fig. 1).

Group 1, representing bedrock influence: mainly Al, Si, Ti, Zr, kaolinite, quartz and most of the trace elements;

Group 2, opposite Group 1 and representing spring impact: mainly Ca, Sr, calcite and aragonite;

Group 3: mainly Fe, P, As and organic carbon. The elements in this group were not closely linked as in the other groups, but correlative tendencies were observed.

The identified factors enabled the soil and sediment samples to be divided into families.

1. Samples associated with spring 3 were mainly influenced by elements from Group 1 (bedrock).
2. Half of the samples associated with spring 1 were characterized by elements from Group 2 (spring), the other half being influenced by elements from Group 1 (bedrock).
3. Samples associated with spring 2 were intermediate between groups 1 and 2.

As concentrations (Group 3) in the soils and sediments decreased from spring 1 to spring 3.

Discussion

Ca and Fe concentrations in the water decrease from spring 1 to 3, inducing a decrease in soil impact as evidenced by the chemical and mineralogical data. These springs probably derive from a same reservoir (as evidenced by unpublished isotopic data). Iron is lost first, due to the precipitation of oxyhydroxides from spring 1; the thermodynamic calculations showing this water to be oversaturated with respect to Fe oxyhydroxides are in agreement with field observations. Ca is lost from springs 2 and 3 and carbonates are formed; little Fe oxyhydroxide precipitation occurs. The impact of spring 3 on the soil is slight due to its lower concentrations in Ca and

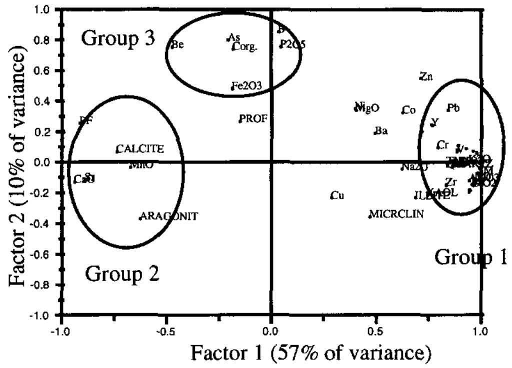

FIG. 1. Factor analysis of chemical and mineralogical data for the soil samples at the studied springs.

Fe, and possibly also to agricultural use of this soil diluting the spring signature. In all cases, spring influence does not extend beyond several meters, indicating a short distance mobility of elements in this environment.

Conclusion

The three springs induce soil differentiation. Their impact on the soil is clear for major elements and can also be observed for minor elements such as As. In all cases this impact is only over a short distance from the springs. In addition, spring impact decreases from spring 1 to 3 with decreasing element concentrations in the water.

References

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