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Weathering of sandstones studied from the composition of stream sediments of the Kupa River (Croatia)

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ABSTRACT

Elemental compositions of the <2 mm fraction of three sediments sampled along the Kupa River are presented. On plots of $\log(SiO_2/Al_2O_3)$ *vs*. $\log(CaO+Na_2O)/K_2O$, the sediments plot closest to average sandstone compositions. On plots of weathering indices A *vs*. B (Kronberg and Nesbitt, 1981) the sediments plot close to basalt, terrestrial crust and granite. X-ray diffraction of the <63 μm fraction suggests chlorite, vermiculite and mica are present as weathering products in the upper, middle and lower stream sediments. Depletion of some elements in the sediments suggests loss of elements from the sediments due to dissolution of minerals.

KEYWORDS: weathering, sandstones, stream sediments, moderate climate, Kupa River, Croatia.

Introduction

THERE is extensive literature concerning rock weathering and its influence on the regulation of the 'greenhouse effect' and global climate (Kump *et al.*, 2000; Roy *et al.*, 1999; Gaillardet *et al.*, 1999; Frančišković-Bilinski *et al.*, 2003). Chemical weathering is one of the processes controlling landscape development of catchments (Johnsson, 1993; Critelli *et al.*, 1997; Le Pera and Sorriso-Valvo, 2000). It also has implications for provenance studies (Nesbitt *et al.*, 1996) and the loss of elements from sediments and soils (Dalai *et al.*, 2002).

The present paper is part of a larger investigation into landscape development within the Kupa River catchment. It focuses on weathering studied via small-river geochemistry. The Kupa River catchment predominantly drains sandstone, under moderate climate conditions. Stream sediments were sampled from the upper, middle and lower course of the river. We suggest that sandstone weathering, determined from chemical analysis of stream sediments, will follow the theoretical path of rock and soil weathering described by Kronberg and Nesbitt (1981). Also, it is assumed that the loss of some elements during weathering of sandstones can be confirmed from sediment analysis.

Study area

Samples were taken at locations 204, 209 and 207, the upper, middle and lower reaches of the Kupa River, Croatia (Fig. 1). Details of the hydrology and geology of the catchment have been reported elsewhere (Frančišković-Bilinski, 2007). The Kupa River originates in the Risnjak National Park (Croatia). At Osilnica (Slovenia), the river has a confluence with Čabranka River, which mostly flows through sandstones. In its upper reaches, the Kupa River flows through dolomites, middle and upper Triassic limestones and clastites and Malm limestones, dolomites, breccias and flysch. In its middle reaches it flows through lower Pliocene unbounded clastites and limestones and then Holocene sediments. In its lower reaches it flows through Holocene sediments, lower Pliocene unbounded clastites and upper Pliocene gravels and clays until its inflow to Sava River at Sisak.

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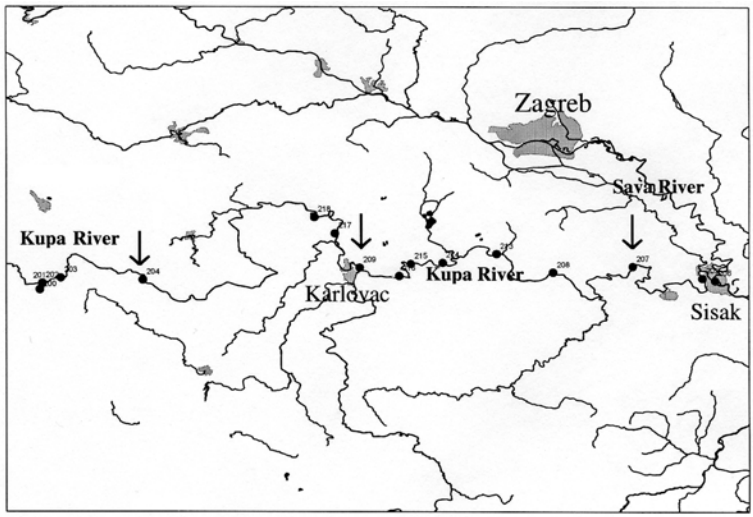

FIG. 1. Study area of Kupa River with selected sampling locations pointed by arrows: 204 (N 45.47208, E 15.08508); 209 (N 45.50001, E 15.57669) and 207 (N 45.50300, E 16.2000).

Materials and methods

Stream sediments were collected during April 2007, air dried, sieved to <2 mm and ground using a mortar grinder Pulverisette 2 (Fritsch, Germany). Major elements were determined by ICP-OES and trace elements by ICP-MS by ACTLABS, Canada. The mineral composition of the <63 μm fraction was determined using a Philips X-Pert MPD X-ray diffractometer. Crystalline phases were identified using Powder diffraction file (1997).

Results and discussion

The composition of the <2 mm fraction is presented in Table 1. Compared to average compositions the composition of the sediments suggests that they are the weathering products of sandstones (Fig. 2). The data in Table 1 were used to calculate weathering indices after Kronberg and Nesbitt (1981) using the following equations:

$$\text{Index A} = (SiO_2 + CaO + K_2O + Na_2O)/(Al_2O_3 + SiO_2 + CaO + K_2O + Na_2O)$$

$$\text{Index B} = (CaO + K_2O + Na_2O)/(Al_2O_3 + CaO + K_2O + Na_2O)$$

Samples plot close to the locations of basalt, terrestrial crust and granite (Fig. 3). The average temperature at the sampling sites does not vary significantly, while average rainfall decreases in a downstream direction. According to the classification of Jessey (2008) this places the Kupa River at the boundary of 'moderate chemical with frost action' and 'moderate chemical' classes.

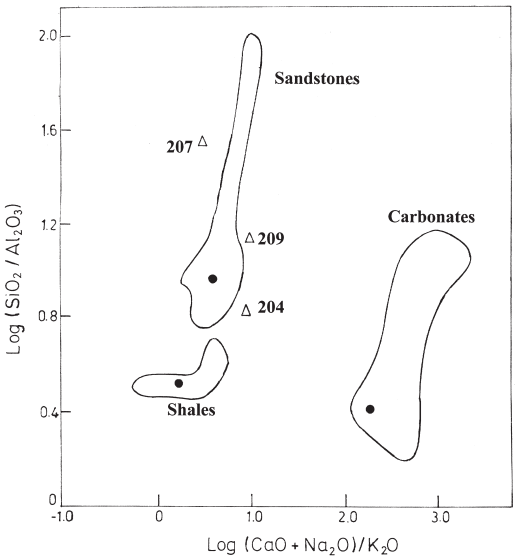

FIG. 2. Composition of the studied stream sediments (<2 mm fraction) compared with those of sandstones, shales and carbonates. The average values of each rock type are represented by a dot. Modified from Prohić (1998).

TABLE 1. Geochemical characterization of selected stream sediments (<2 mm fraction) and the detection limit of each component. Values for oxides are in % and for elements in ppm (mg/kg). Weathering indices (A, B) and meteorological data are included.

Component	204	209	207	Detection limit
SiO_2	75.68	80.90	80.90	0.010
Al_2O_3	6.64	5.64	2.30	0.010
Fe_2O_3	3.53	2.78	1.09	0.010
MgO	4.84	1.88	0.22	0.010
CaO	8.81	8.74	1.62	0.010
Na_2O	0.69	0.98	0.44	0.010
K_2O	1.03	0.86	0.65	0.010
TiO_2	0.41	0.45	0.09	0.001
P_2O_5	0.09	0.15	0.05	0.010
MnO	0.03	0.03	0.04	0.001
Sc	8.00	8.00	2.00	1.000
V	52.00	48.00	15.00	5.000
Cr	30.00	80.00	<20	20.000
As	13.00	7.00	6.00	5.000
Rb	41.00	34.00	21.00	2.000
Sr	67.00	62.00	27.00	2.000
Y	15.00	17.00	6.00	2.000
Zr	168.00	203.00	43.00	4.000
Sb	9.90	6.80	3.50	0.500
Th	4.50	4.20	1.90	0.100
Ba	233.00	230.00	136.00	3.000
U	1.80	1.50	0.60	0.100
Pb	7.00	17.00	<5	5.000
Index A	0.928	0.940	0.973	
Index B	0.613	0.644	0.541	
Av. temp. (ºC)	10.3	10.9	10.9	
Average annual rainfall (cm)	124.5	109.0	88.3	

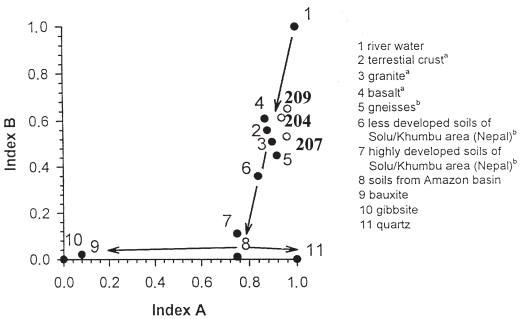

FIG. 3. Theoretical paths of rock and soil weathering based on indices A and B of Kronberg and Nesbitt (1981). [a] Data from Wedepohl (1969); [b] Data from Bäumler *et al*. (1991). Data from this work are represented by open circles.

Quartz, calcite, dolomite, albite and muscovite were detected in the <63 μm fraction of the three sediment samples. Traces of chlorite, vermiculite and mica were found in samples 204, 209 and 207, respectively.

The concentrations of Al_2O_3, Fe_2O_3, MgO, K_2O, V, As, Sb, Rb and U decreased significantly downstream and are thought to have been lost from the sediments by dissolution of some minerals.

Conclusions

Comparing the Kupa River stream sediment geochemistry with average rock compositions suggests that the sediments were the weathering products of sandstone. On a plot of Kronberg and Nesbitt (1981) weathering indices the sediments plot close to basalt, terrestrial crust and granite. The local climatic conditions fall on the boundary of Jessey's (2008) 'moderate chemical with frost action' and 'moderate chemical' classes. Quartz, calcite, dolomite, albite and muscovite were detected in the <63 μm fraction of all the sediments. Traces of chlorite, vermiculite and of mica in the <63 μm fraction of the sediment sampled from the upper, middle and lower reaches of the river respectively are thought to be weathering products of the sandstone. Decreased concentrations of several elements downstream suggest dissolution of some minerals from the sediments.

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