Variability of the chemical index of alteration (CIA) in the Paraná River suspended load

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Much of the chemical variation resulting from weathering may be expressed in the system Al_2O_3-(CaO^*-Na_2O)-K_2O, where CaO^* represents the calcium in the silicate fraction only. Nesbitt and Young (1982) have derived a Chemical Index of Alteration (CIA) in molecular proportions: CIA = 100 [Al_2O_3/(Al_2O_3+CaO^*+Na_2O+K_2O)].

The average upper crust has a CIA value of about 47 (Mc Lennan, 1993); CIA values of 45–55 indicate no weathering in essence. Kaolinite, chlorite, gibbsite, and bohemite have CIA values of 100, whereas smectite and illite have values in the 70–80 range. Primary minerals have much lower CIA values (Nesbitt and Young, 1997). It follows that the proportions of clay minerals and primary minerals in a bulk sample will introduce substantial variation in the resulting CIA value.

In this paper we report on the CIA variability in the Paraná River total suspended sediments (TSS). The procedure suggested by McLennan (1993) was followed to correct for calcite, dolomite, and apatite.

The Paraná River has a drainage basin of 2.8 × 10^6 km^2. Annually, it delivers ca. 500 km^3 (15700 m^3 s^{-1}) of water to the SW Atlantic Ocean via the Río de la Plata. The upper Paraná supplies over 70% of its annual runoff. Its flow regime is clearly influenced by the ENSO events which, when occurring, substantially alters its flow characteristics (Depetris *et al.*, 1996).

The upper Paraná drainage basin is mostly covered with sedimentary rocks (Jurassic-Cretaceous), flood basalts of the same age, and rocks from the crystalline basement (Precambrian). The upper Paraguay drainage basin (Mato Grosso) partially includes the Brazilian shield; marine sedimentary rocks as well as intrusive and volcanic (basic) rocks are common. The Bermejo and Pilcomayo rivers, Andean tributaries of the Paraguay, drain areas with varied sedimentary and metamorphic rocks, as well as Quaternary sediments.

Due to steep, sparsely vegetated slopes in continental and marine formations, the Bermejo river, with less than 5% of the Paraná total drainage area, supplies almost 50% of the Paraná River sediment export rate of *c.* 80 × 10^6 t y^{-1} (28.6 t $km^{-2}y^{-1}$).

Depth-integrated TSS samples were collected during 1971-1973 in the Paraná drainage basin within the framework of the UNDP-Argentine Government ARG. 31 Project. A set of those samples was recently analysed by standard analytical methodology for major components at the Centre de Géochimie de la Surface (CNRS/ULP), Strasbourg (France).

Figure 1 shows the CIA variability at the Paraná-Santa Fe cross-section, about 600 km upstream from the Paraná mouth, and in major tributaries. A three-fold variation in discharge (8600–26300 m^3s^{-1}) triggered a relatively small variation in CIA (65.5–77.4). Correlation between discharge and CIA in the Paraná main stem is not significant, with wider CIA variability during low discharges than at high flow. As expected, high-relief tributaries, with high sediment yield, show lower CIA values (Table 1), and broader variability (Fig. 1) than the Paraná.

TABLE 1. TSS yield and CIA values in high-relief tributaries

River	TSS yield ($t.km^{-2}$ y^{-1})	CIA ± s.d.
Bermejo	2660	57.4 ± 18.9
Pilcomayo	1267	65.6 ± 4.2
Pescado	2765	62.8
S. Francisco	612	52.5 ± 16.4

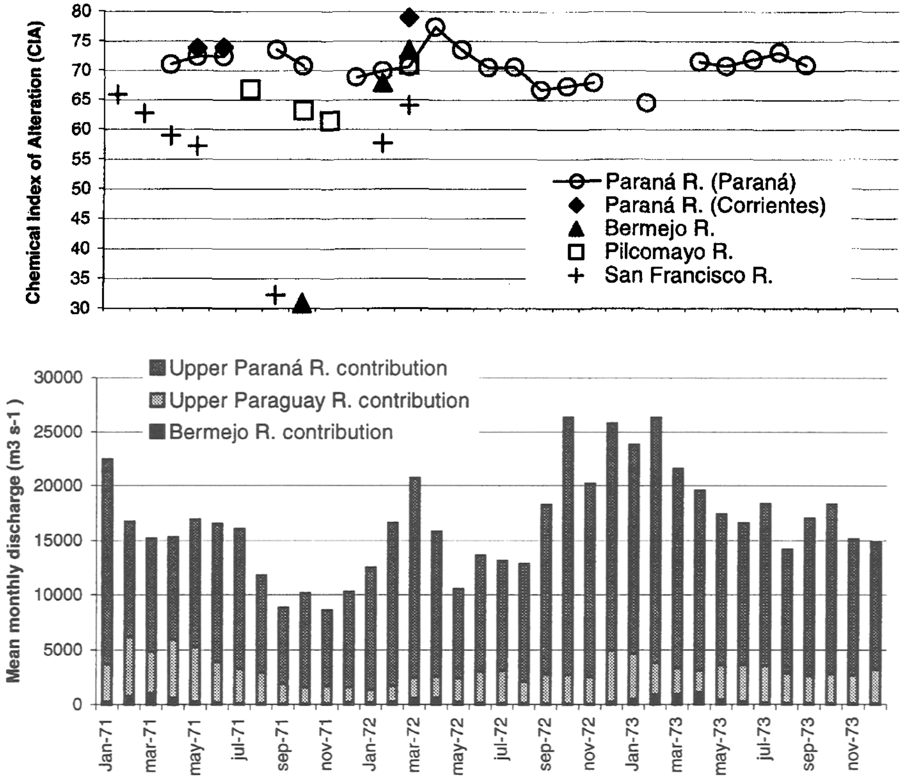

FIG. 1. Paraná River discharge at Paraná (600 km upstream from mouth) split into the contributions of major tributaries (lower); CIA variation at the same cross-section and CIA values of major eroding tributaries.

TSS grain-size distribution probably accounts for the marked difference observed between the tributaries and the Paraná (Fig. 1). High CIA values in the Paraná River are correlated ($r = 0.74$, $p<0.01$) with high quartz relative contents (as determined by x-ray diffraction). Finally, it has been possible to calculate a discharge-weighted mean CIA value of 70.9 for the Paraná River. This mean value is considerably lower than the value of 81, previously estimated by McLennan (1993) as representative of the Paraná.

References

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