Chemical weathering in the Krishna Basin and Western Ghats of the Deccan Traps, India: Rates of basalt weathering and their controls

A. Das, S. Krishnaswami, M. M. Sarin, and K. Pande

1Planetary and Geosciences Division, Physical Research Laboratory, Ahmedabad 380 009 India
2Department of Earth Sciences, Indian Institute of Technology (IIT) Bombay 400 076 India

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Abstract—Rates of chemical and silicate weathering of the Deccan Trap basalts, India, have been determined through major ion measurements in the headwaters of the Krishna and the Bhima rivers, their tributaries, and the west flowing streams of the Western Ghats, all of which flow almost entirely through the Deccan basalts. Samples (n = 63) for this study were collected from 23 rivers during two consecutive monsoon seasons of 2001 and 2002. The Total dissolved solid (TDS) in the samples range from 27 to 640 mg l⁻¹. The rivers draining the Western Ghats that flow through patches of cation deficient lateritic soils have lower TDS (average: 74 mg l⁻¹), whereas the Bhima (except at origin) and its tributaries that seem to receive Na, Cl, and SO₄ from saline soils and anthropogenic inputs have values in excess of 170 mg l⁻¹. Many of the rivers sampled are supersaturated with respect to calcite. The chemical weathering rates (CWR) of “selected” basins, which exclude rivers supersaturated in calcite and which have high CI and SO₄, are in range of ~3 to ~60 t km⁻² y⁻¹. This yields an area-weighted average CWR of ~16 t km⁻² y⁻¹ for the Deccan Traps. This is a factor of ~2 lower than that reported for the Narmand-Tapti-Wainganga (NTW) systems draining the more northern regions of the Deccan. The difference can be because of (i) natural variations in CWR among the different basins of the Deccan, (ii) “selection” of river basin for CWR calculation in this study, and (iii) possible contribution of major ions from sources, in addition to basalts, to rivers of the northern Deccan Traps.

Silicate weathering rates (SWR) in the selected basins calculated using dissolved Mg as an index varies between ~3 to ~60 t km⁻² y⁻¹, nearly identical to their CWR. The Ca/Mg and Na/Mg in these rivers, after correcting for rain input, are quite similar to those in average basalts of the region, suggesting near congruent release of Ca, Mg, and Na from basalts to rivers. Comparison of calculated and measured silicate-Ca in these rivers indicates that at most ~30% of Ca can be of nonsilicate origin, a likely source being carbonates in basalts and sediments.

The chemical and silicate weathering rates of the west flowing rivers of the Deccan are ~4 times higher than the east flowing rivers. This difference is due to the correspondingly higher rainfall and runoff in the western region and thus reemphasises the dominant role of runoff in regulating weathering rates. The silicon weathering rate (SWR) in the Krishna Basin is ~15 t km⁻² y⁻¹, within a factor of ~2 to those in the Yamuna, Bhagirathi, and Alaknanda basins of the Himalaya, suggesting that under favourable conditions (intense physical weathering, high runoff) granites and the other silicates in the Himalaya weather at rates similar to those of Deccan basalts. The CO₂ consumption rate for the Deccan is deduced to be ~3.6 x 10⁻³ moles km⁻² y⁻¹ based on the SWR. The rate, though, is two to three times lower than reported for the NTW rivers system; it still reinforces the earlier findings that, in general, basalts weather more rapidly than other silicates and that they significantly influence the atmospheric CO₂ budget on long-term scales.

1. INTRODUCTION

Rivers carry the imprints of erosion on the continents in the form of dissolved and particulate materials. Most of the solutes in rivers are derived from chemical weathering of minerals contained in the rocks of the drainage basin. The proportion of various elements in the dissolved phase is a complex function of their relative abundances in minerals and of the mode and rate of their weathering. Chemical weathering of rocks involves consumption of CO₂, a greenhouse gas that exerts strong influence on climate (Berner et al., 1983; Kump et al., 2000; Amiotte-Suchet et al., 2003; Dessert et al., 2003). Several parameters regulate the rate and intensity of chemical weathering and associated CO₂ consumption. These include lithology of the drainage basin, runoff, temperature, vegetation, and relief. In terms of lithology, recent works on basaltic provinces suggest that they weather more rapidly relative to granites and gneisses and that their weathering exerts important control on marine geochemical balances and global change (Meybeck, 1986; Bluth and Kump, 1994; Amiotte-Suchet and Probst, 1995; Louvat and Allegre, 1997; Dessert et al., 2001; Amiotte-Suchet et al., 2003; Dessert et al., 2003).

Deccan Traps (India) is one of the basaltic provinces studied (Dessert et al., 2001) for determining rates of weathering of basalts and the primary factors that control them. The work presented in this paper is also on the chemical weathering of Deccan basalts, carried out as a part of ongoing investigations on weathering of major lithological basins of India, based on chemical composition of rivers. These studies have been motivated by our quest to determine the role of major land forms in India such as the Himalaya and the Deccan Traps in contributing to dissolved fluxes of elements to oceans and to CO₂ drawdown from the atmosphere (Sarin et al., 1989; Sarin et al., 1992; Krishnaswami et al., 1999; Dalai et al., 2002). More