Silicate and carbonate weathering in the drainage basins of the Ganga-Ghaghara-Indus head waters: Contributions to major ion and Sr isotope geochemistry

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The role of silicate and carbonate weathering in contributing to the major cation and Sr isotope geochemistry of the headwaters of the Ganga-Ghaghara-Indus system is investigated from the available data. The contributions from silicate weathering are determined from the composition of granites/gneisses, soil profiles developed from them and from the chemistry of rivers flowing predominantly through silicate terrains. The chemistry of Precambrian carbonate outcrops of the Lesser Himalaya provided the data base to assess the supply from carbonate weathering. Mass balance calculations indicate that on an average ~ 77% (Na + K) and ~ 17% (Ca + Mg) in these rivers is of silicate origin. The silicate Sr component in these waters average ~40% and in most cases it exceeds the carbonate Sr. The observations that (i) the $^{87}\text{Sr}/^{86}\text{Sr}$ and Sr/Ca in the granites/gneisses bracket the values measured in the head waters; (ii) there is a strong positive correlation between $^{87}\text{Sr}/^{86}\text{Sr}$ of the rivers and the silicate derived cations in them, suggest that silicate weathering is a major source for the highly radiogenic Sr isotope composition of these source waters. The generally low $^{87}\text{Sr}/^{86}\text{Sr}$ ($\leq 0.720$) and Sr/Ca ($\sim 0.2 \text{ nM/}\mu\text{M}$) in the Precambrian carbonate outcrops rules them out as a major source of Sr and $^{87}\text{Sr}/^{86}\text{Sr}$ in the headwaters on a basin-wide scale, however, the high $^{87}\text{Sr}/^{86}\text{Sr}$ ($\sim 0.85$) in a few of these carbonates suggests that they can be important for particular streams. The analysis of $^{87}\text{Sr}/^{86}\text{Sr}$ and Ca/Sr data of the source waters show that they diverge from a low $^{87}\text{Sr}/^{86}\text{Sr}$ and low Ca/Sr end member. The high Ca/Sr of the Precambrian carbonates precludes them from being this end member, other possible candidates being Tethyan carbonates and Sr rich evaporite phases such as gypsum and celestite. The results of this study should find application in estimating the present-day silicate and carbonate weathering rates in the Himalaya and associated CO$_2$ consumption rates and their global significance.

1. Introduction

It is well recognised that the high $^{87}\text{Sr}/^{86}\text{Sr}$ and Sr concentration of rivers draining the Himalaya, particularly the Ganga-Brahmaputra (G-B) have significantly influenced the Sr isotope evolution of the oceans since the Cenozoic (Palmer and Elderfield 1985; Palmer and Edmond 1989; Richter et al 1992; Krishnaswami et al 1992). The source(s) contributing to the high $^{87}\text{Sr}/^{86}\text{Sr}$ of these rivers remains controversial, though many recent studies have addressed this topic as it has relevance to atmospheric CO$_2$ budget and global change (Edmond 1992; Krishnaswami et al 1992; Palmer and Edmond 1992; Derry and France-Lanord 1996; France-Lanord and Derry 1997; McCauley and DePaolo 1997; Quade et al 1997; Harris et al 1998; Blum et al 1998). The high $^{87}\text{Sr}/^{86}\text{Sr}$ of silicates (granites, gneisses and metasediments) in the drainage basins of these rivers have led to the suggestion (Edmond 1992; Krishnaswami et al 1992; Harris 1995) that they exert dominant control over the $^{87}\text{Sr}/^{86}\text{Sr}$ of rivers flowing through them. Palmer and Edmond (1992) based on the observation that the major ion chemistry of the G-B rivers is mainly regulated by

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