Chemical Geology 443 (2016) 54–66

Contents lists available at ScienceDirect

Chemical Geology

journal homepage: www.elsevier.com/locate/chemgeo

Chemical weathering rates and atmospheric/soil CO_2 consumption of igneous and metamorphic rocks under tropical climate in southeastern Brazil

Alexandre Martins Fernandes [a], Fabiano Tomazini da Conceição [b,*], Eder Paulo Spatti Junior [b], Diego de Souza Sardinha [c], Jeferson Mortatti [d]

[a] UNESP - Universidade Estadual Paulista, Faculdade de Engenharia de Bauru, Brazil
[b] UNESP - Universidade Estadual Paulista, Instituto de Geociências e Ciências Exatas, Brazil
[c] UNIFAL – Universidade Federal de Alfenas, Instituto de Ciência e Tecnologia, Brazil
[d] USP – Universidade São Paulo, Centro de Energia Nuclear na Agricultura, Brazil

ARTICLE INFO

Article history:
Received 24 May 2016
Received in revised form 5 August 2016
Accepted 7 September 2016
Available online 9 September 2016

Keywords:
Ribeira Belt
Chemical weathering
Anthropogenic and atmospheric influence
Water-rock interactions

ABSTRACT

Chemical weathering rates and atmosphere/soil CO_2 consumption of igneous and metamorphic rocks under tropical climate in southeastern Brazil were evaluated using the chemical composition of surface waters and fresh rocks and soil (horizon C) in the Upper Sorocaba River basin. Surface water samples were collected between June/2009 and June/2010, and analyses were performed to assess pH, electrical conductivity (EC), temperature and total dissolved solids (TDS), including Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, PO_4^{3-}, NO_3^- and SiO_2. Fresh rocks and C horizon samples were also collected, taking into account their geological context, abundance and spatial density, to analyze major elements and mineralogy. The concentration of TDS and dissolved cations, anions and silica increased during the dry period in relation to the wet period, and the same behavior was observed for pH, EC and temperature. After corrections of anthropogenic contributions (ca. 21 t/km^2/yr) and atmospheric inputs (ca. 19 t/km^2/yr), the annual flux due to chemical weathering involving the igneous and metamorphic rocks was ca. 29 t/km^2/yr. The CO_2 atmospheric/soil consumption in the Upper Sorocaba River basin was ca. 0.2×10^6 mol/km$^{2/}$yr, and when extrapolated to the entire Mantiqueira Orogenic Belt, accounted an estimated consumption of 0.07×10^{12} mol/yr, representing 0.6% of the total CO_2 consumption flux derived from global average silicate weathering. The chemical weathering rates of igneous and metamorphic rocks in the Upper Sorocaba River basin were estimated at 15 m/My, respectively. The main weathering process in this watershed was the monossialitization, with partial hydrolyses of bedrock minerals, except quartz, which was not weathered and remained in the soil profile. The annual specific flux derived from igneous and metamorphic rocks at Upper Sorocaba River basin could be compared with watersheds in tropical climates. However, this value is higher than in other North American, European, Asian and African granitoid watersheds, and lower than in montane watersheds.

1. Introduction

The determination of the chemical weathering and physical erosion is of interest to geoscientists, as this phenomenon provides the parameters needed for better soil exploration, in order to assist establishing agricultural fields and human settlements. Besides, the balance between these phenomena contributes to the geomorphological modeling of the Earth's surface. Chemical weathering of fresh rocks is the main mechanism of CO_2 consumption from the atmosphere and, consequently, has the basic function of moderating the Earth's climate. The physical erosion is related to soil loss, acts on the weathered surface by removing the cover and carrying the particulate matter. In both processes, the dissolved and particulate materials are transported through rivers to the oceans, resulting in the deposition of Ca and Mg carbonates (and smaller amounts of Fe and Mn) and sediments, respectively.

The chemical weathering can be evaluated from the silica mass balance or from models using the dissolved sodium, calcium, potassium, magnesium and silica and total dissolved load concentrations, where inputs from rainfall require corrections (Amiotte-Suchet and Probst, 1993; Bain et al., 2001; Boeglin and Probst, 1998; Boeglin et al., 1997; Clow and Drever, 1996; Dessert et al., 2001; Dessert et al., 2003; Dupré et al., 2003; Edet et al., 2013; Gaillardet et al., 1997; Gaillardet

* Corresponding author at: 1 – Avenida 24-A, n° 1515, C. P. 178, CEP 13506-900, Bela Vista, Rio Claro, São Paulo, Brazil.
E-mail address: ftomazini@rc.unesp.br (F.T. Conceição).

http://dx.doi.org/10.1016/j.chemgeo.2016.09.008
0009-2541/

et al., 1999; Gao et al., 2009; Gibbs, 1967; Grasby and Hutcheon, 2000; Gurumurthy et al., 2012; Johnson et al., 1968; Kattan et al., 1987; Land et al., 1999; Laraque et al., 2013; Li and Zhang, 2008; Li et al., 2014; Liu et al., 2016; Louvat, 1997; Louvat and Allègre, 1997, 1998; Louvat et al., 2008; Millot et al., 2002; Nkounkou and Probst, 1987; Oliva et al., 2003; Pacheco and Van der Weijden, 2002; Peray, 1998; Probst, 1986; Probst et al., 1994; Semhi et al., 2000; Stallard and Edmond, 1981, 1983, 1987; Tardy, 1968, 1969, 1971; Van der Weijden and Pacheco, 2006; Wang et al., 2016; White and Blum, 1995; Wu et al., 2013; Xu and Liu, 2010; Zakharova et al., 2007; Zhang et al., 2016).

The Earth's upper continental crust is constituted of ca. 25% for granitoid rocks, with their chemical weathering controlled mainly for temperature and runoff (Oliva et al., 2003). The Brazilian Southeast region is marked by the presence of Mantiqueira and Tocantins orogenic systems, where outcrops igneous and metamorphic rocks, and part of the São Francisco Craton (Fig. 1a). Due to their areal extent and the strong susceptibility to chemical weathering of these rocks under tropical climate, these areas play an important role in the global consumption of CO_2. Surprisingly, no chemical weathering rates have been proposed for igneous and metamorphic rocks under tropical climate in these orogenic systems located in South America. Only few studies have focused on the chemical weathering rates of silicate rocks under different climates in Brazil, i.e. (a) equatorial climate: silicate rocks (igneous, metamorphic and sedimentary) in the giant Amazon River basin (Mortatti and Probst, 2003); (b) tropical climate: high grade metamorphic rocks of granulite facies in Bahia State (Moreira-Nordemann, 1980), Poços de Caldas alkaline rocks in Minas Gerais State (Bonotto et al., 2007) and sedimentary (mainly sandstones and mudstones - Conceição and Bonotto, 2003, 2004) and basalts (Conceição et al., 2015) rocks from Paraná Sedimentary basin in São Paulo State; (c) semi-arid climate: metamorphic (gneiss, amphibolite and quartzite) in Bahia State (Moreira-Nordemann, 1984).

A study involving a mass-balance in a large basin would allow to estimate the dissolved material flux of the Mantiqueira and Tocantins Orogenic Belts, characterizing and quantifying the respective chemical weathering rates and atmospheric/soil CO_2 consumed during the water-rock/soil interaction process. However, this research would be very complex because of the different types of rocks, climate, soil

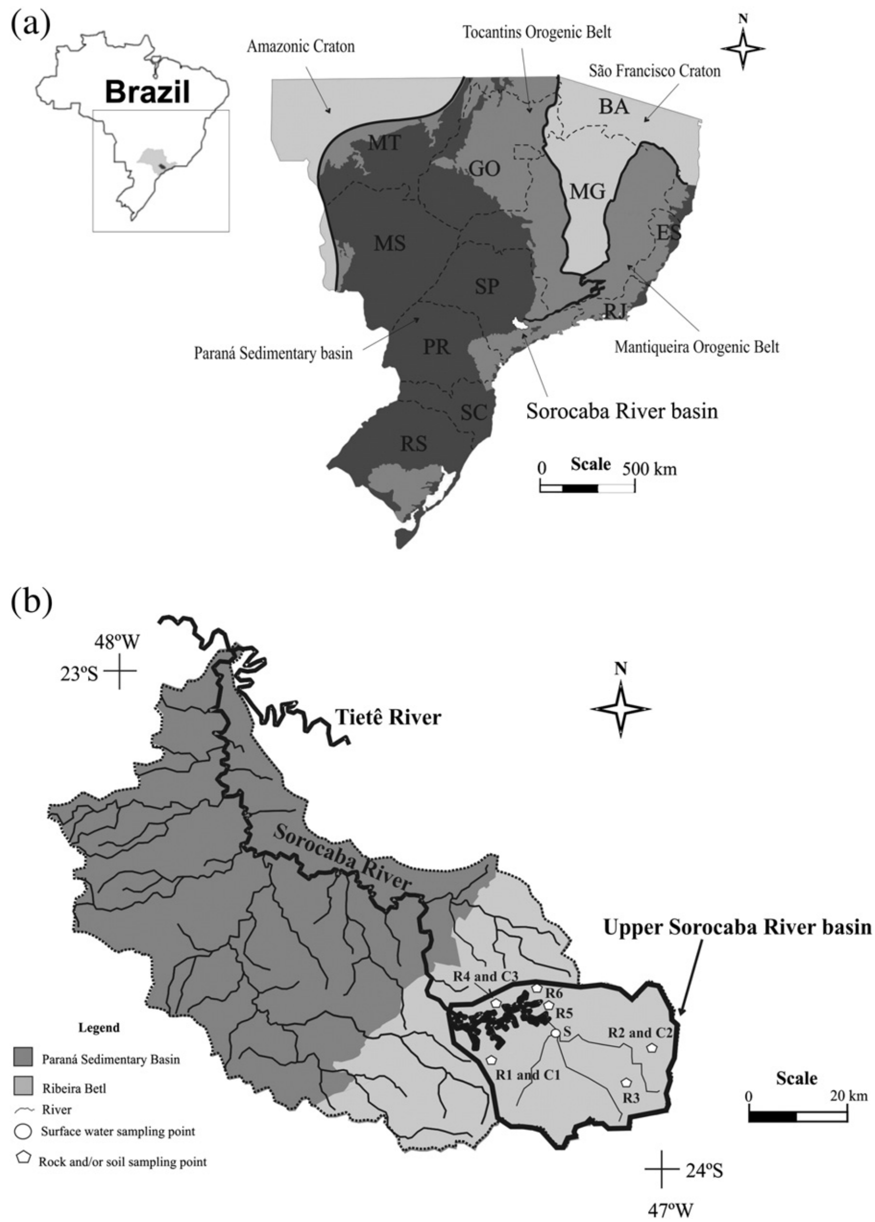

Fig. 1. Map of eastern South America showing the main geological units relative to the Cratons, Orogenic Belts and Paraná Sedimentary Basin (a) (Modified from Hasui, 2010). The upper Sorocaba River basin with location of the sampling points (b). R1, R2, R3, R4, R5 and R6 = fresh rocks; C1, C2 and C3 = soil (horizon C); S = surface water.