Preliminary chemical and isotopic characterization of cold and hot-spring waters from Nepal

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Metamorphic degassing from active collisional orogens supplies a significant fraction of CO_2 to the atmosphere, thus playing a fundamental role even in today's Earth carbon cycle. Appealing clues for a contemporary metamorphic CO_2 production are represented by the widespread occurrence, along the whole Himalayan belt, of CO_2 rich hot-springs mainly localized along the major tectonic discontinuities such as the Main Central Thrust (Becker et al., 2008; Evans et al., 2008; Perrier et al., 2009), and by the recent discovery of gaseous CO_2 ground discharges which may be variably associated with the hot-springs (Perrier et al., 2009; Girault et al., 2014). Recent geochemical and isotopic studies suggest that CO_2 is released at mid-crustal depth by metamorphic reactions within the Indian basement, transported along pre-existing faults by meteoric hot water circulation, and degassed before reaching surface. Thus, further studies should be undertaken to better constrain the carbon budget of the Himalaya, and, more generally, the contribution of collisional orogens to the global carbon balance.

In order to test the occurrence of CO_2 gas discharges not associated to hot-springs, a systematic chemical and isotopic characterization of cold-springs located along major tectonic discontinuities is needed; the isotopic signature of stable isotopes of carbon, hydrogen and oxygen is, in fact, useful to identify the water source and to individuate possible mixing phenomena.

Few chemical and almost no isotopic data are actually available for cold-springs of the Nepal Himalaya, especially regarding those located at high-altitude and in remote areas. In the framework of the Ev-K_2-CNR SHARE (Stations at High Altitude for Research on the Environment) Project, we have therefore started a preliminary chemical and isotopic study on high-altitude cold-springs located at different structural levels in the eastern Nepal Himalaya. The preliminary chemical and isotopic data obtained from these high-altitude cold-springs are compared with those obtained from well-known hot-springs located along or close to the Main Central Thrust.

Twelve cold-springs have been sampled from the Khimti Khola, Likhu Khola, Dudhkhund Khola and Irkhuwa Khola catchments. The Khimti, Likhu, Dudhkhund and Irkhuwa rivers cross the main tectonostratigraphic units of eastern Nepal Himalaya, flowing across the Greater Himalayan Sequence (GHS) and the Lesser Himalayan Sequence (LHS) and crossing the Main Central Thrust Zone (MCTZ). Four of the investigated cold-springs are located in the MCTZ, and eight are located in the upper GHS domain (GHS-U) (Fig. 1a). As concerning the hot-springs, seven samples have been collected from the well-known localities of Tatopani-Kodari, Tatopani and Ratopani in the Kaligandaki valley (Fig. 1b), Tatopani in the Myagdi valley, Syabru Bensi and Trisuli in the Langtang Himal. All these hot-springs are located within the MCTZ except for Tatopani and Ratopani in the Kaligandaki valley and Tatopani in the Myagdi valley, which are located in the LHS, immediately below the MCTZ.

The analyzed cold-springs are characterized by low discharge temperature varying between 3°C and 23°C. They are characterized by a very low salinity (TDS<150 mg/L, except for one sample, in which TDS <500 mg/L) and a correspondent very low conductivity (<200 μS/cm). The pH varies between 6.5 and 7.3 and the samples are Ca–Mg–HCO_3^- in composition (Fig. 1c) (see also: Evans et al. 2001, Becker et al. 2008).

The analysed hot-springs show different compositions, ranging from Na–Cl to Na–Ca–Cl types, are typically characterized by high amounts of total dissolved solids (TDS up to 4700 mg/L), vary in

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temperature between 40 to 60 °C and have a pH in the range 6.8–7.7 (see also Evans et al., 2004; Becker et al. 2008, Perrier et al., 2009). Interestingly, the chemical composition of the hot-springs associated with gaseous CO_2 discharges from the ground (Syabru Bensi and Trisuli, sample 4A and 4B) is partially overlapped with that of some cold-springs (Fig. 1c).

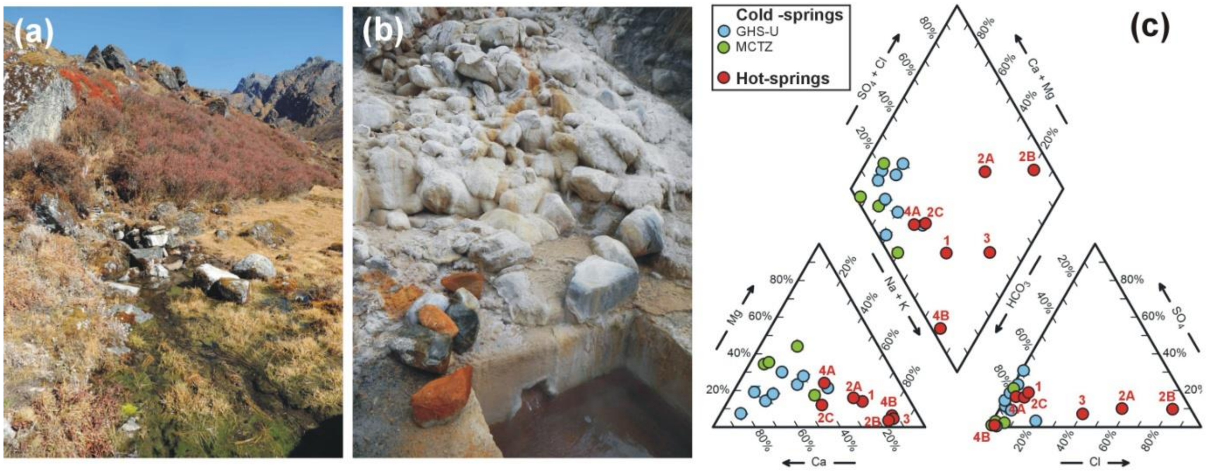

Figure 1. (a) Example of a high-altitude cold-spring in the Likhu Khola valley of eastern Nepal. (b) Example of a hot-spring with associated travertine deposits in the Kaligandaki valley (sample 2B). (c) Piper Diagram of the investigated water samples, showing the Ca-Mg–HCO_3^- composition of the cold-springs and the variable compositions of the hot-springs, from Na–Cl to Na–Ca–Cl types.

The very low total dissolved solids (TDS) of most of the analysed cold-springs hampered the possibility of analyzing their carbon isotopic composition; only for one sample the TDS was high enough to precipitate significant carbon for the isotopic measurement of the Dissolved Inorganic Carbon (DIC). The measured $\delta^{13}C_{(DIC)}$ value of this cold-spring water is strongly negative (-22 ‰) and contrasts with the moderate negative to significantly enriched $\delta^{13}C_{(DIC)}$ values measured for the hot-spring waters (-18‰ to +5‰). The more enriched $\delta^{13}C_{(DIC)}$ values have been measured for the hot-springs associated with gaseous CO_2 discharges from the ground (Syabru Bensi and Trisuli, sample 4A and 4B).

The hydrogen and oxygen isotopic values of both cold- and hot-springs are typical of meteoric waters and show a very good correlation with the Global Meteoric Water Line (GMWL) of precipitation (IAEA 1970, 2005), lying directly upon or very near the GMWL. The close correlation suggests that the contribution of metamorphic H_2O is negligible (e.g. Becker et al., 2008).

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