Geothermal systems in the Northwest Himalaya

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Conventional energy resources are fast depleting and therefore alternative resources are required to sustain the fast progress and development of any nation. This situation is more pertinent to India where fast growing population and developmental activities are posing major challenges to the government as the country has limited resources of energy. Therefore, focused research should be intensified to explore the potential of geothermal energy resources in India. Realizing its importance, Wadia Institute of Himalayan Geology, Dehradun, has started a major research programme to study geothermal systems of the Himalaya covering Uttarakhand, Himachal Pradesh and Leh-Ladakh regions of India.

Keywords: Carbon dioxide flux, geothermal provinces, heat pump functional unit, thermal springs.

THERE are numerous geothermal provinces throughout India, which are linked to the passive continental margin and tectonics-induced active subduction. Geothermal provinces in India, characterized by high heat flow (78–468 MW/m^2) and thermal gradients (47–100°C/km) have about 400 thermal springs with a considerable discharge. Some of these in the Northwest Himalaya are the potential fields where geothermal energy can be tapped. These include the Puga and Chumathang geothermal springs in Jammu and Kashmir; Manikaran and Tattapani in Himachal Pradesh, and Tapoban in Uttarakhand region. There are several localities in the Himalaya, where hot water bubbles up. These sites could be utilized for geothermal energy and space heating applications. The Wadia Institute of Himalayan Geology (WIHG), Dehradun, has recently initiated a research programme on geothermal energy from hot springs of the Northwest Himalaya. As a part of the academic research activities of the institute, a detailed study of thermal springs was carried out. In view of the societal importance, a geothermal energy demonstration project was undertaken for feasibility studies at Chumathang, situated on the banks of the Indus River (Figure 1).

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The first geothermal heat pump functional unit in India

This is an Indo-Norwegian collaboration project with participation from Iceland, Norwegian Geotechnical Institute, Norway and WIHG. The project was facilitated by the Department of Science and Technology, New Delhi, which is implemented at Chumathang, Ladakh.

We have designed and built the heating system, where a small heat exchanger transfers heat between the hot springs and a radiator heating system as a pilot project. The hot spring utilized for the preliminary project is already in use for pumping hot water up to the restaurant at Chumathang, Ladakh. The excess water from the spring is diverted away through pipes to a nearby washing place. This system is working successfully to heat the restaurant with six rooms round the clock with solar power back-up for the heat pump. One more system which is based on ground-sourced heat pump is being established at the WIHG premises as a part of technology demonstration, which has been designed to operate for heating as well as cooling, both depending on the ambient temperature. It takes advantage of ground temperature maintained at ~22°C, which is higher for winter and lower for summer. First demonstration will be set up at WIHG before it is established in different parts of the Northwest Himalaya.

Degassing of CO_2 flux to atmosphere

As a part of the research programme on geothermal systems of the Himalaya, geochemical and isotopic composition ($\delta^{13}C_{DIC}$, $\delta^{18}O_{H_2O}$ and δD_{H_2O}) of thermal spring waters from Garhwal, Himachal and Ladakh were determined (S. Tiwari, unpublished Ph D thesis). This has enabled to retrieve valuable information about the origin of geothermal fluids and degassing of metamorphic CO_2 emanating through these springs.

The atmospheric CO_2 has presumably moderated the Earth's climate since the formation of water on the Earth's surface. It creates a small reservoir and its size is controlled by the difference between the large fluxes involved in the carbon cycle at geological timescales. Nevertheless, the significance and interdependence of the various geological controls on the CO_2 fluxes to the

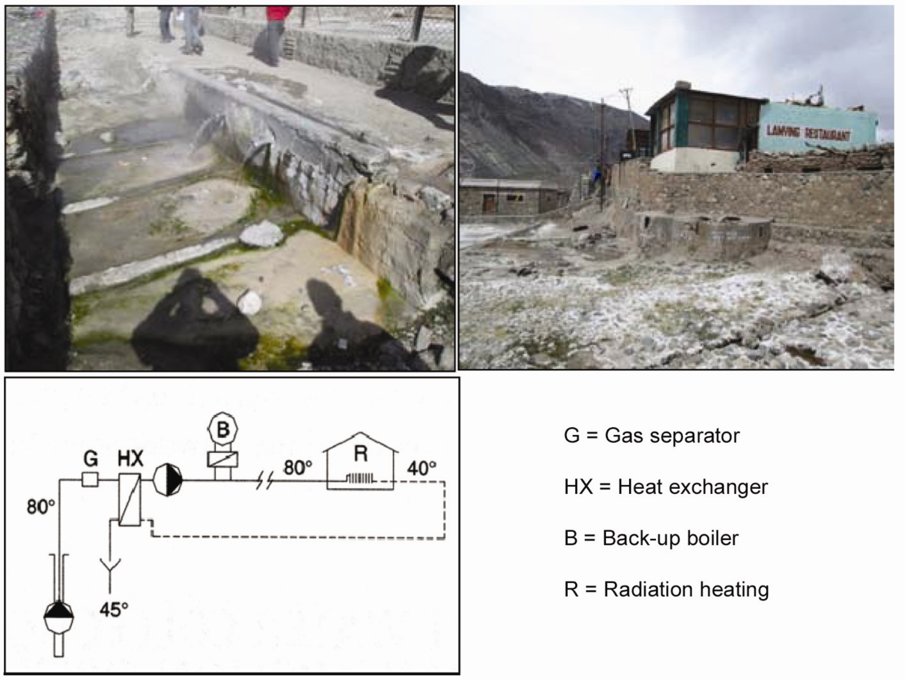

Figure 1. The first geothermal sourced heat pump functional unit in India at Chumathang, Jammu and Kashmir.

Figure 2. Field photograph of Tapoban geothermal spring of the Garhwal region with steam jet and volatiles seen coming out near the vent.

atmosphere are uncertain. The key factor controlling the concentration of atmospheric CO_2 is closely linked with the inorganic carbon cycle, where it is consumed by weathering of Ca and Mg silicates on the Earth's surface followed by deposition as calcium carbonate in the ocean. Further, it is balanced by CO_2 returned to the atmosphere by volcanoes and by de-carbonation and metamorphic processes in the orogenic belts.

The CO_2 flux involved in the inorganic carbon cycle ($\sim 10^{19}$ mole/million years) is large compared to the amount of CO_2 in the atmosphere and the ocean ($\sim 3.2 \times 10^{18}$ mol), for which it must be balanced by the fluxes due to weathering and degassing for an equilibrium concentration of CO_2 in the atmosphere[1,3]. Further, the variations in global weathering rates, operating over a million-year timescale could be supported by a corresponding variation in the supply of CO_2 to the atmosphere. However, the relative significance of various mechanisms of CO_2 outgassing is not fully understood on a global scale. These studies include mantle degassing at oceanic ridges and plume-related volcanoes, decarbonation of subducted slabs with the release of CO_2 through arc volcanoes and metamorphic belts (Figure 2). Some of these have surface manifestations in the form of thermal springs.

Our results with $\delta^{13}C_{DIC}$ in thermal springs from the Indian Himalaya provide evidence for CO_2 degassing along the major thrust zones. Carbon isotope measurements in dissolved inorganic carbon ($\delta^{13}C_{DIC}$) in the geothermal waters show a wide range of variation from –8.5‰ to +4.0‰$_{VPDB}$. The enriched $\delta^{13}C_{DIC}$ compositions are indicative of a process of degassing of volatiles from the region, which has been illustrated with suitable model. This model suggests that when degassing takes place, carbon isotopes fractionate and the degassed CO_2 becomes lighter leaving the remnant water enriched in $\delta^{13}C_{DIC}$. Such enriched $\delta^{13}C_{DIC}$ values have been found from several hot springs of the northwest Himalaya, which indicate their deeper/magmatic origin. These results are similar and consistent with observations from the central Nepal Himalaya[2]. One of the interesting results from this study suggests that the thermal spring having the highest enriched $\delta^{13}C$ (Tapoban) also has

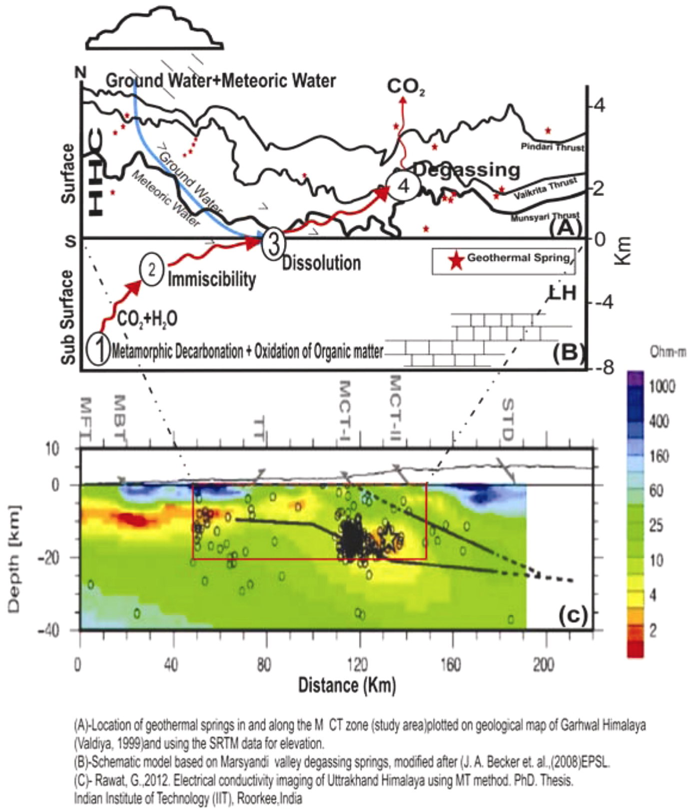

Figure 3. Schematic model for the process of metamorphic CO_2 degassing through geothermal springs of Garhwal region. This shows that meteoric water is the main source of these springs (modified after Evans[2]; S. Tiwari, unpublished).

elevated surface temperatures. Therefore, δ^{13}C values of thermal springs may be used as a proxy to depict their origin in terms of meteoric versus magmatic source.

The thermal springs of Garhwal, Himachal and Ladakh regions, Northwest Himalaya have been extensively sampled and analysed for their major ions and carbon stable isotope composition. These measurements have led to the following observations and conclusion

1. Degassing of metamorphic CO_2 from the Himalayan region (Figure 3) is one of the important contributors to the global carbon budget in the atmosphere.
2. Isotopic compositions of dissolved inorganic carbon ($\delta^{13}C_{DIC}$) in the thermal spring waters of Garhwal, Himachal and Ladakh regions show a wide range of variation from –8.4‰ to +4.1‰. Such highly enriched values of $\delta^{13}C_{DIC}$ are indicative of metamorphic de-carbonation reaction for contributing CO_2 to the fluids.
3. The metamorphic CO_2 flux from 40 thermal springs from the Northwest Himalaya is estimated to be ~2×10^8 mol/year.
4. CO_2 flux from the Northwest Himalaya is higher by two orders of magnitude compared to the Tibetan plateau.
5. Combining all the studies in the Himalayan region (NW Himalaya, Nepal Himalaya and Southern Tibet region), a total CO_2 degassing flux of ~2×10^{10} mol/year could be assigned. This suggests that Himalayan metamorphism acts as one of the contributors of CO_2 into the atmosphere on longer timescale.

Dissolved silica-based thermometry was used in these thermal springs to estimate reservoir temperature. Geothermal springs show average reservoir temperature of 135 ± 15°C in the Garhwal region. Results indicate that high reservoir temperatures exist at Tapoban, Manikaran, Chumathang, Puga and Panamik geothermal fields, which have good potential to generate geothermal energy in significant quantities. Therefore, these areas could be promising for low-cost energy resource in future. Realizing the importance of this issue, WIHG plans to expand its activities towards establishing a Centre on geothermal system research.

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