He-CO_2-N_2 systematics of the Tengchong Geothermal Province, SW China: Degassing along a plate boundary

DAVID R. HILTON[1*], ZHENGFU GUO[2], PETER H. BARRY[1], M. ZHANG[2], Z. CHENG[2]

[1]Scripps Institution of Oceanography, La Jolla, California, USA 92093-0244, drhilton@ucsd.edu (* presenting author).
[2] Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences (CAS), 100029, Beijing, China.

The Tengchong Geothermal Province (TGP) is located on the northeast edge of the Indian-Eurasian plate collision zone, immediately east of the region of low-angle subduction of the Indian plate beneath the Burma microplate. It lies within the Gaoligong fold belt of the Tibetan-Yunnan fold system, between Myitkyina and the Nujiang suture. The TGP is characterized by recent volcanism, geothermal activity, and frequent earthquakes. Seismic evidence suggests that (a) faults in the region extend to the lower crust, with the Tengchong fault penetrating the Moho, and (b) melt in the region is generated in the upper mantle [1]. We aim to determine the volatile systematics of this shear zone by sampling thermal waters and geothermal gases along the Tengchong fault zone and in the nearby Kunming Province. Through analysis of He, C, and N (relative abundances and isotopic compositions) we consider the distribution of magmatic inputs to the volatile inventory, spatial controls on the degassing fluxes, and provenance characteristics of the volatiles.

We report new results from 16 geothermal gas and thermal water locations: 12 along a N-S transect within the Tengchong Block and 4 on the Eurasian plate in the Dali and Kunming areas. In the Tengchong Block, He isotope ($^3He/^4He$) ratios vary between 0.2 and 5 R_A (where R_A is the $^3He/^4He$ value of air), indicating a mixture between mantle (8 ± 1 R_A) and crustal (0.1–0.01 R_A) sources. Carbon isotope ($\delta^{13}C$) values of CO_2 range from -12.2 to -2.8 ‰ (vs. VPDB). $CO_2/^3He$ ratios range from 1.2×10^9 to 5.4×10^{12} with the majority of values falling between 10-100 times greater than the MORB value ($\sim2\times10^9$). Nitrogen isotope ($\delta^{15}N$) values of N_2 range from -2.1 to +5.8 ‰ (vs. air), but the majority are > 0 ‰, consistent with a crustal source. In contrast, Eurasian plate samples are dominated by radiogenic helium and $^3He/^4He$ does not exceed 0.6 R_A. In addition, $\delta^{15}N$ varies from +0.7 to +8.2 ‰, $CO_2/^3He$ ranges from 8×10^8 to 5.4×10^{12}, and $\delta^{13}C$ values range from +0.52 to -14.5 ‰.

The contrast in $^3He/^4He$ ratios between Tengchong and the Eurasian plate indicates that regional mantle degassing is narrowly focused on the Tengchong shear zone. Based on a ternary mixing model, CO_2 provenance is highly variable within the Tengchong Block, with contributions from mantle-derived CO_2, and crustal limestone and organic matter. Most samples have less than 10% mantle contribution, but mantle CO_2 exceeds 60% at two localities. The results are consistent with magma in the crust being derived from the upper mantle - in agreement with seismic evidence - we find no evidence for the presence of a slab-influenced mantle wedge. Thus, deep faulting in the Tibetan-Yunnan fold system must sustain sufficiently high crustal permeability to allow mantle volatiles to degas via the TGP. The results add to a growing body of evidence that strike-slip plate boundaries (e.g., San Andreas Fault and the North Anatolian Fault) represent important pathways for mantle volatile loss although, to date, their relative contributions to the total degassing budget remains unknown.

[1] Wang, C-Y. and Huangfu, G. (2004) *Tectonophysics* **380**, 69-87.

Climatic and geomorphic controls on the erosion of carbon from mountain forest: Implications for Earth's thermostat

ROBERT. G. HILTON[1*], ALBERT GALY[2], NIELS HOVIUS[2], SHUH-JI KAO[3], MING-JAME HORNG[4], HONGEY CHEN[5]

[1]Department of Geography, Durham University, Durham, UK, r.g.hilton@durham.ac.uk (* presenting author)
[2]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK, albert00@esc.cam.ac.uk, nhovius@esc.cam.ac.uk
[3]Research Centre for Environmental Changes, Academia Sinica, Taipei, Taiwan, sjkao@gate.sinica.edu.tw
[4]Water Resources Agency, Ministry of Economic Affairs, Taipei, Taiwan, mjhorng@gmail.com
[5]Department of Geoscience, National Taiwan University, Taipei, Taiwan, hchen@ntu.edu.tw

Erosion of particulate organic carbon (POC) occurs at very high rates in mountain river catchments, yet the proportion derived recently from atmospheric CO_2 in the terrestrial biosphere ($POC_{biomass}$) remains poorly constrained. In these settings, export of $POC_{biomass}$ with large amounts of clastic sediment can drive geological CO_2 sequestration [1]. However, erosion can also mobilise fossil POC from bedrocks (POC_{fossil}) and this needs to be quantified. Here we examine the fluvial transport of $POC_{biomass}$ in suspended sediments of mountain rivers in Taiwan and assess the extent to which climatic and tectonic boundary conditions drive carbon transfer from atmosphere to lithosphere.

In 11 major river catchments in Taiwan, we have previously corrected for POC_{fossil} input using N/C, $\delta^{13}C$ and $\Delta^{14}C$ [2]. Here, $POC_{biomass}$ measurements are combined with water discharge (Q_w, m^3 s^{-1}) and suspended sediment concentration (mg L^{-1}) over 2 years, with samples from flows between 0.1 and 20 times the long-term mean Q_w. In these catchments, $POC_{biomass}$ concentration (mg L^{-1}) was positively correlated with Q_w, with enhanced loads at high flow attributed to rainfall driven supply of $POC_{biomass}$ from forested hillslopes. This climatic control on $POC_{biomass}$ transport was moderated by catchment geomorphology: the gradient of a linear relation of $POC_{biomass}$ concentration and Q_w increased as the proportion of steep hillslopes (> 35°) in the catchment increased. The data suggest enhanced supply of $POC_{biomass}$ by erosion processes which act most efficiently on the steepest sections of forest.

Across Taiwan, $POC_{biomass}$ yield was correlated with suspended sediment yield, and did not limit at high physical erosion rates. Our data demonstrate that, for a constant set of geomorphic conditions, the fluvial transfer of $POC_{biomass}$ from mountain catchments is driven by climate through the activation of erosion and transport processes during heavy rainfall. A move to a wetter, stormier climate should enhance the erosional export of $POC_{biomass}$. In settings with strong coupling between depositional sinks and terrestrial inputs this offers a feedback in the Earth System, whereby climate can modify rates of CO_2 sequestration through erosion and burial of $POC_{biomass}$ [1,3].

[1] Galy *et al.* (2007) *Nature* **450,** 407-410. [2] Hilton *et al.* (2010) *Geochimica et Cosmochimica Acta* **74**, 3164-3181. [3] Hilton *et al.* (2008) *Nature Geoscience* **1**, 759-762.