The CO_2-He isotope and relative abundance systematics of the Central American arc

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We report CO_2 and He isotope and relative abundance data from the Central American magmatic arc. We sampled high-T fumaroles, geothermal wells, boiling mud pots, hot springs and phenocryst-bearing lavas. We collected ~140 fluid and ~30 lava samples covering a total of 41 volcanic centers in Costa Rica (7), Nicaragua (8), El Salvador (10), Honduras (9) and Guatemala (7). The same localities were also sampled for gas chemistry and N-isotopes.

Helium isotope ratios ($^3He/^4He$) reach a maximum of $8R_A$ (where R_A = air $^3He/^4He$) with most values > 5 R_A. Low $^3He/^4He$ values (< $1R_A$), indicating additions of crustal radiogenic He, are found at a small number of localities. Nowhere do we observe values > $8R_A$, indicative of 'high-^{3}He' hotspot contributions. $CO_2/^3He$ ratios vary between 10^9 and 10^{13} covering the entire span seen in the terrestrial environment (hotspots, arc, MORB). However, gas-poor samples and/or samples showing radiogenic He values have outlier $CO_2/^3He$ ratios (< 5 x 10^9 and > 10^{12}). The majority of samples have ratios between 10^{10} and 10^{11} – as at other arcs. The $\delta^{13}C$ of the CO_2 for the majority of samples fall between –5 and –1 ‰ (PDB) consistent with a major slab input to the carbon inventory: however, lower values (~-12 ‰) point to degassing and/or crustal contamination effects.

The entire database has been assessed to identify samples uncontaminated by localised crustal processes (>80% of total), thereby defining the He and C systematics of Central America. Along strike variations (Costa Rica to Guatemala) are used to understand the influence of subduction zone forcing functions (e.g. angle of slab dip, thickness of arc crust) on the He-C systematics. In particular, we explore the effect of forcing function on the volatile output flux from the arc. Across strike variations (mainly from Honduras) are used to assess the extent of slab involvement in petrogenesis as a function of increasing depth to slab. Thus, we use our unique and extensive Central America database to focus on deciphering major controls on both along and across strike variations in arc volatile systematics.

Central America Arc volatiles: Along- and across- arc variations

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Volatile release from the subducting slab into the mantle wedge plays a central role in initiating melting at subduction zones. A fundamental goal of this study is to investigate how efficiently nitrogen and CO_2 are transferred from the slab through the wedge to the surface in the Central America subduction zone.

We collected a total of ~140 gas samples at fumaroles, hot-springs and mud-pots covering 32 volcanic centers in the arc (Costa Rica: 7, Nicaragua: 8, El Salvador: 10, Guatemala: 7) and 9 centers in the back-arc (Honduras). The same localities were sampled simultaneously for CO_2-He isotope systematics. The dry (water free) composition of gas samples is dominated by CO_2 (up to 965 mmol/mol). Samples contain from < 1 to ~ 100 mmol/mol N_2. We see systematic variations along the volcanic front: Costa Rica and S-Nicaragua have low N_2/He (<150), N_2/Ar (<80) and negative $\delta^{15}N$ (- 0.5‰ to –3.0 ‰), similar to MORB (-5 ± 3‰ [1]). N-Nicaragua, El Salvador and Guatemala generally have N_2/He > 1000, N_2/Ar > 80 and positive $\delta^{15}N$ up to 6.3‰, similar to $\delta^{15}N$ measured in seafloor sediments (5.7‰ [2]). The back-arc has consistently low N_2/Ar (< 80) and $\delta^{15}N$ ranging from –0.6 to – 3.5‰. The $\delta^{15}N$ of olivines and fumarole gas discharges from the same volcanic centers are indistinguishable within error, suggesting that both media (phenocrysts and gases) sample magmatic volatiles. CO_2/N_2 varies systematically along the arc: Costa Rica gases have the highest values (up to ~1200 mol/mol); all localities to the north of Costa Rica have low values (< 200); back-arc samples have high values (up to ~2000). CO_2/N_2 (org. + oxidized C) input is estimated at ~ 320 based on ODP legs off Costa Rica [2]. CO_2/N_2 and N isotope systematics suggest that sedimentary nitrogen is off-scraped (or released in the fore-arc) in Costa Rica but not in the rest of the arc. CO_2 continues to devolatilize from the slab in the back-arc, wheras nitrogen is efficiently released below the volcanic front.

References

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