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Magmatic evolution and reconstruction of the Central American land-bridge since Late Cretaceous

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We document by major- and trace elements, selected $^{40}Ar/^{39}Ar$ dating, $^{143}Nd/^{144}Nd$, $^{87}Sr/^{86}Sr$, $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, and $^{208}Pb/^{204}Pb$ as well as $\delta^{18}O$ isotopes on 310 samples from the Cordillera de Panama and the Peninsulas of Sona and Azuero the magmatic evolution and oceanic plate interactions over the last 100 Ma in western Panama.

A first phase of magmatism formed the oceanic basement of the Caribbean Large Igneous Plateau (CLIP). These Basalts were erupted from 95 to 69 Ma (Hoernle et al. 2004). Flat trace element patterns are - apart from some alteration effects - characteristic for the intraplate Galapagos plume (head-) source. Younger accreted terranes with enriched patterns were amalgamated between 70 and 20 Ma (CLIP-OIB). Nd and Pb isotopes from these CLIP-OIBs also argue for an origin from the Galapagos hot spot (Hoernle et al. 2002).

The second major phase partly overlaps the first phase in time. Their arc trace element patterns (depletion in Nb and Ta plus enrichment of the fluid mobile elements such as Ba, K, Pb, and Sr) indicate the initiation of subduction at 71 to 69 Ma (CLIP-ARC) in the region of Azuero and Sona Peninsulas. The EARLY-ARC comprises two major pulses from 68-60 Ma (Chagres Igneous Complex) and 50 to 40 Ma from the length of the Cordillera de Panama. These low K tholeiites and andesites have large variations in Nb, Ta implying that mantle sources region at this time were heterogeneous and variable in incompatible elements prior to fluid enrichment. Their Nd isotopes ($\geq$0.512636) are lowest in this region. Nd-, Sr- and Pb- isotopes shows the EARLY-ARC as a distinct group with mantle sources that is not documented in older or later magmas.

Andesites of the third phase (YOUNGER-ARC, 19-5 Ma) form discrete volcanic centers across the Cordillera de Panama with progressive enrichment from varied tholeiites to more uniform medium-K arc character. These come from a homogeneous and matured source as Nb and Ta depletion is more uniform, only few samples show depleted patterns comparable to the EARLY-ARC. Nd-, Sr- and Pb-isotopes are similar to the present Central American Arc (CENTAM).

The youngest phase consists of isolated adakitic centers along the Cordillera de Panama (<2 Ma). Adakites with depleted HREE patterns are diagnostic of residual garnet in the source. Their Nd-, Sr-, and Pb-isotopes follow the Galapagos Hot Spot trend. Adakites are 'heavy' in terms of $\delta^{18}O$, consistent with a seawater altered oceanic basalt and melting of the leading edge of the Cocos Ridge and CLIP basement at a slab window.

Initiation of arc magmatism at 71 Ma coincides with the cessation of Galapagos plateau-formation, suggesting a causal link. The transition from intraplate CLIP to arc magmatism occurred relatively fast (3 Ma) and introduces a new enriched mantle source. Transition between EARLY- and YOUNGER-ARC (40 to 20 Ma) involves a more homogeneous intermediate composition. This indicates mixing and homogenisation of sub-arc magma sources with time and/or the replacement of the mantle wedge by a homogeneous, relatively undeleted asthenospheric mantle. The break-up of the Farallon plate at this time ($\sim$ 25 Ma) may trigger these changes. The newly established Cocos-Nazca spreading center leads to change in mantle movement, by upwelling below the new ridge. The plate movement direction changed (between 22.7 and 19.5 Ma) from mainly westward for the Farallon plate to northwest for the Cocos plate and southwest for the Nazca plate (Barckhausen et al. 2008). Adakite volcanism (< 2 Ma) started after a gap of 3-5 Ma enabled by the formation of a slab window. Pb isotopes favour melting of the leading

edge of the Cocos Ridge and/or CLIP basement as magma source.

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