Continental arc-island arc fluctuations, skarn formation and long-term climate

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Ocean-continent subduction zones, manifested as a global chain of continental arc volcanoes, were as much as 200% longer in the Cretaceous and early Paleogene than in the late Paleogene to present, when a cooler climate prevailed. In particular, many of these continental arcs, unlike island arcs, intersected ancient continental platform carbonates stored on the continental upper plate. Based on case studies in the Cretaceous Sierra Nevada and Peninsular Ranges Batholiths, California (USA), we show that Paleozoic crustal carbonates underwent extensive decarbonation at all levels in the crust. At mid to upper crustal levels, we observe direct assimilation of carbonates into magmas and ubiquitous evidence for hydrothermally driven skarns. Calc-silicate protoliths are also found in the lower crust, due to retro-arc underthrusting of North American lithosphere beneath the arc: decarbonation occurred by crustal assimilation in deep-seated magma bodies and by thermal metamorphism in a hot (>750 C) lower crust. The widespread extent of crustal decarbonation is evidenced by the occurrence of Cretaceous scheelite bodies from southern California to Alaska. These observations suggest that magmatically induced decarbonation of crustal carbonates was pervasive in the Cretaceous. We calculate that the greater length of Cretaceous–Paleogene continental arcs could have increased global production of CO2 by at least 3.7–5.5 times the present day. This magmatically driven crustal decarbonation flux through continental arcs exceeds that delivered by Cretaceous oceanic crust production, and was sufficient to drive Cretaceous–Paleogene greenhouse conditions. We thus suggest that carbonate-intersecting continental arc volcanoes likely played an key role in driving greenhouse conditions in the Cretaceous–Paleogene. Waning of North American and Eurasian continental arcs in the Late Cretaceous to early Paleogene, followed by a fundamental shift in western Pacific subduction zones ca. 52 Ma to an island arc–dominated regime, would have been manifested as a decline in global volcanic CO2 production, prompting a return to an icehouse baseline in the Neogene. Long-term (>50 m.y.) greenhouse-icehouse oscillations may be linked to fluctuations between continental-and island arc–dominated states.