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We present isotopic (Sr-Nd-Pb) data to determine the geochemical nature of the mantle beneath the Coast Mountains Batholith (CMB). Nineteen mafic (42-52% SiO2) dike and cinder cone samples, ranging in age from Eocene to Holocene, suggest that a transition from a hydrated mantle wedge, to dry, upwelling asthenosphere took place sometime after 10 Ma. Holocene magmas have higher average ϵ-Nd (8.2) and lower initial $^{87}Sr/^{86}Sr$ (0.7029) than the Eocene-late Miocene magmas from the same region (ϵ_{Nd} = 3.5, $^{87}Sr/^{86}Sr$ = 0.7043). Geophysical evidence includes lack of an orogenic root and a sharp, shallow Moho beneath the Coast Mountains at the present day. The Holocene magmas may have been produced and emplaced during the time that dense residues from batholith formation detached from the lower crust and foundered into the mantle. Our delamination model suggests piecemeal removal of batholith residues persisted over a ~50 Ma period, rather than in a single removal event. This model also accounts for the regional extension and exhumation that have been documented in the orogen.

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Elemental and Isotopic Evidence for Positive and Negative Feedback Mechanisms Governing Magmatic Flux in the Coast Mountains Batholith, British Columbia

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New REE data from 80 plutonic rocks from the southern Coast Mountains Batholith (CMB) ranging from 198 - 50 Ma form distinct populations of steeply ($(La/Yb)_N$ = 30 - 65) and shallowly dipping($(La/Yb)_N$ < 10) chondrite-normalized patterns. Nd and Sr isotopes have overall primitive characteristics with initial ϵ_{Nd} from -2 to +8 and initial $^{87}Sr/^{86}Sr$ of 0.7030 - 0.7065. Periods of high magmatic flux (160-140 Ma, 120-80 Ma, and 60-50 Ma) when high $(La/Yb)_N$ was accompanied by less primitive Nd and Sr are preceded by low magmatic flux periods (200-160 Ma, 140-120 Ma and 80-60 Ma) when $(La/Yb)_N$ was low and Nd and Sr appear more mantle-like.

Magmatic flux in the CMB appears have been governed by shortening and thickening in the upper plate, which caused an increase in lower crustal melting. Continued crustal shortening eventually led to a negative feedback in CMB magmatic flux, as the combination of an over thickened crust and crowding of the wedge beneath the arc with igneous residues and lithospheric mantle inhibited underthrusting and the supply of fertile lithologies to the lower crust. Delamination or foundering of igneous residues and mantle lithosphere during low magmatic flux periods alleviates the space problem in the sub-arc wedge and allows renewed underthrusting to initiate the next period of high magmatic flux. This explains why CMB granitoids were generated deeper in the crust with garnet-rich residues (high $(La/Yb)_N$) and less primitive initial ϵ_{Nd} and $^{87}Sr/^{86}Sr$ during periods of high magmatic flux, while during periods of low magmatic flux granitoids were generated at a shallower depth with opposite signatures. Recognition of delamination events in the CMB has important implications for how continental arcs evolve through time.

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Styles of pluton emplacement during contraction or extension, Coast Mountains, British Columbia

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The Coast Plutonic Complex, British Columbia, is an ~ 1800 km belt of plutonic rocks formed in the Mesozoic and Early Cenozoic. We describe the results of strain, kinematic, and geometric analysis across an east-west transect across the Coast Mountains from the Quottoon pluton, which is part of the great tonalite sill, with nearly vertical contacts to the ~ 6 km thick Chief Matthew's Pluton, with shallow dipping contacts. In both cases, the country rocks were at upper amphibolite facies of metamorphism when the plutons intruded. We applied the autocorrelation function (ACF) to estimate finite strain in oriented thin sections of both the country rocks and plutons, cut parallel to the lineation and perpendicular to foliation. The ACF is a Fast Fourier Transform of the image, which is a function of grain size, shape and orientation as well as proportion of mafic and felsic minerals. A minimum estimate of the finite strain can be calculated by taking the ratio of the maximum and minimum axes of the ellipse representing the 96th gray-level contour in the ACF image. The country rocks of the Chief Matthew's pluton consistently record a weak ACF, reflecting a random distribution of grain long axes. This is consistent with the variation in orientation of mineral lineation measured in the field, which, in stereographic projection, defines a girdle parallel to the moderately (~ 20°) southwest dipping foliation. These features suggest a flattening strain field, with steeply inclined shortening. Kinematic indicators consistently indicate normal shearing during pluton emplacement. In contrast, rocks around the Quottoon pluton contain vertical foliations and steeply inclined mineral lineations. Kinematic indicators and northeast vergent folds with steeply dipping axial surfaces are consistent with top to the northeast reverse shear. The measured ACF ellipticity for the Quottoon pluton and its country rock is consistently ~ 0.7 independent of the grain size, indicating fabric development during penetrative ductile deformation. The ACF ellipses define a clear strain gradient across the field area, from high strains near the Quottoon pluton (west), to lower strains around the Chief Matthew's pluton (east). These results show that the Quottoon pluton was emplaced during contraction. The Chief Mathew's pluton intruded during extensional deformation, producing moderate to gently dipping sills. In both cases the plutons have tabular shapes perpendicular to the inferred shortening direction suggesting that pluton geometry is controlled by strain accumulation during ductile deformation.

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Tracking Paleostrain in Arcs Using Magmatic Fabrics in Well-dated Plutons: An Example From the Tuolumne Batholith and Surrounding Plutons, Central Sierra Nevada, California

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Magmatic fabrics in plutons are often interpreted as records of magma flow rather than as records of regional strain in arcs. However, our field studies in the Sierra Nevada, California and elsewhere in Cordilleran arcs, provide examples of the benefits of studying plutons to constrain short increments of regional strain histories and inferred paleostresses. These plutons preserve alignments of magmatic minerals, which reflect increments of strain that are sometimes caused by magma flow during chamber growth, but more commonly record the regional strain in the arc that was imprinted on magma chambers. In the latter case, these 'regional strain increments' during pluton crystallization represent shorter time spans than what can be deciphered in metamorphic host rocks because of the longer histories recorded in metamorphic rocks and because recent improvements in U/Pb zircon geochronology allow documentation of the time magmatic fabrics lock in with high precision (<0.5 m yr). Our studies in the Cretaceous Tuolumne batholith, where we now have >4000 measurements of magmatic fabrics, has led to the recognition of 4 different magmatic fabrics that are, from oldest to youngest: 1) due to localized magma flow in tubes and troughs in an existing chamber, 2) margin parallel fabrics related to boundary effects, 3) an older, NW-SE striking magmatic foliation, and 4) a slightly younger, ENE-WSW striking foliation, both reflecting regional strain. Magmatic lineations are mostly steep and shared by all 4 different foliations. Mapping in and dating of other Mesozoic plutons (165 Ma to 85 Ma) surrounding the Tuolumne batholith documented similar orientations of magmatic foliations and lineations and the same temporal change in the magmatic foliation strikes, suggesting that regional strain related fabrics systemically shifted through time from NW to WNW in this part of the arc. We interpret this change in orientation as likely evidence for a temporally changing paleostress field. The findings of four magmatic fabrics in the Tuolumne batholith and consistent fabric patterns in surrounding plutons emphasize that 1) magmatic fabrics can have diverse causes and do not always record magma flow processes, especially in long lived and complex magmatic bodies such as the Tuolumne; and 2) magmatic fabric studies combined with high precision geochronology are a powerful technique to document paleostrain and inferred paleostress fields in arcs, which can then be used to evaluate changes in plate motions and/or other processes influencing these strain/stress fields.

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Paleo- Stress and Strain Rates in an Intra-Arc Strike-Slip Fault, Sierra Nevada, California

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Structures and microstructures of the Proto-Kern Canyon fault (PKCF), a 130-km-long dextral strike-slip shear zone of the southern Sierra Nevada batholith, provide constraints on displacement, flow stress, and strain rate during arc formation. Shear strain analyses of S-C mylonites indicate ~5 km of ductile dextral slip along the PKCF. But field mapping and measurements of individual plutons and metamorphic pendants show these bodies have much more elongated aspect ratios, of up to 1:17, within the shear zone than outside of it. This suggests significantly higher strain and dextral slip of up to 15 km along the highest-strain zone of the PKCF. Petrographic observations of high-strain igneous rocks near Lake Isabella indicate that deformation started at temperatures of 400-450° C and continued through cooling to ~300° C. Based on $^{40}Ar/^{39}Ar$ dating of hornblende, mica, and K-feldspar, early cooling (~20° C/m.y.) from 88-70 Ma was followed by very slow cooling (~1° C/m.y.). These data, combined with cross-cutting relationships, suggest that dextral ductile shear was active from 90-86 Ma. Grain sizes of dynamically recrystallized pure quartz mylonites in this part of the shear zone were used to estimate flow stresses of 20-40 MPa. Applying mylonitization temperature estimates of 400-350° C and lithostatic pressures of 350-400 MPa (from Al-in-hbl barometry) yields paleo-strain rates along the PKCF of 10^{-13}-10^{-15}/s. Additional quartzite piezometry, as well as calcite piezometry on marble mylonites, should provide further constraints on stress and strain rates along the length and depth exposures of this intrabatholithic shear zone.

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Mafic-Felsic Magma Interactions in an Enclave Mega-Plume, Gobi-Tienshan Intrusive Complex, Southern Mongolia

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