

THE GEOLOGY OF WESTERN NORTH AMERICA (ABRIDGED VERSION)

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The geological history of western North America has been, and continues to be, shaped by its position on the eastern rim of the Pacific Ocean. The modern Pacific Ocean's basin is the successor of the original ocean which split Laurentia - our continent's cratonic core - away from the rest of the Precambrian supercontinent Rodinia, an ocean that widened until in late Paleozoic time, it became Panthalassa, the World Ocean. Unlike the eastern side of the continent, where continental collision was followed by re-opening of the Atlantic Ocean - the "Wilson cycle" - western North America has always faced the same active ocean basin. Its tectonic evolution has always been that of an active margin, affected first by multi-episodic rifting, and then by plate-margin subduction and transcurrent faulting, over a 700 million year period of time. Throughout this long interval, fluctuating regimes determined by relative plate vectors have created the complex and varied geology and topography of the region; its thrust belts, volcanoes, and granite canyons; its scarps, plateaus, and cordilleras.

The geological history of this area can be viewed as four distinct plate-tectonic phases. The Rifting/Open Margin phase lasted from initial breakup at about 700 Ma (late Proterozoic) until 400 Ma (Middle Devonian), when widespread subduction began along the margin. The Oceans and Islands phase commenced as subduction built arcs and the continent retreated away from them, creating a scenario like the modern southeastern Pacific ocean. This phase lasted until about 180 Ma (Early Jurassic), when opening of the Atlantic ocean reversed the motion of North America such that it drove strongly westward relative to the long-standing subduction zones off its west coast, creating a broad zone of compression in the offshore arcs and ocean basins as well as its own miogeocline (Collisional/Orogenic phase). The final, Post-Collisional phase commenced during the Early Tertiary when parts of the East Pacific Rise subducted under the continent and turned the plate margin from pure subduction to a regime with both transcurrent faulting and continued subduction of short, remnant segments. Industrial mineral deposits formed during each of these tectonic phases. Combined effects of two or more phases were required to form some of these deposits.

The Cordilleran miogeocline developed during the Rifting/Open Margin phase, from its inception with deposition of the late Proterozoic, syn-rifting Windermere Supergroup, through the deposition of the thick sequences of Paleozoic-early Mesozoic carbonate and terrigenous

siliciclastic strata that are now beautifully exposed in the Canadian Rocky Mountains. The Mt. Brussilof magnesite deposit is hosted by Middle Cambrian carbonate within this continental shelf sequence. Equivalent platformal strata are best exposed in the southwestern United States, the Grand Canyon being a world-renowned example. The opening of Panthalassa was not a single event in western North America: convincing Cambrian as well as late Proterozoic rift-related sequences occur, and alkalic to ocean-floor basalts in the miogeocline range through Ordovician into Devonian age. The implied protracted nature of this rift event, in contrast to the short-lived and efficient opening of the Atlantic Ocean, continues to puzzle. The exact identity of the missing twin continent or continents, also provides grounds for lively debate, with Australia, Australia/Antarctica, and Siberia attracting the most adherents.

The Oceans and Islands phase began in Devonian-Mississippian time with the first widespread arc volcanism and plutonism along the continent margin: these rocks are recognized from southern California to Alaska. West of the North American miogeocline, a large portion of California, Oregon, Washington, British Columbia, and most of Alaska are made up of rocks of intra-oceanic island arc to oceanic affinity that occur in relatively coherent packages separated from each other by faults. These assemblages, famously termed a collage of "suspect terranes" by Peter Coney and Jim Monger, had uncertain relationships to the North American continent during at least part of their history. Most of them have now been shown either to contain faunas of eastern Pacific affinity (an excellent example can be viewed at the Lafarge limestone quarry near Kamloops, B.C.), or to exhibit sedimentological, geochemical and/or historical aspects that link them, however distally, to the continent. Some, however, are more convincingly exotic imports: the Cache Creek Terrane of central British Columbia with its Tethyan, Japanese-Chinese, late Permian fusulinid fauna; Wrangellia and Alexander, a linear belt on the coasts of B.C. and southeastern Alaska, with its late Paleozoic cold-water, Baltic-affinity fauna; and fragments of continental crust in Alaska with Precambrian ages that are unknown in North America.

At present, the Pacific Ocean is highly asymmetric, its west side festooned with island arcs, its east side bare, bordering a continental margin made up of fragments of just such arcs and marginal oceans. It is reasonable to suppose that both sides of the Pacific were once mirror

images. However, opening of the northern Atlantic Ocean at about 180 Ma destroyed that symmetry. Although earlier compressional events affected the suspect terranes, their thrusting on top of the North American miogeocline dates from the latest Early Jurassic, roughly 183 Ma - the same age as early rift basalts on the eastern seaboard. From that time until the end of the Mesozoic, both suspect terranes and sedimentary strata of the miogeocline were stacked into a complex but overall easterly-tapering thrust wedge. Oceanic terranes incorporated into the wedge have provided both asbestos (Cassiar Mine) and jade deposits. During this Collisional/Orogenic phase, successive Jurassic and Cretaceous magmatic arcs draped across the growing accretionary collage. Numerous dimension stone quarries exploit granites from this phase. The notably voluminous mid-Cretaceous arc was probably linked to an episode of rapid subduction around the entire northern Pacific Rim. Broad plutonic provinces of this age occur from China, through Russia, into Alaska and British Columbia and south into California and Mexico - a spectacular example of the global geological consequences of relative plate motion.

Towards the end the Collisional/Orogenic phase, dextral (Pacific-northward) transcurrent motion became an increasingly important part of tectonic development, with at least hundreds of kilometres of displacement along faults such as the Denali, Tintina, Pinchi and Fraser. By early Tertiary time, thrusting in the Canadian Rockies and Foreland Belt had ceased, and crustal extension was accompanied by volcanism and graben development in southern British Columbia and northern Washington-Idaho. At about 38 Ma ago, the edge of North America began to impinge on the East Pacific Rise, shutting off subduction along increasingly long sections of the margin. Major dextral faults - the San Andreas, Queen Charlotte, and Denali faults - began to express the strong component of lateral motion between the American and Pacific plates.

Some 300 kilometres of crustal extension related to this lateral motion generated the Basin and Range Province in

the western United States. Limited subduction continues today off the coast of Washington, giving rise to the Cascade volcanoes; and the westward turn of the continent margin in Alaska creates a continuing collision zone in the Wrangell and Alaska Ranges, resulting in North America's highest summits. Late Cenozoic uplift, perhaps due to mantle heating events, has rejuvenated the Canadian Rockies and the Coast Mountains. In terms of industrial mineral deposits, late Cretaceous and Cenozoic volcanic and terrestrial deposits of bentonite, diatomaceous earth, pumice, zeolites, and opals have attracted exploration and mining interest.

The saga continues, with the recent February 28, 2001 earthquake in Washington State rattling our knick-knack shelves and causing short term cell-phone and 911 overloads. This west coast is by nature Pacific Rim, not just in cultural orientation, but in terms of day-to-day tectonic reality as well.

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