

V27-12

The Origin of Native Iron and Iron Alloys in Serpentinized Ultramafics

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Native metals of iron, copper, gold and platinum group elements (PGE), and alloys of iron, nickel, cobalt, and PGE occur in serpentinites and partly serpentinized ultramafics representing a wide range of metamorphic grade and tectonic environments (e.g., stratiform intrusions, ophiolites, and mantle xenoliths). Native iron, which is particularly rare in terrestrial rocks, is reported here for the first time in the Acoje Massif (ophiolite), Philippines. Compositions determined by microprobe analyses show a range of 90.2 to 99.5 wt.% Fe, where the remaining components include Co: from not detectable (nd) to 7.0 wt.%, Ni:nd-1.5 wt.%, Cu:nd-0.3 wt.%, and S:nd (phosphorus was not analyzed). Phases found associated with native iron include wairauite, taenite, magnetite, and pentlandite, the latter representing relics of desulfurization. The silicate hosts consist of relict olivine, clinopyroxene, lizardite, and brucite. Native iron is also found isolated from other opaque phases in the serpentine matrix or in finely serpentinized internal fracture faces in olivine.

We suggest that this highly reduced condition is a direct result of a rock-dominated interaction where the fluid phase assumes a passive role. Thermodynamic calculations ($T=25-400^\circ\text{C}$; $P=1\text{ kb}$) show that H_2O and CO_2 are unstable at these low f_{O_2} 's and that the equilibrium fluid composition is $\text{H}_2\text{O}-\text{CH}_4-\text{H}_2\text{S}$ (depending on carbon and sulfur activities). At higher fluid-rock ratios, the process becomes fluid-dominated, thus stabilizing magnetite and higher Fe_2S_3 -sulfides (e.g., Eckstrand, 1975). We further suggest that the oxygen buffering equilibria during the incipient stages of serpentinization in Acoje is a result of the intrinsically low initial oxidation state of the ultramafic protolith (at or below magnetite-iron).

Cascades Volcanism and Implications for Geothermal Resources

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V31A-01

Segmentation of the Juan de Fuca Plate and Volcanism in the Cascade RangeC. S. Weaver (USGS, Geophysics Program, University of Washington, Seattle, Wash. 98195)
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The Cascade subduction zone is formed by the oblique convergence between the Juan de Fuca and North American plates. Along the strike of the subduction zone in Washington and northern Oregon, pronounced differences occur in the earthquake distribution, style and volume of late Cenozoic and Quaternary volcanism, and the teleseismic P-wave delay pattern. We use these observations to define northeast-striking boundaries that divide Washington and northern Oregon into three zones along the Cascade arc: (1) north of Mount Rainier, (2) Mount Rainier to Mount Hood, and (3) south of Mount Hood. We suggest the differences in seismicity and volcanism reflect changes in the interaction between the Juan de Fuca and North American plates. These coincide with and are related to changes in the geometry of the subducting plate. We propose the subducted portion of the Juan de Fuca plate is segmented along boundaries roughly parallel to offsets in the marine magnetic anomalies offshore. The segmentation of the Juan de Fuca plate may be the result of the plate adjusting to the change in the strike of the subduction zone between northwestern Washington and southern Vancouver Island.

We interpret our data as indicating that the dip of the Juan de Fuca plate is steeper beneath northern Oregon than beneath Washington, allowing extensional tectonics to develop south of Mount Hood. As a consequence, this area is characterized by high heat flow, extensive volcanism, and normal faulting. In contrast, the plate dips more shallowly north of Mount Rainier. Horizontal compression dominates the tectonics to the north characterized by strike-slip faulting, with only isolated stratovolcanoes. The zone between Mount Hood and Mount Rainier, where the change in the plate dip is proposed, is transitional, with aspects of both compressional and extensional tectonics observed.

V31A-02

(MVFTEP)

Crustal Structure of the Klamath, Cascade, and Modoc Regions of Northeastern California from Seismic Refraction Data

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In 1981, the U.S. Geological Survey conducted a seismic-refraction experiment in northeastern California that included 95-km-long north-south lines in the Klamath Mountains (KM) and on the Modoc Plateau (MP), and a 225-km-long east-west line from the KM to the California-Nevada state line. Instrument spacing averaged 1 km, and shotpoint spacing 50 km. The KM and MP lines yielded the simplest models. The KM line is underlain by relatively flat high-velocity layers (6.1, 6.3, 6.7, and 7.0 km/s) with low-velocity layers between them. Layer thicknesses range from 1 to 3 km; the 7.0-km/s-velocity layer is 14 km deep. The MP line is underlain by 4-1/2 km of relatively low-velocity (3.3-4.3 km/s) material over a 6.2-km/s-velocity basement. A small velocity step (to 6.4 km/s) occurs at 11-km depth, a velocity step to 7.0 km/s occurs at 23-km depth, and mantle is estimated to be 38-45 km deep. On the east-west line, the KM and MP models are juxtaposed in the vicinity of the Cascade Range.

The fact that the velocity-depth curve for the MP is virtually identical, beneath its surficial layers, to that determined by other workers for the Sierra Nevada leads us to conclude that the MP is underlain, beneath its volcanic and sedimentary rocks, by a basement of granitic and metamorphic rocks that are the roots of magmatic arcs. The finely layered velocity-depth curve in the KM can be related, with the help of independent modeling of aeromagnetic data, to the structural fabric of oceanic plates that is sapped at the surface. We conclude that the volcanic Cascade Range overlies a complex suture region between the KM, underlain by imbricate oceanic plates, and the MP, underlain by the roots of magmatic arcs.

V31A-05

Tectonic Setting of the Southern Cascade Range as Interpreted from Its Magnetic and Gravity Fields

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We have compiled aeromagnetic data from the southern Cascade Range and compared them with residual gravity data from the same region to investigate regional aspects of these young volcanic rocks and the underlying basement. Various constant-level aeromagnetic surveys were continued upward to 4,570 m and numerically smoothed into a single compilation extending from lat 40°10' to lat 44°20' N. This compilation was reduced to the pole, continued upward an additional 10 km, and compared with a magnetic topographic model and with residual gravity data continued upward to the same level. Several intriguing regional features emerge:

- (1) The Trinity ophiolite complex that is exposed west of Mount Shasta probably dips at a shallow angle eastward and continues in the subsurface at least 10 km east of Mount Shasta; (2) Mount Shasta, Lassen Peak, and Medicine Lake volcanoes are situated in a broad magnetic low possibly caused by an upwarp of the Curie-temperature isotherm; (3) Crater Lake is situated at the intersection of various linear anomalies interpreted to be related to structure in basement rocks below the Cascade Range; (4) Three Sisters volcanoes and Newberry Crater are connected by an arcuate magnetic source; (5) a residual gravity trough that we believe represents a major structural depression extends north-south across the entire study area; and (6) except for Newberry Crater, every major volcano in the study area is situated on the perimeter of a local gravity low. We suggest that the gravity lows reflect subsidence of low-density volcanic material relative to denser country rock and that the major volcanoes have developed over structures at the perimeters of their respective depressions.

V31A-04

Hybrid origin of late Cenozoic structural patterns, southern Cascade Range

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Late Cenozoic structural and volcanic patterns of the southern Cascade Range reflect the interaction of three major tectonic components: (1) slow oblique subduction of the Juan de Fuca plate, (2) NW-trending right lateral shear of the Walker Lane, and (3) E-W extension of the Basin Range province. The increasing importance of (2) and (3) southward through the Cascade Range is demonstrated by analysis of structural and volcanic patterns from maps and imagery. The westward bulge of the Cascade arc from Three Sisters to Lassen, and the southward narrowing of the arc-trench gap, imply steepening of the subduction zone that is not explained by temperature-related density variations in the subducting plate. It is proposed that steepening of subduction and bending of the volcanic arc occurred in response to forceful westward spread of anomalous hot mantle from beneath the Basin Range province during the last ten million years.

V31A-06

Interpretation of Tectonic Stress Regime vs Volcanic Style in the Cascade Range

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Structures influencing volcanic style along convergent plate margins have been related to segmentation of the subducted slab (Stoiber & Carr, '73). This approach has been extended to the Cascade Range (Hughes et al., '80); however, extensional deformation to the east of the volcanic front may be more significant. Satellite Radar (SAR) imagery provides a synoptic view of the Cascades which strongly enhances structure. Interpretation of this imagery, plus U-2 and Landsat data, suggests that the interaction between the subduction-induced volcanic front and the westward-propagating extensional regime of the Basin & Range (BAR) is related with the volcanic style of the major vents in Oregon and California. Areas characterized by 'non-coherent' bimodal volcanism and caldera formation (Newberry, Crater Lake, Medicine Lake and Lassen) occur at points where NW trending BAR normal faulting is best developed. Elsewhere, andesitic shields dominate. These observations agree with models of volcanic style vs stress regime (Eichelberger & Cooley, '77). At Crater Lake and Lassen, the extensional deformation intersects the volcanic front. At Newberry and Medicine Lake the vents are developed behind the front. In the latter cases, the extensional environment may be generated by a combination of subduction-related and BAR sources. Lineations of cinder cones between Shasta and Medicine Lake (ML) indicate that the maximum stress orientation changes from N-S at ML to NE-SW at Shasta. Between Newberry (NB) and Mt. Jefferson (MJ) a similar rotation of regional stress from SEW at NB to W-E at MJ is indicated. These rotations are consistent with the relative dominance of regional BAR extension. North of MJ the presence of BAR style deformation is not evident on the imagery.

V31A-06

CENOZOIC VOLCANISM OF THE CASCADES OF WASHINGTONV. A. Friesell, Jr. (U.S.G.S., Menlo Park, CA 94025)
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In Washington State, Eocene andesitic, basaltic, and rhyolitic volcanic rocks intercalated with continental sedimentary rocks and associated with coeval granitic plutons are probably related to the Channeled arc. This Cascade volcanism began during the early Oligocene with the focusing of arc magmatism along the current Cascade trend. Volcanic rocks of the Washington Cascade system, extensively preserved in the southern Cascades, are correlative with the sequences: Okanogan (O)-Stevens Ridge (SR)-Piles Peak (PP) Formations. This sequence consists mostly of andesitic and basaltic materials, although silicic rocks are present sporadically throughout and dominate in SR. Coeval mostly granodioritic to tonalitic plutons include (N to S): the Chilliwack (34, 38, and 34 m.y.), the Cloudy Pass (22 m.y.), the Index (34 m.y.), the Grotto (23 m.y.), the Snoqualmie (23, 38, and 18 m.y.), the Teton (13 to 24 m.y.), the Spirit Lake (21 m.y.), and the Silver Star, and their retines of associated stocks.

The O, a thick pile of altered well-bedded dacite to andesitic breccia and volcanoclastic sedimentary rocks alternating with lesser rhyolitic, basaltic, and andesitic flows and local ash-flow tuffs, yields 25 to 36 m.y. ages. The O crops out mostly between Snoqualmie Pass and the Columbia River. SR unconformably overlies the O, consists of quartz-bearing tuff and bedded volcanic sedimentary rocks, and yields 22 to 27 m.y. ages. The SR crops out widely around Mt. Rainier and sporadically elsewhere between 48° and the Columbia River. The PP, consisting of andesitic flows and subordinate breccias, volcanic sedimentary rocks, and quartz-bearing tuffs, yields 20 to 34 m.y. ages. It is widely present between Snoqualmie Pass and the Columbia River.

Both the extrusive and intrusive rocks produced during this long-lived subduction-related igneous event are the underpinnings on which the late Cenozoic volcanoes of the Cascades are built.

V31A-07

Regional Interpretation of Gravity Data from the Cascade Range

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We recently assembled a data set containing 32,000 gravity stations to prepare a complete Bouguer anomaly map of the California, Oregon, Washington, and Canadian Cascade Range region.

Positive gravity anomalies associated with the Coast Range and Klamath Mountains are probably related to dense oceanic material in these accreted island-arc terranes. Shallow mantle may be the cause of the Columbia Plateau gravity high. Interestingly, the gravity low associated with the Cascade Range is indistinguishable from the Basin and Range gravity low where they are adjacent in California and Oregon. It is thought that the gravity low in the Basin and Range is related to a low-density mantle. The similarity between the

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