estuary; (3) shallow (less than 10 m) subtidal marine; (4) deeper (greater than 10 m) marine; (5) marine-glaciofluvial delta; and (6) marine ice-contact glaciofluvial.

Microfossil and macrofossil evidence constrains the interpretation of water depth, sedimentation rate, and possibly water temperature and salinity for many of these environments. Radiocarbon dating of shells preserved in glacial-marine and associated deposits indicates that the retreat of continental ice was rapid. Age differences of approximately 1,000 $^{14}C$ yr between shallow-marine deposits at similar altitudes suggest differential isostatic rebound, perhaps related to the regional pattern of ice retreat or to inferred crustal structure.

We propose a deglaciation model that includes: (1) a rapidly retreating continental-ice margin that calved in open marine waters along an irregular isostatically active coastline; (2) rapid eustatic changes; and (3) large sediment volumes transported into marine waters by rivers draining the recently deglaciated landscape.

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## Calcium Carbonate Cementation of Tills Rich in Ultramafic Rocks, Northern Puget Sound Region, Washington

Late Pleistocene tills containing appreciable amounts of ultramafic clasts and matrix occur on and adjacent to ultramafic bodies (commonly harzburgite) in the northern Puget Sound region. Many exposures of such tills are strongly cemented, typically by aragonite, although Mg-calcite and calcite also occur; cement comprises 1 to 6% of the till.

Cementation appears to be controlled by ground water enriched in calcium derived from calcium-bearing pyroxene in the ultramafic rocks. The role of incompletely serpentinized rocks and ground water is indicated by the following observations. (1) Cementation occurs only in association with incompletely serpentinized rocks; other calcium sources (e.g., limestone) are absent. (2) Calcium-rich cemented-till halos surround fresh ultramafic clasts that were glacially transported from source outcrops; completely serpentinized clasts have no cemented halo. (3) Massively cemented till forms preferentially at topographic lows on ultramafic bodies where ground-water discharge is concentrated. At these sites the till is strongly cemented in the wetted zone at and near the bed-rock contact, and the degree of cementation decreases a few meters above the contact.

These tills are unusual in that they contain the first reported $CaCO_3$ cement in till that is not derived from preexisting carbonate materials, although the process of carbonate (ophicalcite) generation from unserpentinized ultramafic rocks has been increasingly recognized in recent years.

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## Plant Megafossils at Carboniferous-Permian Boundary

Plant megafossils are relatively common below and above the Carboniferous-Permian boundary in terrestrial beds and have been used to recognize the systemic boundary in this facies. However the systemic boundary in the terrestrial realm seems to be different from that used in marine sequences. To resolve this difference, any purely terrestrial section must be correlated with one which has interfingering marine and terrestrial beds. Plant megafossils were collected from the Upper Pennsylvanian and overlying Permian(?) sequences in West Virginia, where the age assignment of the Dunkard Group has long been controversial. Similar collections in the uppermost Pennsylvanian and lowermost Permian of Kansas were used for a correlation of the two sections. The lithofacies in the two areas are generally similar and both contain indicators of both wet and dry conditions. The plants occurring in rocks formed under relatively dry conditions change more rapidly and are therefore more meaningful for stratigraphic comparisons. The changes in the flora can best be expressed by the sequence of first occurrences (and to a limited extent, extinctions). The appearance of *Callipteris*, and specifically *C. conferta*, is clearly the best recognizable event in this stratigraphic interval. Based on these findings, the Washington coal bed in the Washington Formation, lower part of the Dunkard, would correlate approximately with the Topeka Limestone (middle Virgilian) of Kansas.

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## Depositional and Structural Controls on Heavy-Petroleum Tar Sands in Santa Cruz Mountains

Heavy petroleum occurs in limited amounts as tar sands within the western Santa Cruz Mountains. The largest accumulation of petroleum is in the middle and late Miocene Santa Margarita Formation. The Santa Margarita rests disconformably on pre-Tertiary Salinian basement rocks and unconformably on the Monterey Formation (middle Miocene) and older Tertiary rocks. The Santa Cruz Mudstone (late Miocene), which conformably overlies the Santa Margarita Formation, provided an initial seal for petroleum entrapment. The distribution of petroleum apparently is related to the depositional environment of the Santa Margarita and to later structural development.

The Santa Margarita Formation is a tidal dominated marine shelf deposit. An 8-km wide northeast-trending facies of unidirectional, large-scale cross-strata of uncemented sand and gravel represents a zone of intense tidal currents; this facies provided a conduit for initial petroleum migration. Westward homoclinal folding, including northeast-trending and southwest-plunging compaction anticlines, formed structures for initial petroleum entrapment within the cross-bedded facies.

Strike-slip movement on the San Gregorio fault system formed a postdepositional conjugate fault-and-fracture system in the western Santa Cruz Mountains. Where petroleum had accumulated on structures, faulting caused injection of the petroleum sand into overlying siliceous mudstone; these injections range in width from a few centimeters to 200 m. Faulting and associated clastic injections also formed partial seals across structures within the Santa Margarita Formation. The maximum thickness (30 m) of tar-saturated sandstone occurs in fault traps downdip on southwest-plunging anticlines within the cross-bedded facies. Petroleum accumulations also occur in stratigraphic traps where sand pinches out on paleotopographic highs, in structural traps in fault-bounded blocks on homoclinal folds, and in possible diagenetic traps where sandstone rests on marble.

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