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DEPOSITIONAL AND TECTONIC HISTORY OF TERTIARY SEQUENCE ON CONTINENTAL MARGIN OF BRITISH COLUMBIA

Sampling and seismic profiling in the Tofino basin west of Vancouver Island have disclosed a thick sequence of Tertiary rocks ranging in age from Eocene to Pliocene. Most of these rocks were deposited in deep-water environments and subsequent uplift has exposed them in many areas. Eocene and Oligocene sediments were deposited in a belt along the present shoreline area off Vancouver Island, whereas Miocene and early Pliocene rocks are present farther seaward. Later Pliocene rocks form a regressive sequence overlapping the older Tertiary in most areas.

Several major periods of deformation resulted in faults, folds, and diapirs on the continental shelf. Deformational patterns show a marked change from north to south. North of Brooks Peninsula, including Queen Charlotte Sound and Hecate Strait, sediments are generally undeformed by folding but are truncated by faults along the steep continental slope. The Kyuquot uplift south of Brooks Peninsula exposed Eocene and Oligocene rocks across the shelf. Farther south, Miocene and Pliocene rocks unconformably overlie the uplift. Folding increases southward, culminating in an area of diapirism off Nootka Sound. Elongate diapirs trend parallel or subparallel with the coastline.

Tectonic features observed on the shelf and slope probably can be explained best by a consideration of the configuration and projected relative movements across spreading centers and along transform faults off the coast of British Columbia. The juxtaposition of differing tectonic styles may be due to the presence of a triple-point junction which has subsequently migrated north.

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RADIOLARIAN DEFINITION AND PALEOECOLOGY OF LATE MIOCENE TO EARLY PLIOCENE IN SOUTHERN CALIFORNIA

The late Miocene to early Pliocene appears to be well represented by radiolarian faunas in formations in southern California. From radiolarian biostratigraphic studies in southern California the writers suggest that the base of the Mohnian (as represented by the section at Newport Bay) is equivalent to the base of the *Ommatartus antepenultimus* Zone of Riedel and Sanfilippo, and the top of Delmontian (as represented by the Malaga Mudstone at Malaga Cove) is within the *Pterocanium prismatium* Zone of these same writers. The uppermost occurrences of *Prunopyle titan, Lychnocanium grande* and *Theocyrtis redondoensis* and the lowermost occurrence of *Lamprocyclas heteroporos* occur relatively close together and represent the Miocene-Pliocene transition in the Malaga Cove section. The most reliable datum plane for the Miocene-Pliocene boundary in southern California might be the lowermost occurrence of *Lamprocyclas heteroporos,* for this appears to be an evolutionary event.

From radiolarian paleoecologic studies in southern California we suggest that the late Miocene to early Pliocene was a period of paleotemperature fluctuation with sea surface temperatures fluctuating as much as 10°C. The radiolarian diversities also fluctuated during this same period with a general trend toward a diversity decrease upsection. There were differential (selective) radiolarian extinctions during this same period in that "shallow water" (epipelagic) forms appear to be more severely affected than deep or tropical submergent forms.

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INTERPRETATION OF MIOCENE SHALLOW MARINE DEPOSITIONAL ENVIRONMENTS USING SEDIMENTARY STRUCTURES

Comparison of sedimentary structures in certain sedimentary rocks with those that form in the modern environment can provide a powerful interpretive tool. An example can be drawn from a well-exposed middle Miocene marine-nonmarine transition in the southeastern Caliente Range, California. Within this transition, shallow-marine sandstone (part of Branch Canyon Sandstone) intertongues on the northwest with marine siltstone (Saltos Shale Member of the Monterey Formation), and intertongues on the southeast with nonmarine redbeds (part of the Caliente Formation). Flow structure in extrusive basalts in the upper part of the transition and paleocurrent features in overlying Miocene alluvial deposits indicate that the shoreline at the time of deposition trended north-northwest.

The marine-nonmarine transition consists of a succession of individual progradational sequences that extend westward (seaward) into marine strata. The sequences exhibit a fairly consistent internal stratigraphic arrangement. A typical complete sequence has a basal unit of unbedded siltstone (Saltos Shale) lying on an erosion surface. A thin zone of conglomerate commonly occurs within the siltstone directly above the lower contact. The siltstone grades up into bedded or unbedded fine-grained sandstone (Branch Canyon Sandstone). This fine sediment is sharply overlain by a coarse, pebbly, crossbedded facies of the Branch Canyon, which grades upward into finer and predominantly planar-bedded sandstone. The planar-bedded sandstone grades up into muddy structureless sandstone that in turn grades up into red or green mudstone (Caliente Formation), which caps the sequence.

The progradational nature of the sequences implies that the fine-grained sandstone near the base was deposited in the marine environment somewhat shoreward from the gradationally underlying siltstone, which locally contains marine invertebrates. Bedding, where present in the fine sandstone, is defined by concentrations of biotite; the bedding is either planar or shows medium- and small-scale cross-stratification. Bioturbational disruption abounds. Crossbedded lenses of well-sorted granular sand are interbedded with the fine sand in its upper part. Foresets in these lenses dip predominantly toward the southeast. Similar structures form in response to the passage of waves in modern high-energy environments. The foreset orientation thus suggests that during the time of deposition the waves approached from the northwest.

The coarse, pebbly sandstone that sharply overlies the fine-grained sandstone is the thickest and best exposed unit of most sequences. Bedding is generally well developed, and bioturbational structures are rare. Pebbles tend either to occur as lag deposits scattered along extensive erosion surfaces within the sandstone or to be concentrated within conglomeratic beds. Crossbedding is abundant and dips predominantly west-southwest (offshore); a small secondary mode dips south-southeast. This secondary mode may reflect the influence of longshore currents resulting from the oblique approach of the waves with respect to the shoreline. A few large-scale crossbedding units dip east and southeast and suggest the presence of offshore bars trending oblique to the coast, parallel with the prevailing wave crests. The dominantly offshore-dipping crossbeds are best explained as the result of rip currents. The erosional contact at the base of the coarse sandstone resembles the contact formed at the base of rip channels in the modern environment.

The planar-bedded sandstone in the upper part of the sequence is well sorted and contains planar concentrations of magnetite that resemble those formed on the upper foreshore of modern beaches. Many planar laminations are inversely graded like those that form at present in the upper swash zone. Where attitudes were measured, most of the planar beds dip gently seaward (west), which also supports a beach origin.