

Regional Tectonics, Sea-level Change, and Prehistoric Site
Distribution on the Northwest Washington Coast

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In order to place the known cultural history of the Northwest Coast within an ecological perspective, Fladmark (1975) and others have argued for the development of a holistic framework *that relates culture* history to a uniform series of geological events. In particular, Fladmark (1975) attempted to relate the culture history of the Northwest Coast to the dynamics of sea-level change during Holocene times. The essential core of that argument is that two divergent sea-level histories characterized the Northern and Southern Northwest Coast, with "sea-levels significantly higher than present north of central Queen Charlotte Sound, and sea-levels significantly lower to the south." These divergent sea-level histories were seen to correspond with the emergence of distinctive cultural traditions. Between 10,000 and 5,000 BP, a core-and-blade technology in the northern region was to be "associated with raised beaches and distributed along the whole coast north of central Queen Charlotte Sound," while "to the south...there occurs contemporaneously an entirely different tradition characterized by large leaf-shaped bifaces and a lack of a true core-and-blade technology."

It is suggested that this correlation reflects the divergent effects of higher and lower sea-levels on the coastal environment, and corresponding divergence of cultural adaptive strategies.

Following mid-Holocene sea-level "stabilization" in both regions, midden sites began to develop after ca. 5,000 yr BP as the productivity of salmon runs increased, allowing sedentary settlements to form. The development of shell middens themselves was seen as a dependent, rather than an independent, variable in this process:

There is no evidence to directly relate initial stabilization of the land-sea interface with increases in the productivity, cultural utilization, or preservation of shellfish; instead a causal relationship may be traced through intervening stages in which development of climax salmon runs produced the energy surpluses necessary for dense, seasonally sedentary population aggregates, and the accumulation of massive cultural deposits (Fladmark 1975: 292).

Thus, two essential ideas were proposed in Fladmark's (1975) initial thesis: (1) divergent sea-level histories before 5,000 yr BP on the Northern and Southern Northwest Coast; and (2) an adaptive "homogenization" after 5,000 yr BP as midden sites, reflecting subsistence based on salmon fishing and shellfish collection developed in all areas in association with more sedentary lifestyles. Thompson (1978) reviewed this thesis, adding additional complexity from the specific perspective of the Southern Northwest Coast. Noting a lack of data for early Holocene sea-level history in the region, she nevertheless appears to agree with the notion - following Larsen (1971) - that sea-level history in the Southern Northwest Coast has been characterized by rising sea levels since ca. 9,000 yr BP. Although there is some debate as to the rapidity of this sea-level rise, and whether "sea level gradually approached its current height" or whether a true "stabilization" of sea-level took place between 3,000 and 5,000 yr BP, the accepted model for the Southern Northwest Coast region was one based on a rising sea-level since early Holocene times. The consequence of this sea-level rise was a probable inundation and loss of archaeological sites dating between 4,000 and 9,000 yr BP, and a possible loss of later sites if sea-level curves showed continued gradual rise rather than stabilization.

Both Fladmark (1975) and Thompson (1978) ^{raise} the possibility that tectonic factors may have affected the pattern of postglacial sea-level rise. However, Fladmark suggested that such factors were much more relevant to the Northern than the Southern Northwest Coast.

On the Southern Coast, sea-level curves begin to parallel general eustatic sequences after ca. 8,000 yr BP, suggesting that isostatic adjustment is essentially complete by that time. However, at the northern end of the coast...sea-levels appear to have been strongly affected by tectonic factors.

Any tectonic factors operating on the Southern Northwest Coast were thought to be "localized" in effect. Thompson (1978) reiterated this notion that tectonic effects could have "altered local environments" on the Southern Northwest Coast. She raised the possibility that such tectonic effects could lead to emergence as well as submergence, but noted that "recent geological literature [in the early 1970's] does not suggest that it has been an important factor."

While they have taken place in the area, the extent to which tectonic movements may have affected prehistoric occupation and archaeological site preservation cannot be determined until detailed local studies are available (Thompson 1978: 32).

One problem common to both Fladmark's and Thompson's reviews of the relationship between sea-level history and Northwest Coast prehistory is the lack of data from the outer coast in the Southern Northwest Coast region. Fladmark's contrast between the

Northern and Southern Northwest Coasts was based on a contrast with the southern inner coast; he noted that [at the time] "published sea-level data are non-existent for the western part of the Strait of Juan de Fuca, and the west coast of Vancouver Island" (Fladmark 1975: 149-150). All of Thompson's examples for both archaeological and sea-level data were also from the inner coast of Washington state. Since that time, a great deal of new data - both archaeological and geological - has emerged from the outer coast of the Southern Coast region. Perhaps the time is ripe for a new synthesis of Southern Coast prehistory based upon those new data.

This paper attempts to offer a few suggestions toward such a goal, based upon a synthesis of paleoenvironments and culture history developed as a part of a research design for the Olympic Peninsula region, currently being undertaken for the US National Park Service by the Office of Public Archaeology at the University of Washington. The thesis that is suggested here is that the east-west distinction in sea-level histories discussed by Fladmark for the northernmost portion of the Northwest Coast (i.e. the region from the Queen Charlotte Islands north to southeastern Alaska) also applies to the Southern Northwest Coast as well, although the cause [in both regions] was different than that originally suggested.

Late Pleistocene Environments and Human Occupation of the Olympic Peninsula Region

No evidence of occupation has been found in the Olympic Peninsula region predating 13,000 yr BP. The entire Peninsula region was apparently ice-free during the long Olympia Interglacial, radiocarbon-dated to between 30,000 and 60,000 years ago. It was, however, covered in various fashion by the succeeding Fraser and Vashon glacial periods, extending from ca. 24,000 to as late as 13,000 yr BP (Thorson 1980, Stuiver et al. 1978). After this point in time, ice apparently only impeded human occupation of the interior uplands; the late-glacial Sumas stage, dated between ca. 11,500 to 10,000 yr BP, apparently affected only those regions (Fladmark 1975). Furthermore, areas of the southern Peninsula were not affected by the Fraser and Vashon ice lobes (Thorson 1980). Thus, both the coastal plain and the southern Peninsula region would have been available for human occupation by ca. 13,000 yr BP.

An excellent palynological record is available from the outer coast of the Olympic Peninsula for this time period. The interval between 16,000 and 11,000 yr BP is particularly well represented in sections from the Hoh River valley (Heusser 1974, 1977) as well as from Wessler bog to the northeast of Ozette lake (Heusser 1973). The Vashon/Evans Creek stades were among the coldest of the Late Pleistocene, culminating ca. 13,000 yr BP, and were associated with a greater development of grasses and

forbs as well as a proliferation of alder after the late-glacial maximum. Shrubs increase in the pollen assemblage after 14,500 yr BP, however, and by 11,000 yr BP alder, pine, and spruce represent 50% of the pollen. It was this cool, moist environment with locally boggy areas that served as a habitat for certain hydrophilic late Pleistocene megafauna such as mastodons, ^{the remains of} which have been found at what has been described as the earliest known human site on the Olympic Peninsula, the Manis site at Sequim.

With the withdrawal of the Late Pleistocene ice, climatic conditions in the Peninsula region were controlled both by world-wide climatic amelioration of the early Holocene period and by local air current phenomena restricted to the Northwest region. This is again reflected by palynological data from the region. The early Holocene interval is well represented from the Hoh River valley and also from cores in the Bogachiel River area. ^{to} During this period, arboreal pollen increases from ca. 50-90% of the total assemblage, and shifts from domination by alder (11,000-10,000 yr BP) to spruce and hemlock, and finally by Douglas fir (after 8,500 yr BP). This reflects a shift from an earlier cool, moist climate to a warmer, dryer climate. Florer (1973) finds similar trends in marine sediment samples taken off the outer coast. Heusser (1977) argues for a July temperature maximum at this time of ca. 16-17 degrees C, or about 1-2 degrees above modern values.

Associated with these climatic changes were eustatic changes in sea-level resulting from the reductions of [World-wide] ice volumes. It can be assumed that a major component of early Holocene sea-level change was eustatic in origin. However, isostatic phenomena were also critical, particularly in areas near the ice front. After recession of the Vashon ice, late Pleistocene sea-level ranged well above present from ca. 13,000 to 11,000 yr BP. On the eastern Peninsula, the magnitude of this rise ranged from ca. 50 to 200 m above present, with most values falling in the range of 100 to 150 m above present sea-level (Larsen 1971). On the outer (western) coast of the Peninsula, however, sea-level rose less dramatically between 13,000-11,000 yr BP, with maximum values of sea-level rise ranging from ca. 15 to 50 m above present. The magnitude of this difference was probably due to the greater ice loading on the Strait of Juan de Fuca and Puget Sound areas of the Peninsula (Thorson 1980). Fladmark (1975) noted a similar phenomenon in tracing the differences in Late Pleistocene/Early Holocene sea-level history of the Queen Charlotte Islands and the adjacent region of the inner coast:

The Queen Charlotte Island curve stands in marked contrast to mainland sequences, and in many cases is diametrically opposed. This is felt to be a result of distance from areas of major glacial loading, producing either: (a) greater concordance between the pre-10,000 yr BP portion of the Queen Charlotte curve and general eustatic trends, or (b) forebulge effects causing crustal displacements of opposite sign to those in adjacent regions of maximum isostatic depression.

The fact that outer and inner parts of the coast do have disparate late Pleistocene sea-levels is supported by variation in geographic location of peak glacial accumulations (Fradmark 1975: 170).

Following deglaciation, however, a rapid emergence began to occur, probably as a result of the thinness of the ice sheet in the region as well as the relative closeness of the region to the receding ice mass. A similar rapid postglacial emergence occurred along the Maine coast in the northeastern US, probably as a result of the same combination of forebulge effects and a thin remnant ice mass (Yesner 1983, Crossen 1984, Stuiver and Borns 1975). By ca. 9,250 yr BP, sea-level had fallen to its maximum postglacial level, on both the Northeast and Northwest Coasts. In Maine, sea-level fell to as much as 40 m below present levels, but the magnitude was not as great on the Washington coast because of the smaller load of the Cordilleran ice mass. However, data from the inner coast of Puget Sound as well as the Fraser Lowland (based on dates on buried peats) suggests that sea-level did fall as much as 11 m below present (Larsen 1971). Similar data for the outer coast of the Olympic Peninsula, however, suggest that sea-level may have fallen only to 1-2 m below present levels. This appears to be substantiated by the existence of wave-cut platforms at approximately that level (cf. Baldwin 1939). Again, this variation in sea-level histories was probably due to differences in late glacial ice loading. Archaeological sites dating to this time period should be potentially *detectable*, although they would likely be affected by subsequent sea-level rise, depending on the area in question. By 7,000 yr BP, however, the effects of isostatic rebound had greatly diminished.

Between 7,000 and 4,000 yr BP, cool, moist conditions gradually began to increase in the western region of the Olympic Peninsula. Pollen diagrams from the Hoh River, Bogachiel River, and Humptulips areas indicate that hemlock and spruce were gradually increasing and cedar was migrating into the region, while at the same time alder and Douglas fir were gradually declining. These gradually cooling temperatures, however, did not affect the magnitude of eustatic sea-level rise. In fact, eustatic sea-level rise now began to outstrip isostatic effects and led to a rapid submergence of shorelines. Because isostatic effects had been greater on the inner coast, the rapidity of early Holocene coastal submergence between 9,000 and 4,000 yr BP may also have been greater on the inner coast. Nevertheless, because postglacial sea-levels had fallen only a meter or so along the outer coast, early Holocene sea-levels in that area probably rose to a point significantly above their modern level.

At this point, the sea-level histories of the eastern and western Peninsula took on a very divergent character. As Thompson (1978) noted, the early Holocene period from 9,000-4,000 yr BP is the most difficult to deal with in terms of reconstructing sea-level histories, but accumulating data from a variety of sources indicate the magnitude of the divergence

between the outer and inner coasts (e.g. the east coast of Puget Sound). These data suggest that, following a higher-than-present mid-Holocene sea-level stand, sea-levels have continued to fall along the outer coast, while they have continued to rise along the inner coast. That is, a mid-to-late Holocene pattern of submergence characterized the inner coast, while a pattern of emergence characterized the outer coast.

Active uplift, tilting, and faulting of the coastal margin is indicated in terrace formations along the outer coast, from Copalis north to Cape Flattery. Indications of this uplift have been known since the turn of the century. Uplift and tilting affects Tertiary and Quaternary deposits alike, and has probably been occurring since Tertiary times. The evidence, reviewed in the 1930's by Baldwin (1939), suggests that the uplift has been continuous throughout this period, and is not solely the result of Pleistocene isostatic phenomena. The tilting and faulting of the sediments, in particular, suggests the importance of tectonic factors. Today we know that the direction of tilt follows the subduction of the Juan de Fuca Plate and is related to tilt occurring in the adjacent Olympic Mountains (Adams et al. 1980). Furthermore, tilting and faulting occurs within Holocene as well as Pleistocene sediments.

Unfortunately, few examples exist for raised beaches that would indicate the nature of maximum mid-Holocene sea-level rise and subsequent emergence or uplift (falling sea-level). Although there is evidence for raised beaches in sections between Kalaloch and the Hoh River as discussed by Heusser (1972) and Florer (1972), no sections have yet been found that yield radiocarbon dates younger than 16,700 yr BP. In the area near Winslow, however, on the eastern side of the Peninsula, however, Gower (1978) has recently recorded evidence for "uplifted shallow-water marine sand and gravel deposits containing mollusks and some wood." He further notes that "mollusk shells collected 4.9 m above present sea-level yielded a radiocarbon date of $3,260 \pm 80$ yr BP," while "wood from about 2.4 m above sea-level was radiocarbon dated at 4530 ± 90 yr BP." There is also some evidence of wave-cut scarps in the region between Cape Flattery and Point Grenville, which was noted as early as the turn of the century (Arnold 1906). Similar wave-cut scarps on western Vancouver Island have also been used as substantiating evidence for higher mid-to-late Holocene sea-level stands and subsequent coastal emergence.

Western Vancouver Island, which appears to show a similar profile of Holocene emergence as western Washington (or the Queen Charlotte Islands), has also produced a number of other types of substantiating data for this emergence (Clague et al. 1982):

(1) A number of elevated beaches have been recorded, including a 7 m beach at Yuquot radiocarbon-dated to 4,230 yr BP; a 3 m beach at Tofino dated to 1540 yr BP; and a 1 m beach at Hesquiat Harbor dated to 680 yr BP.

lake cores, including one from Village Lake on the Hesquiat Peninsula measured at 3 m elevation and dating to 2,760 yr BP.

(3) Uplifted cave deposits have been identified, some of which include archaeological materials. The latter includes two sites on Hesquiat Harbor ca. 2 m above sea-level which date to ca. 1300 to 1700 yr BP.

Taken together with the data on terraces of the coastal margin, these data suggest that uplift has taken place throughout the Holocene, but that only in the mid-to-late Holocene period were its effects observable as first isostatic and then eustatic phenomena no longer came into play. This tends to contradict earlier models which suggested that tectonic factors were only locally important on the Southern Northwest Coast, and that east-west differences in Holocene sea-level histories were best explained as a byproduct of isostatic phenomena. In order to demonstrate that tectonics are responsible, however, it is necessary to do two things: (1) to demonstrate that such processes are still occurring, and (2) to develop a general model to explain them.

A number of Canadian investigators (Clague et al. 1982, Vanicek and Nagy 1980, de Jong and Siebenhauer 1972) have demonstrated that such processes are occurring on the west coast of Vancouver Island. Using data from precise relevelling surveys along the coast as well as from secular trends in tides, they have suggested a current sea-level fall ranging from ca. 1.6-1.9 mm/yr, e.g. at Tofino. Interestingly, this is exactly the same range of values - 1.6-1.9 mm/yr - that one gets if one plots recently falling sea-levels based on the physical evidence from the raised beaches, elevated marine/freshwater boundaries in lake cores, and uplifted cave deposits! Balazs of the National Ocean Survey, NOAA, has recently published some preliminary reports which suggest that for Neah Bay similar rates of emergence may have been characteristic of the recent past, based again both on precise relevelling surveys and secular tidal changes. Encouraged by these reports, I obtained from NOAA a complete profile of recent relevelling work on coastal benchmarks associated with tidal gauges for Neah Bay, Mukkaw Bay, and Toke Point (Willapa Bay) along the outer coast. According to my calculations for Neah Bay, benchmarks set in 1954 demonstrate an average sea-level rise of .14 feet or 1.94 mm/yr, while benchmarks set in 1959 show an average sea-level rise of .11 feet or 1.97 mm/yr. Simultaneously, tidal data from the Neah Bay station at Fish Wharf show a secular change of .11 feet in 20 yr or 1.67 mm/yr. In addition, tidal data for Toke Point show an even greater rise of 2.17 mm/yr, although these are based on a much shorter interval (10 yr). However, these data all fall well within the same range previously established by Clague et al. (1982) for the west coast of Vancouver Island. Furthermore, they compare favorably to an estimate of 1.50 mm/yr uplift which can be derived from the raised beach on the east coast of the Peninsula. According to Croes and Blinman (1980), there are also indications that uplift has taken place at the Hoko River site:

Modern counterparts of this surface [on which the Hoko site is constructed] lie approximately 1.5 m lower in elevation, although they are apparently identical to the laminae in other respects. A major change in river discharge could conceivably account for the elevation differences, but it is unlikely that the sedimentological resemblances would be maintained. A more parsimonious explanation is that the base level of the river (sea-level) has fallen approximately 1.5 m since the site was formed. Independent evidence of recent relative sea-level change (probably tectonic uplift) has been accumulated by Dr. Parke Snavely, Jr., USGS, at Clallam Bay, approximately 8 km to the east of the Hoko River mouth (pers. comm.). His preliminary estimate of 2 m of change in the past 2,000 years is in reasonable agreement with the Hoko River model (Croes and Blinman 1980: 83).

These data suggest that late Holocene uplift in the northern Olympic Peninsula region has been occurring at the rate of 0.5-1.0 mm/yr. These data are very distinctive from the data for the inner (mainland) coast of eastern Puget Sound, which shows a current rate of submergence of ca. 0.9 mm/yr (Balazs and Holdahl 1974, Aldo and Balazs 1979). Even greater rates of subsidence have been calculated for the inner British Columbia coast, e.g. at Port Atkinson which shows a rate of subsidence of 1.2-1.3 mm/yr (Clague et al. 1982, Fladmark 1975). The rates of inner coast submergence, furthermore, correlate well with the submergent Holocene curves produced by Larsen (1971) and others, and with the numerous observations of submerged archaeological sites on the inner coast.

The general theory which subsumes the above observations is, of course, plate tectonics. The observed emergence of the outer coast and submergence of the inner coast has been attributed to the pattern of subduction of the Juan de Fuca plate, which is subducting below Puget Sound and across the channel subdividing Vancouver Island from the adjacent inner coast. The fault zones associated with the subduction of this plate have been traced in detail (Gawer 1978), and seismic studies and other geophysical investigations have related these fault patterns to magnetic and gravity anomalies in the Juan de Fuca Strait and Puget Sound (Danes et al. 1965, Rogers 1970, MacLeod et al. 1977).

What are the consequences of these data for the archaeological site record from the Olympic region? Sites older than 4,500 yr BP, and located less than 5-7 m above the modern coastline, would likely have been obscured by mid-Holocene sea-level rise. Since that time, however, it is unlikely that coastal sites would be destroyed by that phenomenon; any site destruction would be promoted solely by erosional processes. Thus, one would expect a relatively complete record of mid-to-late Holocene archaeology in the outer coastal zone. This would be particularly true for the region extending south to Point Grenville, where an uplifted terrace ranging to 100 m above modern sea-level might contain evidence of older sites. Indeed, preliminary data provided by Gary Wessen suggest that older sites on the outer coast, contain-

ning "Olcott" components and dating at least in excess of 2,000 yr BP, are associated with "second" or "third" terraces behind the current beach. Examples of this include Sand Point (45CA201), which is found on an 18 m high marine "second" terrace behind the beach. Wessen has recently produced bracketing dates of 2270 and 1600 yr BP for this site, but the site at one time did produce a radiocarbon date of 6,065 yr BP (Wessen 1981, 1984). A second example would be the Norwegian Memorial site (45CA252), a 1.5 m deposit located on a terrace 12 m above, and ca. 100 m behind, the modern beach. A third example would be the Tongue Point site (45CA16) on a small terrace at Crescent Beach campground, which has produced three radiocarbon dates ranging from 2220 to 2565 yr BP). These sites and others show potential for clarifying the relationship between earlier occupations of the Olympic coastal zone and the divergent sea-level history of this area.

Certainly, as Matson (1976) has stressed, sites like Glenrose Cannery suggest that "Olcott"-related sites may have had a maritime orientation in mid-Holocene times. Grabert (1975) has developed a hypothesis of increasing maritime orientation for the eastern side of Puget Sound, and a similar framework has also been applied by Bergland (1983) to the Olympic Peninsula region. Bergland classifies the Hoko River wet site and other sites containing earlier (pre-2,000 BP) components (such as at Sand Point) as part of an "Early Maritime Tradition," suggesting increased specialization on marine resources over time. One thing, however, is clear: we cannot explain any relative absence of early coastal sites in comparison to the much larger numbers of late prehistoric coastal sites simply by the effects of a rising sea-level which has drowned a record of earlier-existing coastal sites! Another thing is also certain: we cannot use stabilization of river gradients and development of "climax" salmon runs as the evolutionary model to explain that apparent proliferation of late coastal sites, at least in the Makah region of the outer coast. Such coastal stabilization might help explain an increased availability of shellfish resources, as I have suggested for the development of late prehistoric middens on the Maine coast, but this requires that we view the development of shell middens as an independent, not a dependent process (on development of climax fish runs). In general, better evolutionary models need to be developed in order to explain the late prehistoric proliferation of coastal sites. Optimal foraging theory, for example, may have a role to play in explaining why shellfish resources were utilized relatively late. Perhaps stress on big game resources was a relevant factor here. Models involving factors such as population growth may need to be called upon to explain an increasing maritime orientation in an area where subsistence was largely focused on migratory whales, sea-mammals, and offshore, deep-water fish.

What we need now are two things: to develop a methodology to relate these earlier occupations to observed sea-level history, and to develop better models to relate these observations to evolution of prehistoric cultures in the outer coastal zone. To

this end, four specific methodological recommendations might be offered:

(1) to further prospect for earlier sites on well-preserved geomorphic features along the coastal zone, particularly uplifted marine terraces;

(2) to further prospect for caves which may have preserved earlier coastal sites in uplifted environments;

(3) when such sites are identified, to attempt to uncover any sedimentological evidence of former beaches (e.g. in the form of basal sterile soil in the midden deposits), and to relate the position of such beaches to modern sea-level; and finally

(4) to undertake further coring work in the outer coastal zone in an attempt to obtain better dates on Holocene sea-level history in this region.

Simultaneously, we need to improve our cultural-evolutionary models for the outer coastal zone. In any case, I think that we can now begin to develop such models within the context of an east-west differentiation in late Holocene sea-level history, whose primary determinant appears to be plate tectonics.

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Abstract:

An accepted general model for sea-level history in northwestern Washington has been developed by Larsen and applied to coastal archaeology in the region. This model involves a late Holocene submergent coastline obscuring evidence of early-to-mid Holocene sites, explaining their absence in the coastal region. However, recent geological data based on releveling surveys suggest a very different model of sea-level history for the outer Washington coast, involving an uplifting coastline that existed throughout much of the Holocene. Absence of early coastal sites in that region thus cannot be explained by the effects of sea-level rise; an alternative evolutionary model for regional cultures is considered.