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Ghost Walkers of Turtle Island: Submergence, Ecology and Coastal Migration into the Americas.

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ABSTRACT

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Master of Philosophy

GHOST WALKERS OF TURTLE ISLAND: SUBMERGENCE, ECOLOGY AND COASTAL MIGRATION INTO THE AMERICAS.

By James Martin Carey

North and South America were the last great landmasses to be inhabited by human beings. An investigation of a sample of sites claimed to be older than 11200 BP will show that early human occupation of the Americas occurred earlier than 14000 BP and that the distribution of these sites gives no indication of the route by which the Americas may have been settled. It is shown that coastal migration via the West Coast is a theory that, while believable, is beset by the problem of lack of evidence predating 11200 BP. Why would coastal inhabitants leave no trace of their existence? The use of submergence to explain site absence is explored using West Coast sea level measurements. It is shown that the effects of sea level rise differ depending on the proximity of the glacial ice-sheets and the gradient of the coast against which this rise occurs. The effects of sea level rise are shown decline towards the south so that the likelihood that submergence has affected sites here is slim.

Modern environmental features on the North American West Coast are analysed from maps of the coastline. Resource data and topographic features are compared along the coast using arbitrary cells that allow identification of areas where change occurs. The use of modern data is tested using local evidence for the same features since the LGM. The evidence shows that since the LGM each part of the coast experienced environmental changes yet some of the constraining data did not change and had the effect of limiting the areas where change occurs to near where modern changes were observed. It is concluded that if coastal migration is a viable theory then the groups to first populate California must have hugged the coastline, utilising the marine resource and rarely venturing inland thus leaving little trace on currently subaerial landscapes.

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Introduction.

...the turtle swam forward and said, "Use my back to bear the weight of this piece of Earth. With the help of Kitchi-Manitou, we can make a new Earth." Nanaboozhoo put the piece of Earth on the turtle's back. Suddenly, the wind blew from each of the Four Directions, The tiny piece of Earth on the turtle's back began to grow. It grew and grew and grew until it formed a mi-ni-si', or island in the water. The island grew larger and larger, but still the turtle bore the weight of the Earth on his back. Nanaboozhoo and the animals all sang and danced in a widening circle on the growing island. After a while, the Four Winds ceased to blow and the waters became still. A huge island sat in the middle of the water, and today that island is known as North America. (Ojibway Creation Tale).

The continents of North and South America were the last great landmasses to be inhabited by human beings. It was not until after Africa, Europe, Asia and even Australia had been inhabited by modern humans that these two continents were explored and colonised. This isolation is explained by the great ice sheets and massive oceans that formed obstacles to migration. So it was relatively late in human history that the first people appeared in America yet the traces of their first movement have yet to be found. How did these people navigate their way around the obstacles that had prevented access for so long and when they did how did they adapt to the land they found?

The age of the first American settlement is controversial, yet some understanding of it is essential to understand what sort of obstacles may have existed during the first peopling and how old sites in the Americas could be. An investigation of a sample of sites claimed to be older than 11200 years BP will show that early human occupation of the Americas occurred as early as 14000 year BP and that the distribution of sites within the sample analysed gives no clear indication of the route by which the Americas may have been settled. Following this the main theories of American colonisation are discussed including the emergence of mammoth tracking hunters from an ice free corridor, circumvention of the ice sheet via the West Coast by fish eating whalers and colonisation from the Iberian peninsula by Solutrean tool wielding mariners. It is shown that coastal migration via the West Coast is a theory that, while believable, is beset by the problem of lack of evidence predating 11200 years BP. Why would people living on the coast leave no trace of their existence? Could the 'Timewalkers' of human prehistory be ethereal ghosts that inhabit landscapes but leave no trace, ghostwalkers perhaps? Explanation of this lack of evidence often focuses on the destruction of sites along the coast by rising sea levels or the unsuitability of the environments encountered for supporting populations.

The use of submergence as an explanation of site absence is explored using sea level measurements from the West Coast. It is shown that the effects of sea level rise differ depending of the proximity of the glacial ice-sheets and the gradient of the coast against which sea level rise occurs. In addition, seismic events since the Holocene increase the likelihood that the central section of the coast would have decreased preservation or discovery of sites. The differing effects of sea level rise are shown to be greatest in parts of the north and decline towards the south so that due to the cliff-like coast and distance to the nearest glaciation in California the likelihood that submergence has affected sites here is relatively slim. This means that an alternate explanation for the lack of early Californian sites must be sought.

Environmental features on the North American West Coast are analysed using a method of extracting information from maps of the coastline. Modern climate, vegetation, geology and marine resource data as well as topographic features are compared along the coast using arbitrary cells that allow visual identification of areas where change occurs. From this it is shown that the coastal resource does not form one homogenous corridor but several adjoining corridors where groups might have to change subsistence strategies to continue southward movement. The use of modern data is tested using locally acquired evidence for the same environmental features since the Last Glacial Maximum. The evidence shows that over the millennia since the Glacial Maximum each part of the coast experienced many environmental changes yet some of the constraining data which did not change, such as elevation, had the effect of limiting the areas where change occurs to near where modern changes were observed. It is also shown that while much of the Californian area was similar to today the marine resource was vastly increased compared to today thanks to a combination of rocky shores due to low sea levels and increased upwelling within the Californian current due to southward shift of the Pacific jet stream. This implies that groups that reached the West Coast of North America in time to colonise sites inland by 14000 years BP would have had time to adapt to the Californian environment and so there must be the possibility of sites existing in this region if coastal migration occurred. It is concluded that if coastal migration did occur then the groups to first populate California must have hugged the coastline, utilising the marine resource and rarely venturing inland thus leaving little trace on currently subaerial landscapes. The potential for such groups to leave traceable remains in submerged contexts on the Californian coast is then postulated as the next major issue that needs to be resolved to prove coastal migration was the means by which the ghostwalkers first inhabited Turtle Island.

Chapter 1. The Clovis Conundrum.

What constitutes the earliest evidence for human presence in the Americas? This question has beset American archaeology from its conception to the present day. In this chapter, the earliest acceptable sites in the Americas will be discussed and the ways in which scientists measure whether a site is real and correctly dated are described. Beginning with the complexes characterised by distinctive fluted points first discovered at Folsom and Clovis this chapter will outline the theories and debate surrounding the timing of the first entry of human beings into the Americas. It will then examine a dozen sites of supposed antiquity to establish the depth of time within which human colonisation took place. This will represent an original effort to place the human peopling of the Americas in a chronological framework that can form a starting point for further exploration. The review of published sites will show that human antiquity in the Americas predates 14255 BP and that it is distributed through a wide range of environment types over the whole of two continents.

As in comedy, in archaeology timing is everything. In order to orient the later examination of early sites within a disciplinary setting a brief history of discovery and research in American prehistory is required. Discussion of when the first humans entered the Americas must include the remains found by George McJunkin, former slave and foreman of the Crowfoot Ranch near Folsom, New Mexico. In 1908 McJunkin discovered the remains of fossil animal bones in the heavily flood damaged Wild Horse Arroyo. After McJunkin's death in 1926, a crew working for the Colorado Museum of Natural History attempted to recover a bison skeleton and in doing so discovered the first Folsom point. Excavation that year and the following uncovered more points and a panel of respected scientists including Barnum Brown, Frank Roberts and Alfred V. Kidder quickly decided that the points were definitely deposited at the same time as the bison. This conclusion not only proved human occupation of the Americas was of some antiquity but led to the search for other similar sites. In a gravel pit near Clovis, New Mexico Folsom points and bison bones were found above a layer containing similar points and mammoth bones. These points were the oldest so far found in the Americas. Later sites such as the Lehner, Blackwater, Naco and Ventana sites in Arizona, as well as the Domebo site in Oklahoma and the Dent site in Colorado would establish the correct age for this assemblage.

The age of the Clovis assemblage was not established immediately. In 1959 Haury, Sayles and Wasley published the results of one of the first Clovis sites to be excavated and dated using the new radiocarbon method (1959: 2 – 30). The Lehner site was located near Hereford, Arizona in the San Pedro Valley. The site is a kill site where thirteen Clovis type points were found in association with the remains of nine immature mammoths and elements of horse, bison and tapir. Eight butchery tools were also found, as were two hearths (ibid: 2). The projectile points carried the distinctive fluting that characterises Clovis points, and for which a function has not been agreed. The geology of the site indicated a date of 13000 years old (Antevs 1959: 34). However, an interesting point about the Lehner site was the radiocarbon dates from the hearths. Three of the dates from the Arizona radiocarbon laboratory were obviously too young to match the geology at 7205 ± 450 BP, 7022 ± 450 BP and 8330 ± 450 BP. Removal of contaminants and subsequent re-dating produced dates of 10900 ± 450 BP and 12 000 ± 450 BP averaging 11850 ± 50 BP (Haury et al 1959: 24). Samples from the nearby Copenhagen and Michigan caves gave dates of 11180 ± 140 BP and 11290 ± 500 BP.

In 1964 Haynes published the radiocarbon results from five of the six Clovis sites where Clovis points had been found in situ (1964: 1408 – 1413). The Dent site in Colorado gave a date of 11200 ± 500 BP. Blackwater No. 1 gave a date of 1170 ± 360 BP and Naco in Arizona was dated to 9250 ± 300 although this was using the same solid carbon method of dating that gave misleading results at Lehner and thus the dates were justifiably dubious. Domebo in Oklahoma was dated to 10123 ± 280 and 11045 ± 647 BP, the latter date being supported by Haynes (ibid: 1410). The final site was Ventana Cave in Arizona that had a date of 11300 ± 1200 BP. Haynes' conclusion was that Clovis projectile points were restricted to sediments between 11000 and 11500 years old and underlying sediments were without evidence of human occupation. Haynes theorised that a population coming across a landbridge from Siberia could have passed through an ice-free corridor in the northern glaciation. From here, they could have populated the North American continent within 1000 years (ibid: 1412).

Blitzkrieg.

The rapidity of population expansion hypothesised by Haynes seems astonishing yet found support in Paul Martin's 1973 article that describes a model of how such expansion may have occurred. Martin hypothesised that the extinction of 31 genera of large mammals in the New World that died out at the end of the last ice age could have been brought about by an influx of hunter-gatherers (1973: 969 – 974). These populations would have entered via an ice-free corridor approximately 11500 years BP and expanded across the whole of North America within 350 years. Over a further 1000 years, they would have spread down to the tip of South America populating the whole of the continent by 10500 years BP (Figure 1). Since this hypothesised expansion caused the destruction of so many forms of the large mammal population, it inevitably must have shrunk following its initial high. Archaeologically this process would leave few kill sites since coexistence of humans and individual large mammal species would have only occurred for a single decade.

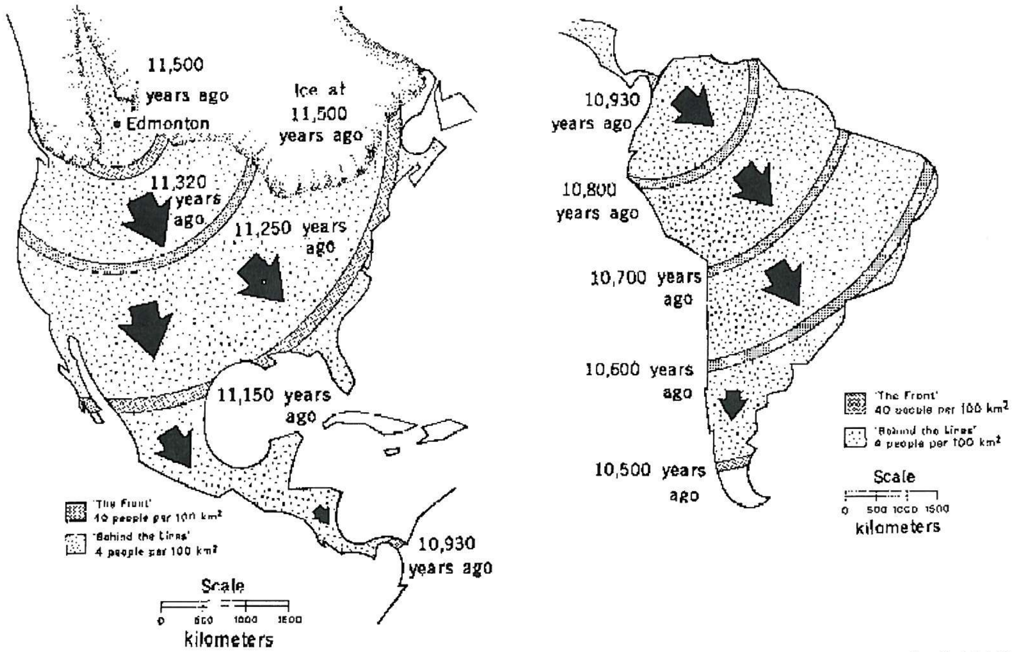


Fig. 2 (left). Sweep of the front through North America. As local extinction occurs, the hunter moves on. Fig. 3 (right). Sweep of the front through South America. Local extinction accompanies passage of the front. (Figures 2 and 3 are not drawn to scale.)

Figure 1. Blitzkrieg expansion (Martin 1973: 969 – 974)

In the most often referred to rebuttal to the "Blitzkrieg" theory Whitley and Dorn provided an in depth test of Martin's model as well as that put forward by Haynes in 1966 which allowed for a longer timespan between entry into North

America and the noticed spread of Clovis culture (Whitley and Dorn 1993: 626 – 647). Whitley and Dorn also tested Hassan's model from 1981 that specified a much longer migration, around 8000 to 10000 years and therefore an entry of 25000 to 20000 years ago. Whitley and Dorn's work highlighted some problems with Martin's assumptions and subsequent results. Firstly, there are plausible dates for pre-Clovis sites such as Monte Verde, Chile and Pedra Furada as well as their own dates from dating rock varnish implying the Clovis complex was predated by earlier occupation and making the initial colonisation date Martin specifies obsolete. Second, carefully evaluated South American sites could not feasibly have been founded within a Clovis first framework since the population growth Martin specifies is not applicable to early hunter-gatherers in the Americas. Martin's theory is based on population growth of 3.4% per year observed in Pitcairn Island populations and is too high for non-sedentary hunter-gatherer populations. Haynes's population growth figures are lower but his occupational spread rate of 6.4 kilometres per year does not take into account the variety of environment types that expanding populations would have had to negotiate and adapt to. The third problem Whitley and Dorn highlight is that mitochondrial DNA reconstructions of genetic divergence support pre-Clovis population spread. However there are problems with Whitley and Dorn's analysis.

Steele, Gamble and Sluckin have produced an exploration of Paleo-Indian expansion into South America which refutes Whitley and Dorn's assertion that Clovis ancestry for South American sites is impossible given feasible rates of population expansion (1998). Steele et al updated the dates or calibrations used by Whitley and Dorn and added an extra site as a replacement for a less securely dated site in the same tradition. They also calculated the distances for each site, both Great Circle and road distances, assuming roads follow the most likely routes through the landscape solving the problems of the homogenous landscape postulated by both Martin and Whitley and Dorn. They then performed a least squares regression analysis of the relationship between dates and distance from El Paso in North America. They found that if they discarded the site of Monte Verde, one of Whitley and Dorn's examples that challenged Martin's model, they could produce a correlation between site age and distance, in which site age decreased with movement south. They conclude that if Monte Verde could be safely discarded the South American sites can feasibly be settled post-Clovis. However, they acknowledged the need for more accurate radiocarbon dates on South American sites to estimate their true age.

Whitley and Dorn's point that rapid expansion cannot happen is refuted then but the two other points they raised must be addressed. They asserted that mitochondrial DNA reconstructions of genetic divergence support pre-Clovis population spread. Genetic research points to a very different date for the early occupation of the Americas than the Clovis first hypothesis suggests. The conclusion Cavalli Sforza reached from genetic evidence suggests 32000 years ago being the point where the migrant population broke from its parent group (Cavalli Sforza 2000: 62:63). While certain aspects of genetic research in the Americas are convincing, for example the Asian origin for Paleo-Indian populations, interpretations of the timings are problematic. The Wallace group of geneticists place an initial colonisation between 21000 and 42000 years ago based on mtDNA lineages, entirely different from the date of 15000 years ago put forward by the Greenberg group analysing linguistics. This, though, is different from Joanna Nichols date of about 35000 years ago based on language diversity (Nichols 1992:228). Steele et al's paper questions Whitley and Dorn's use of mtDNA assertions because they believe the assumptions about the rate of evolution of mtDNA are questionable (1998). The genetic question is not yet resolved then.

The remaining point Whitley and Dorn made is that of pre-Clovis sites in the Americas (1993: 642). If sites exist in the Americas that predate Clovis then the whole of Martin's model and any other Clovis first models must be revised. The Whitley and Dorn rock varnish dates have been shown to no longer be reliable but it is the presence of other claims for pre-Clovis dates that keeps the debate about the timing of first people in the Americas open.

Early Sites

McJunkin's discovery at Folsom came about during a period of fierce scientific debate on human presence in America during the Pleistocene was hotly debated. It was only when the Folsom points could be observed in situ that irrevocable proof of Pleistocene antiquity for human presence in the Americas could be supplied. The reason this site and none before could do so was because it met criteria laid down by Thomas Chamberlain in 1903 that specified what a valid site would contain.

> *The primary requirement is a human skeleton, or an assemblage of artefacts that are clearly the work of man. Next, this evidence must lie in situ within undisturbed geological deposits in order to clearly demonstrate the primary association of artefacts within stratigraphy. Lastly, the minimum age of the site must be demonstrable by primary association with fossils of known age or with material suitable for reliable isotopic age dating* (Haynes 1969: 714).

The Folsom site met these criteria, as do many Clovis sites. However, any site that is supposedly pre-Clovis must also meet such criteria. Many sites are proposed as pre-Clovis but refuted on these criteria. Krieger, MacNeish and Morlan have all produced lists of sites they believe to predate Clovis yet comparison of these lists shows that sites rarely appear on more than one list implying problems with their validity as outlined by Chamberlain (Meltzer 1993: 62). Additionally, some believe that not all Clovis sites would meet these criteria if put to the test. In a strict application of the criteria to Clovis sites Roosevelt et al, throw out all but five High Plains Clovis sites that are the only ones they say meet the criteria. Based on these sites they place the Clovis horizon at 11200 to ca. 10800 BP (Roosevelt et al 2002: 202). While this means that some sites in South America may be contemporaneous with Clovis and thus Clovis was not first, it also proves Clovis sites are valid rather than disproving them. As Meltzer states '*The point, of course, is that Clovis sites long ago met the criteria.*'

So far, little consensus has been reached on the existence of pre-Clovis sites in the Americas with the possible exception of the Monte Verde II site in Chile. In order to study the first occupation of the Americas it is first necessary to establish what the earliest possible date for human presence may be. The aim is to establish a chronological baseline after which human occupation of the Americas was probable. Instead of analysing all sites purporting to be pre-Clovis to create a comprehensive review, twelve sites in both north and South America have been selected. These sites have been published to an extent where analysis is possible from the literature and their locations are shown in Figure 2. While there are more available for discussion for the purposes of this dissertation it is useful to select a sample of the current sites that may predate Clovis and see which, if any, meet Chamberlain's criteria. This will allow questions of routes and migrations to be addressed within a logically argued time-scale.

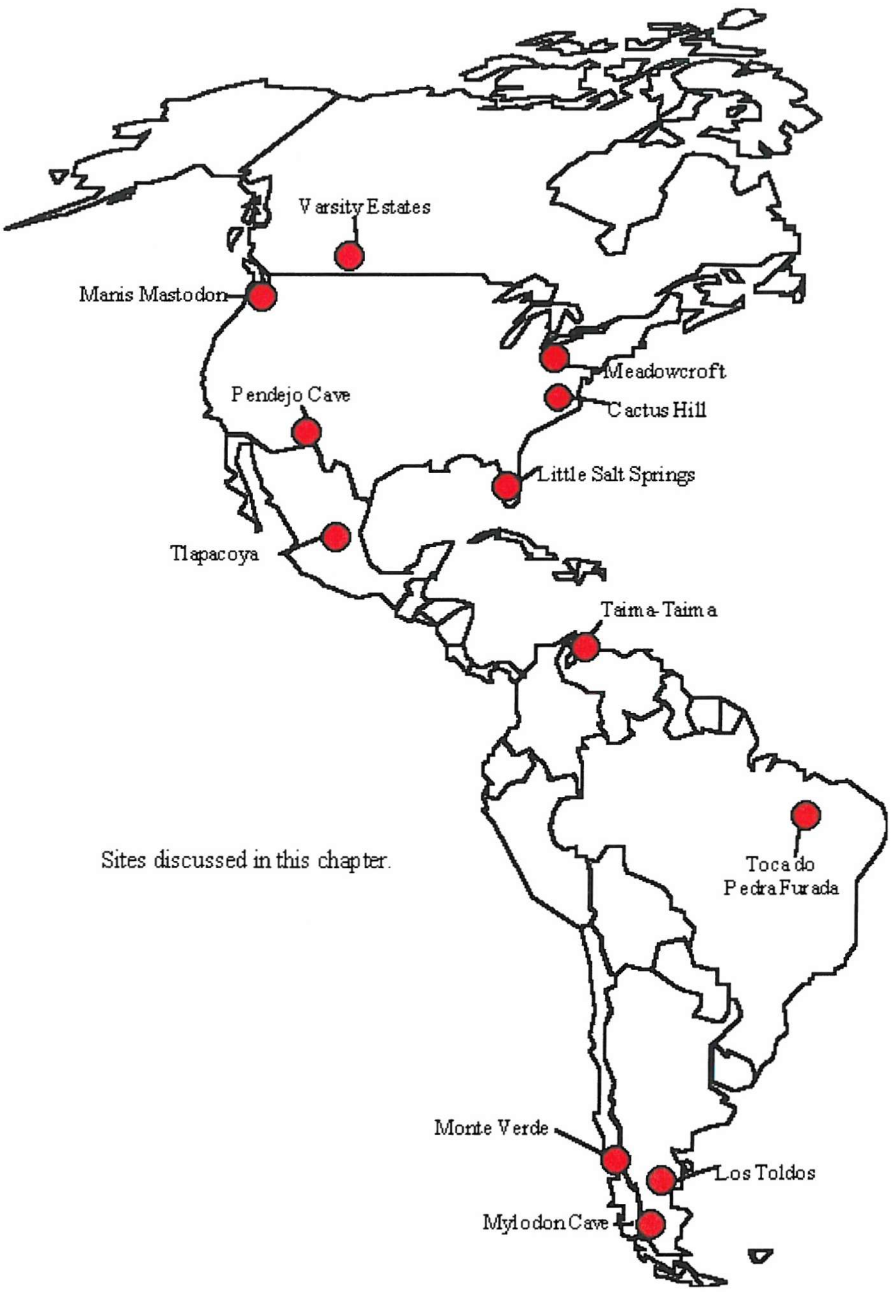


Figure 2. Map of sites discussed in Chapter 1.

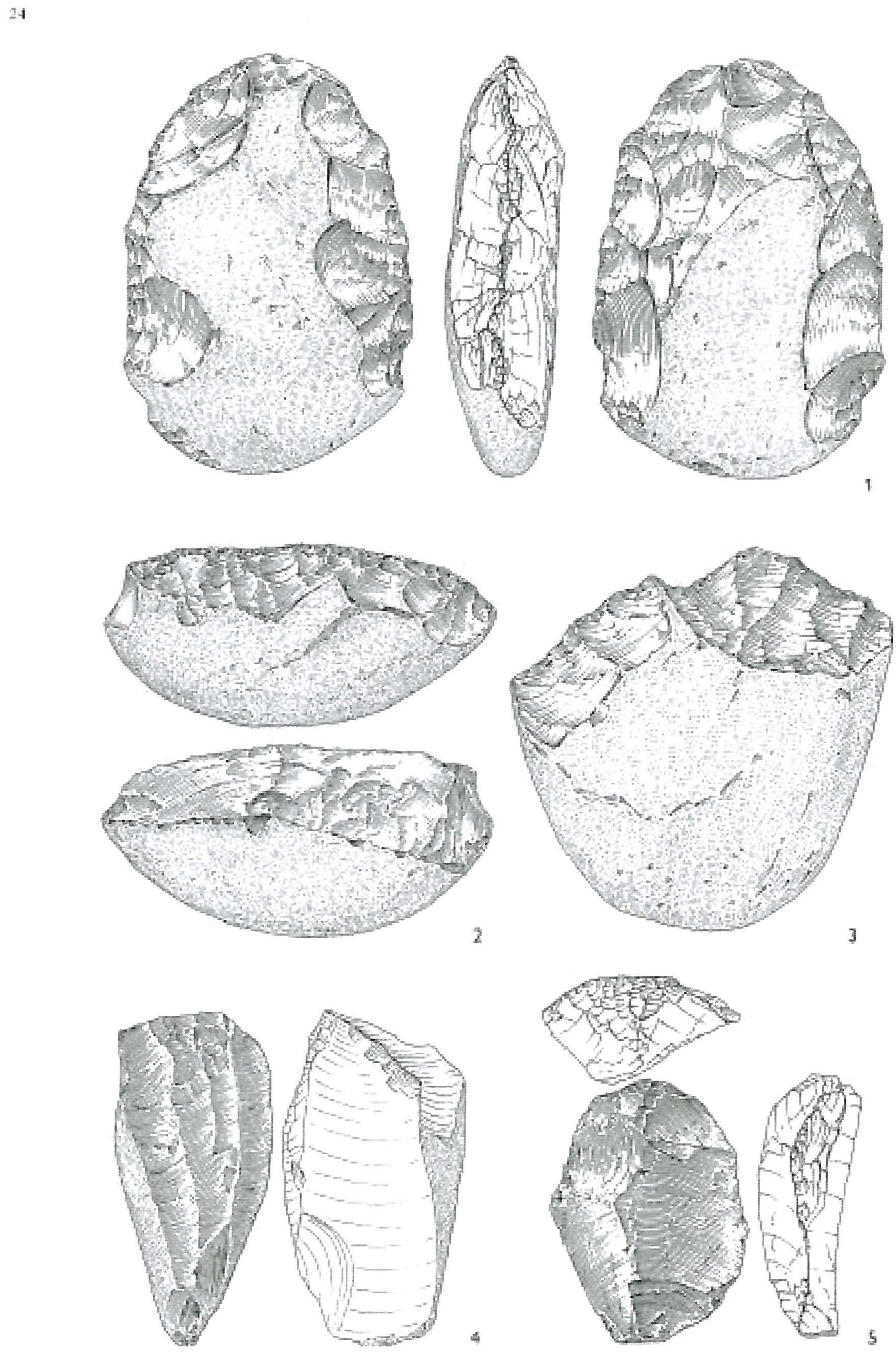
Early Sites in the Americas.

Varsity Estates. Alberta.

The Varsity Estates site is located in Alberta, Canada, 23 metres above the current course of the Bow River. It consists of two sites known as Varsity Estates and Silver Springs of which Varsity Estates has been excavated in detail. At Varsity Estates Jiri Chlachula describes two series of stone artefacts (1996:298). The first series consists of 16 flaked pieces; the second consists of 40 artefacts found in glaciolacustrine deposits. Chlachula believes the first series were disturbed by glacial advance implying a preglacial date for them. The second series he believes to be undisturbed since they have a "uniform and fairly fresh appearance without any apparent traces of fluvial aeolian abrasion on flaked faces and edges" (Chlachula 1996: 298). Also the assemblage was found within an area of $2m^2$. There is no direct dating associated with the first or second series deposits. There are dates of 21330 ±340 BP for glacial advance around 300 kilometres to the north in Edmonton, central Alberta and cosmogenic 36Cl dates of 17000 to 21000 BP from glacial erratics 100 km south of Calgary. Chlachula believes that these dates provide a chronology for glacial advance in this area (2002: 27). This, he argues, means both series must have been deposited in the period ca. 21000 to 17000 BP and subsequently the area was re-glaciated (2002 28).

The illustrations of some of the upper series assemblage make a persuasive case for their artefactual nature since some look like obviously humanly modified tools (Figure 3); however Young *et al* question their authenticity. According to Young *et al*, the tools are not necessarily humanly modified and the reconstruction of the glaciation and environment Chlachula uses is suspect (1998: 449 – 453). Rather than coalescence of the ice sheets being excluded as Chlachula describes, Young *et al* believe the opposite to be the case and Chlachula's reconstruction is wrong (450 - 451). Young *et al* also state that while uncommon some artefactual objects may have been formed in a dynamic glacial environment quite naturally (453). Chlachula's rebuttal states that since 50 unnamed Old and New World archaeologists believe the artefacts to be real they probably are (1998: 457). However, it is the dating of the artefacts that makes this site suspect according to the criteria laid down by Chamberlain. The geology does not provide a compelling argument that this site was established during an interval between glacial advances and the method of dating is not good enough to meet the criteria for a valid site. While this site is of interest not merely because of its potential for preglacial settlement it offers but also because of the unusual nature of its stone tools it cannot be said to provide irrefutable proof of the kind required.

Figure 3. "Artefacts" from the Varsity Estates Site. (Chlachula 2002: 24)



Manis Mastodon. Washington.

In 1977 Carl Gustafson, Delbert Gilbow and Richard Daugherty visited a site owned by Mr and Mrs. Emmanuel Manis where excavation of a pond had produced two mammoth tusks. Excavators sorting through the backdirt from the excavation located many fragments of bone including a rib with a fragment of bone embedded in it (Figure 4). Subsequently, the archaeologists found a molar that showed the animal remains were those of a mastodon (Gustafson *et al* 1979: 157). Continued sorting of the backdirt found worked bone and a bone object tapered at both ends. Excavations then continued at the site in January, June and August 1978. Gustafson *et al.* believe that while the embedded bone point cannot be taxonomically identified it is not possible that it could be a fragment of adjacent mastodon bones. X-rays showed the point was tapered and embedded to a depth of 2 centimetres in the rib. Healing had occurred after penetration probably for a period of three or four months (ibid: 158). While the recovered rib was not in a stratigraphically intact context, the remains of the Mastodon were found on a layer composed of glacial drift and overlain by a brown alluvium (ibid: 160). Radiocarbon dating of seeds and woods in the bone-bearing layer produced a date of 12000 ± 310 BP and dating of micro-organics produced a date of 11850 ± 60 BP (ibid: 158). There seems little doubt that the rib with the point embedded in it came from the same animal however apart from a flaked cobble spall there were no other obviously human artefacts associated with the mastodon. The flaked cobble spall may or may not be cultural (ibid: 163). In addition to this, the mastodon skull was rotated 180° and was highly fragmented. Gustafson believed this to be evidence of human agency as were cut marks and scratches on bones moved two metres to the north of the main carcass (ibid: 161).

While the rib with the embedded point was found out of context, the obvious association with the rest of the mastodon carcass shows it to have come from the same animal. The nature of the bone point is more ambiguous but it is hard to believe it came about as anything other than the result of human agency. The evidence of healing around the wound show that somehow a tapered bone point was thrust into the flesh of a living mastodon with enough force to penetrate the bone to a depth of 2 centimetres. Since the bone is not obviously a tooth or claw there seems no other explanation for its presence other than human intervention. If the stratigraphic association were intact, this would be irrefutable evidence of human presence in Washington between 11790 and 12310 years BP. Discarding this would seem to be an exercise in pedantry rather than science especially since the flaked cobble spall was found in association with the animal.

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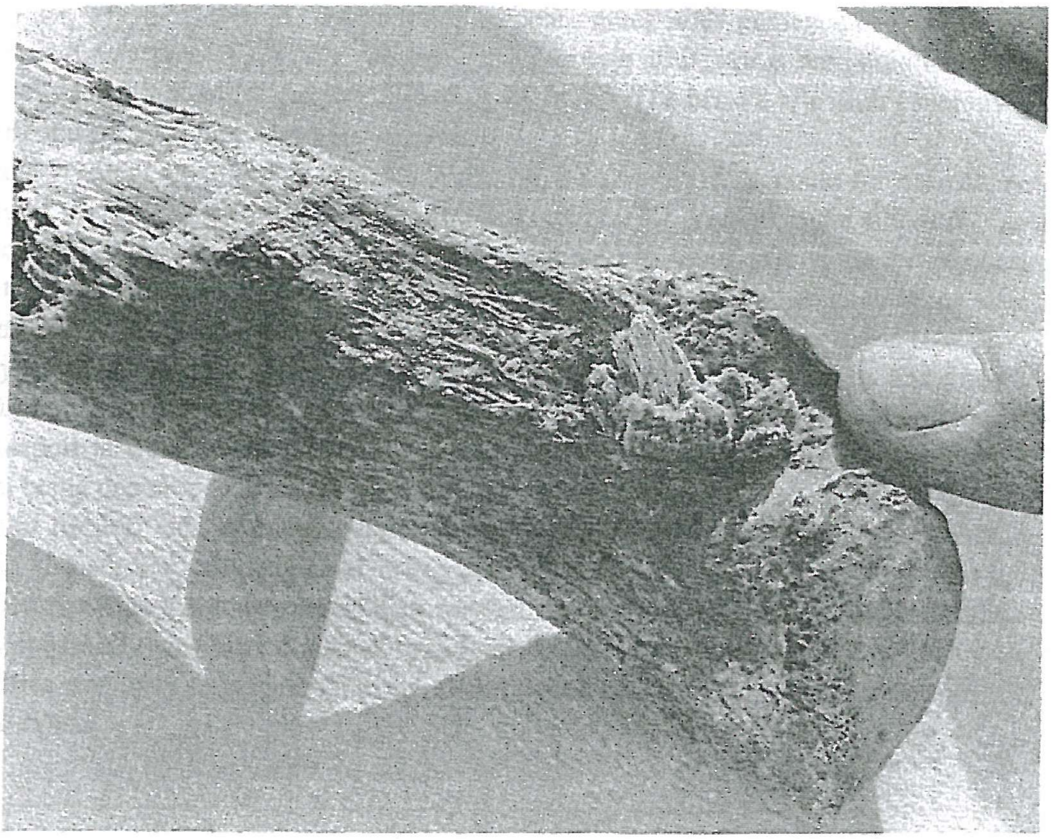


Figure 4. Manis Mastodon Bone Point embedded in rib. (Gustafson et al 1979: 159).

Meadowcroft Rockshelter. Pennsylvania.

Meadowcroft Rockshelter is located in the southwest of Pennsylvania. The site is on the bank of the Cross Creek near the Ohio River (Adovasio *et al.* 1978: 632). Excavation took place between 1973 and 1977 and was of a thorough standard. Microstrata within natural levels were examined and pertinent phenomena photographed four times, in black and white and colour formats (ibid: 635). The cultural features consisted of firepits, firefloors, refuse/storage pits and ash/charcoal lenses. Lithic technologies include "bilaterally retouched rhomboidal flake "knives"(herein referred to as Mungai knives), blades, unifaces, bifaces, gravers, and microengravers, denticulate pieces, and a quantity of lithic debitage" in addition to lithic bone wood shell, basketry, cordage, and ceramic materials (ibid: 644). Mungai knives are shown in Figure 5. Adovasio *et al.* emphasises that all these cultural materials were located under rockfall securely dated to ca. 10000 BC.

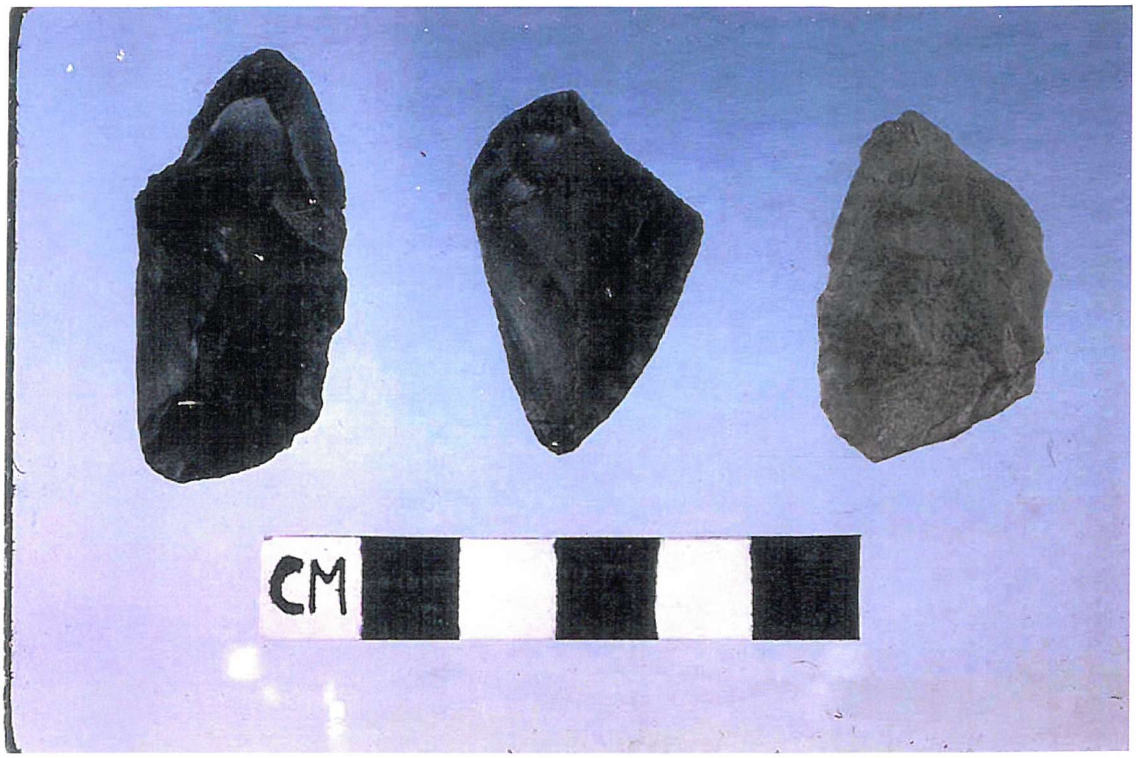


Figure 5. Mungai Knives.

(**http://people.delphiforums.com/MCCONAUGHY/meadowcroft/pbiface1.htm**)

The lowest occupation layer seems to be stratum IIa with a diminutive microblade industry. Faunal remains found in the upper layers include mollusc shells, feathers, claws, eggshells and fish scales. Mammal bones are abundant and there is much white tailed deer present as well as wapiti and smaller game including birds. Floral remains include hackberry, walnut, dwarf hackberry, hickory and some nutshells and charred cenophod seeds (ibid: 648).

The radiocarbon chronology of Meadowcroft Rockshelter consists of 52 dates from charcoal found in the firepits, firefloors or charcoal features as well as two pieces of carbonised basketry (Adovasio *et al.* 1990: 349). The earliest culture bearing level, stratum IIa, carries radiocarbon dates between 21000 BP. and 9000 BP. The upper part of this stratum has undeniable cultural objects in association with an oldest radiocarbon date of 14255 ± 975 BP on charcoal from firepits (Adovasio *et al.* 1978: 643). The lower part of this stratum has a sequence of radiocarbon dates leading back to 21000 BP with possible cultural association (Adovasio *et al.* 1990: 350).

The dates from Meadowcroft have been questioned on three counts. Robert Kelly believes the thinness of the deposit containing cultural materials means that bioturbation is a danger. He says that the deposition of Stratum IIA was slow; the average thickness is 90 centimetres over 13000 years so deposition averaged 6.9 centimetres every thousand years (Kelly 1987: 332 –334). Adovasio *et al* have responded to this by pointing out that the stratigraphy is clear and intact and no evidence for cross-horizon artefact movement is present (Adovasio *et al.* 1990: 349).

Jim Mead states that the floral remains are suspect since they do not include spruce or boreal pines as one might expect from looking at samples from the nearby New Paris No. 4 sinkhole, and Buckle's Bog -Shenandoah Valley pollen profiles (Mead 1980: 579-580). The faunal remains also do not include species one would expect from boreal or arctic environments (ibid: 579). Adovasio *et al*'s defence is that faunal remains are all modern or Holocene. Those earlier cannot be identified as they are charred, calcined or highly fragmented and unidentifiable (1980: 593). The only identifiable species from the lower levels are antler from white-tailed deer and known tolerances of modern species do not preclude their presence in boreal environs. Similarly the floral remains are mainly confined to above stratum IIa although deciduous elements have been found lower down indicating deciduous presence in proximity to glacial ice sheets.

The third criticism questions the integrity of the radiocarbon dates. Haynes points out that "*Abandoned strip mines occur within half a mile of Meadowcroft, and Cross Creek is polluted by mine effluent. A coal (vitrinite) lens occurs within the shelter. Therefore, coal or chemical derivatives thereof are the most likely sources of contamination*", or some of the "mung" mentioned by Adovasio could actually be misidentified charcoal (Haynes 1980: 583). Haynes believes the samples from Meadowcroft are contaminated in such a way as to add considerable age to stratum IIa. The mechanics of such contamination are the groundwater in the shelter that would have polluted the lower strata with mobile organics (ibid: 585). Haynes also mentions that as yet it has not been possible to test the samples in such a way to preclude contamination (ibid: 587). Adovasio *et al.* have answered by pointing out that there is no coal seam in the Rockshelter, and that a small band of vitrinised wood in the Rockshelter is much lower than the cultural deposits and in any case not soluble by any percolating mechanisms that have existed in the Rockshelter. Also if levels were contaminated by the vitrinite it would have to contaminate all the levels, not just those with pre-Clovis dates. Additionally, the "mung" is not similar to charcoal so cannot be equated to it (1980: 590). Later, Tankersley and Munson (1992) would raise the same questions but including the later, Holocene, dates with much the same response thus adding little to the debate apart from reinforcing doubt through their addition to the weight of speculation in the literature.

The questions raised by Haynes, Mead and Kelly are thorough and learned but the archaeological evidence does not support them. Until Haynes can subject charcoal samples from the site to his own standard of scrutiny it is not possible to discount its dates on this basis. The Haynes and Mead allegations are refuted by the thoroughness of the archaeological excavation itself. The site would benefit from being published in detail as Monte Verde has been so analyses such as Mead's can be based on complete information. While the earlier Stratum IIa dates may be associated with human activity the earliest certain date at present is that at 14255 ± 975 BP.

Cactus Hill.

Cactus Hill is sited in Sussex County, Virginia 45 miles south of Richmond (McAvoy and McAvoy 1997). The site was discovered by Col. Richard Ware of Petersburg who contacted Mr. H.A. MacCord who, in turn, filed a report with the Virginia Research Centre for Archaeology. The site was a sand pit on top of a dune surrounded by deforested areas and eroding rapidly, a situation that led to some sampling in 1991 and its excavation in 1993. Four areas of the site were defined, A, B, C and D of which C was subjected to the sampling in 1991. The remaining three areas A, B and D were subjected to excavation, B and D under the direction of J.M. McAvoy and area A under M.F. Johnson.

Area D consisted of a large continuously excavated area with five soil zones. Zone 1 is dark greyish brown organic filled sand that overlays the other layers and was mechanically removed. Zone II was yellow brown medium sand, also mechanically removed. Zone III was yellowish brown sand with a light to moderate density of cultural material in the upper portion. These cultural artefacts represented Late, Middle and Archaic periods. Zone IV was sterile yellowish brown coarse sand with some modern roots and Zone V was light yellowish brown coarse sand with pebbles also sterile. No Paleo-Indian occupation was evident in Area D; the oldest occupation evident being the Archaic layers in Zone III dated to 9240 ± 190 BP. The microstratigraphy in Zone III is of interest because evident strata of sterile sand separate cultural layers indicating stratigraphic integrity.

Area B consisted of a series of smaller excavations also containing five zones, Zone I being the overlying dark greyish brown sand and Zone II the yellow brown medium fine sand with some Woodland period artefacts present. Zone III was yellowish brown medium-fine sand with artefacts of Middle Woodland to Paleo-Indian age. Of the entire Area B, only one excavation unit, 4/22, contained bands of sterile sand between excavation units and hence could be defined as stratigraphically intact. The other excavation units, particularly heavily occupied areas, contained intermixed Archaic age till. The underlying Zones IV and V were sterile as in Area D. No units provided a radiocarbon date older than 10920 ± 250 apart from unit 2/9 which had a date of 15070 ± 70 associated with stone tools underneath a layer containing Clovis artefacts. While this stratum is positioned below Clovis bearing layers and has given a pre-Clovis date, its stratigraphic integrity is poor. While it seems probably that this site does contain a pre-Clovis presence, it is not proven to the standards demanded for this study although currently efforts are under way to better establish the stratigraphy of the site. Thus Cactus Hill cannot yet be said be a valid pre-Clovis site.

Pendejo Cave. New Mexico.

Pendejo Cave was discovered in 1976 in Orogrande New Mexico, during a survey by the University of Texas. It is a situated in the south face of the Rough Canyon limestone cliffs yet faces north. Thirteen metres deep from north to south and eight metres high it was test-pitted in 1990, and subsequently excavated in 1991 and 1992 (Chrisman *et al* 1996: 361). The evidence for pre-Clovis human occupation consists primarily of a selection of fire hardened clay nodules with what appears to be human skin prints (Figure 6). These were found in layers C2 with dates of 12970 ±

170 BP, 12370 ± 80 BP and 12240 ± 70 BP the earlier of these dates coming from hairs found in the strata, the latter date being from charcoal located four metres from the prints. More prints were found in layer I that dated from 32000 ± 1200 BP to 35960± 790 BP on duplicate samples of charred oak and in Layer K, dates for which range from >28000 BP to > 36920 BP based on carbon and charcoal. In this layer, two lithic artefacts and an *Equus* phalange were found. Eight post-Clovis prints were also found; one associated with a cactus fibre sandal dating to 5480 ± 60 BP. According to Chrisman *et al,* the stratigraphy in the cave was extremely clear-cut, there being up to 24 identifiable strata, of which zones E and K were cemented by water seepage (ibid: 363). Analysis of the friction skin prints showed them to be formed by human touch based on the number of ridges per centimetre and the location of pore marks on the ridges, as well as the fact that the local habitat could not support other large primates (ibid: 371 – 373).

There are two arguments that question the veracity of the Pendejo Cave site as a pre-Clovis contender. The first is put forward by Dina Dincauze who excavated on the site for one day during the 1991 season (Dincauze 1997: 554-555). Dincauze excavated in one of the zones directly above the first fingerprint find and observed burrows occupying almost all of zones F, G, and H, and they had damaged a great part of Zone I. As well as this evidence for bioturbation, there was also evidence for a massive rock fall in this square. Dincauze also believes that the locations of the burrows were not present in the excavation profiles. In addition she mentions that she was not fingerprinted to rule her out as a source of the friction prints, as other excavators had been. Dincauze suggests that Holocene remains in the upper strata provide a source for contaminant artefacts in the lower strata. Chrisman, MacNeish and Cunnar have responded by saying Dincauze's excavation area did not encompass the area where finds were made and that these areas were stratigraphically intact (1997:556- 557). They also state that fingerprinting of the crew had never been necessary as experiments showed that once the clay had been fire-hardened it could not take fresh prints. The reason Dincauze did not see the burrows marked on the excavation profiles was because she simply was not looking at the right profiles. Finally Chrisman *et al* say that the hair that produced radiocarbon dates of 12370 ±80 and 12240 ± 70 proved to be human through amino acid testing. Another hair was found next to some charcoal dating to 19180 ± 290, although they do not say that they have dated this hair itself (ibid: 558).

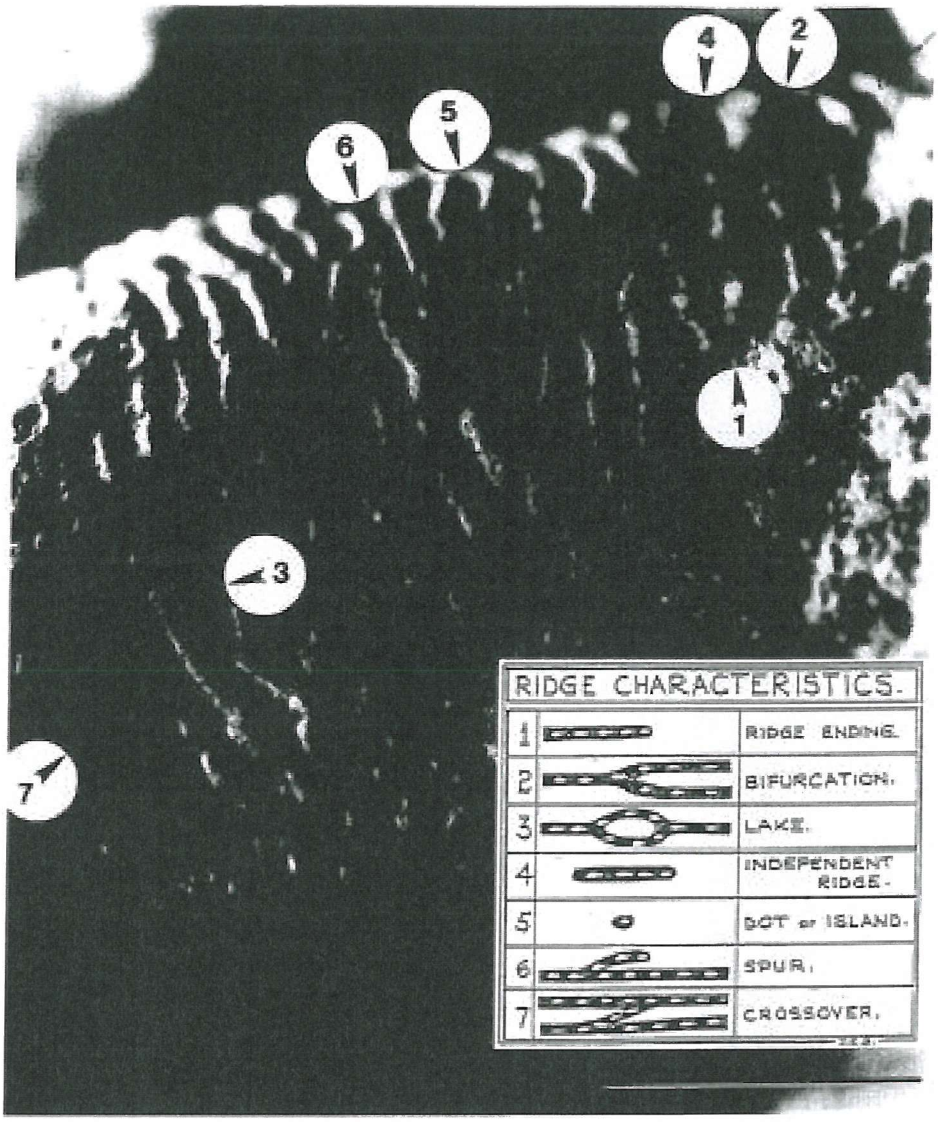


Figure 9. Detail of Figure 8 E-core whorl (G1897). Arrowed numbers indicate usual characteristics of primate friction skin (see table). Bar = 1 mm (48.3 ×).

Figure 6. Detail of fingerprint from Pendejo cave.(Chrisman et al. 1996: 372)

The second argument against the sites validity is put forward by Shaffer and Baker (1997: 559 – 560). This states that the illustrations accompanying the 1996 article presenting the site do not tally with their descriptions. They say that from the pictures and accompanying scales the number of ridges are vastly different from those originally published. For example they state that *"the specimen in Figure 9 is baked clay dated to 13 000 BP. Using the 1 mm scale provided...6-7 ridges are apparent. At this frequency, a total of 60 – 70 ridges per linear centimeter would be well above the 13 – 19 stated in the text..."* (ibid: 560). Chrisman's response is short and points out that the photography of the ridges has a tendency to distort the scale and the scales provided are mainly for illustration but that he will review the magnifications for the final report (1997:561). For their analysis, Chrisman's Pendejo cave team used casts of the artefacts using dental silicone that allowed them to make a more accurate count of the ridge frequency.

Shaffer and Baker's criticisms do not stand up since such a challenge should really be based upon first hand experience with the artefacts and replication of the methods used to count the ridges. Dincauze's criticism although based on only one day at the site is more worrying since it is based on first hand knowledge and the possibility of bioturbation cannot be entirely dismissed. This lays serious doubts on the earlier artefacts and their stratigraphic association. While a distance between artefact and dating material of 4 metres (Chrisman *et al* 1996:363) would usually be adequate in a disturbed environment such as Pendejo cave it is less convincing. The dates taken directly from human hair are more persuasive, however the publications do not provide any information about how much hair it was possible to sample and until this is published it is hard to judge the validity of the dating. As it stands now Pendejo Cave certainly provides evidence of Paleo-Indian occupation but dates before 12370 ± 80 are distinctly dubious. Those dates on the human hair seem to be the most adequate evidence for pre-Clovis occupation in this site.

Little Salt Springs. Florida.

Little Salt Springs is a large flooded sinkhole located near Charlotte Harbor in southwest Florida (Figure 7). Originally thought to be a shallow pond, it was discovered to be 68 metres deep by divers (Clausen *et al* 1979: 609). The site has formed a useful water source for people and animals for at least 10980 years, possibly longer. The evidence for early human occupation at the site is a land tortoise, of a now extinct species, turned onto its back and impaled by a wooden stake presumably to kill it (ibid: 609). This stake was found between the carapace and plastron and Clausen *et al.* believe the intention was to pierce the pleuroperitoneal or pericardial cavities. The tortoise itself was radiocarbon dated to 13450 ±190 years BP while the wooden stake was dated to 12030 ±200 years BP. This find was located on the lower re-entrant of the sinkhole where the hourglass profile begins to open out again after reaching its minimum width of 25 to 30 metres. Also on this ledge were bones from mastodon, bison, ground sloth, other land tortoises, both extinct and extant, turtle, rattlesnakes and rabbit. The lower part of the shell and some long bones are carbonised and under and around the tortoise was fire-hardened clay. This is interpreted by Clausen *et al* as evidence of cooking, the animal having been turned on its back and killed with a wooden stake then being cooked and eaten in situ. Clausen gives no other details about the stratigraphic context of the remains so while the evidence seems plausible it does not yet meet the criteria applied for validating pre Clovis sites.

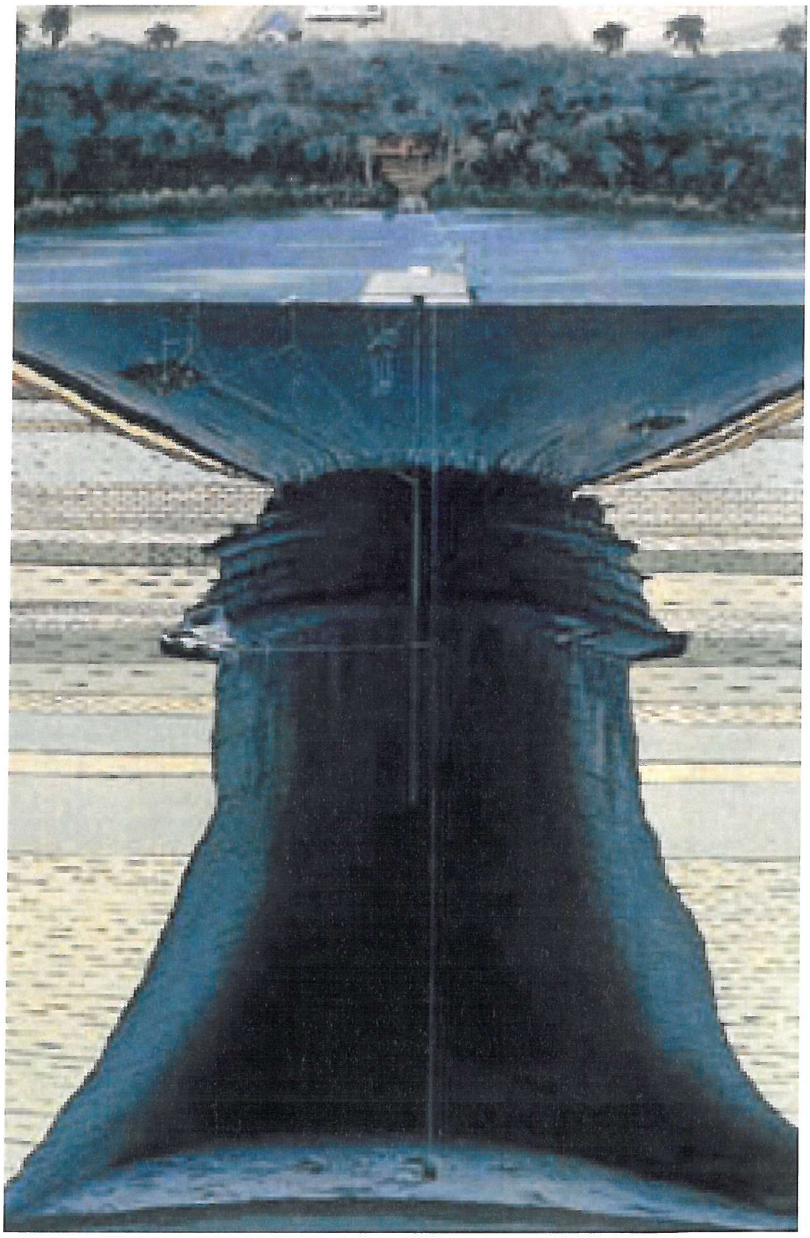


Figure 7. Little Salt Springs Cross Section.
(http://mgg.rsmas.miami.edu/students/caz/LLS.htm.)

Tlapacoya. Mexico.

Tlapacoya is located 20 km southwest of Mexico City. The site is known for being the location of two early skulls found in the Upper Toluca Pumice layer, a product of volcanic activity. One of these skulls was dated to 9730 ± 65 years BP, the first directly dated human from Mexico (Gonzales *et al.* 2001: 705). Two trenches were excavated at the site, Tlapacoya I on a hill by an old lake, and Tlapacoya II, by a cave. In Tlapacoya I a hearth with foreign obsidian flakes and local flakes and blades was found and dated to 24000 ± 4000 years BP. Tlapacoya II yielded an obsidian blade lodged under a tree that was dated to 23150 ± 950 years BP (Dixon 1999: 96). The problem with the evidence from the hearth is that the error found for the radiocarbon dates is too large to accept. While the foreign and obviously worked flakes are definitely artefacts they require better dating. The flake found below a tree trunk in Tlapacoya II could have been deposited after the tree died. Therefore Tlapacoya I fails to meet the required standards on the basis of its dating, while Tlapacoya II fails because of its lack of stratigraphic integrity.

Taima-Taima. Venezuela.

Jose Cruxent and Alex Krieger discovered Taima-Taima in north Venezuela in 1962. Subsequent excavation produced mastodon and glyptodon bones, as well as El Jobo points and a uniface knife or scraper (Bryan *et al*: 1978: 1275). One point was found in the right pubis of the mastodon (Figure 8) Radiocarbon dates ranged from 12000 to 14000 years BP. Because of doubts about these dates preceding Clovis and reservations about deposits being possibly disturbed by spring action, a 1976 excavation season was undertaken by Jose Cruxent with Alan Lyle Bryan and Ruth Gruhn. The excavation found the bones of a mastodon lying on its left side; the cranium, cervical vertebra and some upper thoracic vertebrae were missing, as was the right forelimb. Cut marks were evident on two ribs and a tendon attachment point on the left humerus. Four stratigraphic units were identified, units ascending from I - IV. Unit III was a black organic clay, 30 centimetres thick, with six stratigraphically consistent radiocarbon dates between 10290 ± 90 to 9650 ± 80 years BP (ibid: 1277).

The mastodon was found in unit I with wood twig fragments interpreted as the mastodon's stomach contents. Dates from these twigs are 12980 ± 85, 13000 ± 200, 13880 ± 120 and 14200 ± 3000 BP.

The deposition of the mastodon remains and its association with artefacts is questioned in Lynch's overview of South American sites (1990: 12-36). Lynch believes that the artefacts and bones form a secondary deposit that has been mixed both by upwelling water and wallowing animals. He also believes artefacts could have "sunk through the waterlogged clay and sand to join the bones of the mastodon at the impermeable base of the waterhole" (ibid: 18). Gruhn and Bryan rebut this by pointing out that the upwelling watermarks are well documented within the excavation, away from the mastodon area. Also the deposits are clearly stratified with a paleosol dividing Clovis age sediment from Unit I where the mastodon was found. This, they say, prevented mixing of later material (ibid: 343). Additionally Gruhn and Bryan point to the evidence of butchery that Lynch has overlooked and that has been reconstructed by palaeontologist Casamiquela (ibid: 344). Overall this site is stratigraphically intact, has good radiocarbon dates and clear evidence of human agency.

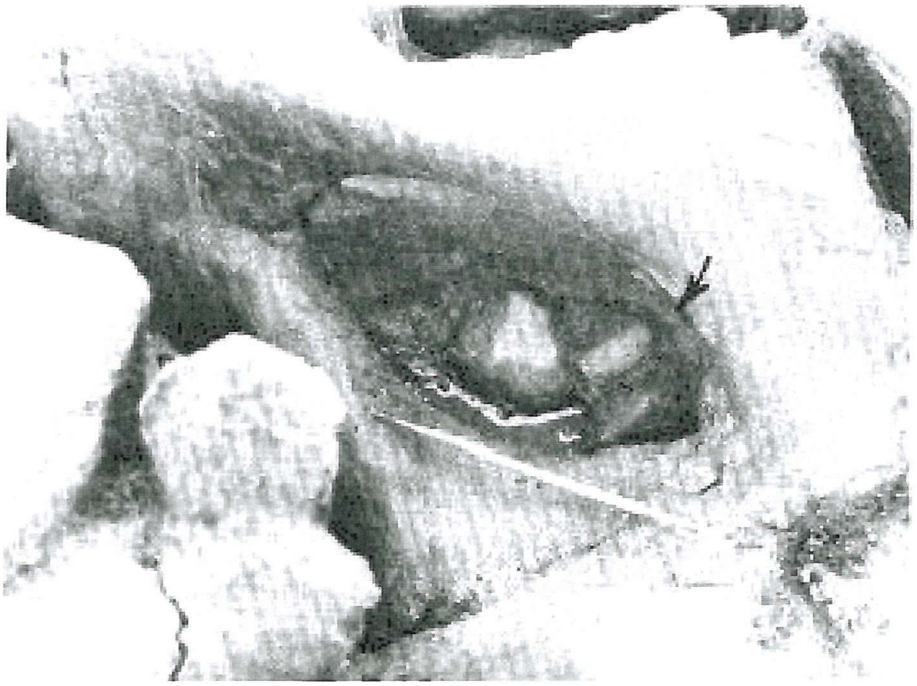


Fig. 2. The mid-section of a quartzite El Jobo projectile point in situ within the cavity of the right pubis of the juvenile mastodon.

Figure 8. Pubis of mastodon with in situ point. (Bryan et al 1978: 1276)

Pedra Furada - Brazil.

Toca do Boqueiro do Sitio da Pedra Furada, known as Pedra Furada, is a rockshelter in the southeastern part of Piaui State in Brazil. The cave is over 70 metres long and the excavation took place up to an extent of 700 m2. The site was almost completely uncovered, a factor Guidon and Arnaud claim allowed them to interpret the complex stratigraphy in a way that test pitting would not have done (Guidon & Arnaud 1991: 169). Inside the rockshelter, flakes of stone around the edges of structures containing charcoal mark the areas of human habitation. Guidon and Arnaud maintain that humans must have arranged the stones. The charcoal is unlikely to be present due to forest fires because it would not be possible for flames to come from the outside and forest fires would have been rare since the surrounding vegetation is not flammable. Radiocarbon dates have been obtained for the four layers from A to D. Layer A dates from > 48000 BP and 41500 ± 4420 - 3100 BP. Layer B dates are between 41 000 ± 3000 - 2200 BP and 25200 ± 320 BP. Layer C dates from > 25000 to 8450 ± 80 BP. Layer D dates from 8050 ± 170 BP to 6150 ± 60 BP. Layers B and C contain fragments of rock interpreted to be parts of painting spalled from the walls. Tools from the site are made from retouched local quartzite (ibid: 176).

David Meltzer, James Adovasio and Tom Dillehay visited the site in 1993 and raised some questions regarding the veracity of the site. Some radiocarbon dates are out of sequence and the origin of the charcoal analysed may be natural (Meltzer *et al* 1994: 702). They argue that while today's vegetation may not be flammable that of the past could have been. In addition, the charcoal lenses are thick and diffuse, a feature Meltzer *et al* believe to be concurrent with natural fire deposits rather than man-made ones. Borrero adds the thought that while forest fires may be uncommon in this area, over the period of time the shelter dates to what can be considered uncommon? With a time-scale of tens of thousands of years even uncommon phenomenon can cause appreciable effect (Borrero 1995: 602- 603). Meltzer *et al.* are dissatisfied with the stratigraphy of the site, saying that ignoring the micro-stratigraphy is detrimental to an understanding of the dates, and thus hiatuses in the dates are not explained (1994: 704). The artefacts are also questioned, all are quartzite from nearby sources and all are possibly natural (Figure 9). A statistical analysis of rock fall within a dynamic environment such as this rockshelter shows one may expect to find a similar number of objects that appear to be artefacts produced by natural means (ibid: 705- 708). Also a brief examination of some of the artefacts during the visit showed no use-wear on the edges. Features found during excavation have to be considered within the context of a background of natural cobbles and high-energy fluvial action that could have cause sorting that may create artificial looking features.

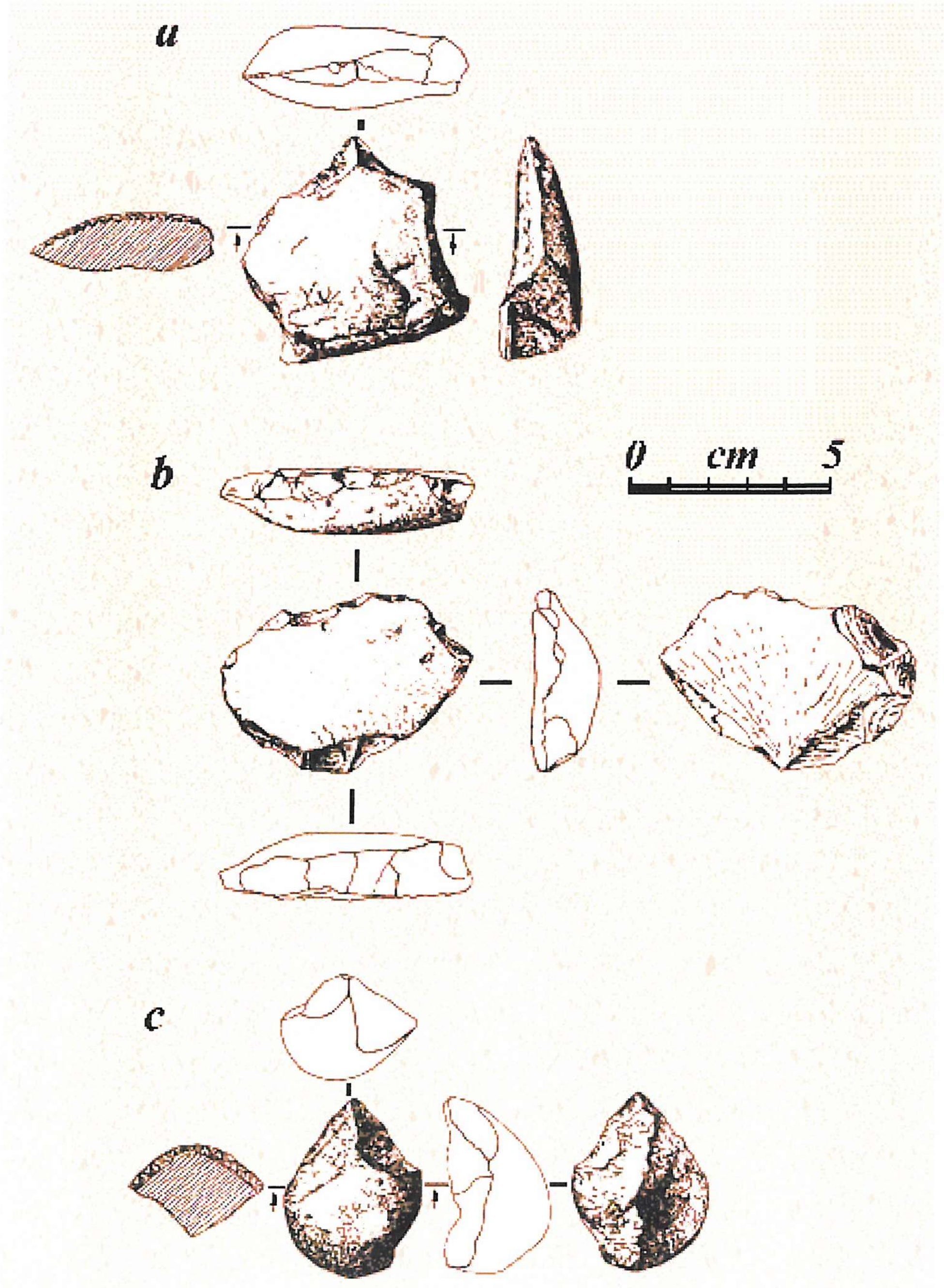


Figure 9. Artefacts from Pedra Furada. http://www.athenapub.com/10pfurad.htm

Guidon *et al* have responded to the criticism by pointing out that as well as including some errors about the site's location Meltzer *et al*'s critique fails to consider how some layers were protected by rock falls. Also they point out that a cursory exam is not in itself sufficient to judge whether edge wear on tools is present or not (1996: 408 - 415). Parenti *et al* (1996) provide a more detailed response defending the site. Why are no residues from natural fires found in other sites in the area apart from Pedra Furada? In addition, if forest fires rarely heat soil beyond 250°C why do thermo luminescence tests from the hearth areas prove temperatures were above this? (1996: 417 - 418). The lithic industries are simple core technologies but show some evolution from the lower layers to the upper (ibid: 418). They also point out that use-wear is hard to detect on quartzite. The features are probably not natural according to Parenti *et al* since they have not observed similar features occurring naturally elsewhere in tropical climates (ibid: 419). Added defence comes from Dennell and Hurcombe (1995: 604), who have performed experiments on quartzite in association with site excavations in Pakistan. Their experiments showed it was hard to produce artefactual breaks in quartzite naturally.

The Pedra Furada site artefacts are ambiguous, as are the features associated with them that provide the radiocarbon dates. Considering that the environment is dynamic, with both rock falls and water action within it, one cannot say that it shows undeniable signs of human presence early in the record. More detailed analysis of the use-wear on the quartzite may prove otherwise but the ambiguities in the radiocarbon dates will also need to be addressed to prove this site has pre-Clovis occupation.

Monte Verde. Chile.

Monte Verde is a site in central Chile situated on the Chinchihuapi Creek. The site contains evidence of dwellings, lithic technologies, and organic remains including bones, cordage and wooden hafts (Dillehay *et al* 1989). This is a well-published site, two volumes having been produced. The first on the paleoenvironment and site context came out in 1989. The second volume on the archaeological context and interpretation came out later in 1997. Much has been written in response to these documents but only three other documents are of direct interest in interpreting the site itself since others reiterate points already made or consider the implications of the site for American archaeology. The first is a summary of conclusions formed by nine archaeologists during a site visit, the aim of which was to establish the credibility of Monte Verde as a Paleoindian site (Meltzer *et al* 1997: 659 – 663). Stuart Fiedel's detailed appraisal is the next relevant article (1999: 1- 12) and the response to this by Dillehay and the rest of his team is the final article (1999: Internet publication).

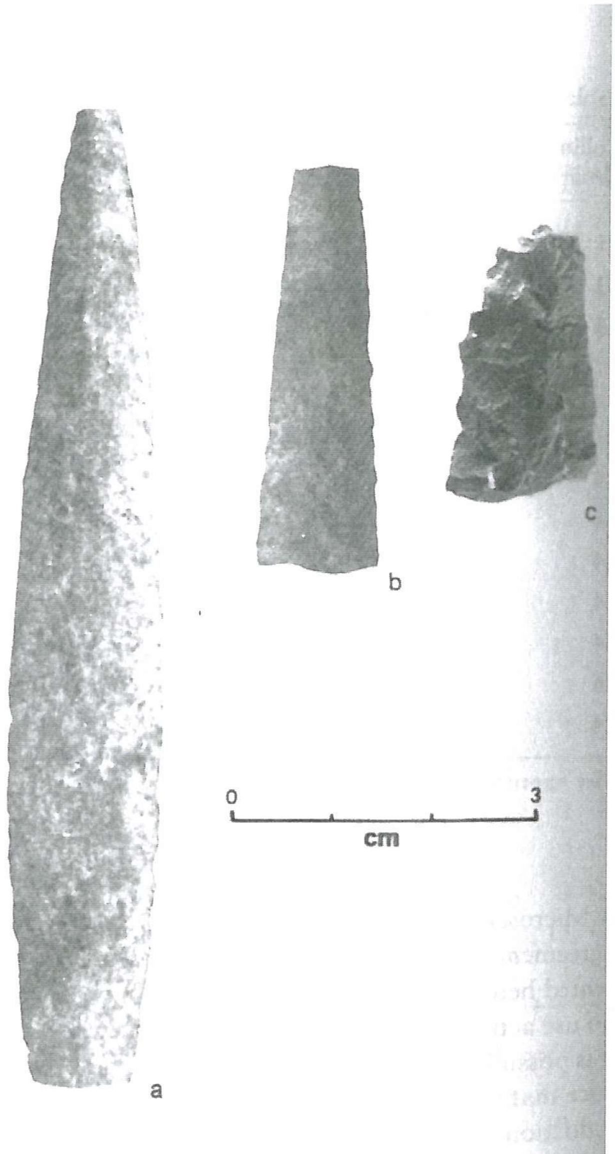


Fig. 14.17. Fragmentary projectile points.

Figure 10. Projectile points from Monte Verde. (Dillehay 1997: 424)

The Monte Verde site is situated on a creekside and represents a well-established Paleoindian campsite. The site was discovered by accident in 1975, woodsmen cutting access along the creek exposed bones later found by a local family. These eventually came to the attention of Carlos Troncoso of the Universidad Austral de Chile and Mauricio Van de Maele of the Museo de Historia y Antropologia (Dillehay *et al* 1989: 4). Van de Maele then asked Tom Dillehay to examine the bones for evidence of human agency and to investigate the creek bank to locate the origin of the bones. From 1978 to 1985 detailed excavations were undertaken. Eight strata were identified, MV 1 – 8, with two significant use surfaces, MV-I and MV-II (1989: 46).

MV–II lies under MV- 5 and contained evidence of lithic technologies, the most obviously human being four bifacially worked projectile points (1997: 425), as well as less obvious lithics such as naturally broken rocks with use-wear on some surfaces (1997: 447). Wooden remains seem to be evidence of a habitation structure (1997: 174).

Perhaps the most remarkable pieces of evidence for human occupation in this site are the footprints found in Area D, zone D (Dillehay *et al* 1997: 105). These three footprints ranging from 13 to 15 centimetres in length are seemingly from the same individual. Layer MV-II has been radiocarbon dated to between 13565 ± 250 and 11790 ± 200 (1997: 44). Removing problematic dates such as those on mastodon bone which Dillehay and Pino believe to be inaccurate, the earliest reliable dates for this layer are five assays from human modified wood. The mean range of dates from this wood is from 12 230 ± 340 BP to 12 780 ± 290 BP, this has a mean overlap of 12570 ± 230 BP (1997: 48). While Dillehay and Pino believe humans at Monte Verde could have been mining fossil bone for use in their artefacts they do not believe the same can be said of wood. They believe the conditions are unlikely to preserve wood well enough for recycling to have been feasible (1997: 49).

MV-I is a lower level dated to 33370 ±530 but the artefacts from this site are of a more dubious nature than those in MV-II are and more investigation needs to be done in this area. The tools primarily consist of single faceted stones, 14 of which were found in this layer (Collins 1997: 463). Other lithics are hammerstones, flakes and multifaceted stones which all seem possibly natural. Collins believes use wear along the edges of some of these stones indicate human use (ibid: 462 – 463).

In January 1997, the site was visited by a group of archaeologists including David Meltzer, Donald Grayson, Gerardo Ardila, Alex Barker, Dena Dincauze, C. Vance Haynes, Francisco Mena, Lautaro Nunez and Dennis Stanford. The aim of this visit was to verify the validity of Monte Verde as an archaeological site. Materials from the site were studied at a presentation in Lexington Kentucky and then the group visited Chile for more presentations and a visit to what remains of the site itself

(Meltzer *et al* 1997: 660). Their consensus was that the MV-II artefacts and stratigraphy were consistent while the MV-I context required more work, although some of the lithics did seem to be artefacts (ibid: 662). They therefore suggested that an approximate date of 12500 years BP is acceptable for this site with a possibility of much earlier occupation.

From the official publication it is clear that Monte Verde contains a use surface of considerable antiquity that meets the criteria of well-dated, well-stratified, undeniably human artefacts. Stuart Fiedel's 1999 article attempted to question the veracity of the site by questioning the quality of the excavation and recording. However Fiedel's points are often not only pedantic in the extreme but ea sily refuted in Dillehay *et al*'s 49 -page response published on the Internet. There is not the space here to outline each of Fiedel's questions, nor is there the need since none adequately challenge the site's nature or its dating. Questions about why there are no pictures of projectile points in situ (ibid: 4) or why a footprint is referred to as a left foot when the picture shows it as being a right footprint (ibid: 11) are really editorial as are most of Fiedel's criticisms. One that is not is the questio n Fiedel raises about evidence of a structure found near the centre of the site. The evidence for this structure consists of a wishbone-shaped sand formation with associated stakeholes (Dillehay 1997: 206-207). Fiedel points out that the dimensions of the hut had been reported as 3.9 metres long and 3 metres wide in previously publications by Dillehay. In the final volume, it was shown it to be 2.3 metres wide and 2.5 metres long on the outside and 1.3 metres wide and 1.7 metres long on the inside. Fiedel also points out that this would cause problems for the supposed interpretation of the structure as a possible dwelling for a medicine man (Fiedel 1999: 12). Dillehay *et al* pointed out in their rebuttal that the hut structure questioned by Fiedel would have been more like that of the Toldos tents of Argentina that use internal poles. The hut would probably not have functioned as portrayed by a National Geographic reconstruction that shows a medicine man treating a patient within the structure (ibid: 38). Fiedel also questions the location of a projectile point in zone D. He states that the mapping for zone D, where the point was found, is chaotic, the grid shifting east by five or six metres in larger scale maps (ibid: 12). Dillehay et al have argued this simply is not true and urge readers to check for themselves (ibid: 38). Having done this it appears that the confusion arises from the two Figures described, 20.1 in the 1997 volume and 3.4 in the 1989 volume (Figures 11 and 12 here). Figure 3.4 shows the exact location of zones set out over the excavation area while 20.1 merely has labels along the top edge, showing Zone D and zone DW. The exact boundary is not shown allowing for some confusion.

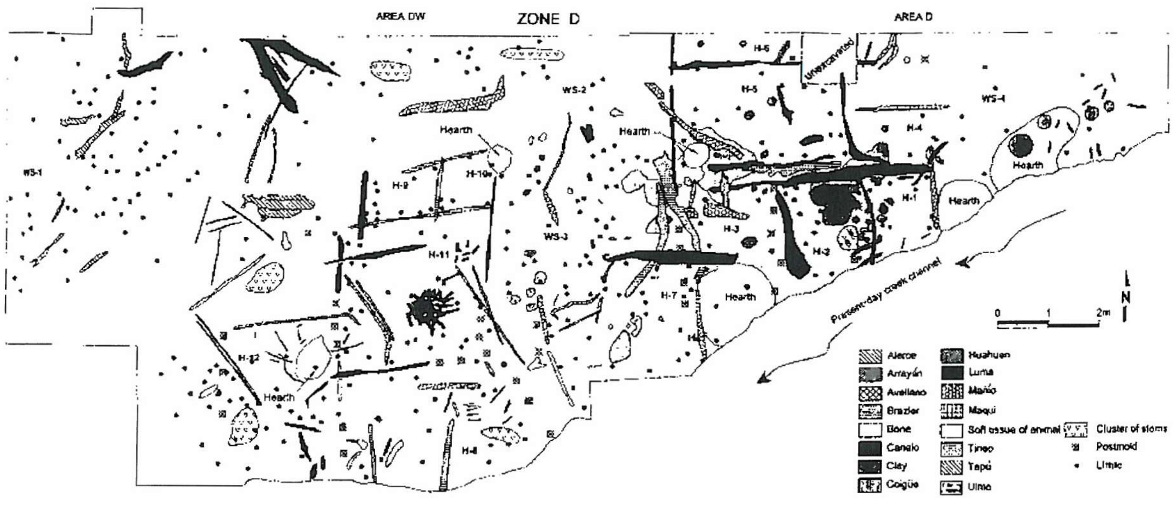


Fig. 20.1. Location of structural remains, features, and refuse areas in Zone D.

Figure 11. Plan of zone D of Monte Verde (Dillehay 1997: 775)

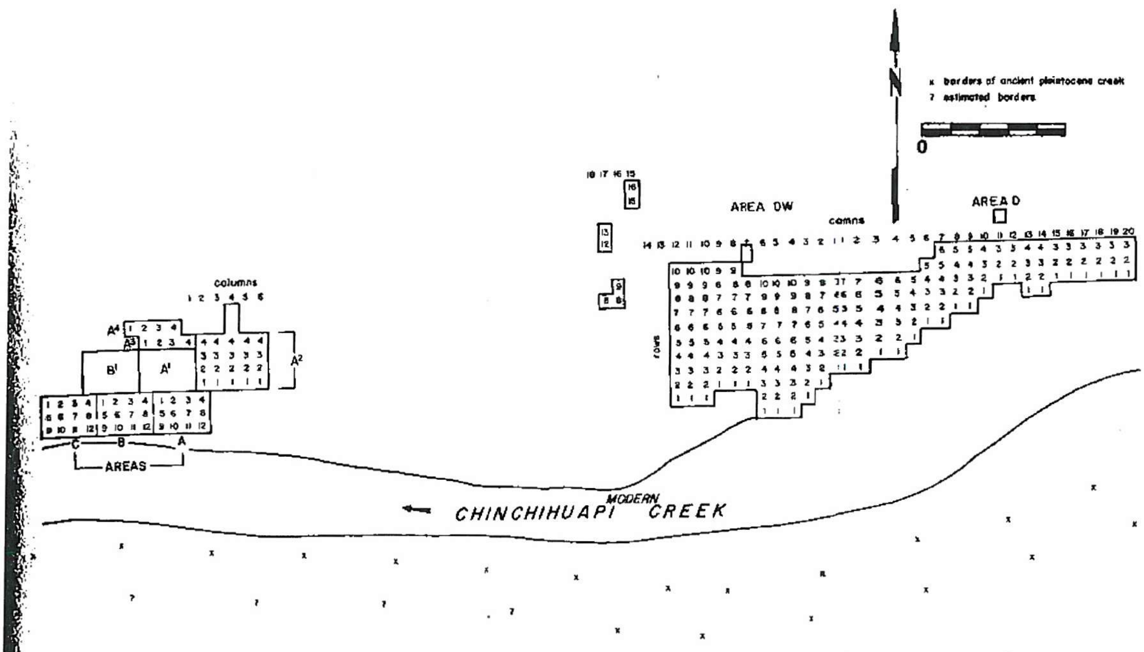


Fig. 3.4. Plan of the excavation grid laid out by columns and rows in the main occupational area of the site, Areas A–D.

Figure 12. Monte Verde site layout. (Dillehay 1989: 49)

The implication in Fiedel's article is that the site was badly recorded and therefore badly excavated; the site is not as portrayed in the publication and key evidence was deliberately left out to give a false impression. Rather than provide feasible alternative explanations for the Monte Verde finds the Fiedel critique really questions the competence of the excavation team and their defence speaks for itself. Their excavation was an interdisciplinary project that took place over two decades. Disparities in the numbering of artefacts are due to changes in strategy in response to the research. Editorial errors cannot be used to invalidate the project and interpretations are explicit in the site volume. Since the site has a secure stratigraphic context, consistent radiocarbon dates and unquestionably human modified objects in its MV-II layer, it easily seems to predate Clovis by at least 1000 years.

Los Toldos, Argentina.

The Los Toldos site in Argentina consists of a number of caves with a distinct lithic complex made up of thick unifacial blades with trimmed edges. Cave 3 is 4.35 metres above the course of the present stream with an opening facing northwest, Cave 2 lies 120 metres northeast of Cave 3 and its opening faces north (Paez *et al* 1999: 71). The earliest date comes from Cave 3 where deep material in level 11 has a single radiocarbon date of 12600 ± 600 years BP. The overlying levels contain guanaco and other game and radiometric tests date it to between 11000 and 10000 BP. This overlying layer contains bifacial subtriangular projectile points (Dillehay *et al.* 1992: 170). Nearby, Cave 2 also contains Toldensian lithic materials and some megafauna, dates for which are between 9500 and 7500 BP. Because of this, Dillehay *et al* believe the Cave 3 deposit probably dates closer to between 11000 to 10000 years BP.

Lynch questions the early date because it was taken from a pooled sample and is thus harder to interpret. He suggest the average of the 12600 ± 600 BP date and a later date of 8750 ± 480 BP taken from a hearth feature would yield a date of 10675 years BP, more in line with expected results for Toldensian features (Lynch 1990: 22). While this is not necessarily true since averaging these two dates does not necessarily produce a meaningful date for the sequence, it is worth allowing that similar local sites have later dates. At Piedra Museo, lithic artefacts and extinct megamammals were found in layer AEP-1 and dated to 12890 ± 90 years BP (Miotti & Cattaneo 1997: 63). Rigorously re-dated samples produced no dates older than 10925 ± 65 (Steele *et al*: forthcoming). The actual dates from this layer proved to be between 10925 ± 65, on *Hippidon Saldiasi* bone, and 9350 ± 130 BP on charcoal.

Since the early date from Los Toldos cannot be said to be accurate, and so far has not been duplicated, it is not possible to say this site does predate Clovis.

Mylodon Cave. Chile.

Mylodon Cave is located in the Ultima Esperanza inlet in south Chile. Sloth, *Mylodon Listai*, remains were originally found there in 1895. Local residents scavenged skin remains from a giant sloth and a piece hanging from a tree later prompted F.P. Moreno to make a few hurried excavations within the cave. Following this E. Nordenskiold and Borg and later R Hauthal (Bird 1988: 225) undertook excavations in 1899. These excavations produced sloth remains, rodent remains and some artefacts (Figure 13). Following the 1899 excavation locals plundered the site for potential valuables to sell. In 1937, Junius Bird excavated more thoroughly finding no human association with the sloth remains. Ten radiocarbon dates from the site are reported to be between 13560 and 12300 years BP. A further three dates are between 10830 and 10200 BP (Dixon 1999: 106). Since there is no real association between the sloth remains and human agency it is difficult to believe this site represents any pre-Clovis human activity.

It is worth discussing the nearby site of Cueva 1 Del Lago Sofia, a narrow rockshelter with deposits containing ground sloth, horse and guanaco remains as well as hearths, side scrapers and flakes (Borrero *et al* 1998: 195). Dates for the archaeological levels seemed to be around 11000 years BP. Mega fauna remains below these levels dated to 12900 years BP. However, the reassessment of radiocarbon ages conducted by Steele *et al.* and mentioned above (see Los Toldos) found that dating of stratified bone associated with human agency at the Cueva 1 Del Lago Sofia site produced dates ranging 10710 ± 70 to 10140 ± 110 BP. A direct date from Mylodon bone at the site, not associated with human agency produced a date of 12250 ± 110 BP (Steele *et al*: forthcoming). This is considerably older than the archaeological remains and one would expect that a similar relationship was present at Mylodon Cave with the Mylodon pre-dating the human occupation.

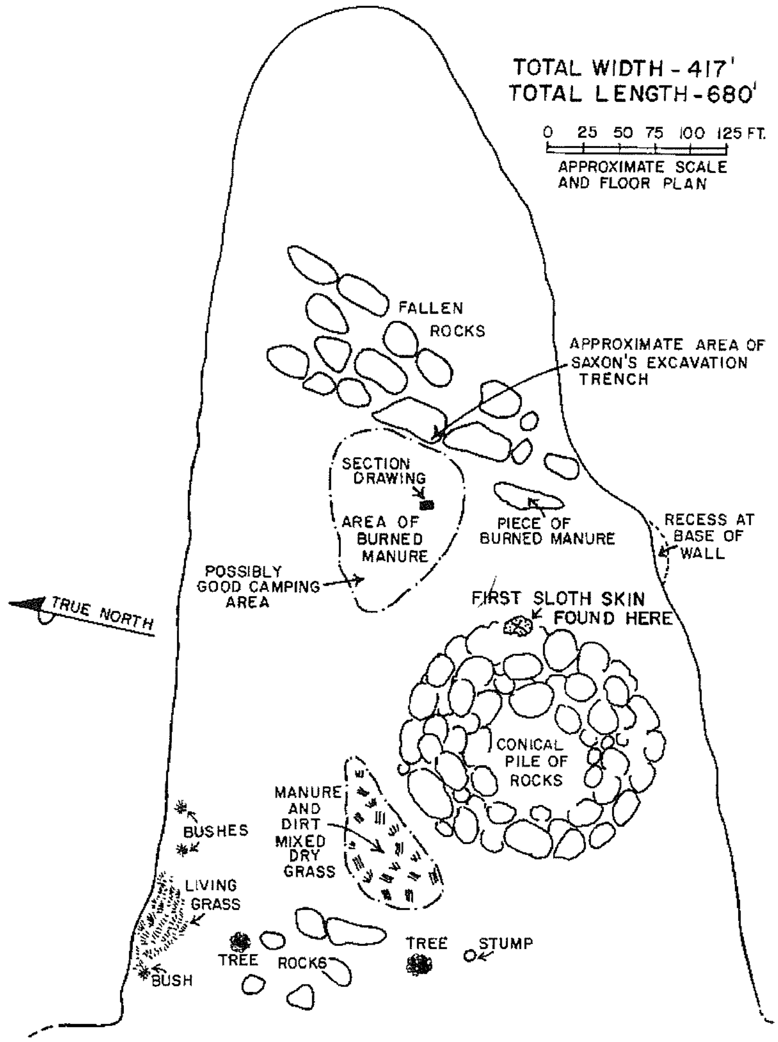


Fig. 96. Drawing of floor of Mylodon Cave.

Figure 13. Drawing of floor of Mylodon Cave. (Bird 1998: 224)

Conclusion.

Five sites meet the criteria stipulated by Chamberlain, of stratigraphic integrity, secure dating and proven human presence. Manis Mastodon in Washington, Meadowcroft Rockshelter in Pennsylvania, Pendejo Cave in New Mexico, Taima-Taima in Venezuela and Monte Verde in Chile adequately meet these criteria for some though not necessarily all of the occupation dates put forward by their excavators. The obvious pattern from these is that there is no pattern. These early sites range from between the edge of the northern glaciation to almost the tip of Chile with sites in between. While this is a selection of the sites claiming to be pre-Clovis in date, they still cover both continents from north to south and from east to west. They include camps and kill sites and are both inland and coastal. Environmental evidence for these sites indicates a wide range of ecological settings. Meadowcroft is set in a deciduous community (Adovasio 1980: 594). Pendejo Cave is set in warm, semi-desert conditions (Chrisman *et al* 1996: 366 –368). At the time the Manis Mastodon died the surrounding area was a treeless open herb and shrub dominated tundra (Petersen *et al.* 1983:228). Monte Verde was situated in a developing forest similar to today, the immediate surroundings containing shrubs, reeds and grasses. Taima-Taima in Venezuela was either semi-desert or savannah (Adams 2000). So local ecology does not link these sites. No earlier dates than 14255 ± 975 from the Meadowcroft Rockshelter are acceptable from the sites discussed above, although Pendejo cave, Monte Verde and Meadowcroft provide slight evidence of earlier occupation. This means that by 14255 ± 975 years BP humans were in the Americas and had occupied a wide area encompassing a range of environmental types. How then do we explain the presence of humans in the Americas at such an early date? If we have established when they arrived, we must then ask how did they arrive?

Chapter 2. Routes into the Americas.

In the previous chapter, it was shown that there is compelling evidence that human occupation in the Americas predated the Clovis horizon by at least three thousand years. This presents an interesting conundrum since while some sites clearly are of this age there is less than one may expect from a continent wide expansion. This increased time depth also poses questions about the route the earliest colonists used to move from Beringia into the area south of the Wisconsinan glaciation. When Clovis was the earliest population in the Americas it was easy to hypothesise that the parting of the Cordilleran and Lauren tide ice sheets was not only the opening they needed but also the explanation for their failure to enter earlier. Earlier colonisation negates this so alternative explanations must be found. It would seem sensible to suggest that the distribution of early sites reflects the route by which colonisation occurs. In this chapter the conflicting theories about routes into the Americas will be discussed. This is followed by an analysis of the sites relevant to one of the more feasible theories, that of coastal migration. Sites located near to the West Coast that are older than 7000 years BP will be examined in order to see if their locations or composition can confirm the theory that humans may have first entered the North American continent by a coastal route.

Speculation about the route by which the first peoples entered the Americas currently focuses on three main theories. The first is that of an ice-free corridor between the masses of the Laurentide and Cordilleran ice sheets (Figure 14). Secondly a coastal migration along the Beringian and British Columbian coast may have occurred, perhaps using boats, or simply utilizing marine resources accessible from the shore (Figure 15). Thirdly, and less popular, early colonisers may have adopted a route across the Atlantic from Iberia. This "Atlantic Paleomaritime" theory is postulated mainly by Stanford and Bradley (2002: 255). Clovis technology, they say, is similar in form to that of the Solutrean cultures inhabiting the Iberian Peninsula. This may mean that the Clovis culture was originally brought to the Americas by peoples skirting land surfaces exposed by lowered sea levels in the Atlantic. The 5000-year difference between Solutrean and Clovis complexes is explained by way of Cactus Hill and Meadowcroft (see previous chapter), which have points that could feasibly be interpreted as similar to Solutrean or Clovis, thus providing the chronological link. Also as more fluted points are found in the east of the North American Continent it implies an origin there rather than from the west. Stanford and Bradley point out that it is not just the lithics that show similarities; antler and ivory tools in both cultures have similarities too. Stanford and Bradley's hypothesis is that since Solutrean peoples had maritime adaptations they may have ventured west towards the Americas eventually founding the first populations there. The key piece of evidence for this theory is evidence of mitochondrial DNA haplogroup known as X, which is absent in Asia but occurs in Europe. However, the problems with this theory are insurmountable. As discussed in the previous chapter the evidence for Meadowcroft and Cactus Hill does not necessarily descend as far back as Stanford and Bradley suggest thus making the timing of their Atlantic Paleomaritime colonisation more problematic. What happened to these people in the 5000 years between leaving Iberia and settling in the Americas? Since the earliest evidence from Cactus Hill and Meadowcroft does not bridge this gap, it makes this theory dubious at best.

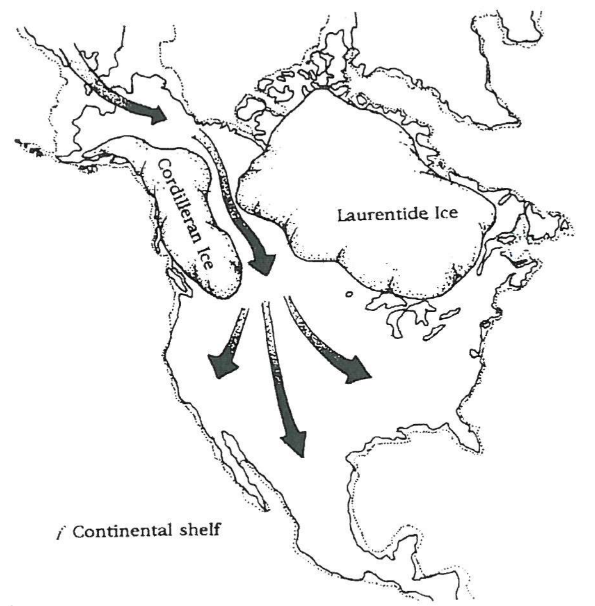


Figure 2.4 The hypothetical interior, or midcontinental, migration route. (Graphic by Eric Parrish.)

Figure 14. The Ice Free Corridor Route. (Dixon 1999: 32)

In addition to the chronological problems with the Atlantic Paleomaritime route the majority of the genetic evidence does not support European colonisation. As discussed in the previous chapter we cannot place a date on the first timing of the first peopling of the Americas from the genetic evidence but it does indicate an Asian colonisation. This is corroborated by the linguistic evidence and the dental evidence. Nichols' work on linguistic grouping suggests a time span of greater than twenty thousand years, which is not corroborated by the archaeological evidence. However, the linguistic analysis does suggest an East Asian origin for the Paleo-Indian migration (2002: 283). Ruhlen believes the language evidence suggest that three migrations into North America occurred, from three different Asian origins, with a single migration into South America (1994: 177 –188). Examination of twenty-nine dental traits in 15000 Native American, Old World and Pacific Basin crania shows that North East Asians are most like Native Americans (Turner C. 1994: 131 – 140). In addition, the long narrow cranial features with small narrow faces are most similar to southern Asian or European populations, not because they migrated directly from these places to the Americas but because migration occurred from north Asia prior to the formation of the distinctive local features observed in the present (Steele & Powell 1994: 144 –163). Therefore, while the genetic, linguistic and cranial data does not adequately date the first peopling of the Americas it does give us a likely origin, Asia and more specifically north Asia.

If the Paleo-Indian origin was north Asia, it follows that the most likely route into the Americas would have been through the Bering land bridge. This landmass, also known as Beringia existed during the last glacial maximum. For this land bridge to form a drop in sea level of fifty metres was required, far less than that of approximately one hundred and twenty metres at the last glacial maximum (Hoffecker et al: 1993: 46). It was thought that by 14000 years BP however rising sea levels would have cut off the land bridge making land migration to the New World after this date impossible however Hoffecker et al believe that sea level did not rise this much until after 12000 years BP (ibid). Archaeological evidence from Beringia seems to back this up, no sites prior to 12000 BP having been found. This coincides well with the postulated opening of an ice-free corridor between the Laurentide and Cordilleran ice sheets that was believed to have occurred at approximately the same time. This would lead one to believe that groups in Beringia at 12000 years BP could have found their way south to found Clovis in the way Martin hypothesised. However as discussed in the previous chapter Clovis was not the original American culture. Even discounting still controversial sites such as Meadowcroft and Taima-Taima, we are still left with the widely accepted Monte Verde II site that predates both Clovis and the hypothesised opening of the ice-free corridor. Accepting the earlier sites, as we must, means that somehow a route south of the ice had to be found prior to the originally accepted dates for the opening of the ice-free corridor. There are two ways of doing this, reassess the dates for migration through the corridor and seriously consider the possibility of a migration along the coast west of the Cordilleran ice.

Methods of Entry: Coast versus Corridor.

Ives, Beaudoin and Magne evaluate the role of this ice-free corridor compared to the possibility of coastal entry (1993: 1 - 54). They conclude that it is not currently possible to exclude either the coastal or ice-free corridor routes based on the available evidence. They state that neither route was feasible for the *entire* period between 21000 and 11500 years ago but both could have been used, not necessarily exclusively, at varying times during this period. At present they say the ice free corridor seems more attractive simply because of the ease with which land survey can be undertaken compared to underwater survey (1993: 1 - 54).

Mandryk et al agree that the coastal and corridor routes do not have to be mutually exclusive in theory but state it is incongruous to concentrate on the ice-free corridor whilst ignoring the potentially more productive coast (2001: 301 - 302). Pointing to calculations of paleoecological records from stratigraphic pollen analysis they say that major portions of the ice-free corridor would have been blocked from 30000 to 11500 BP. In addition, the corridor would have been unable to provide sufficient calories for hunter-gatherers to meet their daily requirements until 12000 BP. They state that the Monte Verde site has forced archaeologists to seriously consider the coastal route, previously dismissed as impossible to traverse or impossible to test (ibid: 304). By looking at the extent of glaciation, types of vegetation and sea level data for the Northwest Coast they see no reason for groups not to have been able to migrate around 14000 to 13000 BP (ibid: 308). They conclude that the coast was not only possible to traverse but was the most likely and only possible route for Monte Verdean ancestors to populate the New World. With this in mind, it is worth examining the predominant theories about how this may have occurred.

The most oft referenced hypothesis for coastal migration into the Americas is Knut Fladmark's 1979 treatment although this was not the first to suggest it. Heusser in 1960, Krieger in 1961 and Macgowan and Hester in 1962 all suggested a coastal hypothesis but never met with general interest (Fladmark 1979: 58). Fladmark proposed that the melt-water in the ice-free corridor would have formed an obstacle to movement that also provided little in the way of fish or other resources. He describes it as 'a landscape dominated by huge shallow pondages, ephemeral and shifting drainage patterns and massive seasonal surges of melt-water, and more importantly, a landscape quite different from Beringia' (1979: 56). He also points out that 'the suitability of a late Wisconsinan corridor for human occupation would be at least partially dependant on whether ice-free areas coincided with mountain, foothill, or plains-plateau terrain' (1979: 56). Therefore, it is not surprising that there are no early sites in the region where an ice-free corridor may have existed.

Fladmark's alternate hypothesis was that the Pacific coast was more habitable than had been claimed. Previous generalisations based on geological evidence from the Strait of Georgia would have to be viewed with suspicion, as this area is one of the few where ice could have occurred in a great thickness. It has been shown many areas along the coast were not blanketed by ice; rather ice was present in smaller areas. With lower sea levels, large areas of land were available for colonisation. This would have been 'a Greenland-like shoreline with a discontinuous strip of unglaciated terrain along the outer coast and seaward slopes, flanked by glaciers flowing out from mountain sources and from ice-caps occupying inner coast and interior basins' (1979: 60). 'Some data suggest relatively abundant marine and terrestrial biota in close proximity to Wisconsinan glaciers' remains of mammoth, mastodon, bison, sea lion, whale, musk ox and 47 species of marine invertebrates (1979: 60). Therefore, resources existed to support human settlement. Man made artefacts on the present day shoreline only date back 9,000 years, when the maximum sea level was achieved. The earliest artefacts found have certain main elements that have parallels in the Diuktai Culture of northeastern Asia so the design may have origins there (1979: 63). Fladmark's final point is that water-craft were in use long before the proposed colonisation of America and it is unlikely that if people crossed the Bering Strait by sea they would have abandoned 'their boats on shore to run joyfully inland in search of 'big game'' (1979: 63).

Fladmark's evidence is mainly negative, based on the ice-free corridor being impractical as a habitat supporting migration, the 9,000-year-old artefact evidence on the current shoreline and the fact that watercraft were used elsewhere in the world.

Even the faunal assemblages are only indicators that the coast could have supported life. According to Fladmark, this lack of positive evidence is a by-product of the rise in sea levels but may also be a result of a tendency for archaeologists to focus on fluted point assemblages. This means they do not spend enough time on longer-lived aspects of Paleo-Indian complexes, such as blades and burins that may 'provide the critical clue to their ultimate origins and relationships' (1979: 65). Lack of physical evidence then is not the same as saying it does not exist; rather perceptions of what a site should look like may influence the identification of such sites.

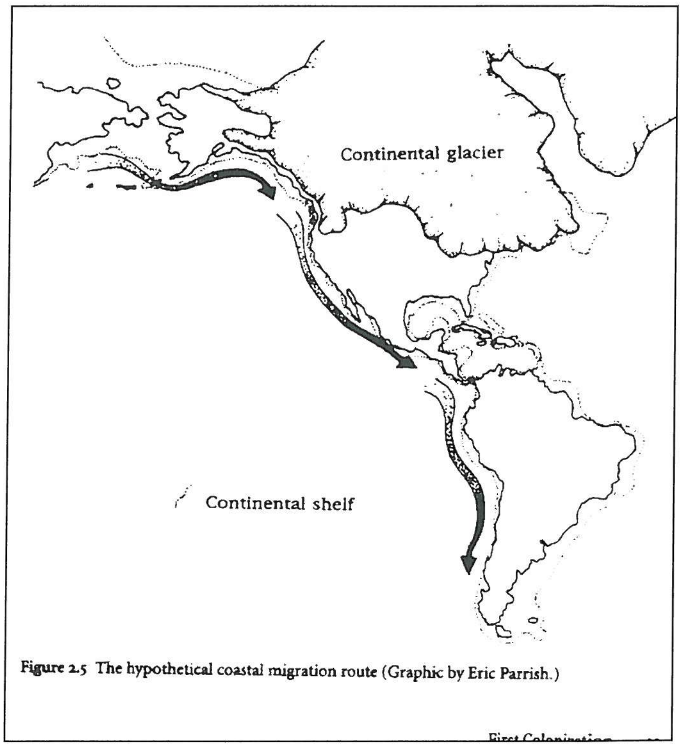


Figure 15. Dixon's Hypothesised Coastal Migration (Dixon 1999:33)

Another proponent of the coastal migration theory is E. James Dixon who takes Fladmark's treatment further still. Dixon hypothesises that there was a coastal migration of the ancestors of the Clovis, Nenana and Western Stemmed Traditions who eventually moved inland adapting their marine mammal hunting technologies to hunting terrestrial animals (1999: 254-256). He points out that the earliest deglaciated route was on the coast, there are sites that predate the ice-free corridor, including Monte Verde. Human remains from 48-PET-409 in Alaska, or the Californian Channel Islands are dated to 11,000 years BP therefore colonisation occurred before this time. In Dixon's opinion, regional cultural adaptation was underway by 11500 to 11000 years ago in the form of technological responses to local conditions so the populations in those regions must have arrived prior to this to have time to adapt. The Paleo-Indian tradition spread from the Great Plains northward by 10500 BP indicating prior settlement. Paleo-Indian subsistence data indicates foraging not big game hunting was prevalent. The atlatl weapon system may have evolved from maritime hunting technologies. Humans elsewhere in the world had watercraft long before America was probably colonised. Technological evidence suggests two colonisation events, one at 13500 years BP using the atlatl and one at 10500 BP bringing the bow and arrow.

Dixon's theory uses Monte Verde II as the end point in a coastal migration hypothesis (Figure 15). Todd Surovell has simulated the migration of peoples via the coast in an attempt to explain the site at Monte Verde. This proves problematic. According to all his simulations, it is unlikely that the coast would have provided a viable habitat for humans to live and migrate down in time to arrive at Monte Verde. This project relies on the Monte Verde site being valid, although Surovell allows that Monte Verde could be later than currently realised, more contemporary with Clovis perhaps, he believes that the evidence from Chile is unquestionably manmade. Alternatively, pre-Clovis sites exist and are yet to be discovered or South America was colonised first, via an oceanic voyage. Surovell rejects the second hypothesis as not viable but accepts that sites prior to Clovis might exist and require a revision to his model (Unpublished: 1 - 40).

Easton has addressed the issues that make the coastal migration theory unpopular (1992:28-41). Easton points out that the ice-free corridor has no evidence to pre-date the earliest points in the United States. Easton suggests that the focus on large animal kills is more a product of the archaeological process and its ingrained sexism than of the way early settlers actually used to live. As for finding proof of such a migration Easton points out the earliest physical evidence for coastal settlement may lie under the ocean, therefore it is here that further research needs to focus (1992: 28- 41).

Ruth Gruhn believes three questions are fundamental to the coastal migration theory (1994: 249 – 256). firstly, was it feasible? Secondly, what concrete evidence is there? Third, why does it have more explanatory power than the interior route? In answer to the first question she believes it was possible from 50000 years ago using simple technologies, citing the Yahgan, of coastal Tierra del Fuego, as an example of a group with a low archaeological signature which could have been capable of such a migration (ibid: 252). As for the second question she says that there is no archaeological evidence to directly support the theory but linguistic evidence from the West Coast implies a longer occupation there than elsewhere in the Americas south of the ice (ibid: 253). The third question, that of explanatory power, condenses down to the fact that Clovis first adherents cannot believe early sites are real, and that the coastal migration theory means they can be explained (ibid: 254). So far though the ice-free corridor may look less likely than it did previously there are still problems of physical evidence that hinder the coastal migration hypothesis. These are not the only potential problems, if we base an argument on the biological potential of a particular route it is expected that opposing arguments will eventually challenge this basis.

One individual who has issued such a challenge is David Yesner. Yesner rejects the concept of a coastal migration in his recent article (2001: 315 – 327). He points out that both the models of coastal migration and corridor entry are based on the biological potential of such routes not evidence (ibid: 315). Only one "scanty" date prior to 12000 years BP has been found (at Bluefish Cave) whereas many Alaskan sites are dated between 11500 and 12000 years BP (ibid: 316). He cites conditions on the Bering seacoast as being unsuitable for supporting colonies of marine mammals and the intertidal zone on the landbridge had "even less to offer human populations" (317). The Bering coast fauna would be limited to ice tolerant or ice dependant pinnipeds, not fur seals or stellar's sea lion as today (ibid: 316). Fladmark's above claim that 'Some data suggest relatively abundant marine and terrestrial biota in close proximity to Wisconsinan glaciers' remains of mammoth, mastodon, bison, sea lion, whale, musk ox and 47 species of marine invertebrates (Fladmark 1979: 60)' is ignored, possibly because it cannot be directly proven that it is relevant to the Bering coast. He admits that sites such as On-Your-Knees cave in southeastern Alaska have human remains, evidence from which suggests some marine resource exploitation. Since these are dated to 9200 radiocarbon years before present (Dixon 1999: 145) Yesner believes these are of too late a date to contribute meaningfully to the debate. Instead, Yesner suggests that the parting of the landbridge would have pushed populations inland, "at the same time, various pull factors were making northern, and interior Alaska increasingly attractive habitats for human occupation brought about by ameliorating climatic conditions and changing vegetational patterns" (ibid: 317).

Everett Bassett is an archaeologist who questions the basic assumption that the coast would have provided a rich source of subsistence for early settlers. In his, so far, unfinished, PhD. thesis he lists problems with the hypothesis. These are:

> *'1) That the archaeological evidence produced by mobile coastal foragers would have been so transitory as to be almost invisible except at a few cave sites, which carry their own interpretative problems; 2) that most sites from prior to about 8,000 BP are now submerged and inaccessible and that many of the more recent sites have been destroyed through coastal erosion or development; 3) that any surviving evidence is greatly overshadowed by the large sites and rich material culture of the sedentary coastal cultures that dominate the later archaeological and ethnographic records; 4) that constraints on mobile foraging behaviour caused by cold water exposure risk have been mostly ignored because they are not a visible constraint on either tropical mobile foragers or higher-latitude marine specialists which, together, make up most of the ethnographic record, and; 5) that resources are traditionally classified ecologically, as being either coastal or interior rather than based on the costs associated with procuring each; an ecological classification does allow us to understand what landscapes were being used but tells us little about how they were being used or what decisions were being made.' (Personal communication).*

Bassett argues that conditions on the Northwest Coast would have been hostile to non-specialist groups who did not invest in more complex buffering technologies that make cold water foraging safer and productive. This combined with Yesner's article paint a bleak picture for coastal migration. However neither conclusively rule out coastal migration just as no physical evidence conclusively proves it. This is not necessarily due to a lack of early sites in the Americas. Instead, it may be due to the attitude of archaeologists to those sites that are claimed to be early enough to require a coastal migration. With this in mind, it is worth exploring the sites that exist on the coast with the aim of assessing their connection with coastal migration. In the following section, sites from along the North American West Coast will be identified and described in terms of age, location and composition. Evidence for lithic use and subsistence behaviour will be included to isolate patterns in the record. As far as possible sites which have been adequately published will be included although in the Oregon and Washington areas some less well published sites are included due to the sparseness of the local archaeological record. Sites should be within a reasonable distance of the coast. Sites that are not well stratified and well dated will not be included, as comparison with sites in the previous chapter requires that the same criteria should apply. Finally, sites should be no younger than the early Holocene so sites should date to at least 7500 years BP.

Coastal Sites.

Alaska.

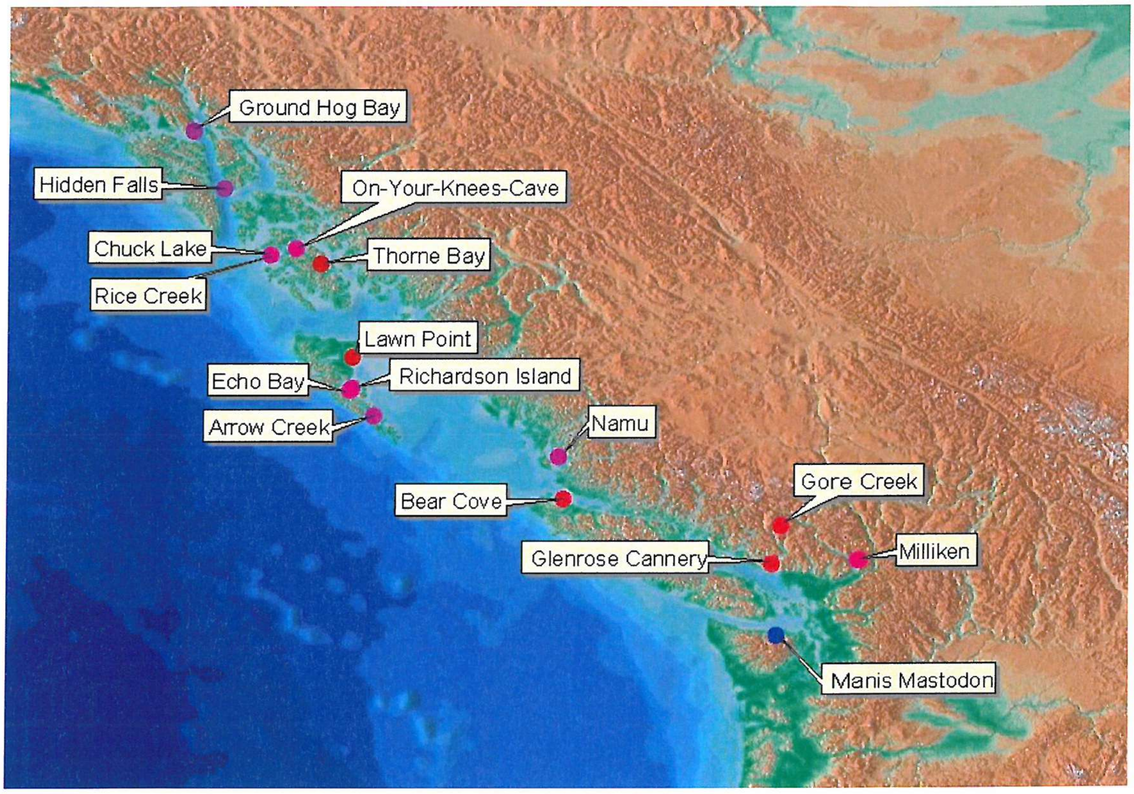


Figure 16 Coastal Sites in south east Alaska and British Columbia

Ground Hog Bay Site 2.

This site is located on the Chilkat Peninsula in southeast Alaska (Ackerman 1996: 424 – 430). The site lies on a glacio-marine terrace exposed after 11630 ± 145 years BP. The current sea level is eleven to twelve metres below the site at high tide and seventeen to eighteen metres below it at low tide. The oldest stratum is component III with radiocarbon dates of 10180 ± 800, 9220 ± 80 and 9130 ±130 years BP. Later research suggested that the overlying component II should be considered part of the same stratum as component III. This layer yielded dates between 8880 ±

125 and 4155 ± 95 years BP. Frontally fluted, wedge shaped microblade cores where made from local argillite. Some obsidian tools were found, the raw material for which originated in nearby Suemez Island or Mt. Edziza. The early layer contained few microblades, although some that were found had evidence of retouching. As well as the microblade industry bifaces, fragments and side scrapers were found, as were several cobble choppers. Ninety percent of the stone finds were made from the locally available argillite. The terrestrial resource consisted of mostly Sitka spruce and western hemlock, forming a forest environment considered too inadequate a resource base to support even small groups. This implies some sort of maritime adaptation, as does the obsidian from Suemez Island.

Hidden Falls.

This site is located on the northeastern shore of Baranof Island in the Alexander Archipelago, Alaska (Davis 1996: 413). The area was heavily glaciated, deglaciation occurring after 16000 years ago. The Hidden Falls Lake is located in the lower end of a hanging valley and the site is just to the east of this. The Earliest Component is made up of six hundred and twelve chert artefacts, one hundred and ninety-eight of which have been modified for use. Microblade cores, microblades, hammerstones choppers, scrapers, gravers, burins and unifacial flakes are all present in the assemblage. This component is made up of stratigraphic units G, H1, H1a, H2 and I. Radiocarbon dating of I gives a maximum date of 10345 ± 95 years BP and a minimum date of 7175 ± 155 years BP. Obsidian finds originated at Suemez Island and Mount Edziza. The local vegetation would have consisted of cool temperate coniferous forest. Subsistence would be possible using *'Abundant sea mammals, birds, fishes, intertidal shellfish, terrestrial mammals and diverse plants'* based on local ecology (ibid: 415). Marine resource use would have been possible and a single fishbone and two clamshell fragments found in the area of scattered hearth remains provides evidence that they were. The foreign obsidian use also indicates a maritime transport technology, as does the site's island location.

Bear Cove.

Bear Cove sits in Hardy Bay on the northeastern tip of Vancouver Island, British Columbia (Carlson 1979: 177 –194). The area had a thick forest of Sitka spruce, western hemlock and red cedar. The site consists of two shell middens nine to eleven metres above the current sea level dated to 8020 ± 110 BP. Three hundred and thirty-two fish bones were retrieved, seventy-two percent of which were rockfish, ten percent salmon as well as some Pacific cod, pollock, sculpin, greenling, dogfish and ratfish. Of seven hundred and five mammal bones recovered seventy-eight percent were sea mammal, mostly dolphin or porpoise but with northern fur seal, sea lion, sea otter and harbor seal as well. Deer made up the majority of the terrestrial mammal remains with some *Canis* and river otter too.

Lithics comprised one hundred and thirty-seven items plus waste flakes and detritus. Pebble cores made up forty-eight per cent of the finds; thirty-five percent were flake tools, six percent biface points and eleven percent miscellaneous hammers, notched flakes or grinders. Four obsidian flakes, one bone, and one antler tool were also found. Some stone tools were abandoned then reused later as indicated by water worn features and retouching.

The evidence for the hunting of porpoise indicates marine transport and the local seal areas are on nearby islands also suggesting the use of boats would have been required to exploit the resource.

Chuck Lake.

On Heceta Island, one of the outlying islands of the Alexander Archipelago is the shell midden site of Chuck Lake. The shell bearing strata are dated to 8220 ± 125 to 7360 ± 270 (Matson & Coupland 1995: 86-87). Since shell normally dates 400 to 800 years too old, Matson and Coupland postulate an occupation between 8000 and 7000 BP. for this site. The shellfish were mainly bay mussels, butter clams and littleneck clams. Ninety percent of the vertebrate assemblage is fish and fifty-eight percent of these are Pacific cod. Other fish were greenling, sculpin and rockfish; rare fish were herring, lingcod, flatfish and salmonids. The sea mammal remains comprised one stellar sea lion and seventeen unidentified remains. Two beaver, two deer or caribou bones were also found. The lithic assemblage included nine microblade cores and fifty-eight microblades, mostly argillite but with some obsidian, quartz, marble and chert. Three cobble cores were found with one modified spall, three abrasive stones and two anvil stones. The island location and the Pacific cod and sea lion remains indicate some maritime transport may have been available but not necessarily. The Pacific cod are known to migrate into shallower waters in spring where they can be caught from the shore with rod and line (ibid 87).

Rice Creek.

The Rice Creek site is situated on Heceta Island in southeastern Alaska (Ackerman 1996(b): 127). The assemblage consists of eight irregular cortex flakes, two primary reduction flakes and two irregular pieces of argillite all located on a glaciomarine deposit dated to 9410 ± 130 BP.

On-Your-Knees-Cave

On-Your-Knees-Cave was discovered on the north end of Prince of Wales Island in the Alexander Archipelago. The site is located in a cave investigated by Tim Heaton for mammal remains. The initial seasons turned up brown bear remains dated to 35365 ± 800 BP and black bear dated to 41600 ± 1500 BP which linked with genetic evidence suggests brown bear habitation here was continuous (Dixon et al. 1997: 699). Other resources included red fox, caribou, deer, river otter, wolverine, ermine, vole, shrew, bat, birds and fish. Later some human bones were found, a mandible, four vertebrae, two rib fragments and a partial right pelvis from a male in his twenties (Dixon 1999: 118). AMS dates on the bones yielded two overlapping dates of 9730 ± 60 BP and 9880 ± 50 BP. Dixon corrects this date using Josenhans, findings for the Queen Charlotte Islands subtracting 600 years to give a figure of 9200 BP. Delta 13 C values of –12.5 0/00 and –12.10/00 parts per million on the mandible and pelvis indicate an extremely high marine diet, similar in fact to that of marine carnivores such as ringed seal of sea otter. The site also contained microblades in association with the human remains. On the other side of Prince of Wales Island is the site of Thorne Bay or Thorne River, which contains microblades, microblade cores and other lithics but little organics apart from charcoal dated to 7500 BP. (Dixon 1997: 691), (Dixon 1999: 129).

British Columbia.

Echo Bay.

This site is on Moresby Island in the Queen Charlotte Islands and occupies the width of the intertidal zone. The main concentration of artefacts occurs within a 500-metre^2 area. These are lithics with no microblade cores but several bifaces, and cobble tools and cobble tools were found (Fedje et al. 1996: 144). Wood from the site dated to 8550 ± 60 BP and a shell dated to 9640 ± 70 BP which if corrected for the marine carbon reservoir by subtracting 600 years gives a date of 9050 ± 70 BP (ibid: 134). The average of these is 8750 BP (ibid: 144).

Lawn Point.

Lawn Point is sited on the east coast of Graham Island in the Queen Charlotte Islands. The site sits directly on a paleo-beach sediment, 15 metres above the present sea level (Matson and Coupland 1995: 88 - 89). The site consists of a flaking station dated to 7400 – 7000 BP with two clusters of argillite microblades, one core numerous flakes and some pebble cores and hammerstones. All lay within a four metre square area. Fladmark suggests that while no direct evidence of subsistence resources remains the seaside setting indicates marine resources may have been utilised (1986: 32). The lack of heated stone indicates that the use of hot rocks to heat food had not yet been adopted and implies a similar technique needed for canoe construction could not have been utilised either. Fladmark believes this has implications for the islanders, ability to cross the Hecate Strait at this time when it was at its widest and may account for the lack of mainland trade materials in early sites on the Queen Charlotte Islands.

Arrow Creek 1 and 2.

Arrow Creek flows into Matheson inlet in the Juan Perez sound on Moresby Island (Fedje et al. 1996: 133 -141). The two sites both lie on the north bank of the creek approximately 60 metres apart. Arrow Creek 1 contains basalt and chert flakes, but no microblades. The oldest radiocarbon date from this component is 9390 ± 60 years BP from an alder leaf. Other dates on hemlock are between 9310 ± 70 and 9150 ± 80. The Arrow Creek 2 site contained much of its lithics in the earliest component dated to before 9000 years BP by a series of radiocarbon dates on wood and shell. The earliest of these dates is 9900 ± 90 years BP on charcoal. The lithics were constructed from local basalt. Mostly these are debitage, some unifacially modified flake tools but there was one microblade core found at the site. A stone construction appears to be a form of fish trap dated to before 9050 BP.

Richardson Island.

This site is located in the Darwin Sound on the west side of Richardson Island (Fedje et al. 1996: 141 – 143). Dates for marine transgression in the area mean the site must have been occupied prior to 8700 BP possibly around 9400 to 9100 BP. The finds consist of three basalt bifaces. Seven form tools, including a backed knife, two end scrapers and four retouched unifacial flakes. Eighteen microblade cores and eleven percussion microcores were found as well as one macrocore.

Namu.

The Namu site is situated on the central coast of British Columbia near the junction of Fitzhugh Sound and Burke Channel (Carlson & Bona 1996: 83). The earliest period of occupation dates to between 9720 ± 150 BP and 7800 ± 200 BP in Zone IIa. The assemblage from zone II is large, consisting of 13700 lithic artefacts, 12000 of which are waste flakes made from andesite (Carlson and Bona 1979:211). Other tools include bifaces, microliths, flake scrapers, utilised flakes, core scrapers and pebble tools, as well as abraders, bolas and hammerstones. Obsidian artefacts were provenanced to the Mount Edziza site, Central coast areas, Obsidian Creek and McKenzie Pass. Evidence of terrestrial mammals utilised included bear, deer, *Canis*, mink and porcupine. Salmon dominated the marine resource but seal, sea lion, beaver and dolphinids were also present. Smaller fish used were rays, dogfish, ratfish, herring, cod, rockfish, sablefish, greenlings, Sculpines and flatfish (Cannon 2000: 104 – 105). According to Carlson 'to settle and subsist there, efficient and effective navigation skills and watercraft would be required" (1996: 99).

Gore Creek.

At Gore Creek in the south Thompson River valley, a burial was found containing the skeleton of a young adult male (Stryd & Rousseau 1996: 184). The remains were dated to 8250 ± 115 BP. Carbon isotope analysis results of –19.4 per mil gave an initial indication that the individual relied solely on terrestrial resources for its protein but later reassessment suggests 8 – 10 % of its dietary protein may have come from marine fish, probably salmon or steelhead (ibid).

Milliken.

The Milliken site is located on the Fraser River, British Columbia. The lowest culture-bearing zone is I that has a date to 9000 ± 150 BP. The site yielded many artefacts including leaf shaped points, formed bifaces, formed unifaces, denticulate flakes, pebble flakes, pieces esquillees, macroblades, utilised flakes, a pebble graver, two small flat modified pebbles, two ground or polished artefacts and a basalt flake. The artefacts are mostly locally available andesite or basalt but some obsidian artefacts were also present. The obsidian was sourced from the Oregon Cascades in Washington State. Five hearths were found as well as stake holes and a possible stone wall. Mitchell and Pokotylo surmise that the tools indicate land animal hunting and point to nearby Gore Creek where subsistence is also primarily terrestrially based (1996: 65 – 82). The only direct evidence for early subsistence are charred cherry pits possibly indicating late summer occupancy. Calcined bone also survived in the lower levels but not in an identifiable state.

Glenrose Cannery

The Glenrose Cannery site is situated on the south side of the Fraser River and dates to between 8150 ± 250 years BP and 5730 ± 125 years BP (Matson 1996 111 - 122). The artefact assemblage consisted of 44 % cobble tools with the rest being made up mainly of flakes and some bifaces. The cobble tools consisted of unifacial choppers and scrapers with some hammerstones. Eleven antler wedges, one antler punch and one antler barbed point were found as were three bone awls, an ulna tool, one blade and one bone pendant were also retrieved. Mammalian resources included Elk, Canis species, beaver, harbor seal and deer. Calculations of the minimum number of species present indicate elk was of primary importance with deer and seal second and third. Marine resources in addition to the harbor seal were salmon, starry flounder, eulachon, stickleback and peamouth sturgeon. Shellfish remains were mostly bay mussel. Of these only starry flounder would not have been available from the shore. The juvenile nature of the elk and deer indicate a summer occupation for the site while the eulachon, stickleback and mussels indicate late spring to early summer occupation.

Mount Edziza.

This extinct volcano lies in northwestern British Columbia and is the source of much of the obsidian found in surrounding areas. Based on the finds from the Ground Hog Bay site we can assume a date of at least 10180 ± 180 BP. Two sources of obsidian occur in this area, a high elevation, concentrated source and a lower diffuse and accessible source (Fladmark 1984: 153). Artefacts made from Mount Edziza obsidian have been found east of the Rocky Mountains, in the Queen Charlotte Islands, southern Alaska and the Yukon Territory (ibid: 144). Finding artefacts on islands that originated from this site gives clear early evidence of maritime travel capability.

Washington.

Manis Mastodon.

This site has been discussed in depth in the previous chapter. For the purposes of this section, it suffices to say it represents a terrestrial mammal kill site. As well as Mastodon, muskrat and bison were also present. Some bone tools as well as a cobble tool were present in the area and there is a possibility that local unmodified stones were also used to assist in the butchery (Gustafson 1979: 160). The local environment was dominated by grasses and shrubs with some willow, buffalo berry and Rosacueae. The earliest date for this site is 12000 years BP.

Oregon

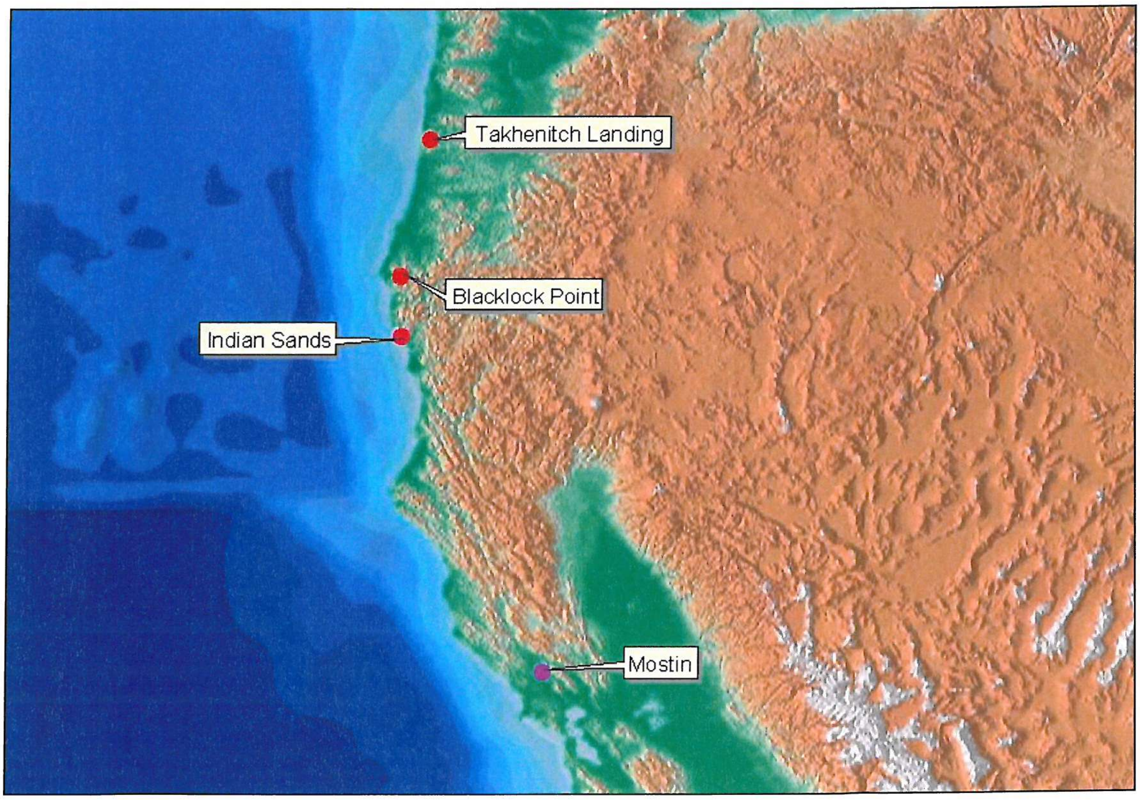


Figure 17. Coastal Sites in Oregon and northern California.

Takhenitch Landing, Blacklock Point and Indian Sands.

Oregon has very few coastal sites of any antiquity and publication of all sites that are present is less aggressive than in nearby areas such as California and Nevada. Of those sites that have been excavated the oldest is found at Takhenitch Landing located on the Oregon coast north of Coos Bay. The site contains only seven non-diagnostic lithic artefacts but many faunal remains. Three kinds of mammal were identified, harbor seal, sea otter and 11 rodent specimens. Bird remains consisted of 33 duck elements and 11 cormorants as well as lesser numbers of unidentified species. Fish were abundant, Staghorn Sculpin, starry flounder, surfperch, tomcod, Pacific hake and herring identified. Pacific hake is an offshore fish while the others could have inhabited the estuary environment that characterised the site at 7960 ± 90 BP (Matson and Coupland 1995: 80 – 81).

Punke describes two other sites on the Oregon coast that have evidence of ancient occupation. Blacklock Point dates to 7560 ± 80 BP and contains leaf shaped, contracting stem, expanding stem and broad stem projectile points. Indian Sands has a lithic assemblage of choppers, fire-cracked rock, cobble spalls and flakes as well as some mussel remains. The site yielded dates of 7790 ± 70 BP, 8150 ± 120 BP and 8250 ± 80 BP.
(http://oregonstate.edu/dept/anthropology/SeaGrantWeb/oregonsites.html).

Legion Park, Mammoth Park, Stafek.

These sites are technically too far inland to be included in this study and very little data is available for them yet. However given the lack of data available for Oregonian coastal sites it is worth mentioning what is known about these locations for comparative purposes. They are all located around Woodburn Oregon but have not yet been fully published. The Mammoth park site yielded archaeological remains in 1996 during the second field season. The majority of the evidence came from strata 12300 to 11300 years old. This consisted of 'Several examples of cut terrestrial mammal bone, some measuring approximately 8 cm in length and 4 cm in width, were documented. One section of a cut limb was also confirmed. Additionally, a cut and polished cylindrical bone fragment resembling a whistle was also observed' (http://www.ndsu.nodak.edu/instruct/schwert/qel/woodburn/woodbrn4.htm). Legion Park and Stafek are also found in Woodburn. 'Within sediments >10,000 years in age occurs the evidence for man in the form of stone and bone tools, and polished bone.' 'Plant macrofossils pr esent within these samples include mostly riparian woodland species -- alder, spirea, dogwood, birch, and lots of emergent aquatics' (http://www.ndsu.nodak.edu/instruct/schwert/qel/woodburn) So while coastal sites are rare it is possible to find early sites in Oregon, at least east of the Cascades.

California.

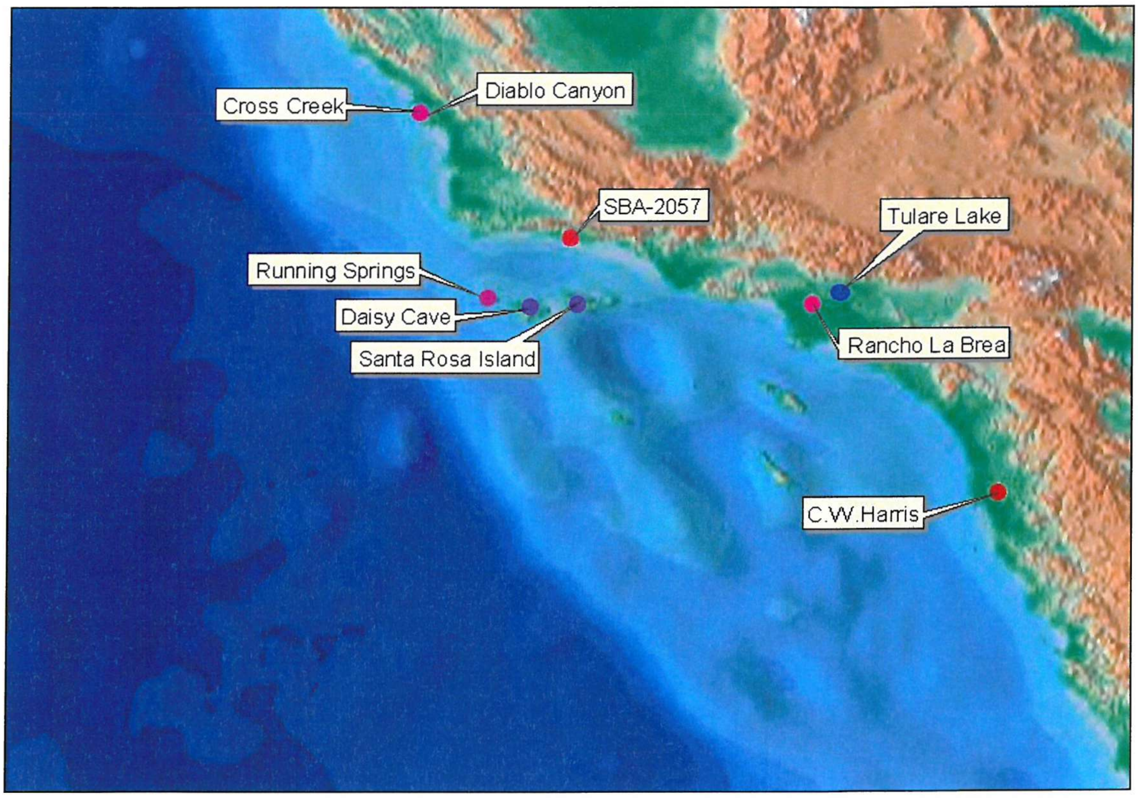


Figure 18. Coastal Sites in southern California

Mostin.

The Mostin is situated on the Kelsey Creek in northern California. The area contained a number of burials, many destroyed by erosion (Dixon 1999: 128 –129). The earliest dated burial was burial 4 and this dated to 10260 ± 340 BP. Burial 1 dated to 9040 ± 200. The subsequent discovery of more human remains at Kelsey Creek gave a date of 11250 ± 240 initially but a later date on bone collagen came out at 10470 ± 490 BP. It is possible that these dates will have been contaminated by geothermal springs. These latter remains gave a 13C measurement of –24.5 0/00 indicating mostly terrestrial diet. Technological remains include three ground stone artefacts, two pestles and a mano all used for seed processing.

Cross Creek.

CA-SLO-1797 at Cross Creek on the central Californian coast represents an early midden component. Dates corrected for isotopic fractionation and marine/ atmospheric 14C discrepancies start at 9900 ± 270, the first in a suite of twelve dates in the same strata that dates to 7500 ± 110 BP (Jones et al. 2002: 217). The artefact assemblage consisted of 74 lithics, including 17 handstones, 12 milling stones, 2 anvils, 20 core/cobble tools, 9 hammerstones, 1 biface 3 side notched projectile points and a fish shaped object. The nearby Monterey chert formation accounted for much of the debitage (97.1%). Shellfish dominated the faunal assemblage including Pacific Littleneck, Washington Clam, California mussel, Gaper clam, Pismo clam, basket cockle and acorn barnacle. A single rockfish vertebrae was also found. Terrestrial resources included a single deer antler that could be identified and twelve unidentified fragments. In the older strata this cannot be due to bad preservation as the PH value of 8.00 would preclude this. Jones et al. interpret this as meaning land resources were simply not a major part of the subsistence strategy here (ibid: 222). Jones et al hypothesise that such an early adaptation possibly indicates a coastal migration.

Daisy Cave.

The Daisy Cave site is located on San Miguel Island in the Californian Channel Islands. The oldest strata at the site is stratum G with corrected dates on shell of 10700 ± 90 BP and 10600 ± 70 BP. A date on charcoal was 10390 ± 130 BP (Rick et al. 2001: 595 – 613). The assemblage had an impoverished terrestrial resource component, the largest mammals present being fox and skunk. The marine resource was abundant 27430 fish bones recovered, some from taphonomic factors other than human. However, fish was the dominant subsistence resource as the lack of digestion marks on many of the remains meant they were probably processed and eaten not consumed whole as animals would have done. Two-hundred-and fifty-two individual fish were identified made up of 18 different taxa. Fish comprised 50 to 65 percent of the diet with shellfish forming 30 to 40 percent. Sea mammals and birds were supplemental. The earliest lithic technologies at the site were expedient flakes from stratum G. The younger strata, E and F, contained a large number of bone fish gorges and cordage remains were found in the early Holocene strata. Rick et al. infer that the types of fish remains found indicate a use of rod and line fishing with some sort of nets. Access to the kelp beds that formed the habitat for many of the fish species would require maritime transport, as would initial occupation of the island.

Arlington Spring/Santa Rosa Island.

The Arlington Springs site on Santa Rosa Island consists of the remains of two weathered human femurs found 37 feet below the surface of a hillside on Santa Rosa Island, California. The bones consisted of the head and shaft of one femur and the shaft of a second femur. Charcoal directly associated with the bones was dated originally to 10400 ± 2000 BP, the large error due to an insufficient sample. A second sample from the same horizon was taken later and this gave a date of 10000 ± 200 BP (Orr 1962: 417 – 419). Oakley managed to conduct comparative analysis of the uranium, fluorine and phosphate contents that show these bones were probably not intrusive burials but actually were of high antiquity (Oakley 1963: 1172). Johnson led a reinvestigation of the site in order to verify the antiquity of the bones and confirms that they are over 10000 years old, using purified collagen to get a date of 10960 ± 80 BP from the bones themselves and 11490 ±70 BP on directly associated rat collagen (Stafford 2002: SAA conference). On the same island 'a repeating pattern of burned mammoth bones, fire areas, abalone shells at a considerable depth in terrestrial deposits, and chipped stone tools are found, and have been dated variously from

12500 to 29700 years BP' (Orr 1962b: 219). This is no longer considered a feasible association.

SBA 2057

The site of SBA 2057 lies on the Santa Barbara coast in Canada del Aqua Caliente. The site is a shell midden 16 metres above sea level and one kilometre from the present coastline (Rick et al 2001: 621 – 633). The earliest adjusted date for the site is 8400 ± 100 BP two other dates of 8040 ± 95 BP and 7960 ± 100 BP were also taken. Rick et al suggest occupation of the site at 8350 ± 150 BP. The artefacts at the site include a metate fragment, 16 utilised flakes and 123 pieces of debitage. Three thousand and eighty fish bones were retrieved, 3048 teleost, 32 elasmobranch all of which inhabit bays and estuaries. Nets must have been used to capture some of these animals while harpoons or fish spears would also have been required.

Tulare Lake, Diablo Canyon and Buena Vista Lake.

The Tulare Lake occupation is associated with fish; bird and mammal remains probably obtained from the lake and dates to 11450 ± 340 BP although Dixon gives no more information about this site (Dixon 1999: 200- 201). Diablo Canyon is a shell midden on the south-central California coast that produced date of 9320 ± 140 BP and 8960 ± 190 BP (Jones et al 2002: 215). Deer shellfish and birds were exploited here (Jones 1991: 419 – 443). Buena Vista Lake is located near Tulare Lake and has similar artefacts as well as the remains of shellfish, birds, turtles, fish and deer (Dixon 1999: 204). It possibly dates to 8200 BP.

La Brea

The Rancho La Brea tar pits in Los Angeles yielded some remains of a human skull thought to be that of a female of middle age (Merriam 1914: 198 –203). Later Berger gave a radiocarbon date of 9000 ± 80 BP for these remains (Dixon 1999: 130)

C.W.Harris.

The C.W.Harris site lies next to the San Dieguito River in San Diego County, California (Warren 1967: 168 – 185). The artefact assemblage is varied and consists of knife blades, projectile points, a crescent amulet, engraving tools, choppers, hammerstones, core hammers and various scrapers. The earliest date for this site is 7080 ± 350 BP.

Conclusion.

The initial observation that can be made based on these sites is that there are very few early coastal sites on the American West Coast. Of the thirty sites described above only fifteen pre-date 9000 years BP and only seven are older than 10000 years BP. If we postulate a date of 15000 BP as the latest date that could have seen settlers enter the Americas in time to populate Meadowcroft and Taima-Taima we would expect to see some evidence to support this on the coast. If seven currently known sites date between 10000 and 12000 BP should we expect a similar number in the preceding two millennia? Secondly, the oldest site in the selection is the Manis Mastodon site in north Washington State, a site that lacks the evidence of exploitation of coastal resources displayed in other sites. In the Washington and Oregon area there are possible inland sites at Woodburn which may be contemporary with the Manis site but not on the coast. In fact, the Washington and Oregon coast is entirely bereft of early coastal sites, as is arguably the Vancouver Island area. Between Namu in British Columbia and Mostin in California no coastal sites exist that predate the Indian Sands site at 8250 ± 80 BP. This is odd since inland sites such as those at Woodburn and Fort Rock, not discussed here since it is located too far inland, are much older than this date. Figure 19 shows the sites plotted by latitude and age demonstrating that apart from the Manis Mastodon site the central section remains bereft of sites until well into the Holocene. Thirdly, as shown in Figure 19, the oldest truly coastal sites are situated in the south, in the Californian Channel Islands, and the surrounding area contains many of the other very old coastal sites. Of the northern sites, in British Columbia and Alaska, the oldest is Hidden Falls at 10345 ± 95 years BP. Also of interest is the fact that Hidden Falls is one of the oldest sites yet is in one of the most northern parts of the study area. Distribution of remains is generally not differentiated along the coast. Fish and shellfish remains are found in sites throughout the study area. While most of the human remains found are from California there are also remains from Gore Creek and On-Your-Knees Cave in the north. Sites with no evidence for marine exploitation in the form of fish remains, technological artefacts location or which have a terrestrial dominance in the record, either from faunal remains or diet reconstruction are limited to south of Gore Creek and Namu but this may be due to the sampling process rather than being a real observation. The final observation is that sites do not become numerous along the coast until relatively late, after 9000 BP.

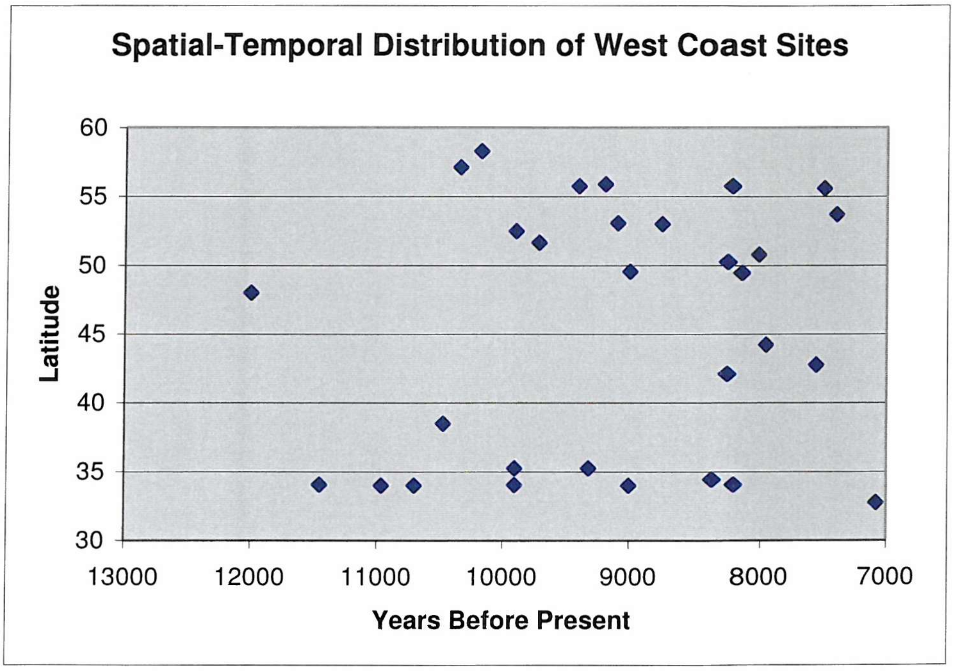


Figure 19 Sites plotted to show spatial-temporal disparity.

So, if the Americas were colonised via a coastal route why are no sites on the coast as old as others inland and in South America? In addition, why are those sites that are on the coast distributed in the way they are, with older sites in the south and no sites on the Washington and Oregon coastlines? Why do northern sites postdate southern Californian sites? There is a variety of possible answers to these questions. Possibly the most immediate thought is that maybe the site distribution directly reflects coastal colonisation, perhaps the coast was colonised later than areas inland because coastal migration did not occur? Perhaps site location is a result of sampling bias. Population density on the West Coast is highest around parts of California and the one could make a case for a some bias in the way sites have been found purely on the basis that the presence of more people would mean more finds. Easton and Gruhn both discussed the possibility of site submergence being a factor in the current failure to conclusively prove that coastal migration occurred. We know sea levels have changed since the last glacial maximum, would this, or other taphonomic factors account for the lack of sites on the coast and the distribution of those that remain? Finally, perhaps ecology plays a part. Could habitation occur at different rates and in different ways according to the local environment and inherent problems new populations would have had adapting to it? So we have four theories, late colonisation of the coast, sampling bias, taphonomy and finally, ecological boundaries. Of these theories the latter two, taphonomy and ecology, will be explored in the following chapters to see if it is possible to reconcile West Coast site distribution and the coastal migration theory of the first peopling of the Americas.

Chapter 3. Submergence effects on site distribution.

Introduction.

In his exploration of early man sites in America Meighan questions, "*whether the submergence of early sites might have removed from the archaeological record all the evidence of very early humans in the New World*" (1983: 445). In Meighan's opinion, it is unlikely that submerged coastlines can be used as an argument for early occupation since what submerged sites that we do know of are not truly ancient. Also Meighan states that "*all truly coastal sites in the USA earlier than about 5000 BP must now be below sea level*" apart from areas where shellfish may have been taken far inland for exploitation although he does not state how far this is. Accepting that some counterbalancing factors may isolate early sites from the water, Meighan argues that not all early sites would be preserved underwater; instead, some should be expected to be found on land. As proved in previous chapters this is the case, sites as predating 11000 BP can be found on some parts of the coast while the Cross Creek site indicates the use of maritime resources at a distance of possibly twelve kilometres from the contemporary shoreline. Meighan' s review was written before the publication of Monte Verde and during the period of the Meadowcroft excavation so does not take into account these sites. Had it done so the question would not be whether submergence could remove all evidence of early humans but possibly could it remove all the evidence of early human migration routes? As described in chapter 2 Gruhn and Easton both postulate submergence as a key factor in the failure to prove coastal migration occurred and the point is reiterated by Dixon (1999), Dillehay (2000), Erlandsen et al (1998) and Fedje (1996) among others. Meighan's point about submerged sites not being early enough to provide evidence of early human occupation is a debatable one. In the same volume as Meighan's analysis Patricia Masters describes underwater search and survey techniques that resulted in the retrieval of artefacts possibly dating to up to 9000 years BP within depths of five to twenty-five metres (1983: 198). Notwithstanding the stratigraphic integrity of such surface finds, Masters accepts that the distribution of reported sites may depend on the frequency of diving in an area and the depth to which SCUBA equipment can be safely used. If sites are older than this they would possibly in deeper water, where sports diving and SCUBA equipped survey teams could not effectively go. The attempts in the Queen Charlotte Islands to locate paleoshorelines and retrieve artefacts described in Chapter 2 have resulted in localities at depths greater than 150 metres being isolated, far deeper than even commercially trained diving can operate so the current lack of submerged sites cannot fully be explained by their absence. Thus, Meighan's reservations about currently known submerged sites are refuted. In order to investigate the probability that the reason for the lack of sites on the coast between 14500 and 11450 BP is due to rising sea levels, an understanding of the timing of sea level rise in the areas of interest as well as the extent of the landscape this will cover is needed. Sea level rise along a steep gradient such as a cliff face will have less potential to submerge sites than the same rise over a shallow incline (Figure 20).

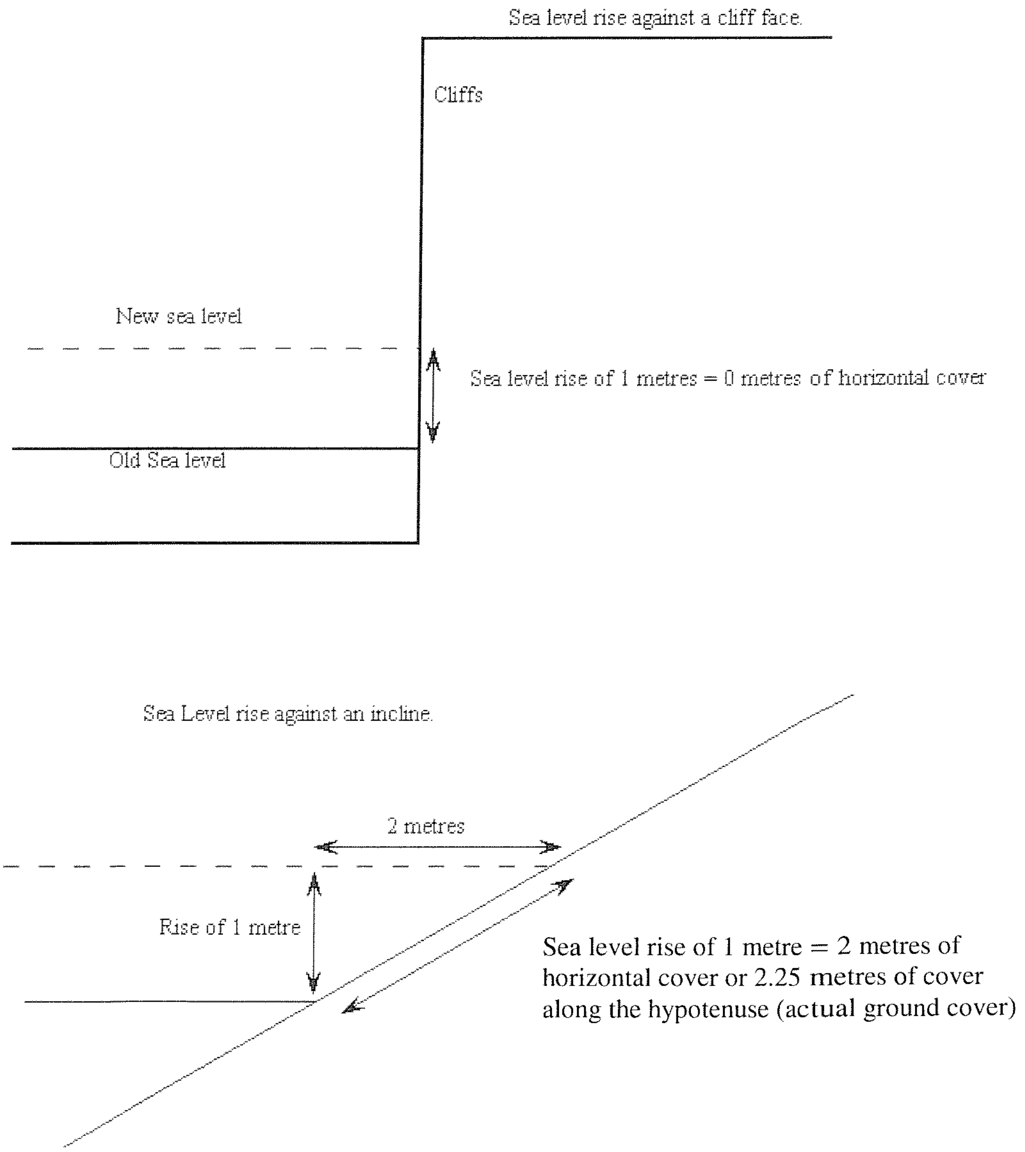


Figure 20. Differing effects of sea level rise.

In this chapter sea level change along the North American West Coast will be discussed within the context of global sea level studies. Changes in sea level along the coast will then be applied to bathymetric data to assess the possible extent of submergence and isolate patterns that may explain the distribution of sites described in Chapter 2 and the lack of sites bridging the chronological gap between known coastal and inland occupations. What will not be attempted here is a reconstruction of the coastline at the last glacial maximum or at any stage since. Of interest here is the relative extent of areas submerged since the last glacial maximum. Investigation of this will enable correlation of varying sea level effects with the distribution of site ages previously discovered. The sea level datum is generally assumed to be mean sea level and that is the datum used here when referring to sea level of depth of water.

General Studies of Sea Level Change.

Sea level changes are normally modelled using relative sea level curves such as those by Dyke and Peltier (2000). According to these models, the sea level since the last glacial maximum was generally several metres below its present day level and they are often used on a broad scale to show where paleoshorelines previously existed. These put the shoreline at the last glacial maximum some 120 metres below its present day level. Daniel Stanley presents a cautiously optimistic synthesis of the currently available data in order to assess the suitability of it for creating general sea level models (1995: 1- 6). While prior to the 1970s eustatic sea level change was thought to be nearly simultaneous globally scientific thought following the 1970s realised that local changes are more complex and areas that were thought to be stable are more mobile than previously thought due to faulting, isostatic loading, sediment deposition and geoidal variation due to core-mantle changes at great depths. Synthesis of radiocarbon-dated sea levels from around the world resulted in a "*remarkably wide ranging distribution of points above and below the present sea level*" (ibid: 3). Stanley describes the quest for a single stable reference point as frustrating since it simply may not exist, but some general observations lead to optimism that it may. Global wave cut platforms dated to 18000 years BP exist approximately 120 to 125 metres below the present sea level and deltaic formation between 8000 to 6500 years ago indicates the end of a rapid sea level rise and the start of more gradual increase.

So far, Stanley believes it is too soon to produce a truly global curve but it cannot be dismissed as impossible. This remains to be proven although research into sea level changes described next in this chapter argues against it.

For the purposes of this study the use of a generalised curve such as Stanley seeks is unsuitable not only since it may not exist, but also since it is variation between areas that may cause differences in distribution of surviving sites. In addition, sea level change has varying effects dependant on the type of coastline where it occurs. Differences in the gradient of a coastline mean sea-level fluctuations can have a minor or major effect. If sea level rises on an area with a steep gradient, such as a section of a cliff, a rise of several metres will have little effect on the overall nature of that coastal region (Figure 20). Should the same change occur on an area with a very shallow gradient large areas can be flooded and the coastline changed considerably (Figure 20). The delta area of the Ganges-Brahmaputra Rivers is one such area. A sea level rise of half a metre over the next fifty years would be enough to flood one thousand square kilometres or one tenth of a percent of the country's landmass (Davis 1997: 65). Therefore, sea level rise may occur at different rates on the American coastline but it is also necessary to understand that its effects vary depending on local topography. Even by ignoring depositional regimes which could make large changes in the coastline, yet are harder to document, it can be shown that topographic differences influence the effect of sea level change throughout the North American West Coast.

Sea Level Change in America.

It is the most northern part of the North American continent that has attracted the most attention in terms of ancient migration routes as, according to McManus and Creager,

> *'Unlike the continental fringe that is the typical continental shelf, where rising sea level merely translates the waters edge farther inland from the fringe of the continent, Beringia was land bridge, where rising sea level continually narrowed and finally severed a land connection for certain animals and plants. As sea level rose an increasingly effective barrier was established between Asia and* North America...' (1984: 323).

Estimates vary for when the Bering land bridge was finally parted, Marincovich et al have published results that put the parting of the land bridge about 7,400 – 4,800 years ago based on analysis of marine bivalve molluscs called Astarte (2001: 329 – 335). They also admit that the problem of dating the creation of the Bering Strait is a challenging one (ibid: 329). However with some tacit acceptance that watercraft may have been used since the colonisation of Australia at least 40000 years ago this division may be less relevant. McManus and Creager's 'increasingly effective barrier' may not be that at all. However, as described in the previous chapter the glacial extent on the West Coast means that sea level data is especially important for assessing routes from Beringia. Further south changes in sea level and the related changes in the extent of the land may have profound implications for site survival. However locally applicable sea level curves for the West Coast are not universally available and as described later it is often the case that curves drawn from the east coast are used as analogues.

In 1968, Milliman and Emery took radiocarbon dates from the past 35000 thousand years to produce a sea level curve for the Atlantic shelf of the Continental Untied States (1968: 1121 –1123). Previous attempts were, they say, hindered by "*the dearth of radiocarbon dates greater than 15000 years and the identification of stable shelves*". The most common indicators used for such curves were dated shallow water molluscs, mainly *Crassostrea virginica* and salt marsh peat samples – which Milliman and Emery preferred to the freshwater peat used by other authors since freshwater peat can occur at elevations higher than sea level. Since there were the previously mentioned difficulties in finding radiocarbon dates older than 15000 BP using these methods Milliman and Emery extended their curve using alternative indicators. Oolites form in shallow saline lagoons and mineralogical studies show that for the north Carolinian and Florida oolites studied this was true for the periods they dated too. Those from North Carolina dated between 17000 and 29000 BP while the Florida oolites were mostly younger than 14000 BP. In addition, some Coralline algae and hermatypic corals that inhabit depths shallower than 20 metres yielded dates ranging from 11000 to 19000 years BP although this admittedly yields a large error bar. Two samples of beachrock from north Carolina were also dated. Beachrock is formed in the intertidal zone and is recognisable and thus usable for establishing marine limits within the tidal range. The study took 80 radiocarbon dates from such data to produce a curve with which sea level could be modelled for the period along the Atlantic Coast. The results indicated significant trends, beginning with a high stand 30000 – 35000 years ago when sea levels were near current levels. Levels fell slowly until 21000 years ago followed by a rapid descent between 21000 and 16000 years ago. At this stage, the maximum depth of approximately –130 metres was achieved. The transgression had begun by 14000 years ago with sea levels rising rapidly until 7000 years ago when a very gradual increase took over. Significantly, the transgression postdates previous expectations that said it started at 19000 BP based on the time of the glacial maximum in the Americas. Discrepancies between this curve and that for Texas are explained by referring to dates from sites elsewhere in the world, including Mexico, the Caribbean, Florida and the east China Sea. This suggests that the Atlantic shelf curve is eustatic, that is based on water volume, and that the Texas shelf must have undergone uplift during the Holocene thus forming the discrepancy. The Texas shelf sea level curve referred to is that published by Emery and Garrison in 1967 using 13 piston cores ranging in date from 7000 to 20000 BP (1967: 684 – 687). At the time, this was the largest set of such radiocarbon dates from this period. The Curray curve referred to by Gearhart et al. and discussed later in this chapter is according to Emery and Garrison, adjusted using other data, as the Texas samples do not produce enough detail alone to justify the construction of a compound curve.

The sea level curves for the glaciated area of North America have been collated and databased in the study by Dyke and Peltier (2000: 315 –333). These are local relative sea level curves synthesised from the RSL database for northern North America. Three types of relative sea level curve are identified for the glaciated portion of North America. first are those from heavily ice-loaded areas that are records of continuous emergence. There are 130 such curves in the database based on either datable material related to a specific paleoshore or materials that must have fallen above or below a particular shoreline. For the kind of curve indicated by features above the shoreline, dates are obtained primarily from driftwood or sea mammal remains. However these are only available for the central and eastern Canadian archipelago where raised beaches have abundant driftwood or whalebone. The second kind of curve is based mainly on ages from marine mollusc shell that must form below sea level, preferably the spatially restricted *Mytilus edulis*, and archaeological or terrestrial deposits which must form above sea level. Drawing curves from such data requires subjectivity since the dates and depths form "*a cloud of data points on at least one side of the curve, preferably on both sides*" (ibid: 317). The assimilation of such curves requires reasonable spatial distribution, and Dyke and Peltier believe too few Pacific coast sites exist to form a coherent pattern of postglacial emergence. However, they do have curves formed for sites in the Fraser Delta in southern British Columbia and Victoria that show emergence in the late Pleistocene and early Holocene followed by some Holocene submergence, very different from the East Coast histories (ibid: 320). The coast of British Columbia is the location of the deepest postglacial low stands observed by Dyke and Peltier. At 10500 BP, the sea at the north end of Vancouver Island regressed to lower than –95 metres following a high stand of 27 metres at 13000 BP. The Queen Charlotte Islands saw the shoreline at –153 metres at 12400 BP rising to 14 metres above sea level by 9000 BP. This massive submergence following such a low stand may be indicative of forebulge migration and collapse combined with general eustatic rise but comparisons with the Barbados curve indicate that eustatic rise can only account for 61 metres of this observation so 106 metres of forebulge collapse is required to explain the remaining amount of submergence. This could be explained by short response times and sharp crustal flexure indicative of low mantle viscosity or a thin lithosphere in this area. Alternatively, glacioisostatic stress may have distorted the plate tectonic stress field in the area leading to tectonic subsidence in the Late Pleistocene (ibid: 330).

The main importance of sea level rise to this study is as a way of explaining differing site survival and to predict areas were submergence is likely to inhibit this. Cheryl Ross has assimilated some current knowledge about ancient North American coastlines and produced models using the Terrainbase DEM dataset and Grass 4.1 software. These have been modelled on a continental scale in order to assist with early migration studies and show what areas of Quaternary landscapes are still visible today and therefore, what chance there is of site survival in these areas (Ross 1997: 18). The simulation took the form of a computer modelled buffers set along paleoshorelines and effectively cropped by modern submergence. By using the expedient system of buffering 20 kilometre intervals from the past shoreline Ross presents a ready reference for seeing how any given area of the modern shoreline might contain remnants of those from the past. According to these reconstructions most of northern America's West Coast extended further than it does in the present day. Ross's research shows that due to differing sea-level rise there is a probability that past sites are subaerial in California's south coast (1997: 21) while to the north a greater amount of paleolandscape may be still submerged. Ross discusses Johnson's work in the Californian borderlands which suggests that the land surface in the Channel Islands area would have been vastly larger than present 18000 years ago, and Meighan's description of sea level rise on the Californian south coast, which states that sites on the coast were present but probably submerged (Ross 1997: 20-21). Ross details these as corroboration of the potential for archaeological remains to exist in the area but their description implies that such remains would be largely submerged. Why then would this show "*a direct correlation between areas of the highest potential for site location, predicted by the Paleocoastlines of North America model and the evidence presented here from research conducted at the local scale*"(Ross 1997: 24)? The Northwest Coast portion of Ross's study is supposedly corroborated by findings from Josenhans that shows a low stand of -153 metres off the Queen Charlotte Islands. This matches the predication that early coastlines from approximately 15000 BP are largely submerged with little of the nearshore area surviving. This is despite evidence presented by Ross that "*due to extensive post-glacial tectonic activity and glacioisostatic rebound, Mann and Hamilton are convinced that generalised curves of eustatic sea level change cannot be applied to many areas of the North Pacific*" (Ross 1997: 25). Ross also documents evidence of uplifted shorelines at Kitimat Fjord yet these are ignored by the model produced. This illustrates that when generalised sea level models are applied local data does not necessarily corroborate it. Instead, it is necessary to examine sea level changes at a local scale to determine the suitability of the application of generalised curves. Next, such an examination will take place using findings reported in the literature to assess the nature of sea level rise on a scale where general, global curves are inappropriate. Wherever possible dates are given in uncalibrated radiocarbon years, exceptions are noted in the text.

Alaska and British Columbia.

Barrie and Conway (1998) present the results of cores from the asymmetric marine trough between southernmost Alaska and the Queen Charlotte Islands. The glacial history of the area is covered in a later chapter, but it suffices to say that after a maximum advance at 16000 BP retreat was completed by 13500 to 13000 BP (Barrie

And Conway 1998: 113 – 123). A core from marine sediments in the northern Hecate Strait yielded dates of 14380 BP in a depth of 37 metres. Barrie and Conway state that this implies that relative sea level 14380 years ago was above the 30 metre bathymetric contour but was probably no higher than present. Three cores from an area nine kilometres to the south are representative of a terrestrial tundra environment dated to 13790 BP. Using the standard 600-year reservoir correction this is interpreted as a significant fall in sea level over 590 years. A core taken in water 77 metres below mean sea level at the junction of the Hecate Strait and Dixon Entrance yielded organics with dates between 12520 and 12690 BP. Therefore rapid regression occurred between 14400 and 12400 BP. The maximum low stand was reached after 13000 BP and remained until 12400 BP. In eastern Dixon Entrance, this lowering was approximately 80 metres while in central Dixon Entrance it was approximately 150 metres.

In the Dogfish Bank area off the east coast of Graham Island, in situ tree roots reported by Luternauer were found 95 metres below mean sea level (Josenhans et al 1997: 73). This indicates subaerial exposure in this area dating to 10500 BP. Preglacial lake deposits have been found 170 metres below mean sea level southeast of the Moresby Archipelago. These findings are indicative of a subaerial exposure in this area lasting from 13200 to 10000 BP. If these sites were above sea level at this time depression of the land surface due to ice loading cannot have been extensive, implying little isostatic loading from the Queen Charlotte Islands glacial cover. Transgression in the Queen Charlotte Islands will have reached 14 metres above present sea level between 9000 and 7000 BP whereas at Cape Scott, on Vancouver Island, a maximum of 27 metres was reached and 30 metres was reached at Bear Cove Bog in the same area and Hesquiat Harbor reached 25 metres above sea level. Dates for these transgressions are around 13000 ± 110 BP (ibid: 75).

In the Hecate Strait area lie a number of submerged basins and paleolakes that record a history of contact between freshwater and marine sediments (Josenhans et al 1995: 71). The transition between such sediments is marked by the change in diatom from cores and dated using wood fragments. Josenhans et al collated 267 radiocarbon dates, 86 from archaeological sites, 52 from raised paleobeaches, 30 from lake cores and 99 from marine cores to produce sea level curve for the area. This was combined with digital terrain mapping of the seabed to identify paleolandscapes and their present depths. The lowest point on the sea level curve is marked by a paleodelta from

Juan Perez sound at 153 metres below present sea level which is 33 metres deeper than the maximum estimated eustatic sea level low stand at –120 metres. Josenhans et al. argue for the paleodelta being indicative of the local sea level at the time of its formation. However, the date for the Juan Perez low stand is 12400 BP at which stage eustatic sea level was approximately 90 metres below present indicating a possible 63 metres of forebulge elevation. The curve rises rapidly following this low stand reaching a maximum of 14 metres above present sea level at 9050 BP and dropping over the next 3000 C_{14} years followed by a more rapid decline to present values from 6000 BP. The digital mapping programme revealed that at the -153 metres low stand that a meandering river system dominated the local landscape.

During the deglacial period in this area there was an abundant sediment supply off the Canadian coast. The limit of the sea level low stand is marked in Dixon Entrance by outwash plains at the -150-metre contour (Barrie and Conway 2002: 173). The transgression stage also saw abundant sediment supplies forming drowned terraces varying from 70 to 100 metres below mean sea levels on the inner shelf to 100 to 120 metres on the mid shelf and 150 to 200 metres on the outer shelf. Deltas would have also been forming along shorelines during the early transgression. The environments formed would have been drowned and preserved by the rapid sea level rise of approximately 5 cm per year. By the time of the potential high stand of 13 to 15 metres above present sea level during the early Holocene the coast of Graham Island would have become rocky apart from on the northeast tip where continuous sand and gravel beaches formed (ibid: 181).

Vancouver

Based on a synthesis of radiocarbon ages from deltaic, glaciomarine and terrestrial sediments on Vancouver Island's coastal lowlands with corroboration from tilts of late glacial lake shorelines in the Puget lowland and British Columbian interior Clague and James believe isostatic uplift in this area can be very well constrained (2001: 78). Their study indicates extremely rapid uplift in the area linked to rapid deglaciation. The Courtenay area on the east of Vancouver Island had radiocarbon dates indicating a marine limit of 150 metres above present sea level which dropped to below 21 metres above present in a few hundred years around 12000 BP. At Parksville southeast of the Courtenay area sea level fell from 108 to 52 metres in a few hundred years. This rapid rate of isostatic uplift in southwestern British Columbia declined during the Pleistocene/Holocene transition although the land continued to rise. This culminated in shorelines below present during the early Holocene that was followed by marine transgression underway by 8000 BP. This is supported by other cores from the Vancouver and Victoria areas taken during the summer of 2000 by the Geological Survey of Canada (James et al 2002: 1 – 7). Six sites between 23 metres and 73 metres above sea level were sampled dated with a marine reservoir correction of 390 years based on the assumed correction of approximately 800 years reduced by 410 years for normalisation procedures not used in the initial assumption. Where the boundaries between marine/glaciomarine and freshwater units were located, complex diatom analysis was undertaken which showed a transition from marine to freshwater conditions in all cases with no return to marine conditions. At Victoria sea level was shown to have dropped from 60 metres above sea level to its present limit between 12500 and 11500 years BP. In the Fraser Lowland the sea level curve portrays a drop from 175 metres above presents sea level at 12500 BP. By 12000 BP, it was at 80 metres followed by a slow decline over the next five hundred years to 60 metres. By 11300 it had dropped to 30 metres then slowly dropped to 10 metres at 10000BP. This study disagrees with prior results for the Fraser lowland that indicate a resubmergence event between 12000 and 11000 BP because, in the opinion of James et al, radiocarbon dating techniques have changed since the previous results were analysed.

Washington/Oregon

The sea level history of the Washington and Oregon area is far less well known than that of the area directly to the north. When Gearhart et al attempted to assess sea level change for the Washington, Oregon and northern Californian regions in their report for the Mineral Management Service of the United States Department of the Interior; they found little research had been done in the area (1990: II-21). The situation has not changed extensively since. Gearhart et al's solution was to apply eustatic sea level fluctuation curves to the West Coast by adjusting them for regionally observed tectonic influence. While they are aware of Nardin's sea level curve for southern California (see below) Gearhart et al. decided a more appropriate analogy would be the curve created by Curray for the Texas coastline, although they do not describe their reasons for this. The tectonic uplift data they suggest applying is derived from individual observations described by various authors within unpublished dissertations, articles and a coastal terrace study produced by Golder and Associates of Redmond, Washington for the Washington Public Power Supply System. It is assumed that the use of such figures as applied to the generalised sea level curve for Texas is acceptable although without more explicit justification it is hard to see why this curve and not Nardin's southern California curve is used since both are described in the report. An additional caveat to the Gearhart et al sea level curve is the dismissal of the effects of isostatic rebound which, in their words, is overwhelmed by rapid rate of sea level rise in the early Holocene (ibid: II-38). This is controversial since arguably the same can be said of tectonic uplift. In addition, application of the same sea level curve to different parts of the coastline is not necessarily valid.

Anundsen et al. have taken samples from Lake Carpenter in the Puget Lowlands in north Washington. These provide a record of inundation events in a lake situated approximately 9.5 metres above the present sea level (1990: 149 – 161). The method used was to subject cores from 22 selected depths to diatom analysis and radiocarbon dating. The different composition of the sediments revealed would show whether the sample came from a marine or freshwater environment or a transitory stage in between the two. The outlet of the lake was measured to be 8.2 metres above sea level with between 1 and 1.5 metres of erosion, resulting in an altitude of 9.5 metres above present sea level during the late glacial period. When sea level was above 9.5 metres, the lake would have been a marine environment, reflected in sediment deposit. During periods of reduced sea level, the sediments would reflect the reduction in inorganic sediments and increase in brackish or freshwater fauna. The results were dated using a 760-year correction to allow for the marine carbon reservoir, although comparison with other dated sediments indicates this is less accurate for older sediments. The 760-year reduction is based on figures calculated for Puget Sound waters but beyond 12000 BP, differences in ocean mixing and circulation change this leading Anundsen et al to suggest a lesser reduction may be appropriate. The sea levels they established are relative to the 9.5 metre threshold defined by the lake outlet. This results in a series starting from 13800 BP where sea level dropped below 9.5 metres above present. Between 13700 and 13600, a rapid transgression occurred after which sea level fell, not to return. While these results have no measure of the amplitude of sea level rise, they show that the curve applicable to areas of Vancouver and southern British Columbia are probably more applicable in northern Washington than that calculated by Gearhart et al's method. Further south where the effect of ice loading was lessened the curve might be more similar to that proposed by Gearhart et al or Nardin et al with continual emergence rather than any history of submergence following the eustatic low.

The uplift data applied by Gearhart et al. for their sea level reconstructions comes largely from the study of marine terraces in the study area that have emerged following formation underwater (Muhs et al 1992: 121). These step like platforms are good for shoreline studies since they are horizontal platforms the inner edge of which is a good indicator of mean sea level. Based on the sea level data from Barbados, New Guinea and elsewhere high stands have been established 125000, 105000 and 80000 years ago. Dating of exposed marine terraces using uranium series analysis and amino acid geochronology allows those created at the time of these high stands to be identified and when compared with the sea level at the time of formation and that of the present day calculations of uplift can be made. Muhs et al (1992) performed just such an analysis on terraces from southern Oregon to the Baja peninsula and established that uplift in the Cascadia area is high compared to moderate uplift in the area west of the San Andreas Fault. Further south in the area of the Baja peninsula uplift proved to be non-existent (ibid: 130). The uplifts recorded for the Cascadia region measured between 0.45 to 1.08 metres per thousand years compared with 0.15 to 0.35 metres per thousand years west of the San Andreas Fault. Clearly, these measurements are reliant on assumptions of sea level status from the time of the high stands that means they are reliant on sea level curves constructed for Barbados and New Guinea. Even so, they do demonstrate the possibility that considerably more tectonic uplift was taking place in the northwest part of the coastline than the southwest making comparison with Nardin's southern California curve problematic for the Pacific northwest.

One of the main reasons behind the current lack of useful sea level curves for the Northwest Coast area south of the Queen Charlotte Islands is because as well as differing tectonic uplift and ice-loading effects the seismic history for this area differs from that nearby. According to Atwater while the evidence from marine terraces indicates uplift of less than 0.5 millimetres per year on the Washington coast, similar to the figures described above, benchmarks taken over the last 50 years indicates a more rapid uplift of 2 to 3 millimetres per year (1987: 943). The reason for this is tectonic subsidence, or earthquakes. Evidence of rapid burial of peaty layers on the

Washington coast is indicative of rapid tectonic subsidence, as is the lack of tidal marshes that would form if submergence occurred due to isostatic or eustatic submergence (ibid). The Cascadia area of the Northwest Coast of North America is situated next to the Juan de Fuca plate. This is a triangular tectonic plate that sits between the Pacific plate and the Cascadia subduction zone, where the Pacific sea bed meets the continental shelf (Heaton and Hartzell 1987: 10). According to Clague most plate margins have records of earthquakes in the historical period of magnitude 8 or more (1997: 439). The Cascadia subduction zone has no such earthquakes recorded not because they do not happen in this area but because they simply have not occurred in the period of recorded history. Buried wetland soils indicate submergence caused not by sea level rise but subsidence caused by earthquakes along the Juan de Fuca ridge. Drops of 0.5 to 2 metres in elevation are inferred from the elevation of mud layers after submergence, this is too much for any nonseismic processes (ibid: 445). Earthquakes have occurred on average once every 500 years since at least 6000 to 7000 years ago as indicated by buried scarps detected by ground penetrating radar. These actually occur at intervals of between 200 and 700 years and the last such quake occurred in 1700 AD. The conclusion is, according to Clague, that earthquakes do occur regularly in this area and that the next quake is on its way (ibid: 449). Earthquakes from before the beginning of the Holocene are not documented but dating of earthquakes from the preserved effects is difficult. That several such earthquakes have occurred during the mid to late Holocene is evidence enough of alternative submergence events that would affect site survival and detection.

Since the earthquakes documented occur underwater often hundreds of kilometres offshore they are usually accompanied by tsunamis (Atwater 1987: 943; Clague et al 1997: 447; Heaton and Hartzell 1987: 168). Documented tsunamis hitting Japan may well have been formed by Cascadian seismic events and these large waves would have engulfed the Pacific northwest between Vancouver and north California as well, heading up river valleys and across beaches and dunes (Clague 1997: 447 – 451). These tsunami would have had profound effects on local ecology, populations and archaeological sites. In many parts of northwest North America, there exist large conifers over 500 years in age, the Sitka spruce being a good example. According to Benson et al. the Sitka spruce can live for up to 750 years yet they are vulnerable to saline conditions. An earthquake in Alaska in 1964 lowered an 800 kilometres strip of coastline by half a metre (Benson et al 2001: 141). Almost all the local spruce were killed. By 1973, the post earthquake deposits had become 1 to 2 metres thick and by the late 70s, spruce had started to grow in the area again. Between 1680 and 1720, the Cascadia plate area ruptured causing an earthquake that turned the coastal spruce forest into tidal flats just as the quake in 1964 did in Alaska. Examination of spruce in the Washington area shows that few predate the time of the quake and earthquake killed trees were analysed for ring width pattern matching that put the earthquake between August of 1699 and May 1700. Written records from Japan describe a tsunami on January 26th 1700 that may have originated here. The forest on the northwest American coast did not become re-established until the 1800s spreading seaward from inland as shown by increasing younger trees closer to the coast (ibid: 146). This earthquake "reset an ecological clock" (ibid: 140).

Tsunami action associated with earthquakes also impacts the settlement and archaeological preservation potential in the Cascadia area. From a study of 30 archaeological sites in the Cascadia region Hutchinson and Macmillan formed a chronology of site occupation and abandonment associated with tsunami events (1997: 81) The thirty sites were divided into three groups dependant on region. The Nootka group were sites located in the Nootka Sound, Hesquiat Harbour and Clayoquot Sound area and were located behind pocket beaches or on relict beach terraces. The location of these sites meant tsunami effects would be amplified and the effect on settlement was correspondingly highest in these sites although sea levels potentially 2 metres above present would have increased the tsunami effect. The Barkley group are located on the shores of the Barkley Sound and in general, these sites would have been subject to amplification that is more moderate. The Olympic group were based on narrow terraces at cliff bases in the Olympic peninsula and tsunami waves would have been weakly amplified. The latter two groups showed less evidence of site abandonment associated with tsunami and earthquake events than the Nootka sites showing that sites subject to tsunami hazards may be abandoned either permanently or temporarily after such an occurrence. Sites in the Salmon and Nehalem rivers on the north Oregon coast show evidence of burial under sandy deposits probably caused by tsunami action (Minor & Grant 1996: 772 – 781). Overlying the sandy deposit tidal flat deposits were found. Rapid submergence caused by seismic disturbance obviously does not just encourage site abandonment in some areas of Cascadia but can bury the traces as well. This may mean that sites are preserved under tsunami layers currently submerged or buried. The seismic disturbances on the West Coast are relevant to the discussion of site survival dependant on submergence in two ways. One, sea level curves for this area are harder to obtain due to the complications arising from extensive tsunami deposits. The second is that the depth of such deposits may make conventional site prospection techniques less effective thus reducing the number of sites found.

California.

According to Bloom California's coast is characterised by active tectonics with regional strike-slip faulting while the north was made more complex by movement of the Puget lobe of the Cordilleran Ice (Bloom 1983: 225). Since the Pacific coast was almost devoid of continental shelf, seaward regression caused by sea level lowering was only likely to be in the range of a few kilometres, which while significant is of lesser magnitude than changes in the North. The Californian channel islands would have been larger but not connected to the mainland while the mainland coast would have had no major changes in size apart from the San Francisco drainage. Uplift would not have been great where the right-lateral strike slip dominates but in the area where east-west transverse structures cross the San Andreas system uplift increases, for example the Ventura region which would have had uplift of approximately 10mm per year during the late Cenozoic. In areas of strongest uplift, some Holocene terraces have been found 40 metres above sea level. For the last 15000 years Californian coastal history has been one of submergence due to deglaciation further north.

Nardin et al, consider the application of sea level curves derived from supposedly tectonically stable parts of the world as flawed. In their opinion, "*few coastal areas can be considered truly stable because, in addition to eustatic and tectonic components of sea level change, there appears to be a significant isostatic component relating to loading of the sea floor by glacial meltwater*" (1981: 332). Instead, they believe sea level curves to be valid only for the areas in which they are measured. Using a series of high-resolution seismic reflection profiles as well as vibracores and radiocarbon dates they examine the stratigraphy and sedimentology of the Santa Monica shelf for the period following 18000 BP. The bottom of the curve is defined by a channel eroded into the shelf break at 85 metres below sea level. This channel erodes the shelf break to a depth of 127 metres below present sea level. The curve rises reasonably slowly to a depth of 24 metres below present sea level between 12000 and 13000 BP. Following this erosion of Pleistocene strata 56 metres below present sea level at 11000 BP indicates sea level drop to around 46 metres allowing for 10 metres of wave action (ibid: 333). This is followed by a slow rise to present levels by 2000 BP.

Discussion

As can be seen from the discussion above the rate of sea level rise along Americas West Coast is varied dependant on the coastal formation as well as the extent of isostatic loading and local eustatic variation. The effects these differences have can be seen if local bathymetric data is combined with modern day shoreline maps to delineate the extent of currently submerged landscapes. By combining the GTOPO30 and ETOPO2 datasets from the United States Geological Survey a good resolution map of the coastline could be constructed with the addition of bathymetric contours at the best resolution manageable for this scale of study. The maximum sea level low stand was derived from the sea level data described in previous paragraphs, and the area between this contour and the present day shoreline coloured to illustrate the extent of submerged landscapes. Figure 21 shows the Queen Charlotte Islands with the maximum low stand of 153 metres presented by Josenhans et al (1997) forming the lower boundary. As can be seen the extensive sea level lowering in this area results in a considerable amount of submergence following the glacial maximum. It is also known that the sea level rose to above present levels during the early Holocene so wave action may have aided site erosion above the boundary defined by the present sea level illustrated here.

Because of the problems described in ascertaining a sea level curve for the Cascadia region formed by Vancouver Island and the states of Washington and Oregon as well as the northern most part of California it is postulated that the Curray curve used by Gearhart et al. and modified with their tectonic figures could act as a proxy for the lower part of this area. Application of the same tectonic uplift data to the Nardin et al. curve could produce a disparity of up to twenty metres (Figure 22) but it must be accepted that the massive seismic disturbances associated with the Cascadia subduction zone make arguing for either curve possibly dubious. It is arguable that since the results produced by the Curray curve produce the largest area of submerged landscape for the purposes of an evaluation of possible site submergence it is more applicable.

As illustrated in Figure 22 the extent of this submergence would still be less than that of the Queen Charlotte Islands but extensive nonetheless. With the added destructive potential of the magnitude eight earthquakes documented in this area pre-Holocene site survival or discovery becomes more improbable.

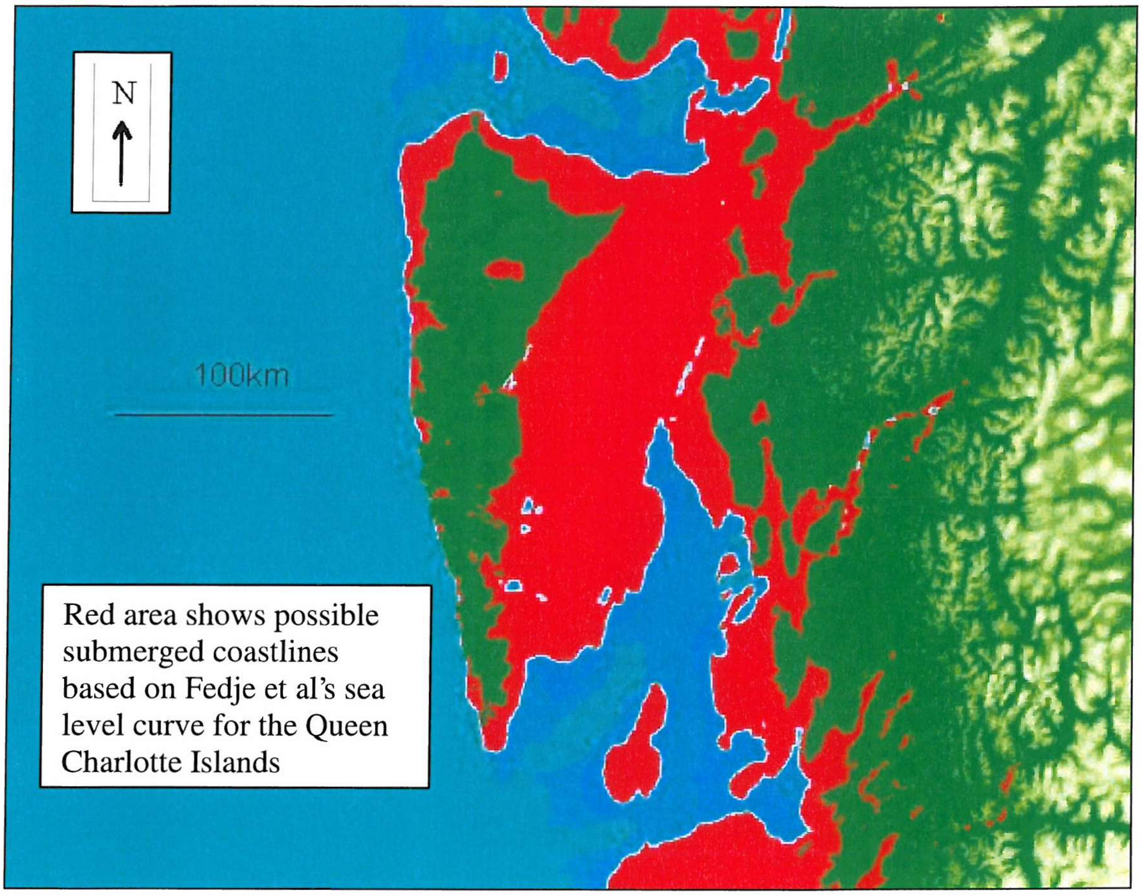
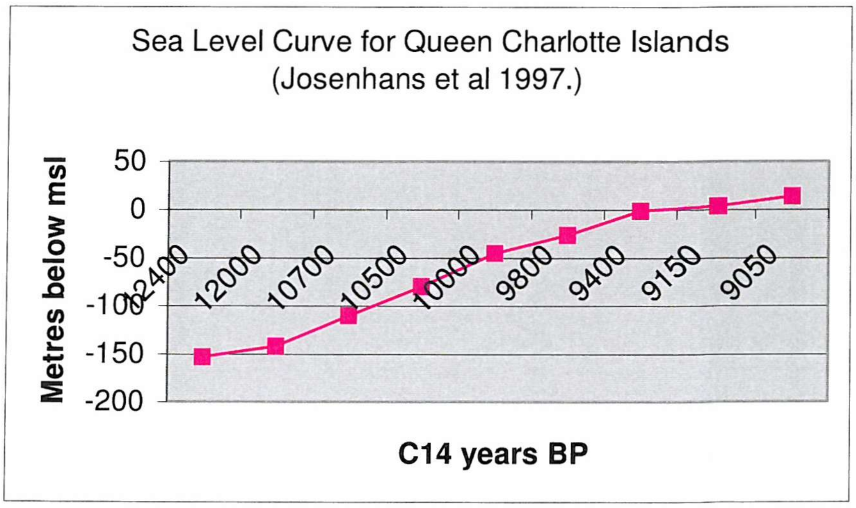


Figure 21. Submergence in the Queen Charlotte Islands.



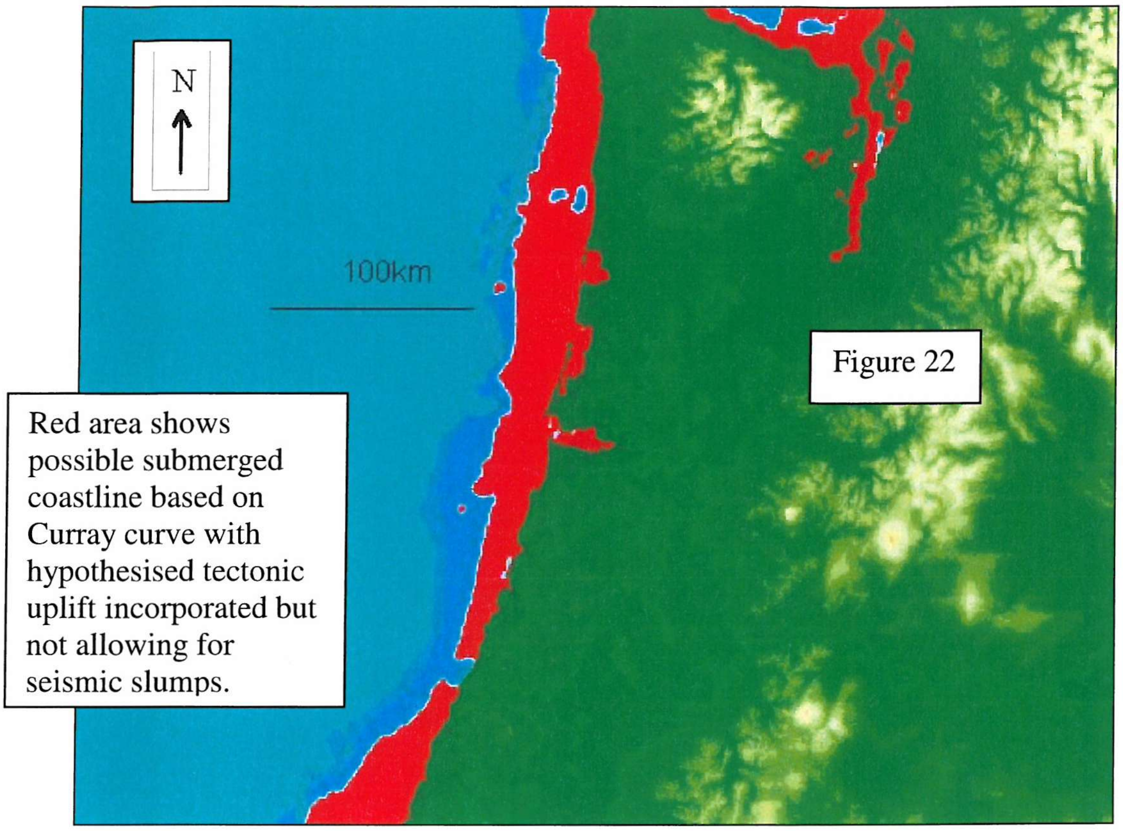
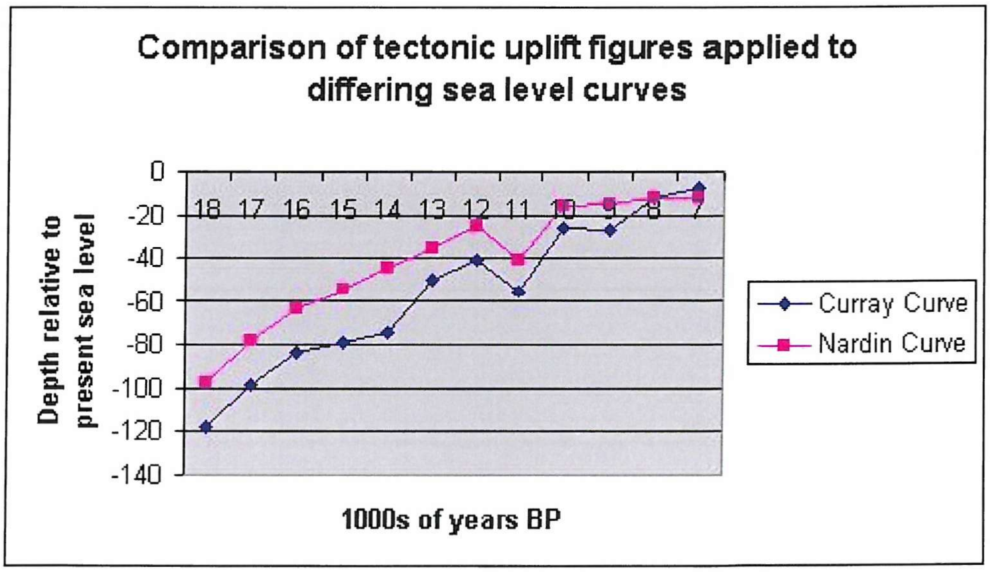


Figure 22. Submergence on the Washington/Oregon Coast.



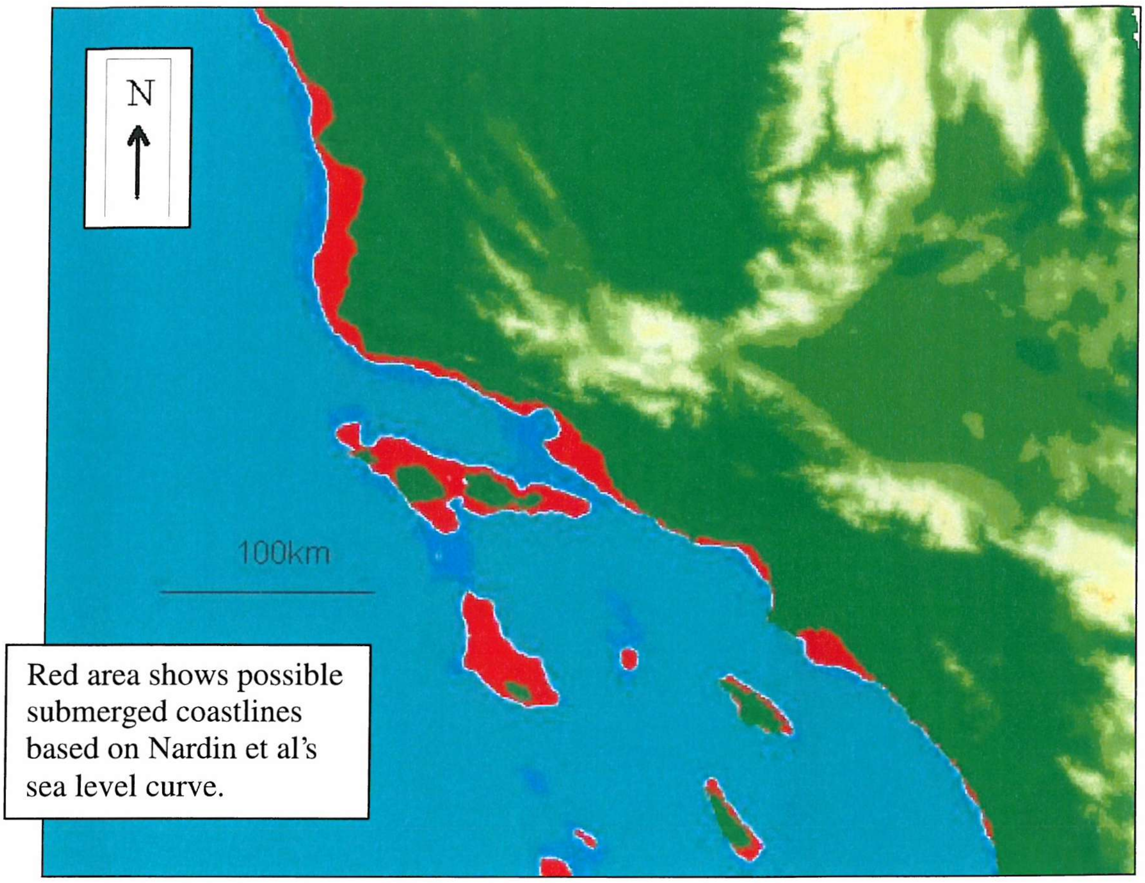
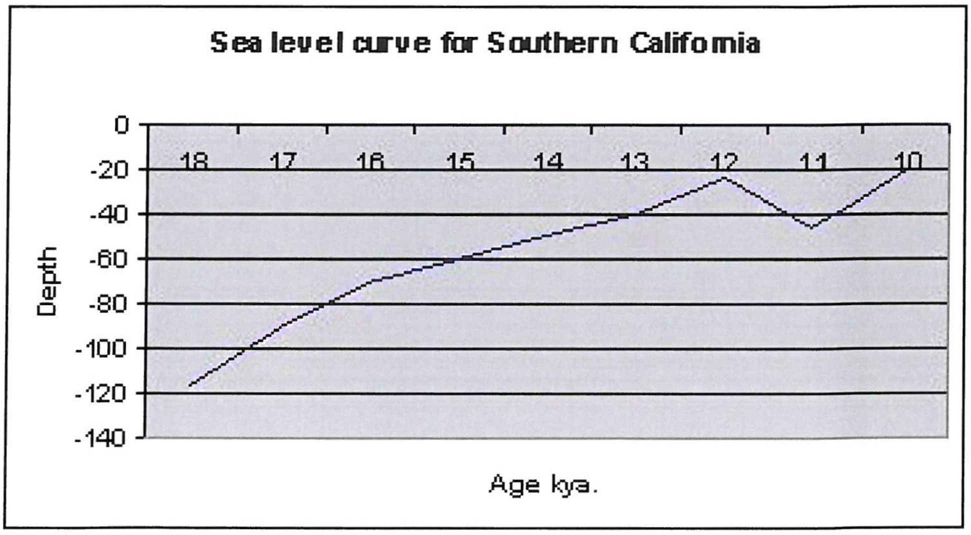


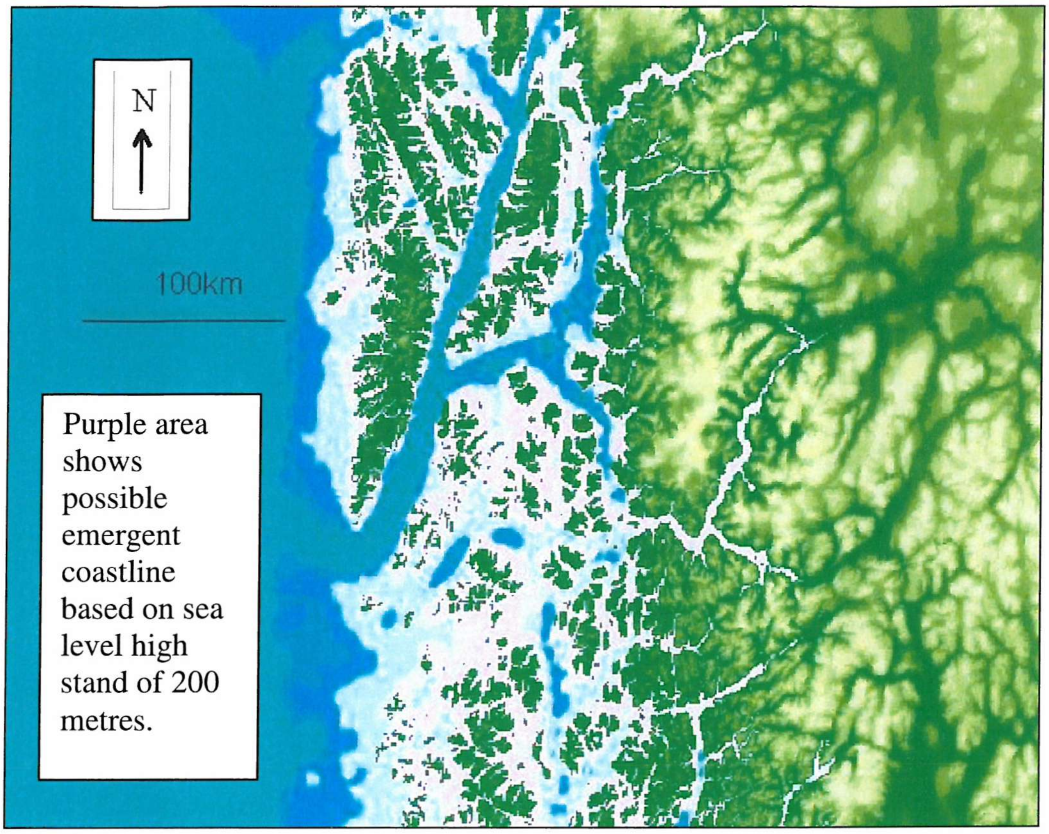
Figure 23. Submergence in southern California.



The Southern Californian coast is subjected to less sea level rise than found further north and in addition does not have the same seismic activity that may make northern sites less visible. Earthquake activity on the southern Californian coast is restricted to the terrestrial or nearshore areas, thus does not produce tsunami type waves as evidenced in Oregon or Washington. The coastal bathymetry is also steeper so sea level rise in many parts would have less impact than it would in the north. Figure 23 shows the southern Californian coast and Channel Island area with the red area defining areas of coastline submerged since the sea level low stand as defined by Nardin et al. The mainland exhibits very little submergence with some areas showing none at all at this resolution. As Johnson described though large areas of the Channel Islands are now submerged since the bathymetry here slopes more gradually than on the mainland. This has obvious implications for site preservation, the oldest sites described in Chapter 2 appear in the Channel Islands and locally this area is most susceptible to submergence.

Two areas not yet discussed are those of southwest Alaska and Vancouver Island. These two areas were subject to heavy ice loading and experienced emergence following deglaciation. Theoretically, the emergent landscape could contain preserved sites. Figures 24 and 25 show the area possibly exposed since glaciation based on the 200 metres high stand at Kitimat Fjord in Alaska and 150 metres in the Courtnay area of Vancouver Island. However, the seismic conditions that affected the Washington and Oregon coastlines would have affected at least the western shore of Vancouver Island decreasing the potential for site survival here and partially explaining the lack of sites so far found in this area. The emergent areas of Southwest Alaska may however provide good potential for site survival and it is here that some of the oldest sites in the study area were found.

Figure 24. Emergence of land in Alaska



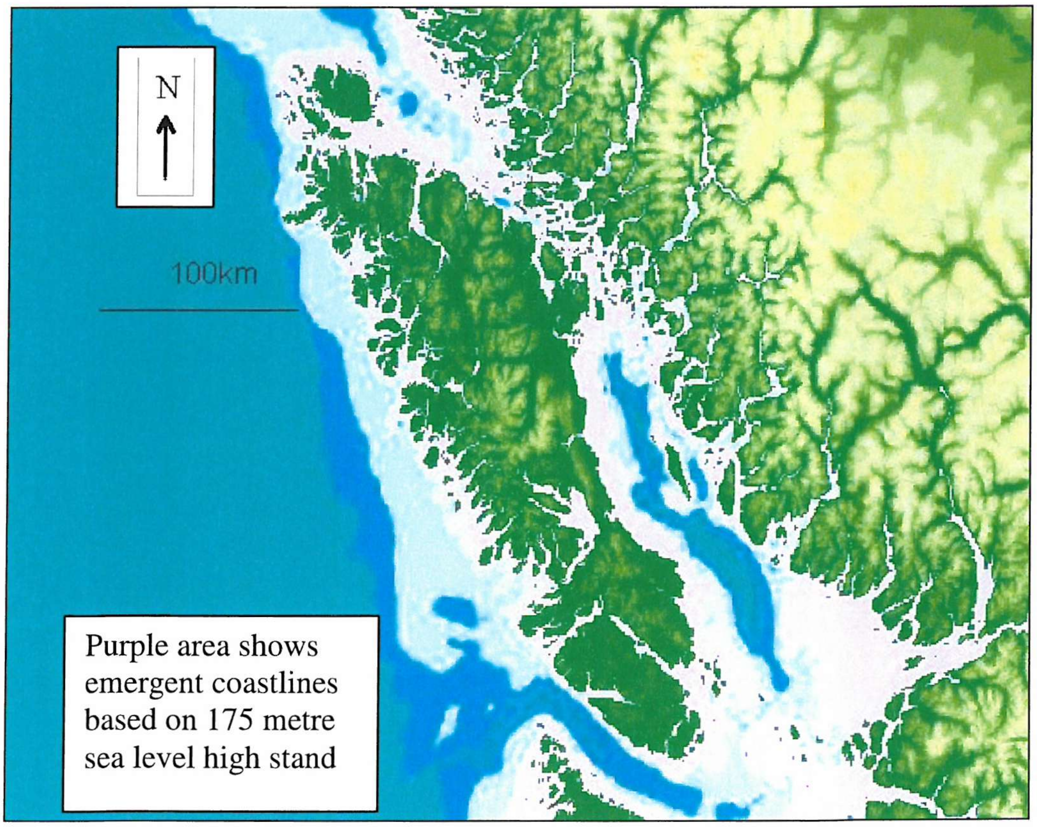


Figure 25. Emergence of land around Vancouver Island.

The extent of sea level rise along the West Coast varied. A rough approximation would say that the north experienced extensive submergence with lesser submergence as one moves south until the southern Californian area was reached where very little submergence of the mainland occurred. Figure 26 shows a stylised representation of how this may have occurred with populations distributed evenly across a differentially submerging coast. Islands or fjord lands may skew the distribution since sites that should be submerged are preserved or populations using limited subaerial space as in the Channel Islands utilise areas that never became submerged. The Californian mainland also preserves older sites since the effects of sea level rise are impeded by the steep coastal bathymetry. This explains the fact that sites in California predate those in the north and that coastal sites in Washington and Oregon are rare even after well-established human populations existed inland. What is missing is an explanation of the lack of very early evidence in the south. If sea level change was less of a factor in southern California why are there no sites as old as Meadowcroft or even Monte Verde? No sites that have been initially thought to predate Clovis have matched the criteria used to judge their validity but if coastal migration occurred in time to populate both continents by 14500 years BP or earlier some old sites should exist on the coast, at least in the south. One explanation is that ecological factors are to blame, either prohibiting movement this far south whilst still utilising coastal resources or because the Californian coastline somehow encouraged populations to live within the ever more narrow strip subsequently submerged.

Submergence of sites in this context has been largely synonymous with destruction, an implication amongst much of the literature that has consciously been passed on here. In areas of rapid sea level rise, the potential for submerged sites to survive is high and the areas where tsunami action inundates large areas very rapidly and leaves a corresponding layer of sediment may provide extremely conducive conditions for preservation. However, while near-shore, shallow water sites may be amenable to survey and excavation the depths involved for much of the late Pleistocene landscape would preclude this and at this present stage this equates to destruction, or more correctly lack of discovery.

Conclusion.

Southwest Alaska has the potential to contain surviving pre-Holocene sites on currently subaerial landscapes. Site survival in the Queen Charlotte Islands would be inhibited by relative sea level rises from a 153 metre low stand since the Last Glacial Maximum. Vancouver Island's emergent landscapes wo uld have been influenced by seismic disturbance at least during the Holocene possibly destroying sites or burying them under massive silt layers. This seismic activity partially explains the lack of early sites in Washington, Oregon and north California in association with rises in sea level from a low stand of between 120 and 100 metres below present levels. The southern Californian mainland was less affected by submergence than northern areas although the Channel Islands may have experienced quite considerable submergence events. That sites in southern California are older than sites in the north is to be expected given the submergence patterns described yet no sites are old enough to convincingly explain the population of Meadowcroft Rockshelter or Taima-Taima 14500 years ago or even the more generally accepted Monte Verde 12500 years ago. Ecological factors must be investigated to explain the disparity between early sites on the southern part of the coastline and early sites inland.

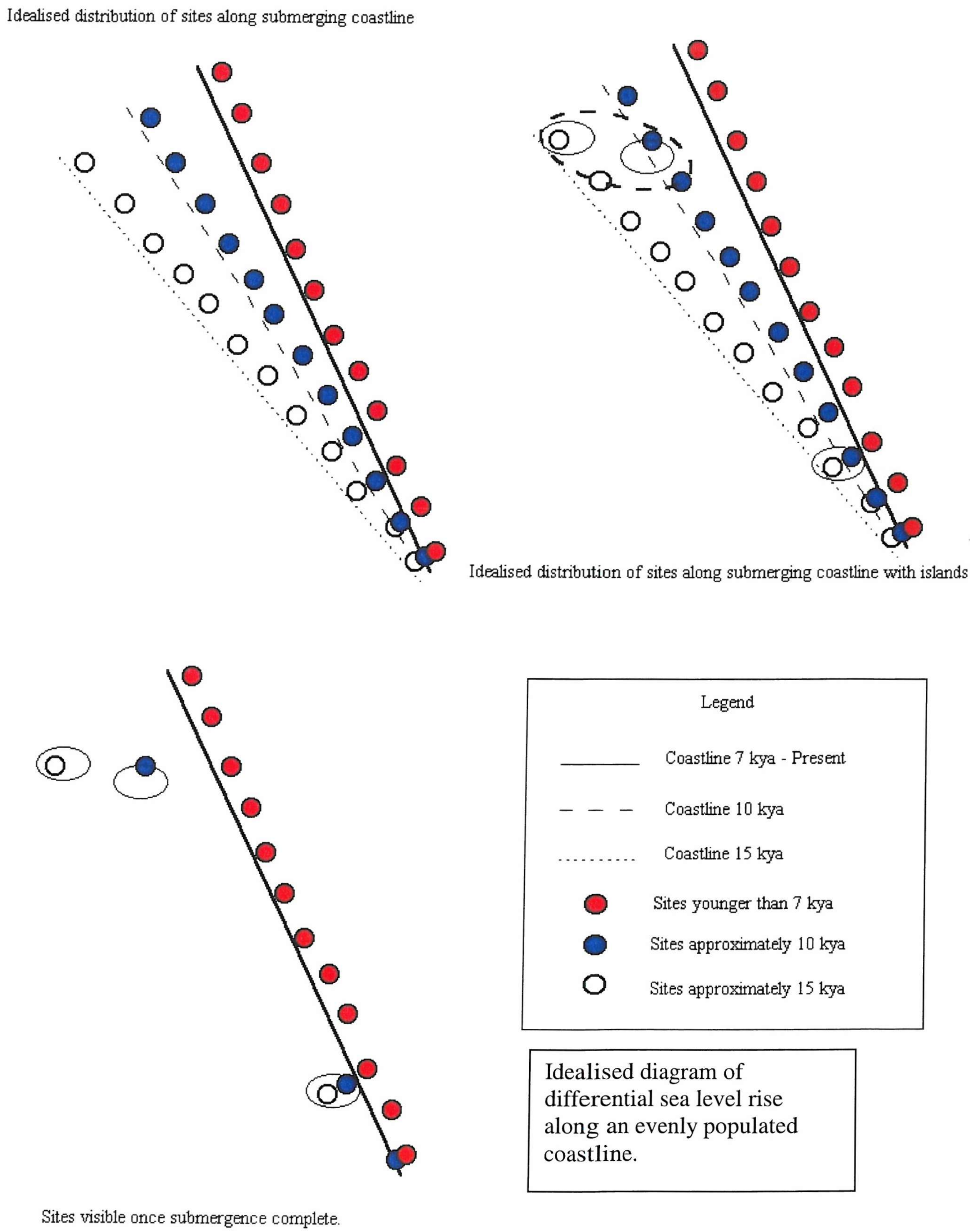


Figure 26. Stylised explanations for observed site distribution related to sea level rise.

Chapter 4. The Coastal Environment(s).

Introduction

In the previous chapter, it was shown how the likelihood of sites being hidden or destroyed by submergence decreases with latitude along the West Coast of North America, due to differential sea level change, different effects of sea level change due to gradient and seismic disturbance events. Since these explanations for the absence of very early sites on the coast become less plausible in the south of the study area, we must then consider other reasons for failing to find coastal sites assuming that early populations entered America via a coastal route. In Dixon's treatment of the coastal migration theory described in Chapter 2, the coast is described as a magnetic resource base, which would allow swift movement but would also prove so attractive that movement inland would be unlikely. Implicit in this theory is the assumption that the coastal resource base was, if not homogenous, similar for its entire length. Figure 27 shows a stylised version of this perception where the terrestrial and marine resources on the coast are so similar they produce a corridor effect.

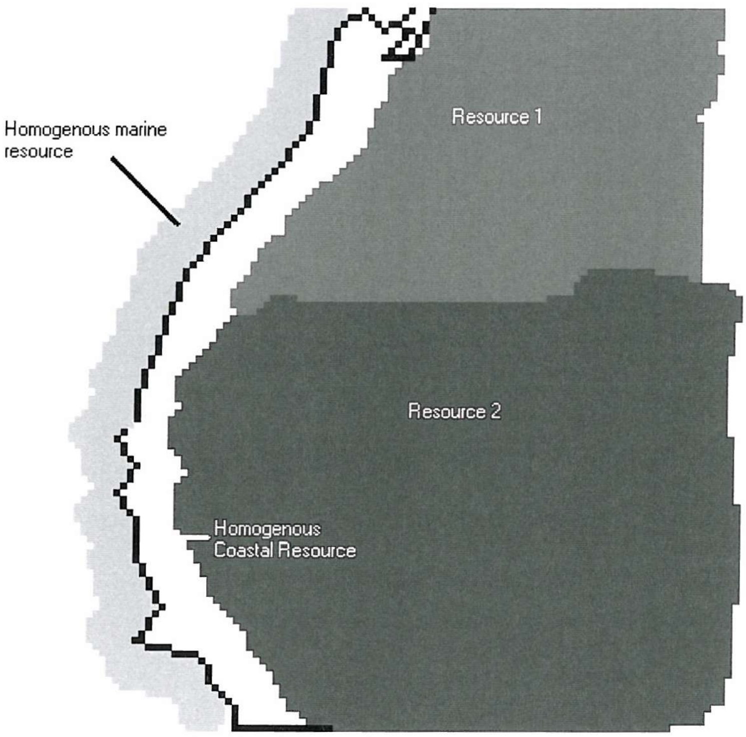


Figure 27. Idealised representation of homogenous resources on the West Coast.

Figure 28 shows an alternative version where the marine resource, being homogenous allows for swift adaptation to changes in the coastal region's terrestrial resource. Finding out whether this is true is the object of this chapter and so it is necessary to characterise the coastal resource base to answer this question. Following this a proposed method of characterising the modern features of the coastal migration route will be described in which regions are defined by virtue of their differences in resource base. After describing this method and exploring the kinds of data applicable and appropriate the results of this characterisation will be analysed to find where areas of change occur that may have impeded population spread. Such changes may lead to either movement inland or changes in strategy with the modern data acting as a proxy for that following the last glacial maximum, a premise discussed in the next chapter.

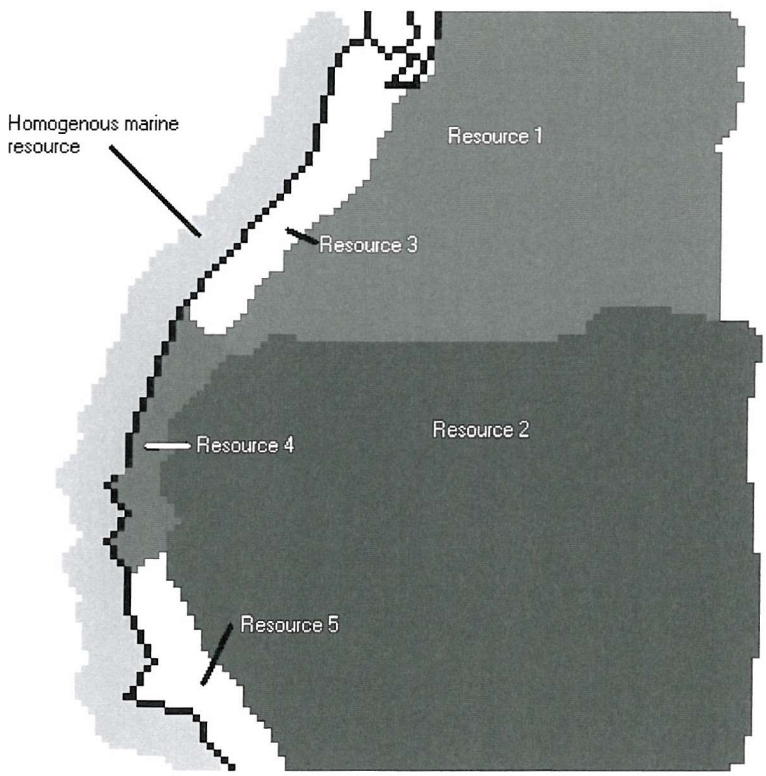


Figure 28. Idealised representation of homogenous marine resources forming buffer for heterogeneous terrestrial resources.

Migration Corridors

Models of human dispersal have changed since Paul Martin's wave of advance model of human dispersal showed human populations spreading out in a continuous wave front regardless of environmental differences (1973). Lanata and Garcia (2002) have taken this concept a stage further by demonstrating that while environmental areas occur in patches they also occur in corridors, which effectively link patches. These corridors can be thought of as a way in which populations can disperse between patches whilst at the same time gaining the knowledge to exploit those areas. Such attempts to understand dispersals contrast with models based on genetic (Cavalli–Sforza 2000) or linguistic data (Nichols 1992), or Martin's 1973 wave of advance model, which work on such a large scale that environmental factors and obstacles such as the ice free corridor are considered just that, obstacles.

Both the coastal migration and ice-free corridor hypotheses begin along very distinct corridors bounded by ice, or ice and water. Following a circumvention of the ice sheets via the coastal route, would the coastline form another such corridor, such as those that Lanata and Garcia describe, defined by habitat and the distance to the sea? If so how far along the coast would migration occur before a move inland was either required or desirable? The absence of sites in early California prior to 11000 BP could be due to its unsuitability as a habitat. Perhaps movement inland could have occurred long before early populations were forced southward. Therefore, does the geography of the coast explain why we have no sites in California?

The geography of the coastal area of North America is dominated by three parallel topographic belts (Patersen 1989: 15). The easterly belt is that formed by the Sierra Nevada in California, this continues as the Cascade Range in Washington and Oregon, the Coast Mountains in British Columbia and then culminates in the Alaskan Mountain range. This is only cut in three places by the river valleys of the Columbia, Fraser and Skeena rivers (ibid: 15). The Middle Belt comprises a line of depressions including the Californian Central Valley, the Willamette valley, Puget Sound and the Coastal channels of British Columbia. As is obvious from these descriptions the north is currently submerged while the south is not (ibid: 16). The western belt is essentially a string of mountains, although sea level rise in the north means some manifest themselves as islands. This strip is made up of the rolling hills of the Coast Ranges in California which carry on up to British Columbia except were they are dissected by San Francisco bay. North of the Strait de Fuca, they become Vancouver Island and the string of islands to the north of this (ibid: 16).

The Pacific coastland area is noticeable for its absence of cold temperatures. North of San Francisco there is a belt with a cool temperate marine climate, dry summers and cloudy rainy winters. In coastal, southern California, a Mediterranean type climate predominates, transitional between the deserts to the south and the northern marine belt. This area experiences desert type summers with temperate winters. Heading inland, the western mountains are characterised by local variation brought about by increasing altitude and additional precipitation, linked with the increase in elevation. Further south lie arid areas rarely reached by water carrying air masses from the west or east. The southwestern desert area experiences dry hot summers and mild sunny winters while the semi-desert and steppe lands to the north are colder in winter and less hot and dry during the summer (Patersen 1989: 27).

Movement to and from the coast is constrained by the mountain ranges that are placed parallel to the West Coast. The post Colombian settlement of the west took place in a variety of fashions, much of it by ship or north from what is present day Mexico. However a great deal of the settlers followed routes overland marked out by the early explorers and fur trappers who initially mapped the region. Overall, most of these followed river valleys to penetrate the mountain ranges; Mackenzie, the first white explorer to accomplish an overland crossing of the continent, did so via the Fraser River (Hillman 1971: 34). Lewis and Clark pushed through the Cascade Range via the Columbia River (ibid: 46). Others made it through at the Upper Klamath, Sutter's fort on the Humboldt and south of the Sierra Nevada near present day Los Angeles (ibid: 83). These routes were by no means straight forward, and the infamous example of the Donner party is a testament to the difficulty of crossing such terrain.

To further examine the possibility that the ecological factors illustrated above could encourage strategic changes or a move inland, a method of comparing the coastal environment is required. How can changes in ecology be shown in such a way that they can be compared and areas where they coincide isolated? Also does the marine resource create a corridor like environment on the coast as Dixon's theory suggests and would it mitigate changes in land resources that would otherwise necessitate a move inland? In order to address these points it is proposed to construct a simplified characterisation of the coastal resource structure with which to define points where the resources in one area are distinctly different from those in the neighbouring areas. While it may be easy to see changes in environment type from the study of a single feature perhaps when multiple features are examined the boundaries may become less distinct. If the vegetation in an area changes from coniferous to deciduous based foliage yet other attributes such as elevation, precipitation and climate stay the same can this be considered distinct enough to cause strategic change or an adjustment of the migratory trajectory? Could it be that where a number of changes in resource occur coincidentally or near-coincidentally a more appropriate boundary can be defined than one where a single change occurs? By better understanding the decisions that would have to be made at such a point the nature of coastal migration may be defined and the likelihood of site existence assessed. In order to do this it will be necessary to find a way of comparing different features of the coastline in a fair manner. If different features can be compared using arbitrarily defined units then areas where changes are near coincident can be identified. Then by incorporating environmental data collected for the American coastline 18000 to 12000 years ago it will be possible to identify whether corridors occur as postulated by Lanata and Garcia, or whether the coastal resource can be said to be an amorphous environment with a mosaic ecology. This will then show whether migrating populations first reaching the Americas via the West Coast would have had to contend with significant changes in the resource base they encounter which may have encouraged them to move inland or slow their progress along the coast.

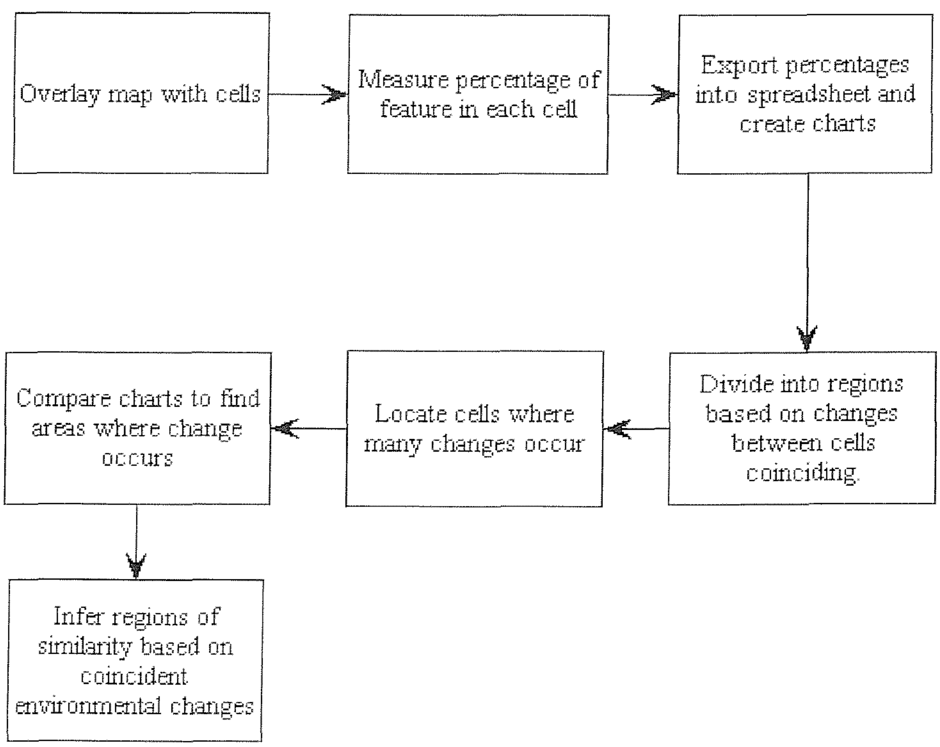


Figure 29. Flowchart showing processes for characterising West Coast environments.

Characterisation, general aim.

The aim of this characterisation is not to find out which parts of the coast were uninhabitable nor is it to locate sites of previous occupation. Instead this model aims to locate areas where environmental change occurs. Specifically these areas will be the points where a group migrating, or expanding, along the coast would find sufficient change in the environmental setting that it would be encouraged to adapt its subsistence strategy accordingly. While this may be a form of predictive model it is not that similar to those described by Warren and Asch (2000: 5-32) or Duncan and Beckman (2000: 33 –58). These would require known sites to be correlated with associated environmental data and from this similar combinations of data could be assumed to have a high potential for site presence. In this case the aim differs slightly in that it is areas of change, not archaeological sites whose location it is hoped to predict. In addition, we have no sites from the period under observation and the resolution of the paleo-data available combined with the large area under analysis makes such an approach problematic. Instead, a coarser resolution model will be of more interest and one that will avoid quantification of factors that cannot be readily quantified, such as different vegetation or geological regions.

To carry out the modelling of the coastal resources of the North American continent we need to establish which resources are of interest. So to answer the question what resources do we need to map, we have to answer two other questions, the first is "what does a region need to support life?" the other is "what features allow exploration and colonisation?"

A. What does a region need to support life?

Water – Fresh water for drinking. This must be fresh, renewable and constantly available.

Food – Animal and plant resources that can be harvested.

Raw Materials – Materials used to make tools, shelter, equipment and clothing. These are primarily stone, wood and animal products.

Fuel – Fuel for warmth and cooking. Either vegetation or animal based fuels such as dung and fat.

B. What features allow exploration and colonisation?

a. Habitation – See above.
b. Exploration – Visibility and accessibility to exploring groups. The ability to move around the landscape and see suitable areas for habitation.
c. Transport – Either the accessibility to move around the landscape or the raw materials to allow obstacles to be overcome with technology. Generally foot but also possibly boat, rope etc.

Exploration is constrained by geographic barriers, be they glacial ice, elevation or watercourses and seas. Some of these can be overcome by technical means, ropes or boats for example. For this characterisation, it is assumed that rivers can be crossed while seas can form a barrier to groups not equipped with watercraft but also a highway for those who do have some sort of marine transportation. The glacial ice is assumed to form a barrier. Elevation is treated more as an obstacle than a hard barrier; it is assumed that given time a group will spread across even the highest elevations encountered in the Americas.

The kinds of resources that are necessary to fulfil the requirements set out in terms of habitation and colonisation are discussed below. For each kind of resource, the kind of data used will need to be established as will the source of such data. Mostly these will be maps and in such cases, the scale and resolution will require justification. Having extracted the required data the representation of it will be necessary.

Within the provisos described above the resolution of resource data may vary depending on resource types. A single stream or a small river may meet the requirement for a renewable water supply and to see them a fine resolution map should be used, as it must show every river that fits these requirements. Alternatively, the amount of precipitation in an area will suffice for the purposes of the model so maps for this would be manageable and acceptable. For other requirements, mapping the location of every resource will not be possible or desirable. The range of animals and their number would be of more use for this model than the location of every individual creature. In fact it would not be possible to map the location of each creature because they are mobile, sometimes greatly so. Calculations of terrestrial resource productivity by archaeologists or anthropologists mostly use the type of habitat as an indicator. For example, Kelly describes how the environmental carrying capacity can be expressed as the population density (1995: 227). The type of environment and how much food it can produce is a key factor in establishing this so it would follow that environmental data of a similar resolution would be adequate for this model.

Which Categories of Data are Appropriate?

Food.

It is possible to go some way to quantifying such characteristics as available food. Robert Kelly (1983: 277 – 307) has produced figures based on ethnographic data that allow us to understand how different ecological regions can produce different levels of primary and secondary biomass. These also show the way to calculate how these figures relate to the amount of food hunter-gatherer groups can extract from them. Since vegetation in areas of high primary biomass are under more competitive pressure they tend to become less usable for humans due to increased height as well as increased xylem and phloem tissue which is inedible (ibid: 285). This in turn has an effect on animals – secondary biomass – which become smaller and harder to extract from. By dividing secondary biomass by primary biomass ($x10^{-3}$) Kelly arrives at a series of figures that demonstrate how fauna in different ecological biomes can be extracted. Ecological regions, ecosystems or biomes are classified at various levels dependent on their floral composition and the climatic factors that influence them. In the scheme proposed by Brown, Reichenbacher and Franson (1998), the first level consists of the hydrological regimes, natural or cultivated upland or wetland vegetation. The second level consists of the plant formation, tundra, scrubland or grassland for example. Level three includes the climatic zones, arctic-boreal, cold temperate, warm temperate or tropical-subtropical. The map of

American biotic communities produced by Reichenbacher et al is drawn at a scale of 1:10 000000 and portrays the vegetation to level four. This level shows biotic communities i.e. northeastern, Cascadian-Sierran, Guatemalan. It is at this level three that anthropologists such as Kelly, base their estimates of resource availability. This is probably fine enough detail for a continental scale analysis of the Americas. For example, Kelly's divisions include tundra, or cold temperate forest that equate to Reichenbacher' s, level three classifications of arctic and alpine tundra or cold temperate woodland or forest, rather than the level four subdivisions such as Alaskan tundra or Sitka coastal conifer forest. This justifies using biotic communities as an indicator of food availability without quantifying such resources and thereby introducing bias from the ethnographic record as criticised by Bassett (perscomm). It is possible to create a descriptive analysis of the biotic communities by showing the composition of each area rather than having to try to assess each area as we think a hunter-gatherer group might have done.

Sea resources for food are, as described, harder to show than those on land. Habitat regions are less well defined and animal ranges are both harder to map and quantify. However, fish catch analyses have reproduced maps of the regions that certain species occupy. These tend to concentrate on commercially sought after fish and tend to map individual species, although the level of detail can be very high. For this model, it will not be necessary to model each individual species location. Rather the range of major groups of marine animal and their estimated numbers would be both adequate and manageable. The *Atlas of the Living Resources of the Seas* published in 1972 does this showing the distribution of demersal resources, pelagic resources, and types of crustacean, whales, tuna and plankton. These are printed on various sized maps using the Mercator projection. Also shown are estimated catch figures for the year 1968 from which the estimated productivity of a particular region may be deduced. Some data from Jorgenson's 1980 *Western Indians* study has also been incorporated for comparative purposes. These include number of species available, predominance of aquatic or terrestrial resources and dominant boat and fishing technologies (Jorgenson 1980). Some sea plant resources may form part of the hunter-gatherer diet but as with plant resources on land these are difficult to quantify for modern data and very difficult to quantify for periods thousands of years ago. If we make the gross assumption that all plant resources can be discounted, as long as the full breadth of animal contribution is analysed in order to include resources such as shellfish that women and children contribute towards collecting we go some way to rectifying this.

Water.

There are two sources of fresh drinking water, rivers (pooling into lakes) and rainfall. While runoff data is more indicative of the area's total water supply it is less likely to be modelled for the period of prehistory this study is concerned with. Rainfall, or precipitation data is more likely to be available and comparing modern maps of precipitation and runoff there seems to be a direct relationship, therefore precipitation maps are probably more appropriate in the long term. Precipitation is shown in maps at a scale of 1:17 000000 for the USA and 1: 10 000000 for Canada. This allows us to quantify this data and compare different regional values.

Raw Materials.

Stone resources of interest are likely to be flint or siliceous deposits with the same qualities as flint, such as obsidian. From geological maps at 1:7 500 000 areas of bedrock formations can be defined. While this does not mean an accurate measure of the actual flint-bearing load can be made it will allow relative probabilities to be compared. However, at this stage it will be satisfactory to describe the geological composition for comparative purposes rather than quantifying them. Other raw materials are much less easy to model: those from plants and animals are not only hard to measure but may be used in different ways depending on the population exploiting them. The quantifying of raw materials based on animal or plant resources is very difficult to quantify or describe and for the sake of simplicity, these must be discounted.

Fuel.

Fuel for fires can come from two sources, plants, which can be burnt, or animals in the form of fat and dung. In terms of predictability, dung may only be viable for groups that have domesticated animals and as such, hunter-gatherer groups may not have placed much emphasis on it. This would need to be verified from the ethnographic record. Equally, fat for burning may only be used where vegetation was too sparse to be used and as such, it may be a factor only investigated in instances of low vegetation. This leaves plant fuel that may be indicated from maps of biotic communities coupled with biomass predictions but even then it will be difficult to quantify. Perhaps it is reasonable to assume that if a region can provide food for a group then finding fuel would not be a problem. For these reasons fuel will not be integral to the model.

Temperature.

Three factors that influence the temperature are the actual air temperature, the wind chill factor and the sea temperature, possibly only of interest to conditions at sea. For this study, the air temperature will be sufficient to characterise a region and wind direction will be included for later comparison with the climatic influences of the paleoclimate.

Mobility and Visibility.

On land ice, gradient and vegetation provide impediments to movement and visibility. Ice is not a problem for a modern map, except in possibly mountainous areas, but will need mapping for the maps of ancient North America. The gradient is problematic as small inclines may form impassable barriers and so a fine detail will be required, assisted by high-resolution digital data. Vegetation is problematic, as little work detailing the effect of vegetation on visibility and movement has been done. For short term movement of exploratory groups little is known, the rate of movement dependant on how the environment is utilised, whether exploration occurs as part of foraging trips or whether specific object orientated expeditions are undertaken. Some work by Glass et al has shown what the effect of vegetation on movement can be for population groups but only for long-term trends and based on the extractive techniques used by groups living in such environments (Glass et al. 1999). Therefore, when we know the population potential of various vegetation types we will be able to get an idea of how quickly they will move. It is proposed that aspects of exploration shall be confined to the constraints formed by high elevation and glacial barriers.

For the next phase of this characterisation, the land-based resources of most interest are temperature, geology, vegetation, precipitation and elevation. Marine-based resources can be incorporated and compared with such land-based resources. The effect ice has shall only become relevant after we start using the maps of the paleo-environment. first, the data needs extracting and collating from the maps.

Table 1. Maps used for modern data analysis.

	Map	Scale Available	Source.
General	Biotic Communities	1: 10 000000	Reichenbacher et al: 1998
	GTOPO30 Elevation	30 arc Seconds	USGS Eros data centre
USA Land	Wind Jan	1: 17 000000	
	Wind July	1: 17 000000	
	Geology	1: 7 500000	
	Precipitation	1: 17 000000	
	Average Temperature Jan	1: 34 000000	
	Average Temperature July	1: 34 000000	
Canada	Geology	1: 10 000000	
	Wind Jan	1: 20 000000	
	Wind July	1: 20 000000	
	Precipitation	1: 10 000000	
	Average Temperature Jan	1: 20 000000	
	Average Temperature July	1: 20 000000	
Sea	Wind Jan	1: 20 000000	
	Wind July	1: 20 000000	
	Temp. Jan	1: 10 000000	
	Temp July	1: 10 000000	
	Current Jan	1: 10 000000	
	Current July	1: 10 000000	
	ETOPO2 Bathymetry	2 arc minutes	USGS Eros data centre
	Fish Distribution	Various	FAO dept. of Fisheries 1972.

Method.

Having established that the resources of interest are temperature, precipitation, geology, vegetation, elevation and marine resources some way of comparing these is needed. In this characterisation it is proposed that the coast be divided into cells and the features of each cell can then be compared. While such divisions are arbitrary the advantage of this method is that it coarsens the resolution used meaning large changes are noticeable and smaller ones are not. If the coastline is divided into such cells, the adjoining inland areas can also be divided so a series of thirty six rows in six columns is created containing approximately 216 cells each of which has its own average value for the characteristics to be studied. The coastal cells are numbered from 1a to 36a from north to south and those adjoining them in the inland area are designated by the suffixes b to f. Each cell was 100 kilometres long 50 kilometres wide in order to cover as much of the 3600 kilometre length as was feasible whilst retaining some chance of noting changes over the 300 kilometres inland.

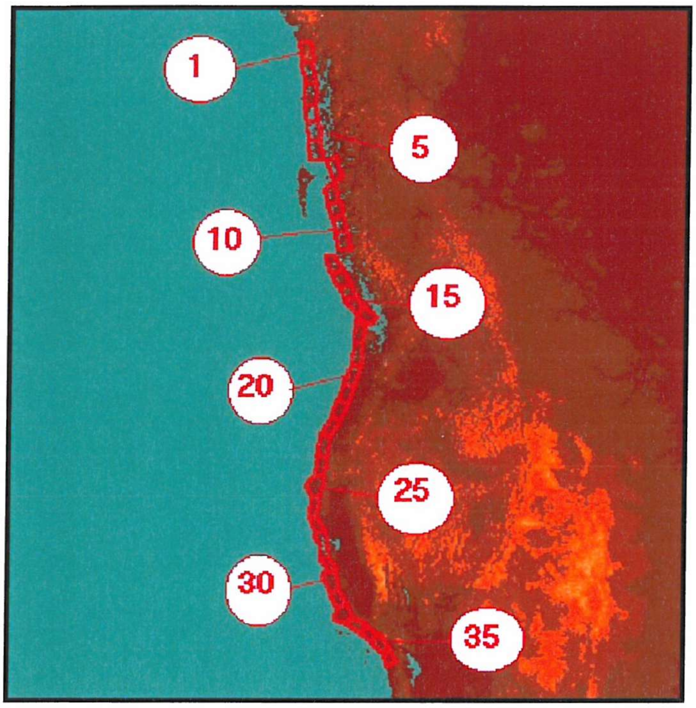


Figure 30. Location of cells along West Coast.

The first step was to overlay the map of biotic communities to the fourth level with translucent paper and divide the length of the coast from approximately 58'50" north -139' 15" west down to the USA – Mexico border into thirty-six one hundred kilometre strips. These strips were measured following the coast and then a region fifty kilometres inland was established to add a second dimension to the study (Figure 4)

Beyond this, five more strips of thirty-six areas were designated. Not all the maps were of the same scale or projection so these overlays had to be recreated for each different kind of map. Each variable previously selected was analysed in terms of these areas. For quantitative characteristics the percentage of each occurrence was measured to the nearest five percent and the mean of these measurements was recorded. Where the upper variable marked on the map had no upper limit the proxy upper limit was established in line with the intervals used for the rest of the scale. For example the upper limit for July temperature on the Canadian map was 70 degrees Fahrenheit + so the proxy limit in this example was 80 degrees Fahrenheit. These readings could then be converted to centigrade.

For variables such as vegetation or geology that could not be quantified the percentage of each occurrence was recorded. The maps for USA and Canada geology used slightly different classifications and these had to be reconciled once the data was extracted. Because the map of biotic communities incorporated both USA and Canada no such reconciliation was required. Other variables such as the modern fish distribution data that only show presence or absence are signified as one or zero respectively.

It is then possible to construct charts from the data extracted showing the strips progressing south and this then allows comparison of each characteristic. If multiple characteristics change in similar areas we can designate this point as a transition, where one distinct region becomes another. In order to test the results of this it is proposed that comparing the regions produced by such a method with those postulated by other authors, such as Kroeber, it is possible to see if significant discrepancies occur.

It is also worth noting here that the distinctions between classifications portrayed on the hardcopy maps means that some geological classifications are lumped together. For example while there are Lower and Upper Tertiary divisions the reconciliation of two maps with slightly differing classifications means Quaternary rock formations are also categorised with the inclusion of some Tertiary formations. At this stage in the process, it is hoped this will not be unduly confusing.

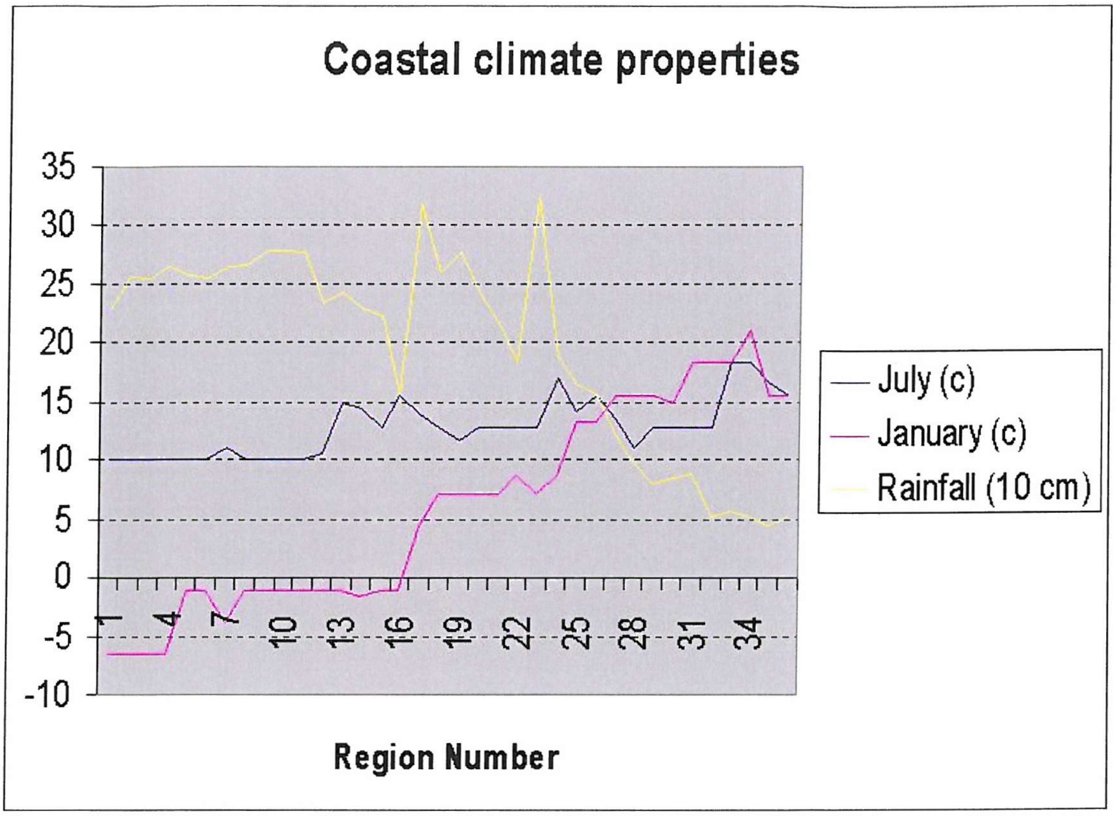
Another potential problem is that of elevation. Moving inland from the West Coast of North America is not merely a move from the coast over a homogenous landscape but a move from a relatively lowland area to the elevated mass of the Cascade Range and Sierra Nevada. This could have implications for visibility and difficulty of movement not contained within this admittedly simplistic study. Elevation data is harder to analyse using the hard copy maps and method described for other factors. Fortunately, it is possible to use digital maps to extract elevation profiles, which shows how change occurs over distance and these can be compared to the other factors in a similar fashion. While hardcopy maps are used for the majority of the data here the use of digital data for the elevation profiling is appropriate since these profiles are formed of a cross section of the cells previously described. While other characteristics such as vegetation or precipitation are easily extracted from hardcopy maps, it is expedient to use computer assistance to extract elevation data. While this method utilises a geographic information system it is to be stressed that in this context it is used for digital mapping rather than a fully fledged GIS analysis. Profiles for elevation were extracted using the Arcview™ GIS and a profile extractor extension. These profiles were taken in two parallel strips, one along the coast and the other 150 kilometres inland. The values extracted were combined to give an average elevation for each cell in the study. A series of subsequent profiles were taken every hundred kilometres along the coast, up to 300 kilometres inland and these were also manipulated to give an average height across each cell.

Changes in Coastal environmental resources.

The data extracted from hardcopy maps is presented in chart form. These show either the average value of a resource in a region, for example rainfall in centimetres, or the percentage of a cell composed of such a resource. This method allows comparisons between resources to be made and facilitates identification of those cells where changes occur. The factors are described below and individual changes are identified. The number of changes that occur in and around a cell is then used to assess whether that cell could be an area that requires increasing adaptation to inhabit.

Rainfall.

Rainfall exhibits a general decline toward the south. Within this trend, three main regions seem to exhibit characteristics unique enough to qualify them as internal trends. The first begins in the north and while not remaining at a static level rainfall only rises slightly as one heads south until cell 11 is reached. Here rainfall levels decline until cell 17 where a sudden distinct rise occurs before a marked decline southward to cell 36. At cell 23, another rise is present but this seems anomalous and since it is surrounded by a very credible declining trend it is probably best ignored.



Temperatures.

January temperatures up to cell 4 are constantly below –5 degrees centigrade (Chart 71). They rise slightly at cell 5 and remain almost exclusively at –1 degrees centigrade until cell 16. At cell 17, a general rising trend occurs all the way to the south. Sudden rises at cells 25, 31 and 33 may mark lesser distinct regions. July temperatures remain similar all the way to the south with an almost imperceptible rise of a few degrees.

Elevation.

Average elevation for each cell rises gradually towards cell 13, dropping to cell 18 then rising to just under 1000 metres at cell 26. Following this it drops quickly to cell 29 then begins a sudden incline to nearly 1200 metres above sea level at cell 34.

Geology.

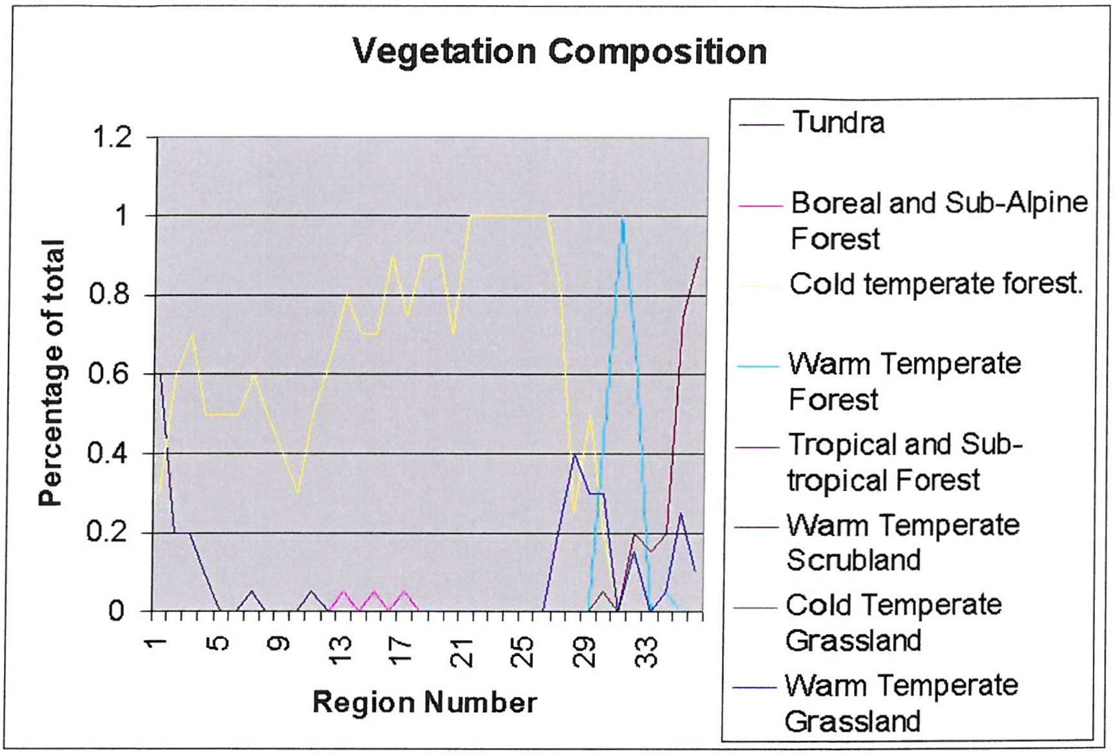
The Quaternary and Tertiary formation also only occurs in small amounts mainly in a group after cell 27. This formation never exceeds thirty percent of the total geological composition of any cell it inhabits. Upper Tertiary geological formations occur only after cell 19 and then are sporadic, varying from fifty or sixty percent to ten or twenty were present. Lower Tertiary formations occur in a large group around the middle of the study area, sometimes making up almost all of the geology of this area as in cells 21 and 22. After cell 23 there are only occasional occurrences of Lower Tertiary formations.

Cretaceous rock demonstrates no identifiable pattern, sporadically occurring throughout the coastal strip and in varying quantities. The Jurassic and Triassic formation occurs in three large clusters, 1 stretching from cell 2 to cell 6, the second from cells 9 or 10 to cell 17 and the third starting from cell 22 and declining all the way to cell 36. Older Precambrian rock is also grouped around the centre of the study area in cells 17 to 23 but in far lesser quantities than Lower Tertiary. After cell 23 it only occurs twice and only forms ten percent of the total formation on each of these instances. The intrusive rocks occur mainly in small amounts, although not always, and mainly in the top half of the coastal strip, clustering within the area from cell 1 to cell 17. Occurring more sporadically after cell 23 it may rise at cells 35 and 36.

Vegetation Changes (Charts 81 – 86).

Arctic and alpine tundra is important north of the study area but within the area itself does not show up much along the coast. This declines rapidly so that after cell 4 only two very slight showings occur and nothing is present after cell 11.Boreal and Subalpine Tundra is very unimportant on the coast, only showing up in cells 13, 15 and 17 in measurable quantities.

Cold temperate forest is important almost all the way south until cell 30. Tentative regions would be from cell 1 to 10, 11 to 26 where it shows a rising trend and then 27 to 30 where it declines. Warm temperate forest seems to take the place of cold temperate forest after cell 30. Also warm temperate scrubland begins an incline after cell 30 until by cells 35 and 36 it has replaced even warm temperate forest. Warm temperate grassland occurs after cell 26 and generally varies in percentage from twenty to forty percent until cell 34 where it becomes less important.



Marine resources.

Modern marine catch data demonstrates various areas where different types of marine resource may occur. There are problems with using such data, the main one being that selection and exploitation of fishing grounds is influenced by more than just presence of stocks. However quantification of the marine resource is desperately difficult to achieve and it may be those results of the effort to do so would bare little relation to the paleo data anyway. Operating then under the gross assumption that modern catches have some relation to the presence and absence of animal stocks the modern data presents as follows. Sperm whale catches occur mostly adjacent to cells five through to 17 and then disappear until cell 34 where much lesser numbers are exploited. Baleen whales are caught in the seas adjacent to cells 9 to 13, 19 to 29 and in lesser quantities from cells 24 to 30.

Demersal fish catches occur in their greatest quantities in the north adjacent to cells 1 to 12 and then in lesser quantities from 13 to 36. Pelagic fish catches occur only after cell 6 and stop at cell 22. These reappear at cells 34 to 36. Tuna catches occur after cell 23 and continue to cell 36.

Crustacean exploitation is mainly limited to crab and shrimp, crab in the north, cells 1 to 16 and shrimp from cell 17 to 27.

Since these results are from data that is not wholly satisfactory it is interesting to compare them to evidence from Jorgenson' s study of the Western Indians (1980). This gives us information for the aquatic contribution to Indian diet, land animal contribution and the types of technologies used to procure marine resources. According to these studies the aquatic resource makes the dominant contribution from cell 1 to cell 23, becoming of secondary importance in cell 24, 25 and 26 and then being tertiary from here to cell 35. In cell 36 it becomes of secondary importance again. Land animal contribution correspondingly is tertiary until cell 23 then varies between being secondary and tertiary until the last cell. Technologies demonstrate similar trends. The preferred boat type is the dugout canoe until cell 26 when the balsa raft replaces it. Harpoon forms, for marine mammal exploitation, vary between using floats as in the areas from cell 1 to 10 and cell 19 to 25 and not using floats as in the area from cell 11 to 18. After cell 27 harpoons are no longer used at all. The fish harpoon is a double pointed variety cell 22 then changes to a mix of single and double pointed throughout the rest of the south. Fish spears (different to harpoons) are present only until cell 18. Fishnets are gill nets until cell 27 where they are replaced by hand nets. This is echoed by the use of fish traps. These appear in the form of weirs until cell 27 where a combination of fish pen or weirs becomes the observable norm. This contributes to difference in marine resource exploitation in those cells above cell 25 to 27 than in those south of it for both modern and ethnographic examples. The annual production of fish in pounds per square mile declines shortly before San Francisco in cell 22 dropping from a constant 800 – 1000 to 100 –199 pounds per square mile and then dropping again to less than 50 pounds per square mile at cell 31. The number of species of sea mammal available also declines in the same places, dropping from 7-8 species available to 1-2 at cell 22 but then rises to 3 or 4 species available at cell 30. After cell 22 fish are no longer the predominant aquatic resource but co-dominate with shellfish. If we compare this with the number of species of land mammals available we see little correlation, cells 1 to 16 have 6 to 10 species available, cells 17 to 23 have 11 to 15 and then cells 24 to 36 have 6 to 10 species available again. This indicates that the decline in aquatic resource dominance is not related to terrestrial mammal species numbers, although this does not take into account the overall biomass of land mammals in each cell. Despite this proviso it does imply that the reduction in aquatic dominance is more strongly linked with a decline in aquatic availability than an increase in terrestrial availability. This is also implied by the fact that terrestrial resources come to co-dominate with aquatic resources rather than dominate, as would be expected if we saw a rise in terrestrial production in the south.

Coastal changes in Environmental Characteristics.

The points where the evidence compiled and described above changes are shown in Table 1. It is actually comparatively rare to get a cell where no changes happen whatsoever. This means that in trying to find areas where changes occur the borders must by necessity be slightly fuzzy. Since we are trying to identify cells where subsistence strategies must change, those cells where changes cluster together are the ones to look for. From the data, change points can be identified at cells 11 to 12, 15 to 19, 22 to 25 and 30 to 34. So it is reasonable to say that while pinpointing the cell changes occur is not possible it is possible to show that significant change occurs over a distance of 200 to 400 kilometres. By using the change points described above it is possible to define five main regions we could describe as regions of similarity (Figure 5)

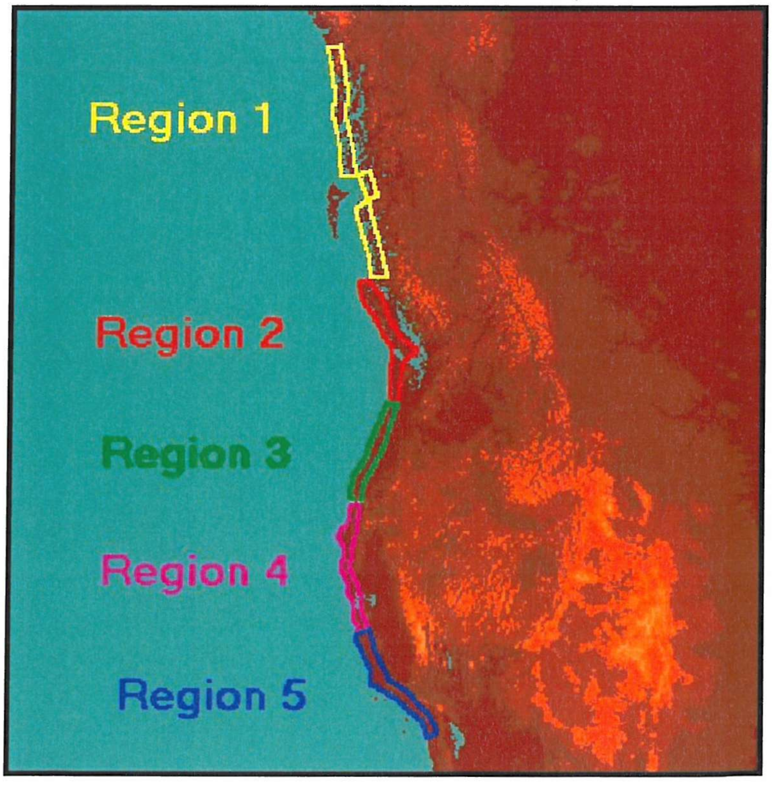


Figure 31. Coast divided into five environmental regions.

Area	Vegetation	Rainfall (m)	Temp	Geology	Important aquatic catches
1	Tundra and cold temperate forest	High 2.3 - 2.7	Very seasonal - 6 -10°C	Cretaceous, Jurassic/ Triassic + Intrusive	Crab, Demersal Fish some Sperm and Baleen Whale
2	Boreal/Sub-alpine forest, cold temperate forest mix	Declining 2.2 - 1.6	Very seasonal - 1 -10°C	Triassic, Quaternary + Tertiary + Intrusive	Sperm whale and crab, some baleen and demersal fish
3	Cold Temperate forest	High then declining 3.3 - 1.8	Less seasonal 7 - 13°C	Lower Tertiary, Older Precambrian	Shrimp pelagic and demersal fish, tuna and baleen whales
4	Cold Temperate forest warm temperate forest and warm temperate grassland	Low 0.8	Less seasonal 7 - 15°C	Tertiary, Quaternary, Triassic	Demersal fish, tuna and some baleen whale
5	Warm temperate grassland, scrubland. Tropical/Sub-tropical grassland	Very Low 0.5	Not seasonal	Tertiary, Quaternary, Triassic	Demersal fish, tuna, some baleen whale and pelagic fish

Table 2. Five regions of the West Coast with similar features.

Region 1, Cells 1 – 11 southwest Alaska to Vancouver Island

This region consists of a mainly cold temperate forest (Sitka coastal conifer forest) with some areas of tundra. Average rainfall fluctuates around 2.5 metres. July temperature is normally around 10 degrees centigrade while January temperature starts at –6 degrees centigrade rising to approximately –1 further south. The summer winds blow northeast while winter winds start northerly changing to north easterly around cell 8. The geology of this region starts as a mix of Cretaceous, Jurassic, Triassic and intrusive rocks changing to Triassic, Quaternary, Tertiary and intrusive around cell seven. The current of the coast heads north all year round. Important modern catches are crab, demersal fish and some sperm and baleen whales. Aquatic resources are the dominant food source and dugout canoes are the dominant boat type. Mammal harpoons have floats, gill nets and seines are the dominant type of fishnet. Weirs with traps and fish spears are present and fish harpoons have double points. Aquatic resources are correspondingly plentiful.

Region 2. Cells 12 –16/ 18 Vancouver Island to Washington/Oregon Border

In this region vegetation changes to a mix of cold temperate forest (Oregonian coastal conifer forest) mixed with small areas of boreal, sub-alpine forest. Rainfall falls from 2.2 to 1.6 metres annually and the July temperature begins to rise from 10

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degrees to 15 degrees, although January temperatures remain around – 1 degrees C. The geology continues to be a mix of Triassic, Quaternary, Tertiary and intrusive until cell 16 where it changes to a mix of Lower tertiary and older pre-Cambrian. July wind direction blows northwest but January winds continue to blow northeast. Sperm whales and crab continue to be important modern catches but baleen whale and demersal fish catches drop off at cell 13. The current in this region is still northerly. Dugout canoes still dominate the boat types and the aquatic contribution to the diet is still predominant. Harpoons no longer have floats. Other marine technologies do not change. Aquatic resources are plentiful with 800 to 1000 pounds per square mile of fish available and 7 to 8 species of sea mammal available.

Region 3. Cells 16/18 – 23/24. Washington Oregon Border to Cape Mendocino

Cold temperate forest (Oregonian deciduous and evergreen forest) continues in this region but it is not mixed with any other significant type of vegetation. Rainfall rises sharply to over 3 metres a year then declines until it reaches less than 2 metres at cell 22. Rainfall then rises to 3.2 metres before sharply declining to 1 metre at cell 27. Temperature in July fluctuates between 13 and 17 degrees C. January temperature continues to rise from 6 degrees C. to 15 degrees C.
July winds change again blowing east while January winds start blowing to the south. Geology changes at cell 23 becoming a combination of Tertiary, Quaternary and Triassic. Instead of constantly flowing north the current flows south in summer but north in winter. Important marine catches are shrimp, pelagic and demersal fish, tuna and baleen whales. While preferred boat type, fishnet and fish weirs remain the same the mammal harpoons once again have floats and fish spears are no longer in use. Fish harpoons remain double pointed and the aquatic resource is dominant. This corresponds with plentiful aquatic resources not changing from those in the cells to the north.

Region 4. Cells 23/24 – 29. Cape Mendocino to San Jose

This region is characterised by a mix of cold temperate forest (Oregonian deciduous and evergreen forest), warm temperate forest and warm temperate grassland. The temperature is hardly seasonal at all, both January and July temperatures being around 13 to 15 degrees. Rainfall continues to decline. The January wind changes once more blowing south while July winds continue to blow east. Geology does not change, nor does current. Important catches are Baleen whale, although in reduced numbers, demersal fish and tuna. Crustacean catches cease to be important. It is around the beginning of this region that dugout canoes give way to balsa rafts and mammal harpoons disappear. Fish harpoons become single pointed and fish spears are still absent. Aquatic resources are no longer dominant but become of either secondary or tertiary importance. This is probably linked to the marked decline in fish production that occurs here and the drop in sea mammal species available. It is also here that shellfish rise in importance in the aquatic part of the diet.

Region 5. Cells 30 – 36 San Jose to US/Mexico border.

Vegetation here is mainly warm temperate grassland and scrubland and tropical, sub-tropical grassland. Rainfall falls to 0.5 metres annually and both July and January temperatures rise to between 15 and 20 degrees C. Wind direction, geology and currents do not change significantly. Baleen whales and pelagic fish are once again slightly important catches while demersal fish and tuna remain so.

The biggest change in terrestrial resources occurs just south of San Francisco at region 5 where the cold temperate forest disappears to be replaced by the grasslands and scrublands. It is also around this region that the temperature becomes far less seasonal and annual rainfall decreases. This coincides with a change in wind direction as well as the disappearance of whales and crustaceans as major catches. Preferred boat type here is the Balsa raft and mammal harpoons and fish spears are absent. Fishnets are hand nets and fish traps are pens or weirs. The aquatic contribution to the diet is of tertiary importance. Fish production drops here to less than 50 pounds per square mile while sea mammal species rise to 3 or 4 available.

What factors change as one moves inland?

In this section the modern data extracted by the characterisation method described earlier will be examined. This is intended to find out how environmental resources of interest to hunter-gatherer groups may change as one moves away from the coast. This model relies on two assumptions, the first being that the modern data used for each element is representative of that element. This may be mitigated by the fact that it is change over distance that is of interest rather than actual quantities. The second assumption is that movement inland would be perpendicular to the coast. This is partially a product of the way the coastal area was divided into cells. It is also partially because this model is interested in change over short distances and a perpendicular line is the best way to fairly measure such resources. It should also be noted that the features within this study represent an average over fifty kilometre intervals heading inland. Rainfall, temperature and elevation can be quantified but vegetation and geology have to be shown as percentage of a cell. These are measured to the nearest five percent. It should also be noted that rather than analyse each row of data those every five hundred kilometres are analysed. This is for ease of analysis and those elements of vegetation or geology that occur in trace amounts of less than five percent are discarded for the same reason.

Climate.

Rainfall mostly exhibits an obvious trend declining as one moves further from the coast. In the south, this trend changes and more local variation occurs, declining rapidly then rising again or the reverse, rising then falling over the final one hundred and fifty kilometres. Change is generally reasonably gradual although in some circumstances large drops over a short distance occur as at one thousand kilometres along the coast where it drops from twenty six centimetres to under fifteen in fifty kilometres. The July temperature is stable, especially in the north where little change occurs throughout. Further south more variation occurs either rising a few degrees for each fifty kilometre move inland or rising more rapidly then falling away again over the final one hundred and fifty kilometres. The January temperature is subject to more sudden changes yet in the north the trend is to fall steadily moving towards the east. Drops of up to ten degrees may occur. In the south, the temperature is generally hotter and fluctuates more as one heads inland. Changes are less pronounced rarely being more than five-degree shifts.

Vegetation.

The five biome types that occur in enough quantity to use are arctic and alpine tundra, boreal and subalpine forest, cold temperate forest, cold temperate grassland

and warm temperate forest. Of these arctic and alpine tundra, boreal and subalpine forest and cold temperate forest dominate while cold temperate grassland and warm temperate forest occur in lesser quantities.

Arctic and alpine tundra occurs mostly in the north and while prevalent from the coast inwards at the very north five hundred kilometres further south mainly exists further inland. Quantities vary quite significantly, jumps of thirty to forty percent not unusual. Boreal and subalpine forest is subject to more rapid increases and occurs closer to the coast. Change over fifty kilometre intervals can be pronounced, for example dropping from fifty percent composition to ten percent at the fifteen hundred kilometre mark. Cold temperate forest is the most common biome on the West Coast. It can be susceptible to change often declining as one heads inland. Change can be rapid but more often takes place over one hundred and fifty kilometre intervals or more. Often decline occurs when competing with arctic and alpine tundra or boreal and subalpine forest. Warm temperate forest does not appear very regularly in this subject area normally appearing inland in small amounts. Cold temperate grassland occurs in the south but is reasonably rare. It occurs away from the coast and rises gradually over one hundred and fifty kilometres.

Elevation.

Elevation exhibits similar patterns all along the coast. In the north, it rises over the first one hundred to one hundred and fifty kilometres, falls for fifty to one hundred kilometres and then rises again for the final one hundred to one hundred and fifty kilometres. In the north it may simply rise for one hundred and fifty kilometres then fall again. Change can be very rapid, in some case going from under one thousand metres to over three thousand in fifty kilometres. In other situations a more gradual change occurs yet this still could still be described as rapid occurring as it does over one hundred kilometres or slightly more.

Geology.

Cretaceous geology mostly occurs in relatively small amounts, less than thirty percent of a cell although, on occasion it may occur more frequently. From the areas sampled it would appear that it occurs closer to the coast, being absent after two hundred kilometres inland. Change is hard to measure for such small quantities. Jurassic and Triassic exhibits no obvious pattern save for being more common inland in the north, while in the south it is more common closer to the coast. Change occurs over one hundred to two hundred kilometre stretches and shifts of twenty to forty percent are not uncommon.

Upper tertiary rock generally occurs in small quantities so change is often not particularly pronounced. In some cases it can be common, over seventy percent, and exhibit pronounced change as at three thousand five hundred kilometres where it rises from twenty to twenty five percent to sixty, eighty and the sixty percent again. Lower tertiary also occurs in small quantities but for some exceptions where aver seventy percent can occur. Change is also rapid here with a drop from seventy five percent to ten percent exhibited at two thousand kilometres south.

The older Precambrian occurs in large quantities around the middle of the coastal stretch at two thousand to two thousand five hundred kilometres. In small quantities near the coast it rises around the one hundred to one hundred and fifty kilometre mark until it almost totally dominates the cell composition.

Lower Palaeozoic rock occurs in small amounts in the north, over one hundred and fifty kilometres inland. Change is reasonably pronounced a jump from ten percent to forty percent not untypical. Upper Palaeozoic rock occurs rarely and may show a shift upward over three hundred kilometres inland.

Quaternary rock is also rare and occurs in small quantities although a rapid shift to ninety percent from twenty percent is exhibited at three thousand kilometres south. Intrusive rocks are common, occurring throughout in large quantities. No discernible pattern emerges but this is unsurprising since by their nature they are intrusive rocks. Shifts can be very abrupt, going from nothing to seventy five or eighty percent over 50 kilometres.

Inland changes in environmental characteristics.

The climate elements show discernible patterns as one heads inland, rainfall becoming less while July temperature remaining steady. January temperatures also decline heading inland in the north although for all three of these elements the south sees more variation, particularly so for January temperature. This fits in with Patersen's assessme nt of increasing aridity further inland as well as the changes in temperature described. These changes are noticeable over short distances though, sometimes changing abruptly. The topography Patersen describes matches that found in this model. In the south three bands occur, two mountainous separated by a valley area. In the north, since one mountain range is partially submerged and manifests itself as islands the elevation seems to simply rise then fall. Again, this can occur over short distances, one hundred kilometres being enough to see a rise of nearly three thousand metres. Passages through the mountains have been shown to be rare and sometimes dangerous. Geology shows no pattern that can be explained by it location near the coast, again not surprising since geology is not dependent on topography or climate as vegetation is. However, it is shown that the geological composition from one area to the next can be radically different. If geology has any bearing on hunter-gatherer distribution, this will be of interest.

Vegetation does show patterns, influenced as it is by elevation, proximity to the coast and climate. Cold temperate forest dominates most of the coastal region although in the north arctic and alpine tundra competes as does boreal and subalpine forests further south. Changes can be gradual moving inland but abrupt shifts do occur, sometime within fifty to one hundred kilometres. Movement inland then does not merely require leaving the marine resource. Every factor examined here could change suddenly from one cell to the next so a movement of fifty kilometres could result in an entirely new set of conditions. This would have implications for migration since change in environmental conditions requires adaptation of subsistence strategy.

Discussion.

The most significant change in the vegetation along the coast of North America as one moves south is that just beneath the modern Californian border. It is here that grassland; scrublands or desert replace the cold temperate forest due to more arid and warmer conditions and a decline in seasonality. This is not surprising given that other attempts to classify the coastal geographic characteristics say much the same thing. Kroeber's study of the cultural and natural areas of North America includes maps of vegetation areas based on work by Shelford, Dowling, Feinman and Thayer, Malte Kellog and Saunders, Harshburger and finally Lynch. Without exception, they draw a divide between 40 and 42 degrees, either on the border or to the south of it (Kroeber 1963: Maps Section). That this attempt to characterise aspects of the coastal personality does not differ is not surprising, it is useful however that it does not. When applied to paleo-data it is necessary to know whether the method used is reasonably accurate, and by modelling the modern data in this way and comparing it to other attempts to find the same, or similar results, can increase confidence.

The significance of this for the study of dispersals is that a migrating population, or a diffusing one, would have to adapt to different environments whether they moved inland or south. By moving south, they would retain the coastal resources but moving inland would possibly provide a terrestrial resource similar to that which was previously inhabited. This does show that at this scale it is possible to find transition points where a decision would have to be made, whether consciously or as an innate response to the environmental change in which foragers change strategy without the explicit knowledge that they are doing so.

The marine component of subsistence shows that with declining number of sea mammals and fish the aquatic resource declines in importance and technological changes occur. When available fish populations decline massively the importance of shellfish is enhanced and these come to co-dominate the aquatic part of the diet. This not only shows a lack of homogeneity in the marine resource but also demonstrates a direct link between changes in it and technological strategies.

Linked to the question of marine resource exploitation is that of coastal adaptation. Surovell hypothesised that if a group resided more than fifty kilometres from the shore it could no longer be considered coastal and must be described as inland. What this study has just shown is that, in western North America, vegetation and climate do not change radically until one gets approximately 150 to 200 kilometres inland except for increasing the distance from aquatic resources. What implication does this have for coastal migration? If a group residing fifty kilometres from the shore in cold temperate forest can survive without coastal resources why not a group on the coast in the same vegetation type? Is fifty kilometres far enough or would a group have to be beyond one hundred and fifty to be truly inland? This raises the question of what range a population might have and whether coastal adaptations affect this.

Conclusion.

What this part of the study shows is that the coastal strip from southwest Alaska to the Mexican border is not homogenous throughout its length. While individual changes are abundant, these may not be especially significant on their own. A single change in any property studied here could be relatively easy to overcome by technological or strategic means. Where such changes cluster together, one must begin to assume that subsistence strategies would be increasingly pressurised. This may lead to slowing in the rate of migration or a change in direction. In this chapter, it has been shown that clusters of changes can be said to define five regions. There is variation within these regions but most interesting are the borders. These borders would act as impediments in the move south. In addition, the changes that we observe in the modern terrestrial data are often accompanied by changes in marine resource. It is therefore not possible to say that marine resources can be used to buffer effects of change in the terrestrial resource and vice versa. The extent of these regions inland can be generalised, in the previous chapter it was shown that movement 150 to 200 kilometres inland was almost always enough to encounter significant changes in the resource structure. This then means we can justify saying that the modern coastal strip includes five main regions and four significant change points. Each region can also be said to extend no more than 200 kilometres inland, usually 150 metres is a more reasonable assessment. Around the Californian border at cells 23 to 24 the extension of the Salmon mounts towards the ocean narrows the coastal strip briefly but after this point it returns to approximately 150 kilometres wide. This means that if we assume that the changes in environment would discourage movement south this could be an explanation for the lack of sites in California predating the Clovis complex. Could it be that 15000 years ago populations were put off moving into the southern part of the study are by the radical changes they would have encountered? In order to answer this it is necessary to assess whether past environmental conditions would have occurred in the same, or nearly the same, areas as they do today. In the next chapter, evidence for paleoclimates, glaciation, paleovegetation and changes in the ocean resource base will be examined and compared with the findings from this chapter to show whether changes occurred as they do today.

Chapter 5. Paleodata for West Coast Ecological Constraints.

While modern environmental characteristics indicate a series of changes along the West Coast of the Americas this has little influence over initial population movements unless these same changes happened in the past as well. Some modern environmental factors will be largely unchanged since the glacial maximum, topography and geology changing over much greater timescales than are of interest here. Other factors will be fundamentally changed; glaciation becomes a very important factor when previously it was not included. Climate, vegetation and marine resources are also likely to have differed and locally obtained data for these factors will be assessed to compare with the modern values. Although the period from 18000 to 10000 years BP will be studied in this chapter, since we know that colonisation must have occurred prior to 14500 BP, the main period of interest will be 1000 to 2000 thousand years prior to this.

Ice sheet limits.

Ice sheet limits on the North American West Coast are fundamental to the study of possible migration in the area. According to Tushingham and Peltier the Last Glacial maximum occurred approximately 18000 years BP (1993: 125). This is based on maximum ice volumes and global sea level declines related to the locking in of large amounts of water within the ice sheets. At 18000 BP the IGCP project shows the Laurentide and Cordilleran ice sheets in North America to be confluent, characterised by domes, one over Baffin Island and one over Labrador (Lundqvist & Saarnisto 1995:9). The westernmost extent of the Cordilleran glaciation is shown to completely envelop the coastline and all the outlying islands. Retreat from this followed over the next five to six thousand years. In the area where the Cordilleran ice meets the Laurentide sheet no corridor existed until after approximately 12000 years BP. However, the timing of both the ice-free corridor and coastal deglaciation is more complicated than suggested in the IGCP-253 overview.

Glaciation and deglaciation of the coastal area occurred at different times in different areas. For this discussion the coast will be separated into four sections, the southeast Alaskan panhandle, the Queen Charlotte Islands and central British Columbian coast, Vancouver Island and associated mainland coast and north Washington and the Puget lowland. As will be shown the glacial chronology of these areas is more complicated when examined in detail than suggested by broad overviews. This is important for a number of reasons, including sea level rise, habitable zones and site survival.

The southwest Alaskan panhandle extends from Yakutat bay southward to Dixon Entrance. According to Mann and Hamilton the Quaternary history of this area is poorly understood (1995: 459). It does seem that glaciation reached its maximum extent approximately 17000 to 18000 years BP although even during the maximum it may only have extended to the inner continental shelf in areas between major fjord entrances according to offshore mapping of glacial features and ice sheet modelling. This means areas between this could have been ice free and subaerial during the LGM (ibid: 460). Deglaciation followed rapidly, reaching modern limits by 13500 BP. In Dixon Entrance glacial extent is inferred from seismostratigraphic-derived facies architecture revealing diamicton deposition throughout the area. Its nonuniform non-stratified character as revealed by airgun seismic, Huntec DTS sub-bottom profiles and sidescan sonar defines the glacial extent. Apparently attempts at coring this were unsuccessful due to its compaction so deposits that may have been formed by ice contact cannot be differentiated from those formed by ice proximity (ibid: 117). Barrie and Conway's interpretation of this distribution is that the glaciation in the Dixon Entrance reached its maximum between 21000 BP and 15000 BP according to evidence from Mary Point in the south of the entrance. The glacier filled most of the entrance but there is no evidence that it reached the Alaskan Alexander Archipelago (1998: 118). Retreat occurred after 15600 BP according to the deep-sea cores (Barrie and Conway 1998: 113). By 13500 BP, ice had completely left Dixon Entrance (ibid: 120).

Geological and paleoecological studies of late Quaternary sediments of the sea cliff at Cape Ball on Graham Island have shown that this area was ice free 15000 to 16000 years ago, supposedly at the time of its glacial maximum. This is shown by plant remains found within laminated sand and sandy silt deposits that overlie glacial till and produced radiocarbon dates of 15400 ±190 and 16000 ±570 years BP (Warner et al: 1982: 675 – 677). Blaise, Clague and Mathewes present the results of deep sea coring at PAR85-01 in the Eastern north Pacific which combined with radiocarbon dates from Cape Ball, Mary Point and Prince Rupert allows them to reconstruct the chronology of glaciation in the Queen Charlotte Islands (Haida Gwaii) and British Columbian coast. This indicates that the glacial maximum occurred shortly before 15600 BP or 15200 BP if 400 years are deducted for the reservoir effect (1990:292). Deglaciation occurred between 15600 and 15300 BP, which corrected for marine reservoir effect equals 15200 to 14900 BP. By 13000 BP the British Columbian continental shelf was completely deglaciated with the exception of some tongues of ice in mainland fjord that lasted until 11000 to 10000 years BP.

In the Vancouver Island region, Cordilleran ice advanced twice, between 25000 and 10000 BP. The Evans Creek stade saw a maximum advance between 20000 and 19000 BP. This advance reached into parts of Vancouver Island but not the Puget Sound and much of the island was ice-free (Mann and Hamilton 1995: 462). The second advance was during the Vashon stade between 14500 and 14000 years BP and the whole of Vancouver Island was covered by ice that reached the Pacific. Subsequent deglaciation was rapid. The Port Moody interstade that occurred between the Vashon and Evans Creek advances saw ice retreat into the inner fjords and mountain valleys of the British Columbian coast (ibid). Timing of the Vashon stade is fundamental to the study of colonisation in this area. Evidence from Port Eliza cave of the West Coast of Vancouver Island makes it possible to date the advance in this area more accurately. Port Eliza Cave is situated 85 metres above present sea level, considerably higher than the sea level ever rose locally and the sediments contained within it provide a good record of environmental conditions on the island over the last 25000 years (Ward et al 2003). An excavation, 2.5 metre deep, inside the cave revealed three units, one of sandy silt over 50 cm thick, one of laminated clay 2 metres thick and a 20 to 30 cm layer of oxidised, weakly laminated silts. The first layer is interpreted as being a glacial deposition, the second a postglacial lake bed deposit and the third a postglacial and Holocene accumulation of resedimented fines. Unit 1 is aged between 18000 and 16200 BP based on bone from the fill. Unit 3 dates to 9500 BP, although this is not a constraining date as it does not indicate the upper or lower date for the sediment. Other ages from Vancouver Island indicate deglaciation between 14000 to 13500 BP. Diverse faunal remains in the lowest unit include numerous small mammals such as vole and marmot and amphibian, bird and fish remains. The fish remains are mostly marine types indicating that the shoreline was close to the cave. The sediments from Port Eliza cave show that the glacial maximum on Vancouver Island lasted from approximately 15500 to 14000 BP after which rapid deglaciation occurred (ibid). This is a longer lasting maximum than Mann and Hamilton postulated above, starting slightly earlier than their date of 14500 BP.

The northern part of Washington State experienced a glacial extension in the Puget lowlands known as the Puget lobe, connected to this was the Juan de Fuca lobe that led past the Olympic Mountains towards the coast. Wood samples collected from beneath glacial till near Seattle have yielded dates of 15100 ± 300 and 15000 ± 400 years BP (Porter and Swanson 1998: 206). A date on spruce wood found beneath Vashon till in Bellevue near Seattle was dated to 14980 ± 70 yr BP and seven samples of wood from fluvial sediments at Issaquah, Washington gave dates between 14600 ± 100 and 14480 ± 70 BP giving a good limit for the age of the glacial maximum in this area (ibid). This is confirmed by tephrochronologic constraints from Pleistocene lake sediments in the Ohop valley of the Puget Lowland where sediment from the eruption of Mt. St. Helens 14000 to 14500 years BP lie under glacial till (Beget et al 1997: 140). Retreat is marked by dates on freshwater gytta from Lake Carpenter near Kingston Washington of 13600 ± 280 BP and 13700 ± 150 BP and dates from Lake Washington near Seattle on basal gytta of 13430 ± 200 years BP and from Mercer Slough of 13610 ± 80 BP, also on basal gytta (Porter and Swanson 1998:209). In the Fraser Lowland, four readvances of the Cordilleran ice sheet during what is known as the Sumas stade are evident from radiocarbon dates of organic and shell remains in glacial till associated with terminal moraine structures. The outlying stade SI was dated to between 11600 and 11400 years BP (Kovanen and Easterbrook 2002: 211-212). SII is marked by moraines, terraces, kettles and meltwater channels. This represents a stage between 11600 and 11413 years BP (ibid: 214). The third stage, SIII occurred around 10980 ± 250 years BP based on wood in glaciomarine drifts. The fourth stage is represented by a well-defined moraine consisting of interbedded till, sand and gravel. Peat deposits from the nearby northwood bog and Pangborn Lake date to 10980 ± 250 and 10245 ± 90 years BP (ibid: 215-6). These glacially formed features represent a series of retreat and readvance in the glacial ice in the Fraser Lowland in which ice did not retreat at a constant rate but retreated then resurged over a period of approximately 1200 years. This shows that even where ice is undergoing a general retreat local readvance occurs with implications for ecology, site survival and local sea level history.

The glacial history of the West Coast from the southeast Alaskan panhandle to Washington State shows variable ice sheet retreat, differing timings of maximum glacial extent and locally dynamic readvance, stillstand and retreat behaviour. The northern part of the coastline reached its maximum far sooner than areas in the south and began deglaciation far sooner as well. When large areas of the coast in the north were ice-free 14500 years ago, parts of British Columbia were achieving their maximum extent or were undergoing deglaciation processes. However there is evidence that the coastline was not entirely inaccessible even when the ice was at its local maximum extent. Warner, Mathewes and Clague's radiocarbon dates from plant remains on the Queen Charlotte Islands (discussed above) are, they say, evidence of glacial refugia. They argue that the presence of plant remains in the Cape Ball area at the time of the glacial maximum indicates that they must have been present somewhere in the islands throughout the glacial period (Warner et al: 1982: 675 – 677). The presence of some plants in areas of the glaciated coastline is not sufficient to prove that there were areas habitable by man in this area. Heaton, Talbot and Shields have studied the fossil remains of bear species in the Alaskan Alexander Archipelago (1996). In the karstlands of Prince of Wales Island, the fossil remains of black and brown bears have been found dating to just after the glacial retreat (ibid: 187). This has been previously explained as a result of island colonisation being easier in postglacial times due to lowered sea levels or ice bridges but Heaton et al believe they have data which suggests the real reason is due to bear populations surviving in the archipelago throughout the glacial period. Mid-Wisconsinan fossil bear deposits have been found in On-Your-Knees Cave on Prince of Wales Island. These proved to be *Ursus arctos* and *Ursus americanus*, and since these species are not known in the lower 48 states until 12000 years ago their presence in the cave is surprising. Stable carbon isotope studies have indicated a primarily marine diet for the brown bear whilst black bears had an almost purely terrestrial, plant based diet (ibid: 188). Genetic studies help explain their presence. The mitochondrial structural genes cytochrome b was studied for genetic divergence amongst 300 bears throughout the world. This has shown that the brown bears of Admiralty, Baranof and Chicagof islands in the north of the Alexander Archipelago are distinct from all other groups. Given the presence of fossils from the Mid-Wisconsinan period in the area and also those following the glacial maximum Heaton et al conclude that rather than immigration of bears along the mainland coast then onto neighbouring islands bear populations probably inhabited refugia throughout the ice age and were left on the resultant islands when the ice retreated (ibid: 191). They point out the obvious implications this has for human progress since if bears can survive in this area humans could have too.

A similar genetic study of black bears in western North America has been undertaken by Byun, Koop and Reichen (1997: 1647 – 1653). There are seven sub-species of black bear in western North America, of which the most distinct is the Haida Gwaii black bear (ssp. *Carlottae*). This sub-species is the largest black bear in the world with a unique skull structure and extra large molars. This difference is so pronounced that Osgood originally classified it as a separate species. Byun et al. argue that if a comparison of Haida Gwaii, mainland and Vancouver bear populations shows that their mtDNA is similar, it means the present differences came about after glaciation. If they are different, it must mean the Haida Gwaii population inhabited refugia to allow the timescale required for these differences to evolve. The study showed that on the Northwest Coast two geographically structured lineages occur. One is a continental group from British Columbia, the Yukon, Alberta, Montana, Alaska and Pennsylvania. The second group is coastal, inhabiting Haida Gwaii, Vancouver Island, the Olympic peninsula and coastal British Columbia. These results are similar to similar tests of extinct stickleback populations as well as Tellima herb, marten, and short tailed weasel species. The conclusion is that the distinct morphology of the Haida Gwaii sub-species is pre-glacially derived and Haida Gwaii and probably the Hecate Strait were refugia during the last glaciation. Black bears must have survived in Haida Gwaii then recolonised the surrounding area as the ice retreated. This would have been curtailed by ice blocking the route inland, hence the distinction between mainland and coastal populations. Apart from the presence of unusually large bears with distinctively large teeth, there must have been areas of Haida Gwaii that could have supported human populations throughout the glacial maximum. The only proviso is that while bear populations would have pre-existed the formation of the refugium in this area human populations must have arrived subsequently, probably using marine transport.

South of the Cordilleran ice sheet glacial ice located in the mountains of the Cascade range and Sierra Nevada fluctuated in size experiencing an advance between 24000 and 17000 BP followed by advances at 15000 and 12500 BP although many valleys were ice free by 12000 BP (Porter et al 1983: 71 –111).

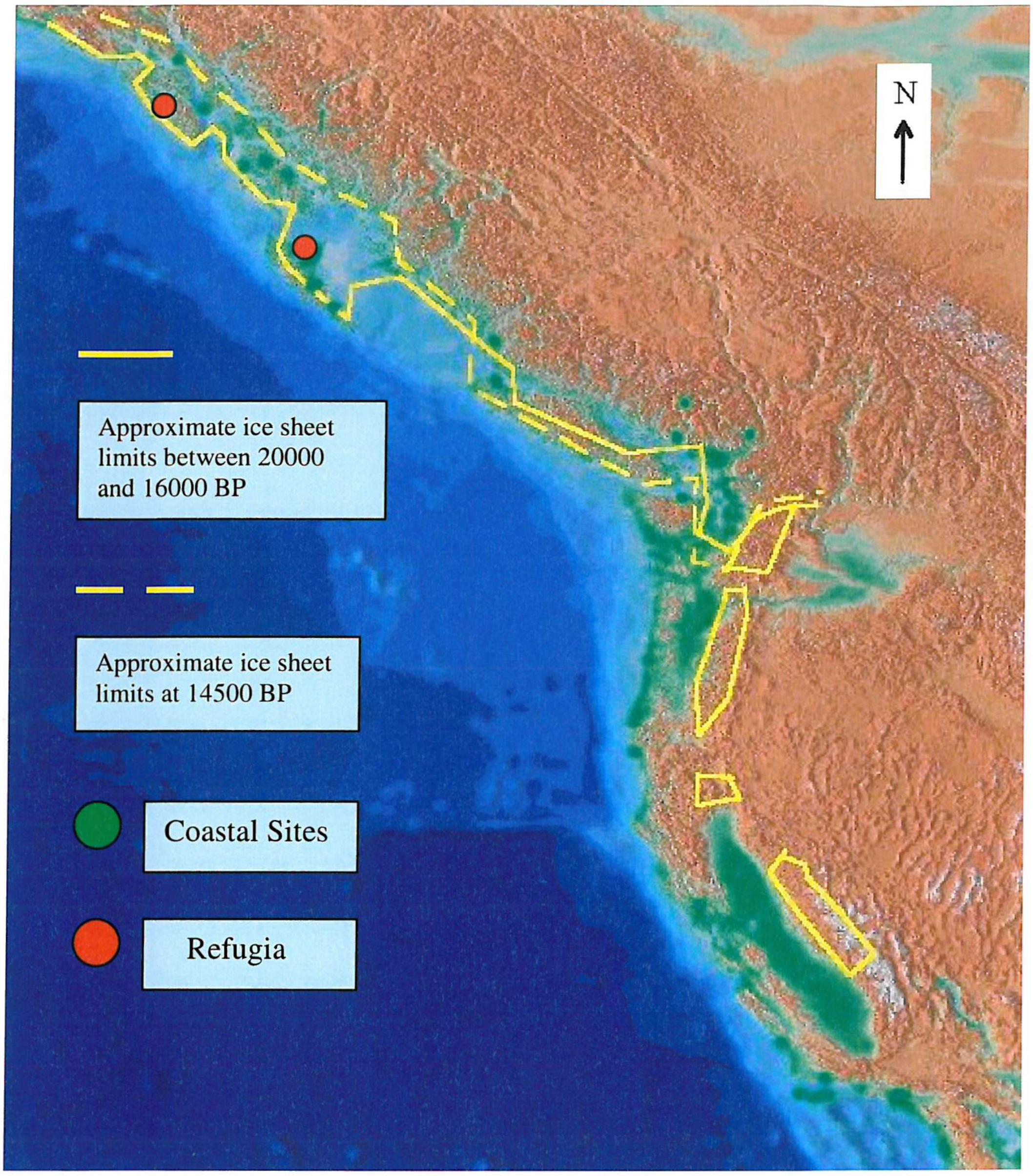

Figure 32. Ice sheet limits.

Vegetation

In the preceding chapter, it was shown how vegetation changes are one of the most important in defining environmental types on the West Coast. Here using data and analysis from the published literature, the types of vegetation to be found on the West Coast after the Last Glacial Maximum will be discussed. Beginning in Alaska and moving south, the kinds of evidence and relevant interpretations will be described in order to facilitate an understanding later in the chapter.

Evidence from the south east Alaskan area is less readily available than for areas such as the Queen Charlotte Islands where extensive work has been published. Following the deglaciation, the south east Alaskan lowlands were dominated by herb tundra with some lodgepole pine and alder reaching the northern archipelago by 13500 years BP (Mann and Hamilton. 1995: 460). The later dates for samples indicating trees in the north are indicative that trees did not survive in refugia during the glacial maximum. At 10000 and 9800, there were climate reversals that saw the Lodgepole pine parkland replaced by shrub and herb tundra. After 10000 BP Sitka spruce, western hemlock and mountain hemlock arrive from the south.

The Queen Charlotte Islands have a wealth of published core samples and analyses which given the glacial history in the area is fortunate as this is an area where habitation is considered very likely. Mandryk *et al.* portray the western coast as a landscape of open tundra with grasses, sedges and dwarf willows and eventually forest in the area of the Queen Charlotte Islands (2001: 306). This agrees with sediments from the Cape Ball samples were made up of glaciomarine stony, clayey silt, overlain by lodgement till and outwash gravel and sand successive sediments (Warner et al 1982: 675). Radiocarbon dates of 15400 ± 190 and 16000 ± 570 BP from these sediments were associated with plant remains of rushes, herbs, dockleaves and some *Potamoyeton* filiforms and *Chura* oospores. The overlying sandy silt contained muskgrass, algae oospores, *calltriche,* water buttercup and some spruce. The drift complex was overlain by woody terrestrial peat dated to 11100 ± 90 although elsewhere on Graham Island this peaty layer dates to 12400 ± 100 BP.

Moving south from the Queen Charlotte Islands, we reach Vancouver Island. According to the glacial history described above, this area experienced glacial resurgence late in its history. However, vegetation prior to this event is well constrained by the available evidence. The Evans Creek stade between 22000 and 19000 BP in Vancouver Island saw the lowlands covered by sub-alpine parkland and possibly alpine plant communities. (Mann and Hamilton 1995: 464). The Port Moody interstade between 19000 to 18000 years BP will have seen diverse vegetation possibly including sub-alpine fir-Engelmann spruce forest and parkland that was later covered by the advance of the ice. Ice-free areas of Vancouver Island contained heaths, grass-sedge-herb meadows and restricted conifers. During the period 12000 to 10000 conifers rapidly colonised the deglaciated areas according to Mann and

Hamilton. The Port Eliza evidence from 18000 to 16000 BP includes bones from Savannah Sparrow and Horned lark that favour open tundra or grassland. Townsend's vole remains indicate a non-forested environment while alpine marmots suggest a cool, open herbaceous environment (Ward et al in press). The area was probably not harsh tundra analogous to today's Greenland coast but an open, partially treed landscape (ibid).

Twelve piston cores taken from the Strait of Georgia east of Vancouver Island yielded corrected dates on shell of 11700 ± 80, 12020 ± 60 and 12470 ± 60 indicating constant submergence (Guilbault et al, 2003: 845). Abundant tree pollen in samples from Sisters Creek, Seymour Valley, Port Moody, Mary Hill and Hollyburn Creek shows that fir and spruce dominated the mainland during the Port Moody interstade 18000 years ago (Lian et al 2001: 945). The Fraser Lowland was relatively temperate with Cattail indicating shallow freshwater marshes in the area while the predominant vegetation of southwest British Columbia prior to the glacial advance was similar to sub-alpine fir, spruce forest and parkland with wet sub alpine meadows (ibid: 949). At Mike Lake in the western Fraser Lowland cores taken yielded pollen dated to 11670 ± 105, 11130 ± 150 and 11430 ± 120 BP with a weighted mean of 11335 ± 75 BP similar to the younger Sumas advance of the ice in this area (Pellett et al: 2002: 151 – 152). The pollen present was that of Lodgepole pine, willow and soapberry. Variation within the samples showed a fluctuation between environmental types. At 11700 BP, the environment would have been similar to current subalpine environments. Over the 1500 years following this fluctuating increases and decreases in Lodgepole pine and shrub alder corresponded with increases in red alder, spruce and fir. From 9550 BP more Douglas fir and red alder appeared along with bracken and some indications of frequent natural fires (ibid: 155).

The Washington and Oregon areas have an extensive and variable vegetation history, partly due to the glacial proximity. 20000 to 16000 years ago western Washington and Oregon consisted of maritime subalpine parkland including spruce, pines, mountain hemlock and western hemlock according to Mehringer (1996: 12) On the glacial margins there were treeless alpine-like communities. After 15000 years BP more spruce, alder and western hemlock appeared. More temperate taxa appeared between 14000 and 10000 years ago and lowered temperatures led to tree lines 500 to 1000 metres lower than today (ibid: 13). Grigg and Whitlock' s studies in Oregon indicate that there was a shift from open subalpine conditions to closed montane forest between 15700 years ago and 14850 years ago. Subalpine forest resurged 14500 years ago and stayed until 12400 years BP despite conditions becoming warmer and wetter, although still cooler and drier than today (1998: 294).

Sediment samples from the area around the Manis Mastodon find in northern Washington show the presence of willow and hornwart fruits dating to 12000 ±310 BP (Petersen et al. 1983: 220). Following this period pines, willow, soapberry, and several genera of *Rosaceae* dominate the assemblage. Some evidence of pine in the assemblage is restricted to the levels expected for long-range transport and so while some spruce may have been present in the area pine was probably not. Between 11000 and 10000 BP a decrease in shrubs was accompanied by an increase in alder and conifer pollen. This leads Petersen et al. to an interpretation of open herb and shrub communities containing some cactus initially with the migration of trees delayed due to drier conditions in this area, than evident to the south (ibid: 228).

Pollen records from Indian Prairie and Gold Lake Bay present a 14000 years history of vegetation history on the Cascade Range in Central Oregon. (Sea and Whitlock 1995: 370). In samples dated to between 13680 to 12400 BP in the Indian Prairie sediment pine, spruce and mountain hemlock were present in high quantities while *Poaceae* herbs were present in moderate quantities indicating a subalpine forest and meadow type environment. Between 12400 and 9950 fir and alder increased in quantity while at the base of the strata mountain hemlock and western hemlock were abundant indicating a closed fir forest. In the period following this, the Indian Prairie sample contains high amounts of Douglas fir and oak fern with relatively high amounts of alder so the environment would have resembled the modern spectra of the Willamette valley. The sample from Gold Lake Bog showed high amounts of pine species dating between 9520 and 4470 BP indicating montane or subalpine forest in this region. Sea and Whitlock believe the samples indicate that between 14000 and 12000 BP pine forest dominated the lowlands of the Cascades with subalpine forest appearing somewhere below 500 metres of elevation. Around 1500 metres of elevation there is no data that indicates glacial ice. Between 12400 and 10000 BP mixed forest spread throughout the areas below 500 metres with fir forest between 500 and 1000 metres of elevation.

Cores taken from Little Lake and Gordon Lake in western Oregon, showed sediments dating back to 13170 and 13040 respectively (Grigg and Whitlock 1997: 291). The Little Lake core was divided into a number of strata between 13170 and

9230 years BP. Between 13170 and 12630 BP there were high percentages of spruce and Mountain Hemlock at the base with abundant fir and pine of various types. Between 12630 and 12390 BP the sample contained high percentages of red alder Douglas fir, fern and bracken. Between 12390 and 12200, there were high percentages of spruce, pine and fir, western hemlock, Sitka alder and Mountain hemlock. This was followed by high percentages of Douglas fir, red alder, fern and bracken pollen between 12200 and 10480 BP. Between 10480 and 9830 pine dominated the assemblage while Alder types, Douglas fir, hazel, oak and bracken types dominated the assemblage between 9830 and 9230 BP. According to Grigg and Whitlock these layers represent periods of subalpine forest followed by montane forest between 13170 and 12630 BP, temperate forest between 12630 and 12390 BP and subalpine/montane forest between 12390 and 12200 BP. Between 12200 and 10480 BP there was a period of Temperate Douglas fir forest. After this, the period between 10480 and 9830 BP was dominated by forest made up of Douglas fir with the final period seeing a mixed forest of Douglas fir, oak and hazel (ibid: 294).

The Gordon Lake core was split into four layers (ibid: 293). The earliest, between 12390 and 13040 contained high levels of spruce, pine, herbs, grassy herbs and ragweed representing a spruce/pine parkland vegetation type. In the strata dated between 12390 and 10870 fir, pine, Sitka alder, mountain hemlock and fern type pollen were present in high quantities indicative of closed montane forest. Between 10870 and 9830 high percentages of pine, fir, Sitka alder and mountain hemlock were present showing evidence of a dry montane forest with pine. The final layer contained Douglas fir types in high percentages as well as Sitka Alder, pine and ferns. This final layer dated between 9830 and 7760 years BP and represent montane/ temperate fir forest (ibid: 294).

California's vegetation was markedly different from that in the north. At Owens Lake in eastern California, a 12-metre long core sample produced pollen samples from 13360 ± 70 BP to 6900 ± 60 BP (Mensing 2001: 57). The deposit between 13500 and 10200 BP was initially dominated by juniper pollen with some Salix. The juniper declines after approximately 12800 BP being replaced by wormwood and goosefoot. Between 10200 and 9800 there is an increase in desert taxa such as goosefoot and ragweed with a corresponding decline in steppe and woodland taxa. Between 9800 and 9550, a short wet phase saw the return of woodland taxa such as juniper. The period following this sees the shift to Holocene conditions with ragweed increasing and juniper declining (ibid: 61). This record marks a change from woodland to shrubland and then desert with an intervening oscillation to wetter conditions allowing the return of woodland taxa.

Seven cores from the continental margin between 32 and 43 degrees north show 60000 years of vegetational and climate changes (Heusser 1998: 252 – 262). The cores were taken from the most northern part of California where it borders with Oregon down to south of the Channel Islands. The last glacial interval, 24000 to 14000 years ago, saw large quantities of conifer pollen, pine and juniper-cypress with hardly any oak or chaparral in the sediments from southern California. This is followed by increases in Juniper-Cypress that peak at 15000 to 16000 BP in two of the southern cores, F2-92-P3 and F2-92-P29. In the third southern core, ODP-893A, Juniper-Cypress peaks at 18000 BP followed by a pine peak at 15000 to 16000 BP followed by increases in oak and chaparral as happens in F2-92-P3. At 20000 BP the northerly cores show see the beginning of an increase in oak and alder. In addition, the pine-dominated sediments give way to herb pollen around 16000 to 14000 BP. After the base of this interval pine increases steadily again. In between the northern and southern cores, core V1-80-P3 near San Francisco Bay sees rapid oscillations of pine and juniper cypress followed by increases in oak and alder at the end of the Last glacial interval. During the glacial/interglacial transition, 14000 to 10000 BP the southern Californian cores see the end of the dominance by conifer species and the start of Holocene type communities of oak woodland, chaparral and coastal sage scrub (ibid: 257). There are occasional resurgences of pine and alder during this period. The central Californian area sees vast increases of redwood and an alder peak starting at 14000 BP and reaching its maximum at 12000 BP. Oak pollen quantities oscillate. In the three northern cores a maximum alder values show where glacial, open pine-dominated woodland becomes closed Holocene type forests. Oak and western hemlock rise as does spruce. The Holocene sediments show the establishment of modern conditions in the north with the southern vegetation showing increasing oak, herb and chapparal pollen and decreasing pine.

After 20000 years ago alpine vegetation existed in the Sierra Nevada uplands and juniper woodland existed lower down and in the desert basins (Woolfenden 1996: 47). After 14000 years ago dense conifer forests were established on the western slopes of the Sierra Nevada. These lasted until 10000 years BP when a dry, open conifer forest with a montane shrub understory took over (ibid: 47).

Climate

R. G. Barry (1983) describes two different methods of paleoclimatic reconstruction. The first are those based on proxy sources, environmental or biologic indicators of climate while the second involves meteorological considerations. Proxy sources include the former extent of snow and ice, frozen ground features, lake levels, oxygen isotopes in ice cores and sand dunes. As well as these physical-environmental sources, there are biological sources that include palynological samples from cores and evidence from pack-rat middens, insect remains and molluscs. While lowering of the snowline is a function of decreased mean temperature Barry explains that snow line estimates suffer in extensively glaciated terrain since the residual features left by snowline decline, such as cirques, may be underestimated due to the presence of pre-existing glacial cirques. In addition, the modern snowline in some areas is above some mountain summits leading to uncertainty in reconstruction of past snowlines (ibid 390). Fossilised periglacial phenomena indicating paleotemperature are limited to ice wedges that only occur close to ice margins but indicate that in these areas the mean annual temperature would have been -5°C when the wedges formed. Lake shorelines are indicative of precipitation levels when allied with reliable dating, between 40000 and 25000 years BP they were generally low in the United States then higher between 20000 and 11000 yr BP indicating higher precipitation during this period (ibid: 392). The use of biological sources requires adequate data for modern environmental conditions appropriate to the insect, pollen or mollusc remains studied. Generally, these yield similar results but occasionally situations occur where the assemblage cannot be related to a modern analogue.

Barry divides climatic modelling based on meteorological behaviour into empirical and numerical-model studies (ibid: 392 – 393). The empirical method often focuses on changes in circulation patterns that could be the primary cause of climatic fluctuations. However, regional studies show 'that even short term anomalies in temperature and precipitation cannot always be closely tied to changes in circulation pattern (ibid). Bryson has formulated a model allying vegetation boundaries with air-mass boundaries that appears to give a good alternative method of modelling climate circulation. Numerical-Model studies involve using paleoenvironmental estimates of surface temperatures to construct a map of isotherms from which circulation maps can be derived (ibid: 393). This can be used to create models of circulation modes using heterogeneous input data unlike that used for the more general circulation models. Three general circulation models of global climate at the last glacial maximum have been derived all of which have certain problems, such as coding errors or underestimates of sea-temperature gradients. What the models do show is that cooler drier conditions existed in the northern Hemisphere while the jetstream moved southward toward the equator and was stronger (ibid).

The CLIMAP project was set up as part of the National Science Foundation's International Decade of Ocean Exploration program in 1971. This involved a consortium of scientists being formed to study global climate over the past million years, particularly that recorded in deep-sea sediment (CLIMAP project members 1976: 1131). The project consisted of a series of experiments in climate simulation, the first of which was a reconstruction of conditions at 18000 BP using four boundary conditions, the geography of the continent, the albedo of land and ice surfaces, the extent and elevation of permanent ice and sea surface temperature patterns. The geography of the continents was approximated with a lowering of the shorelines by 85 metres, a value the members believe will have little significant error at the project's grid spacing of 250 to 500 kilometres. Albedo is the degree of reflection of solar heat energy across varying surfaces (Goudie 1993: 28). The land albedo was based on pollen samples, snowline and sedimentary records while ice sheet limits where derived from literature sources. The sea surface temperature was reconstructed using biological transfer functions and oxygen isotope stratigraphy (CLIMAP project members 1976: 1131). Gates presents the CLIMAP project's initial reconstruction of global climates in July at 18000 BP (1976: 1138 – 1144). The data shows that the surface air temperature over North America was lower than today, in some cases by as much as 10° to 15°C. Glacial areas had higher elevation and albedo due to ice cover leading to lower simulated temperatures. The difference in temperatures south of the ice on the West Coast is shown to be - 13°C around Washington, -11°C in the area of north Oregon, below this and -9°C in southern Oregon. The difference for western California was -11°C.

A later simulation, the Cooperative Holocene Mapping Project uses the same strategy as the CLIMAP project in that it uses both geologic data and models for its reconstructions (COHMAP members 1988: 1043 – 1052). Pollen samples, lake sediments and marine plankton were the main geologic or biologic test data, with mathematical models based on non-linear flow equations and the principles of mass and energy. According to the simulation, the sea temperature at 18000 BP was 10°C lower than today with simulated land temperatures also being lower. The ice-sheets being at their maximum split the jetstream, driving the stronger part of the flow north of the ice while a weaker flow went to the south through the Californian area creating cooler, moister conditions than present. Between the southern stream and the southernmost part of the glacial ice conditions were colder and drier than present, a glacial anticyclone pushing west along the edge of the ice (ibid: 1046). At 12000 BP with general warming the ice sheet was smaller so the Jet stream no longer split, instead moving north to flow along the southern edge of the ice although the very edge of the ice still had glacial anticyclone winds pushing west, although they were no longer as strong as previously.

The climatic modelling described above is of a global scale, so it is useful to compare it with the biological indicators previously described in this chapter for reconstruction of vegetation taxa. The literature sources used for the vegetation reconstructions above produce few inferences about Alaskan and British Columbian climate. Mann and Hamilton describe the British Columbia climate between to 16000 and 25000 years BP as colder and drier than today, but warmer and wetter after this period, although still being cooler and drier than today (1995: 464). On the British Columbian Coast temperatures 5 to 8°C lower than present were combined with precipitation between 700 and 1000 millimetres lower than current levels at 19000 BP. In contrast the Washington and Oregon areas more conclusions are drawn directly from the data. The Puget Trough area had lower precipitation and temperatures were 5 to 7 degrees cooler than today's between 24000 and 16000 years ago. After 15000 years BP ameliorating coastal climates led to tree lines in the Cascades 500 to 1000 metres lower than today. This implies a mean temperature 3 degrees lower than present (Mehringer 1996: 12-13). The area the Olympic peninsula that was home to the Manis Mastodon site had large quantities of coontail pollen which given its present range indicates that summer conditions at Manis were similar to today's 12000 years ago (Petersen et al 1983: 225). Lian, Mathewes and Hicock' s palynological data indicates that the Port Moody interstade in the Fraser Lowland would have experienced mean July temperatures of approximately 13 °C. The Coastal

Western Hemlock present has a tolerance zone of 5.5 to 9.8 °C while the range for Engelmann spruce would be –2 to 2 °C. Precipitation ranges from 400 mm per year, the lower end of the Engelmann spruce range to 2950 mm per year, the upper level for Coastal Western Hemlock (Lian Mathewes and Hicock 2001: 950). This contradicts the dry conditions around the edge of the ice stipulated by the COHMAP model, possibly due to moisture being carried by winds previously thought to dry out the area. At Carp Lake in Oregon, samples show that the climate from around 30900 years ago to 13200 years ago was cooler and drier than now getting warmer and drier after this period (Whitlock and Bartlein 1997: 60). This compares with Grigg and Whitlock's assessment of montane forest records from Gordon Lake, Indian Prairie Fen, Battle Ground Lake and Little Lake in Oregon that show warming the equivalent of a drop of 500 to 1000 metres in elevation or 2 to 3 °C prior to 13170 years BP. After this, there was a rise of around 3 to 5 °C and an increase in precipitation of 100 to 300 millimetres. After 12390 BP, cool humid conditions applied again until a warming and moistening period between 12200 and 10480 years BP (1998: 294).

The authors cited to investigate Californian vegetation also make inferences about paleoclimate based on the biological indicators they have discovered. The pollen indicators from Owens Lake in east California show the mean temperature would have been 9.4 to 4.5 °C lower than now. The presence of Juniper woodland shows that at 16000 BP precipitation would have exceeded 250 mm per year and the mean annual temperature would have been approximately 4- 5 °C. This is similar to studies at Swamp Lake Central Nevada where temperatures were 3.9 degrees cooler in January and 3 degrees cooler in July than today, and the northern edge of the Mojave desert which was 3.2 degrees cooler in January and 4 degrees cooler in July (Mensing 2001: 61). At 18000 BP in packrat middens in Kings Canyon on the southern Sierra Nevada evidence of California nutmeg, single needle Pinon pine, Ponderosa pine, sugar pine, incense cedar, red fir and western juniper show the climate was colder with similar precipitation to today (Thompson et al 1993: 475). The juniper and pine at Clear Lake shows the temperature here was 7 to 8 °C lower than today while precipitation was 300 to 350 percent higher. 12000 BP the presence of ragweed and grasses at Kings Canyon indicate a dry and cold climate although the presence of giant sequoia hints that the temperatures were not excessively cool at this time (Thompson et al 1993: 486-7). The north Central Coast would have been moister as indicated by Douglas fir samples present at Coast Trail Pond. At 9000 BP lake levels dropped in California indicating drier conditions as does the fact that coastal forests give way to coastal scrub and grassland by 1000 to 9400 BP (ibid: 490).

Sea temperatures and productivity.

The CLIMAP consortium modelled the sea surface at 18000 BP using biological transfer functions and oxygen isotope stratigraphy (CLIMAP Project members 1976: 1133). The biological transfer method involves translating numerical descriptions of planktonic biota from sediment cores into sea surface temperatures. The oxygen isotope stratigraphy method relies on differences in calcareous shells within cores being indicative of continental ice volumes. The resultant figures for sea surface temperature in the Pacific during August at 18000 BP were then subtracted from the current values to give a map of anomalies. This shows that the West Coast of North America was considerably different from today in terms of surface temperature. The area from the Alaskan Panhandle to Vancouver Island was over 4°C cooler than present, with the region to the south 2°C cooler. This shows how much change has occurred since the LGM but looking at the absolute temperatures modelled for 18000 BP shows that the 13°C isotherm stretches south along the Washington and Oregon and into north California coastline implying that the temperature was similar throughout. From approximately 38° north the temperature rises to 16°C at the US/Mexico border (ibid: 1132). February's surface isotherms are more horizontally distributed rising from 2°C in Alaska to 16°C at the Mexican border (Imbrie et al 1983: 232). Analysis of Radiolarian microfossils from twelve cores in the north east Pacific, between 33.6° and 54.4°N demonstrate differential warming following the glacial maximum. Corrected radiocarbon dates applied to the stratigraphic record in the core samples show that the increase in sea surface temperatures was split around 40°N. Above this point temperatures warmed by 4 degrees centigrade between 20000 and 15000 BP. Below this latitude they only warmed by 2 degrees centigrade over the period from 20000 to 13000 BP (Sabin and Pisias 1996: 57). The northeast Pacific sea surface temperature record from 16000 BP to 11000 BP in the area around Vancouver Island shows a history of three distinct cold phases with two intervening warmer phases (Kienast & McKay 2001: 1563 – 1566). Based on piston core JT96-09pc and with a chronology created using corrected radiocarbon dates this temperature record corresponds with the Oldest Dryas, the Bolling, the Older Dryas, the Allgerod and the Younger Dryas periods. According to this analysis of C_{37} Alkenone unsaturation temperatures fluctuated from 6 to 7 °C in the cold periods to 9 to 10°C in the warmer periods. The changes in sea surface temperature from the last glacial maximum are of interest to this thesis indirectly because of the changes in climate they produce, but more directly because of the effect on production and thereby the potential for people to utilise marine resources. The present day northeast Pacific can be divided into regions dominated by different planktonic organisms, these are polar, subpolar, transitional, western tropical and eastern tropical of which the subpolar and transitional are present in the subject area (Imbrie et al 1983: 231). The subpolar region currently ends north of the Alaskan panhandle giving way to transitional until tropical waters take over south of the US/Mexico border. According to analysis of microfossil remains the regions at18000 BP were distributed slightly differently to today. The subpolar region was pushed south by an extended polar region so that it stretched down to 38°N. The transitional area was compressed by this, its southern limits as at present but the northern border where the subpolar assemblage ended (ibid: 232).

South of 42° N the Californian, current plays a large part in influencing oceanographic conditions. A series of cores taken across the area of the Californian current in the area south of 42°N was analysed for foraminiferal species assemblages and oxygen isotope data (Ortiz et al 1997: 191 –205). The aim of this analysis was to ascertain the thermal gradient of the water at the last glacial maximum in order to establish likely current flow. Seven cores were taken from the area between Cape Blanco and Cape Mendocino as well as three sediment traps and the foraminiferal species percentages obtained to produce temperature and productivity estimates based on modern analogs for present fauna. Radiolarian paleotemperature estimates as used by Pisias and Sabin (1996) were used to check the interpretation. The results suggest that at the Last Glacial maximum the mean annual sea surface temperature in the area was 3.3° ± 1.5°C cooler than present day temperatures. The cooling was the same across the transect which is important because it means that at the Last Glacial Maximum temperatures were coolest by the coast and increased further offshore, similar to today. If the polar front had been south of this area Ortiz et al believe that local wind forcing would have created a poleward flowing current with a distinctive temperature gradient the reverse of that observed (ibid: 203). Therefore, the Californian current flowed southward at the last glacial maximum. The analysis of productivity showed that levels were probably higher offshore than today but similar in coastal waters. This is indicative of enhanced southward flow and thus the area experienced an oceanographic ecosystem more similar to that found in the present-day Gulf of Alaska than present day California.

The productivity of the coastal area south of 38°N is also influenced at a local scale by climatic factors peculiar to the glacial intervals. Core samples from the offshore, deepwater basins in the Californian borderlands has been analysed to assess the carbon deposition regimes in these areas. Four piston core samples were taken from the Tanner, San Nicholas, Velero and No Name Basins and ground bulk material was used to determine levels of opaline silica, organic carbon and calcium carbon content (ibid: 175). These three levels were used in association with AMS radiocarbon dating to establish chronologies for each core. The results show that the glacial periods had increased accumulation rates of opaline silica indicating increased surface productivity due to the close link between the two phenomena. In addition, the accumulation of organic carbon during glacial periods was approximately twice that of Holocene periods, a feature that cannot be explained by enhanced preservation because conditions were less conducive to preservation during the glacial periods (ibid 185). The conclusion then is that the Californian borderlands experienced a decrease in productivity following the glacial interval. Mortyn et al. explain this as a product of upwelling being enhanced by offshore winds, something that does not happen north of approximately 40°N because the prevailing wind direction was from the south (1997: 187). During interglacial periods this situation ceased as high pressure zones in the Pacific moved north ceasing the intensification of the Californian current.

As shown above the productivity of areas along the length of the Californian current is not constant. At 42° N, the coastal area was experiencing less upwelling during the glacial interval than areas further south so differential productivity is witnessed. In order to investigate this further a series of 17 cores from 42°N to 33°N were taken and analysed for changes in biogenic sedimentation over the past 30000 years (Gardner et al 1997: 297 –255). Changes in the percentage and accumulation of C_aCO^3, C_{org} and biogenic opal were documented at 500 and 1000-year intervals. This led to the conclusion that during the late Oxygen Isotope Stage 3 period at approximately 30000 BP the conditions were very similar to those during the early Holocene. The central Californian coast experienced intense upwelling while this was weak on the northern Californian margin. A dividing line between carbonate rich sediments in the south and opal rich sediments in the north was established at this time around 34°N. The Last Glacial Interval saw the continuance of strong coastal upwelling in the central California area. The last half of the glacial interval saw an increase in biogenic fluxes in the south that moved towards the north from 18000 BP to 7000 BP, stopping at approximately 38°N. The northern Californian cores see a decrease in biogenic fluxes throughout the glacial interval reaching their lowest at the glacial-interglacial transition. The southern Oregon section differs in that biogenic fluxes are enhanced from 20000 BP and increase up to 5000 BP. The implication of this is that the polar front migrated over this area (42°N) and stayed to the north. At the glacial-interglacial transition when the coastal upwelling on the Californian margin suddenly decreased at 13000 BP. Therefore, while the Californian current continued to flow southward throughout the glacial interval its actual effect on the nearby coastal areas differed both on a temporal and regional scale.

Additional changes in the coastal resource are argued by Graham et al who postulate that lowered sea levels 18500 years ago created a rockier shoreline in California than experienced today (2003: 40). This would have been more productive than that found in the present sandy shoreline and combined with higher nutrient levels offshore would have been more hospitable to marine foragers. The enhanced upwelling and its associated increase in coastal nutrients would have provided an ideal location for kelp beds housing large fish such as sea bass, ling cod and rockfish. As well as large fish the kelp beds would have formed a habitat for sea urchins, abalones and other gastropods and the Sea otters that prey on them. Detritus from the kelp beds would have aided nourishment of intertidal habitats. With the end of the glacial period and the rise in sea levels promoting sandy habitats marine productivity in this area would have decreased.

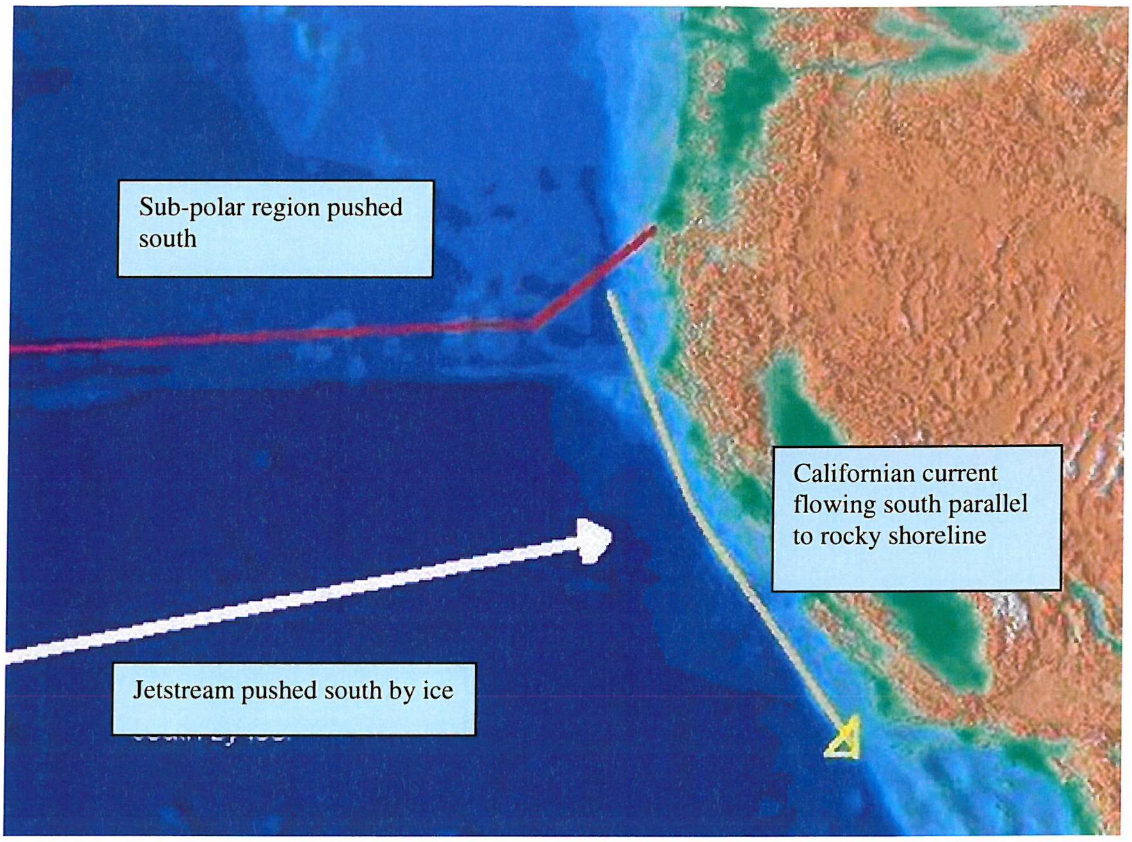

Figure 33. Marine changes.

Discussion.

The glacial history of the Northwest Coast is a surprisingly varied one. In the north, around the Alaskan fjord lands, deglaciation follows the traditional pattern of retreat following 18000 BP. In this area, subsequently exposed landscapes would have provided refuge for travellers from an early stage. However, further south the pattern changes. Retreat from Dixon Entrance and the Queen Charlotte Islands had not begun until approximately 15600 BP and was not complete until 13500 BP at the earliest. The Vancouver Island area and that of the Puget trough, show advance much later, in fact when areas to the north were ice-free. This resurgence would have a taphonomic effect on archaeological site visibility, scouring sites away or burying them under alluvial deposits. It would also have an effect on movement; since the resurgence coincides with dates for Meadowcroft and Taima-Taima, it implies that people were already to the south of this area. Could this mean that groups became cut off from northern relations creating a need to exploit the southern refugium more rigorously?