GUIDEBOOK FOR NW GEOLOGICAL SOCIETY FIELD TRIP TO WHIDBEY ISLAND

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by

DON J. EASTERBROOK

DEPT. OF GEOLOGY
WESTERN WASHINGTON UNIVERSITY
BELLINGHAM, WA 98225

ITINERARY

STOP 1. DOUBLE BLUFF/USELESS BAY

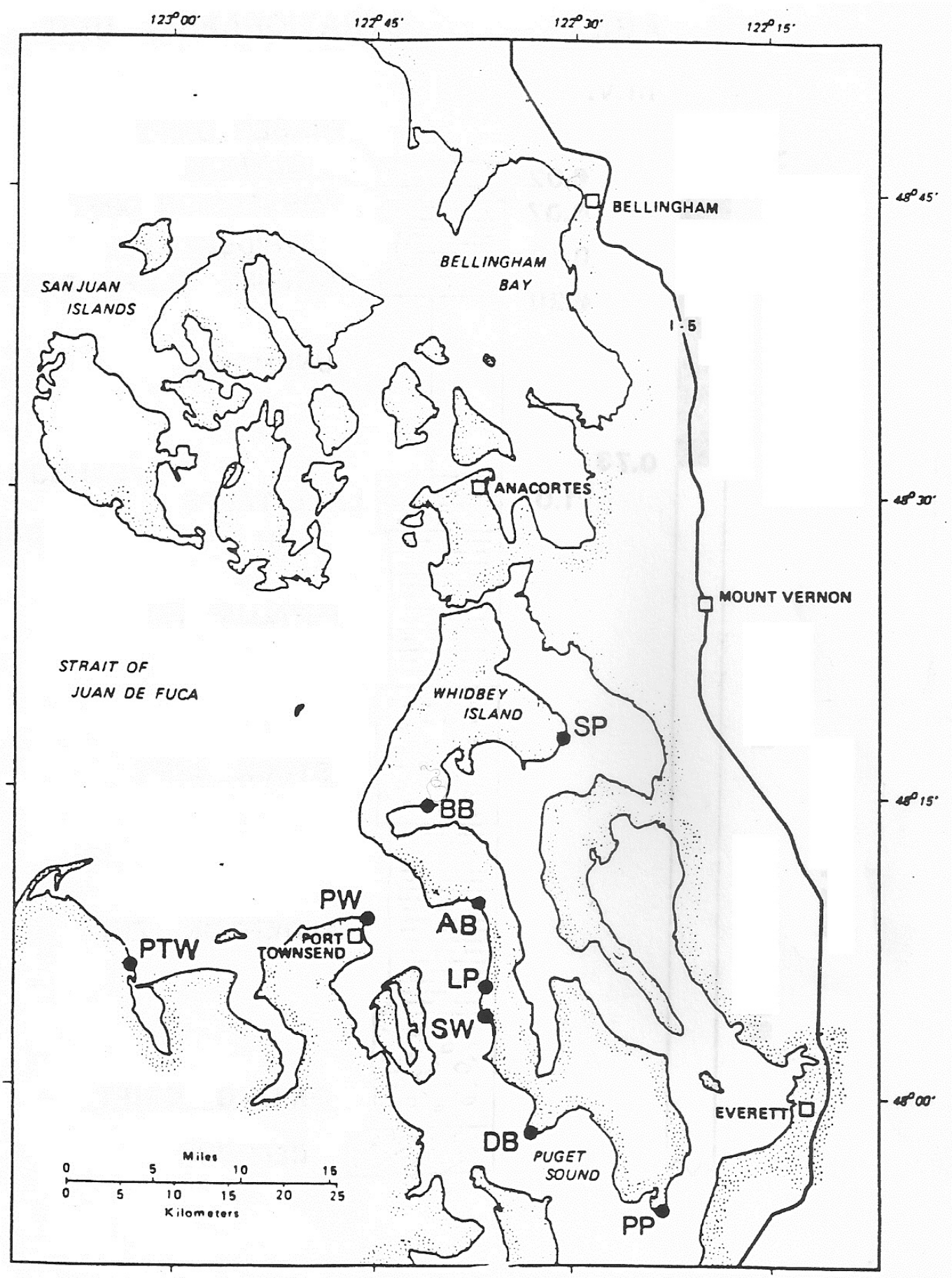
Sea cliff exposures between Double Bluff and Useless Bay serve as type localities for the Double Bluff Driftr and the Whidbey Formation. Park cars at the west side of Useless Bay. Walk westward to Double Bluff about one mile. We will examine the type Whidbey and overlying Esperance sand on the way west to Double Bluff, then look at the type Double Bluff Drift at the west end of the sea cliffs. On the way to Double Bluff, note the striking deformation structures in the Whidbey Fm.

STOP 2 WEST BEACH-PARTRIDGE POINT

This is one of the few places to see the transition from Vashon ice-contact deposits to Everson glaciomarine drift. We will see fossiliferous glaciomarine drift ^{14}C dated at 12,800 resting on Partridge Pt. gravel containing 100 ft. (30 m)-deep kettles. Park at the West Beach parking lot, walk.

STOP 3 BLOWERS BLUFF

Good exposures of pumice-bearing Whidbey Fm. overlain by Possession till and fossiliferous glaciomarine drift. Park cars at Penn Cove Park and walk east along beach.


123° 00'
122° 45'
122° 30'
122° 15'
48° 45'
48° 30'
48° 15'
48° 00'
BELLINGHAM
BELLINGHAM BAY
SAN JUAN ISLANDS
I - 5
ANACORTES
MOUNT VERNON
STRAIT OF JUAN DE FUCA
WHIDBEY ISLAND
SP
BB
PW
AB
PTW
PORT TOWNSEND
LP
SW
EVERETT
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PUGET SOUND
PP
Miles
0 5 10 15
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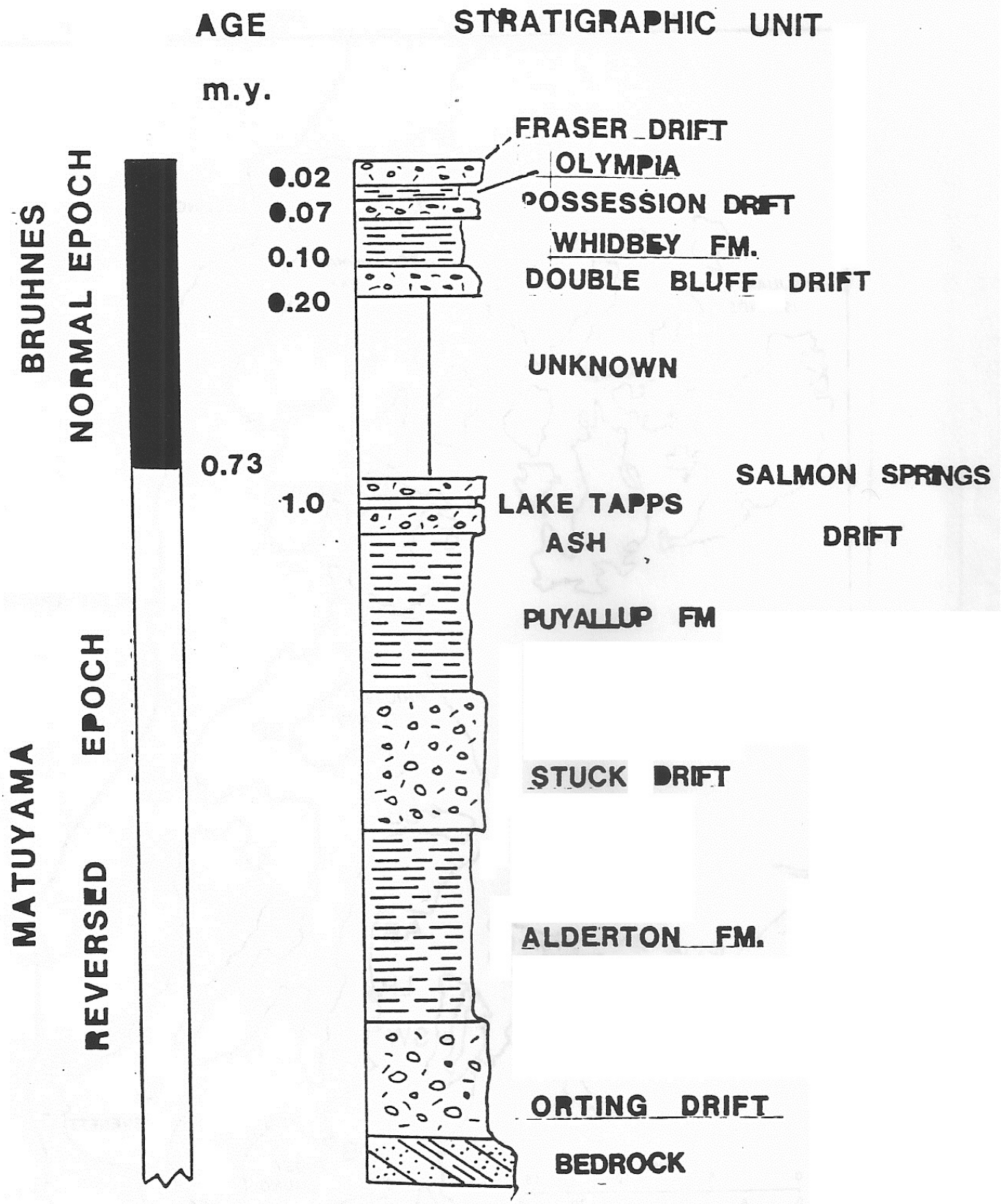
Kilometers


AGE
STRATIGRAPHIC UNIT
m.y.
BRUHNES NORMAL EPOCH
MATUYAMA REVERSED EPOCH
FRASER DRIFT
OLYMPIA
POSSESSION DRIFT
WHIDBEY FM.
DOUBLE BLUFF DRIFT
UNKNOWN
SALMON SPRINGS DRIFT
LAKE TAPPS ASH
PUYALLUP FM
STUCK DRIFT
ALDERTON FM.
ORTING DRIFT
BEDROCK
0.02
0.07
0.10
0.20
0.73
1.0

INTRODUCTION

Pleistocene deposits older than 300,000 years are unknown in the central Puget Lowland at present (Easterbrook et al, 1985). Sediments of this interval probably occur below sea level in the Puget Lowland, but are not accessible.

Drifts of two pre-Olympia glaciations separated by nonglacial sediments are widespread in the central Puget Lowland of western Washington. The Double Bluff Drift (older) and Possession Drift represent advances of the Puget lobe of the Cordilleran ice sheet into the lowland. The interglacial Whidbey Formation between the drifts was formed in floodplain streams, lakes, and swamps. During its deposition, climate was initially cool and moist, as inferred from pollen in peat beds, but subsequently it became much like that of the present in the lowland.

The geologic-climate succession now recognized in the central Puget Lowland is as follows:

Fraser Glaciation
- ***Sumas Stade***
- ***Everson Interstade***
- ***Vashon Stade***
- ***Evans Creek Stade***

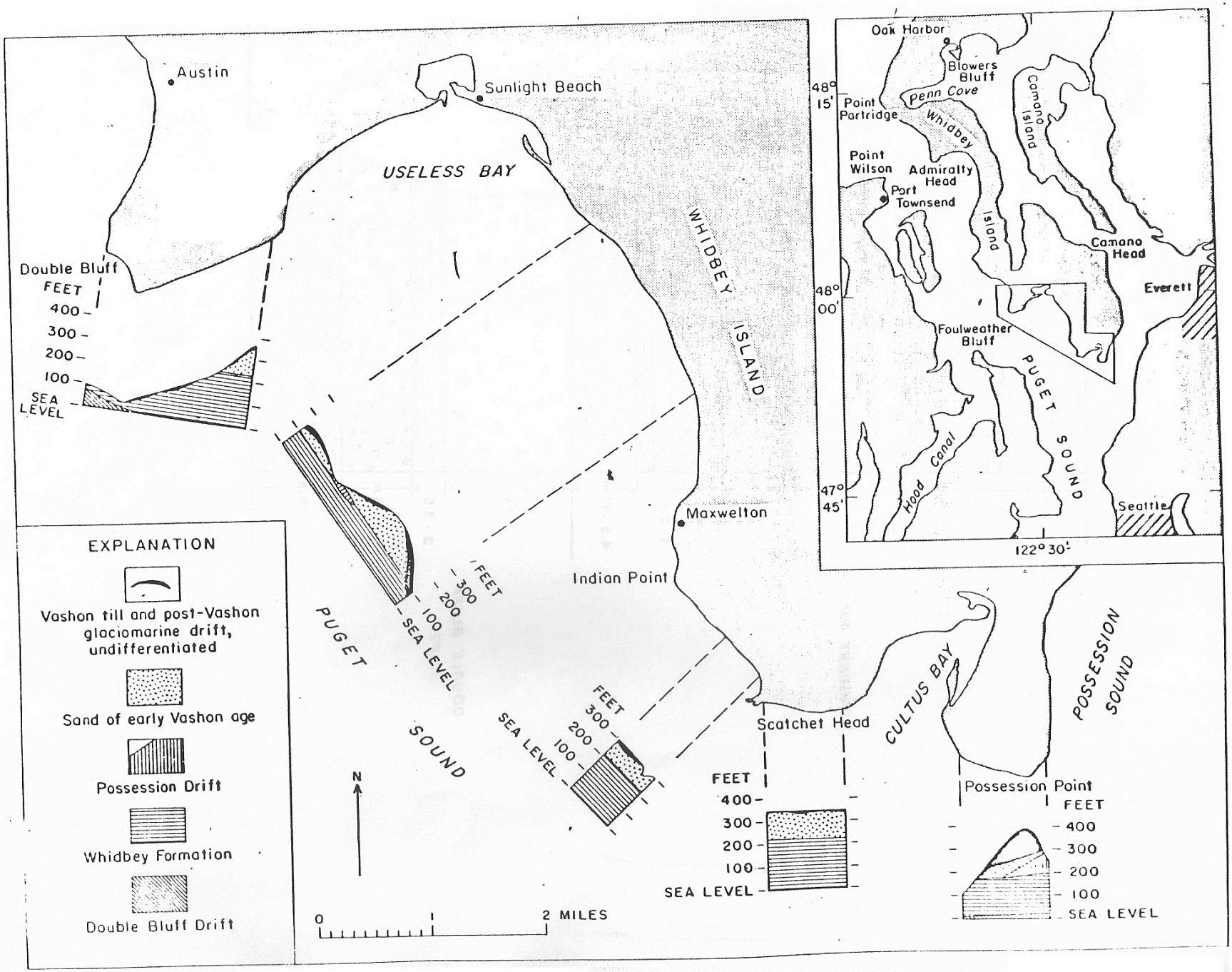
Olympia Nonglacial Interval
Possesson Glaciation
Whidbey Interglaciation
Double Bluff Glaciation

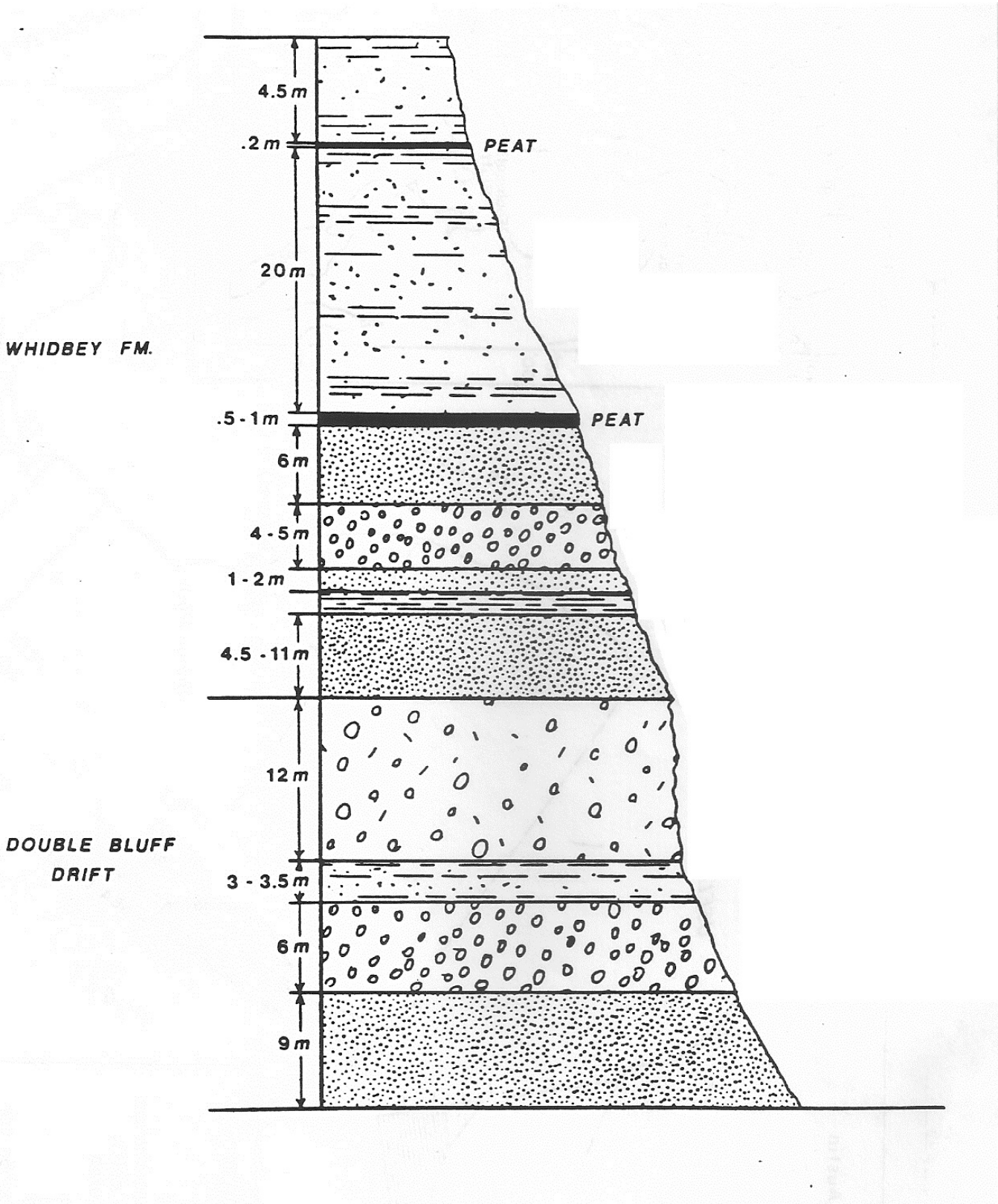
DOUBLE BLUFF DRIFT

The Double Bluff Drift (Easterbrook et al., I967; Easterbrook, 1968) consists of till, glaciomarine drift, glaciofluvial sediments, and glaciolacustrine deposits, lying stratigraphically beneath the Whidbey Formation of the last major interglaciation in the Puget Lowland. Double Bluff Drift occurs at or near sea level in sea cliff exposures and underlying sediments are not exposed. Consequently, no deposits spanning the 500,000 year gap between the Double Bluff Drift and the 1-m.y. old Salmon Springs Drift of the southern Puget Lowland are known. Except for exposures at Double Bluff and Possession Point, the Double Bluff Drift is rarely exposed in the central Puget Lowland. It outcrops in bluffs at or near sea level at Foulweather Bluff, in bluffs half a mile west of Point Wilson, and in bluffs half a mile northwest of Camano Head. Elsewhere, the Double BluffDrift occurs below sea level or beneath younger deposits.

Exposures along the sea cliffs at Double Bluff (Fig. I) were designated by Easterbrook, Crandell, and Leopold (1967) as the type section of the Double Bluff Drift. The type section consists of about 20 feet of gravel overlain by 10-12 feet of sand, silt, and clay and about 40 feet of compact gray till and poorly sorted, crudely stratified diamicton interbedded with sand and silt. About 30 feet of cross-bedded, fairly well-sorted sand underlies the lower gravel unit at the extreme northwest end of the bluff.

Type section of the Double Bluff Drift and Whidbey Formation along the sea cliffs at Double Bluff and Useless Bay.


Austin
Sunlight Beach
USELESS BAY
WHIDBEY ISLAND
Double Bluff
FEET
400
300
200
100
SEA LEVEL
Maxwelton
Indian Point
PUGET SOUND
FEET
300
200
100
SEA LEVEL
Scatchet Head
CULTUS BAY
POSSESSION SOUND
Possession Point
FEET
400
300
200
100
SEA LEVEL
N
0
1
2 MILES
EXPLANATION
Vashon till and post-Vashon glaciomarine drift, undifferentiated
Sand of early Vashon age
Possession Drift
Whidbey Formation
Double Bluff Drift
Oak Harbor
Blowers Bluff
Penn Cove
Point Partridge
Whidbey Island
Camano Island
Point Wilson
Admiralty Head
Port Townsend
Camano Head
Everett
Foulweather Bluff
Hood Canal
Seattle
48° 15'
48° 00'
47° 45'
122° 30'



Stratigraphic section at the type locality of the Double Bluff Drift and Whidbey Fm/

Pebbles of certain pink granite and garnet-kyanite schist in the till and underlying gravel indicate a British Columbia provenance for the drift. On the basis of lithology and texture, the lower gravel is interpreted as proglacial outwash later overridden by the ice that deposited the till.

Toward the southeast end of Double Bluff the drift consists of clayey, till-like layers interbedded with silt and pebbly silt. The stratification of the pebbly silt and the presence of marine shells indicate subaqueous deposition from floating ice.

The top of the Double Bluff Drift is exposed in the low bluffs about a quarter of a mile east of the southernmost point at Double Bluff. Here pebbly-silt glaciomarine drift is overlain by about 10 feet of oxidized sand and gravel that passes eastward beneath a thick section of Whidbey peat-bearing sand and silt.

TABLE 1. TYPE SECTION OF DOUBLE BLUFF DRIFT AND WHIDBEY FORMATION

WHIDBEY FORMATION	Thickness (ft)
Gray, horizontally bedded sand, silt, and clay	15
Peat	0.5
Gray, horizontally bedded sand, silt, and clay	~65
Peat (^{14}C-dated >40,000 yrs)	2.3
Gray to light yellowish brown, partly massive and partly cross-bedded, fine to coarse sand	19
Light yellowish brown sand and granule gravel	13-17
Fine, horizontally bedded sand	4-7
Peat	0.5
Gray silt containing disseminated organic mattter	1.5
Interbedded peat and peaty silt	4.0
Yellowish brown, fine to medium sand, grading westward into crossbedded granule and pebble gravel	15-35
DOUBLE BLUFF DRIFT	
Diamicton consisting of till and stony silt/clay glaciomarine drift containing marine shells (scarce!); lithology indicates a B.C. provenance	40
Horizontally bedded silt, clay, and fine sand, locally deformed	10-12
Gray to yellowish-brown sand and pebble-cobble gravel with cut-and-fill bedding	0-20
Gray to yellowish-brown, cross-bedded, fine to coarse sand	>30

Beach

Chronology

Remanent magnetism of Double Bluff glaciomarine drift shows normal declination and inclination (avg. declination = 1°; avg. inclination = 49°) (Easterbrook, 1976).

Amino acid analyses of shells from glaciomarine drift at the type locality suggests an age of 111,000 to 178,000 based on leucine D/L ratios (Blunt,

Easterbrook, and Rutter, 1987). Amino acid ages of shells in Double Bluff glaciomarine drift elsewhere in the Puget Lowland suggest age ranges of 150-250,000 years (Easterbrook et al., 1982).

Thermoluminescence (TL) analysis of clay in glaciomarine drift at Double Bluff gave an age of 176,000 ± 38,000 (Easterbrook, Berger, and Walter, 1992). A TL age of 289 ± 63,000 was obtained from clay beneath the till-glaciomarine drift unit at the western edge of the bluffs. A TL age of 280,000 ± 81,000 was obtained from clay beneath till correlated with Double Drift on Camano Island, and an age of 251,000 ± 81,000 was obtained from clay beneath similar till at Lagoon Point on Whidbey Island (Easterbrook, Berger, and Walter, 1992).

WHIDBEY FORMATION

Hansen and Mackin (1949) described a sequence of peat-bearing sand, silt, and clay 60-80 feet thick above "sea level till and outwash" at Possession Point. A similar stratigraphic sequence more than 200 feet thick is well exposed in the mile-long sea cliff exposures between Double Bluff and Useless Bay. The sea cliffs 0.3-0.7 mile east of Double Bluff were designated as the type section of the Whidbey (Table 1) (Easterbrook, Crandell, and Leopold (1967).

The Whidbey Formation consists mostly of sand interbedded with silt, clay, peat, and scattered lenses and beds of gravel. Hansen and Mackin (1949) interpreted similar sediments at Everett to be a result of ". . . very slow aggradation by meandering streams flanked by floodplain lakes and swamps." They thought that the lenticular coarse sands and gravels represented channel deposits and that the silty clay and peat were formed in flood-plain lakes and swamps. All of the sediments included in the Whidbey Formation presumably were formed in such a depositional environment.

The Whidbey Formation crops out extensively in the sea cliffs of Whidbey and Camano islands and in places along adjacent coast lines of the mainland, but the base is rarely exposed. Outcrops of the Whidbey are also scarce inland from the sea cliffs because it is usually covered by younger deposits. the Whidbey is separated from deposits of post-Possession age by an unconformity. The base of the formation crops out above sea level at the previously mentioned outcrops of Double Bluff Drift. The overlying Possession Drift is exposed in contact with the Whidbey at only a few places, including Blowers Bluff which we will visit at Stop 3. Elsewhere, the Whidbey is overlain directly by Esperance sand, Vashon till, and Everson glaciomarine drift.

Near the type locality the unit is at least 200 feet thick, but an unknown thickness may have been eroded from the top of the section. More than 300 feet of stratified sediments are exposed in the sea cliffs east of Double Bluff and also at Scatchet Head, but the upper 100 feet in both places apparently consists of younger sediments (Esperance sand) deposited unconformably on the Whidbey. At Possession Point the Whidbey Formation is about 120 feet thick. Stratified sediments at Everett correlated with the upper part of the peat-bearing unit exposed at Possession Point by Hansen and Mackin (1949) may also represent part of the section eroded from Possession Point.

Hansen and Mackin (1949) found lodgepole pine (Pinus contorta), which they thought represented an early interglacial forest, to be the pre-dominant pollen from the lower part of the Whidbey Formation at Possession Point. Higher in the section they found a decrease in lodgepole pine pollen and an increase in balsam fir and western hemlock (Tsuga heterophylla); these changes suggest that warming of the climate followed retreat of the Double Bluff glacier. In the lower portion of the section at Everett, they found a predominance of western hemlock and Douglas fir (Pseudotsuga menziesii) pollen, indicative of further climatic amelioration. Increasing amounts of lodgepole pine pollen in sediments higher in the Everett section, accompanied by disappearance of Douglas fir and decrease in westen hemlock, implies climatic instability, possibly contemporaneous with the advance of glacial ice into the Puget Lowland.

Pollen analyses of peat beds in the Whidbey Formation at the type locality were made by Leopold. The lowest peat beds contain mostly spores, accompanied by small amounts of tree pollen. Pollen in overlying peat consists of about equal amounts of Doulas fir and hemlock, in addition to lesser amounts of pine, Engelmann spruce, fir, and juniper. Alder pollen predominates in the peat near the top of the formation, along with spores and pine pollen. The climatic implications of these pollen assemblages can be inferred from the modern altitudinal distribution of corresponding trees in the Cascade Range of western Washington. This distribution is represented by surface samples from the upper layers of 14 peat bogs at various altitudes on the west slope of the mountains (Hansen, 1947), which show that modern pollen rain in the Canadian Zone (3500-6500 feet) is dominated by pine pollen, containing lesser amounts of . hemlock, and other forms. Pollen rain in the upper Humid Transition Zone (2000-3500 feet) is also dominated bv pine but has numerically more hemlock and Douglas fir than the Canadian Zone. However, modern pollen rain in the lower Humid Transition Zone (sea level to 2000 feet) shows a combined predominance of hemlock and Douglas fir, the latter pollen being more prevalent at drier localities. At all lowland sites, pine is a minor part of the pollen rain, comprising less than 20 per cent of the total tree pollen; Picea pollen is present in small amounts. The following conclusions are reached from a comparison of modern pollen rain data with the fossil pollen assemblages in the Whidbey Formation. The predominance and nearly equal percentages of Douglas fir and hemlock in peats probably represent a climate closely similar to that of the present in the lowland. Pollen having a predominance of alder in association with pine and lesser amounts of other conifers, resembles the modern pollen rain at some places in the Puget Lowland, as shown by samples from a peat bog near the northern end of Whidbey Island (Heusser, 1960). Pollen at the surface of that bog consists of about 50 per cent alder, 10 per cent each of pine and hemlock, and 5 per cent fir. However, the highest peat contains a small amount of Engelmann spruce not found in modern pollen on Whidbey Island. The climatic environment represented by the pollen and spores of beds is not clearly indicated. Hansen and Mackin (1949) inferred that, even at its warmest, the climate of the recorded part of the interglaciation was more moist than that of today. The pollen assemblages in the formation at Double Bluff, however, suggest no appreciable difference from the climate of the present.

Mammoth tusks, bones, and teeth are common on the beach between Double Bluff and Useless Bay. On a good day, I've picked up an armfull of bone and tusk fragments, presumably weathering out of the Whidbey Fm. G. E. Lewis (USGS) has identified a fragment of a cheek tooth, four cheek teeth, a deciduous fourth premolar, a hyoid bone, a first cervical vertebra, and a fragment of ulna from Scatchet Head. According to Lewis, all these fossils are referred to Mammu (Parelephas) columbi Falconer), all of probable Wisconsin age. Several teeth of *Parelephas) columbi* have been identified by Hay (1927).

Chronology

More than 20 radiocarbon ages beyond the present range of dating were obtained from peat beds in the Whidbey Formation. These range from greater than 33,200 to greater than 49,000 years b.p. Amino acid ages of 96-107,000 years b.p. have been estimated on shells from a laminated clay sequence correlated with the Whidbey Fm. at Whidbey Island State Park

Four TL ages have been measured on clay in the Whidbey Fm, (Easterbrook, Berger, and Walter, 1992).

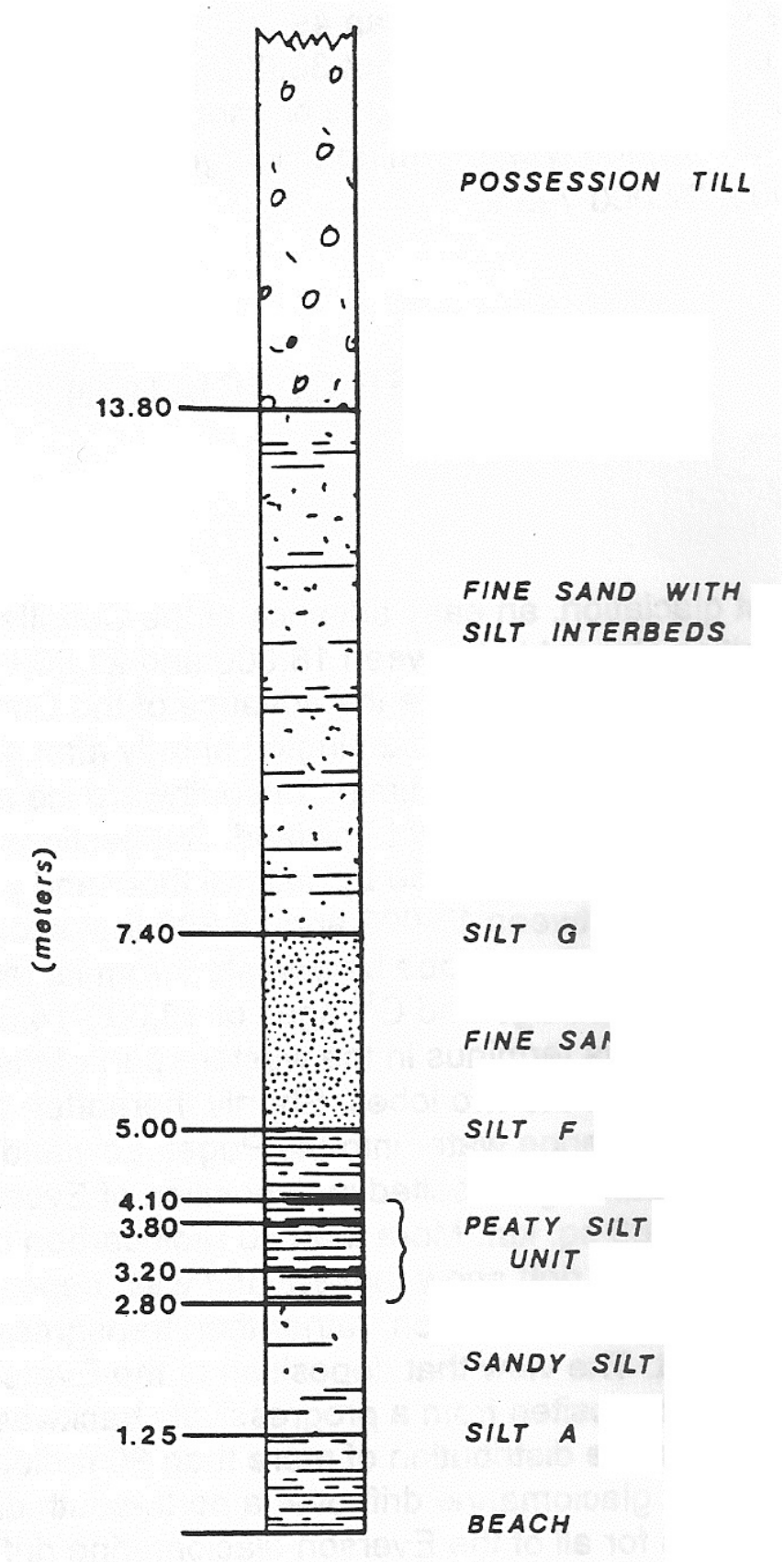
TL Age	Locality
96 ± 37 ka	Lagoon Pt., Whidbey Island
98 ± 16 ka	Blowers Bluff, Whidbey Island
140 ± 10 ka	North West Beach, Whidbey Island
150 ± 44 ka	Pt. Wilson

Possession Drft

Possession Drift consists of compact sandy till, sand and gravel, and till-like, stoney-clay, glaciomarine drift. In places, the till contains many lenses of sand and gravel. The type locality of the Possession Drift is designated as the sea cliffs at Possession Point, where compact gray till is underlain by peat-bearing sand and silt of the Whidbey Formation and overlain by younger sand and Vashon till (Easterbrook, Crandell, and Leopold, 1967). The drift at Possession Point is about 80 feet thick in the eastern part of the bluffs but thins and wedges out to the west. In some sea cliff sections, such as Blowers Bluff, the east side of Useless Bay, and Port Williams on the Olympic Peninsula, Possession Drift consists of gray, till-like, glaciomarine drift containing marine shells and shell fragments.

Possession Drift is very discontinuous, appearing and disappearing laterally within a few hundred vards in sea-cliff exposures. At the tvpe localitv it pinches out laterallv to the west, and its stratigraphic position is occupied by an unconformity between the Whidbey Formation and younger sediments. At many other places, its position is represented only bv such an unconformitv. In exposures where the Possession Drift pinches out laterally, the unconformity between thc Whidbey Formation and post-Possession deposits may be recognized, but more commonly the unconformity is poorly defined where the drift is absent. The base of the drift at Possession Point is about 135 feet above sea level and about 90 feet at Blowers Bluff and Useless Bay; elsewhere it ranges from below sea level to 150 feet above sea level. The next younger stratigraphic unit above the Possession Drift consists of sediments of the Olympia nonglacial interval. However, these sediments are typically absent, and outwash or till of Vashon age directly overlies the Possession.

Calculations based on amino acid analyses of marine shells in Possession glaciomarine drift at several localities suggest an age of about 75,000-90,000 years (Easterbrook and Rutter, 1981, 1982; Blunt, Easterbrook, and Rutter, 1987). Amino acid D/L ratios were measured in shells of six molluscan genera in Possession glaciomarine drift at three localities in the Puget Lowland: Port Williams, Stillaguamish, and Blowers Bluff. Only two genera, Nuculana and Clinocardium were found in



Stratigraphic section at Blowers Bluff

Possession glaciomarine drift at Blowers Bluff on Whidbey Island and at Port Williams on the Olympic Peninsula. Saxidomus, Nuculana, Clinocardium, Hiatella, Mya and Macoma were all present in the glaciomarine drift at the Stillaguamish locality. The shells were radiocarbon dated at 46,500 •+• 1,100 years b.p., but peat immediately overlying the shells was dated as older than 49,000 years b.p. (Minard, 1980). Because radiocarbon dates of shells older than about 30,000 years are much more likely to give dates too young, the peat date is believed to be more reliable and the shells are considered older than 49,000 years. Amino acid age calculations gave a mean age of 80,000 ± 22,000 years.

THE FRASER GLACIATION

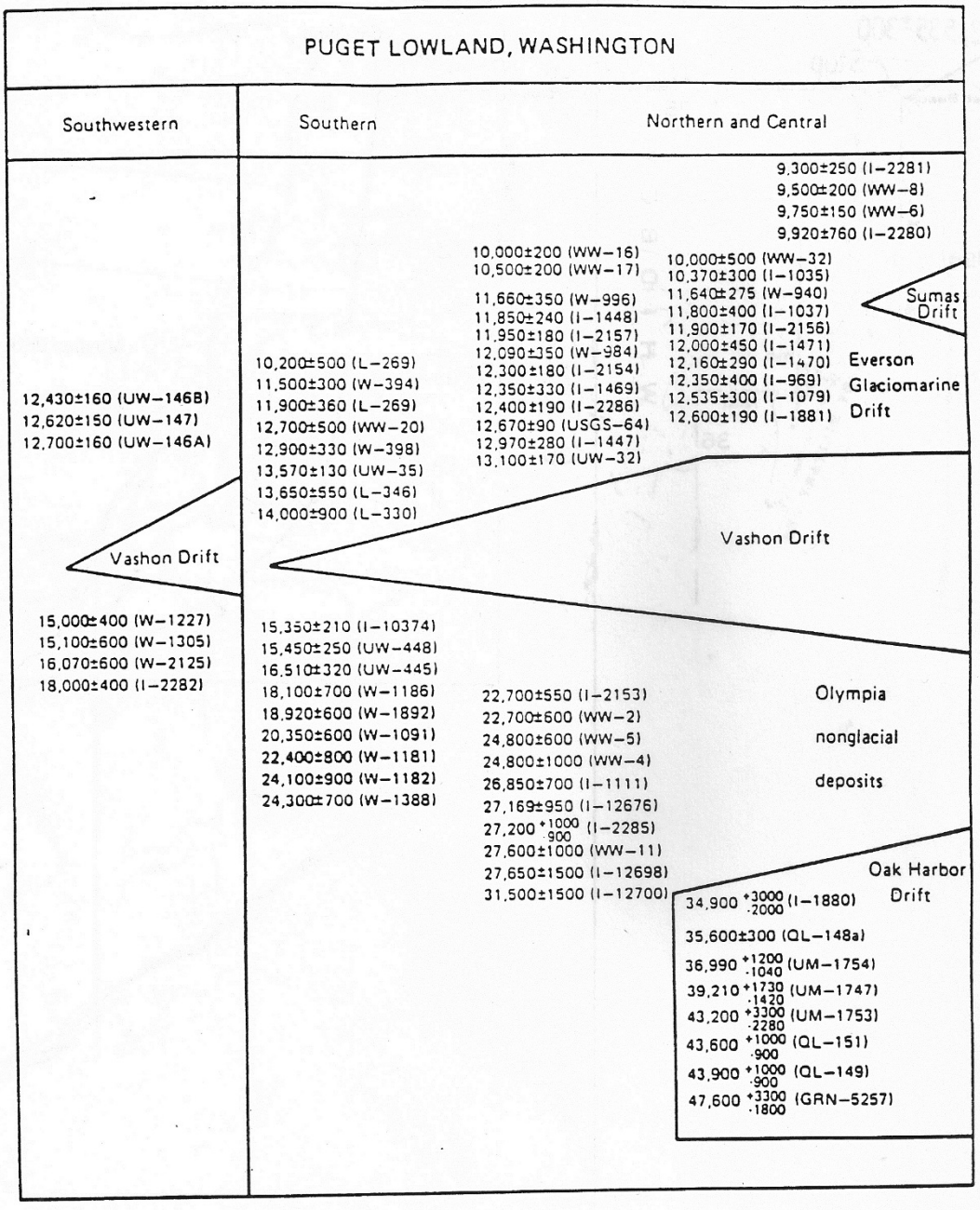
Introduction

During the last glaciation, an early advance of the Cordilleran ice sheet into the Fraser Lowland of British Columbia between 18,000 and 21,500 years b.p. Radiocarbon ages of 17,800-18,700 date the advance of the Cordilleran ice sheet across the international boundary into Washington shortly after 18,000 years ago. Pre-Vashon ages of 15,000-18,000 limit the timing of southward ice advance of the Puget Lobe to its terminus in the southern Puget Lowland. Suggestions that the Juan de Fuca lobe was out of phase with the Puget lobe by several thousand years are not consistent with five radiocarbon dates between 17,000 and 18,300 that show the two lobes advanced synchronously. The Puget lobe backwasted from its terminus to the vicinity of Seattle by 13,400-14,000 years ago and C^{14} ages of 13,000-14,500 date the retreat of the Juan de Fuca lobe from its terminus in the western part of the strait, indicating synchroniety of early retreat of the two lobes. Shortly thereafter, the ice sheet had thinned sufficiently to allow marine water into the Puget Lowland, and floating of the remaining ice by 13,000 years ago resulted in deposition of Everson glaciomarine drift over an area of about 18,000 sq. km. More than 80 radiocarbon dates from shells and wood in Everson glaciomarine drift show that the drift was deposited nearly contemporaneously over the whole region, rather than transgressively from a retreating, calving ice front. The view that deposition of the Everson glaciomarine drift was time-transgressively deposited from a progressively backwasting, calving glacial terminus is untenable because distribution of more than 80 radiocarbon dates from marine shells and wood in glaciomarine drift over a north-south distance of 170 km demonstrates similar ages for all of the Everson glaciomarine drift, regardless of geographic location.

The pattern of isostatic, eustatic, and tectonic events needed to explain stratigraphic and radiocarbon relationships of the Everson glaciomarine drift in the northern Puget Lowland is:

(1) Glacial loading during the Vashon maximum depressed the northern Puget lowland.

(2) Rapid thinning of the Cordilleran ice sheet, which began about 13-14,000



–Radiocarbon chronology of the late Pleistocene in the Puget Sound.