Stratigraphy and Chronology of Late Interglacial and Early Vashon Glacial Time in the Seattle Area, Washington

By DONAL R. MULLINEAUX, HOWARD H. WALDRON, *and* MEYER RUBIN

CONTRIBUTIONS TO STRATIGRAPHY

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ABSTRACT

A conformable late Pleistocene sequence of interglacial and glacial sediments in the Seattle area, Washington, can be divided into three units: a lower, unnamed nonglacial unit; a middle unit, the Lawton Clay Member of Vashon Drift; and an upper unit, the Esperance Sand Member of Vashon Drift. Radiocarbon dates from the lower unit indicate that the Puget glacial lobe of Vashon age advanced into the area at some time after 15,000 years ago—several thousand years later than was previously believed.

INTRODUCTION

The last advance of the Puget glacial lobe into the central part of the Puget Sound lowland of western Washington occurred during the Vashon Glaciation, and was preceded by a prolonged interglacial episode. The transition from late interglacial time to Vashon glacial time is recorded in Seattle by a conformable sequence of sediments—the Lawton Formation of local usage (Stark and Mullineaux [1]; Mackin and others, 1950)—that underlies Vashon till throughout much of the city. These sediments, which were deposited before and during the advance of the Puget glacial lobe, contain three lithologic units deposited under different environmental conditions. Radiocarbon dates for wood from the basal unit in this sequence provide a limiting age for deposition of the sediments and for the advance of the glacial lobe into the Seattle area. In combination with known limiting dates for the retreat of the glacier from the Seattle area, these radiocarbon dates define the approximate duration of the glacier in the area, and also establish a minimum rate of movement of the glacier. The purpose of this paper is to describe and divide the Lawton Formation of previous

[1] Stark, W. J., and Mullineaux, D. R., 1950, The glacial geology of the city of Seattle: Washington Univ. (Seattle) Master's thesis.

usage, and to describe and discuss the chronology of late Pleistocene events in the Puget Sound lowland near Seattle. The stratigraphic studies and the environmental and chronological interpretations were made by Mullineaux and Waldron; the ages of critical wood and peat samples from Seattle were determined by Rubin.

STRATIGRAPHY

The Lawton Formation, as originally described at its type locality at Fort Lawton (fig. 1*B*) by Stark and Mullineaux [2] was divided into two conformable units—a lower clay "phase" and an upper sand "phase." However, the clay "phase" itself can be divided into two distinct but conformable units. The resulting sequence, as described in the measured section and as shown on figure 2, includes: a lower unit of interbedded clay, silt, and sand about 70 feet thick; a middle

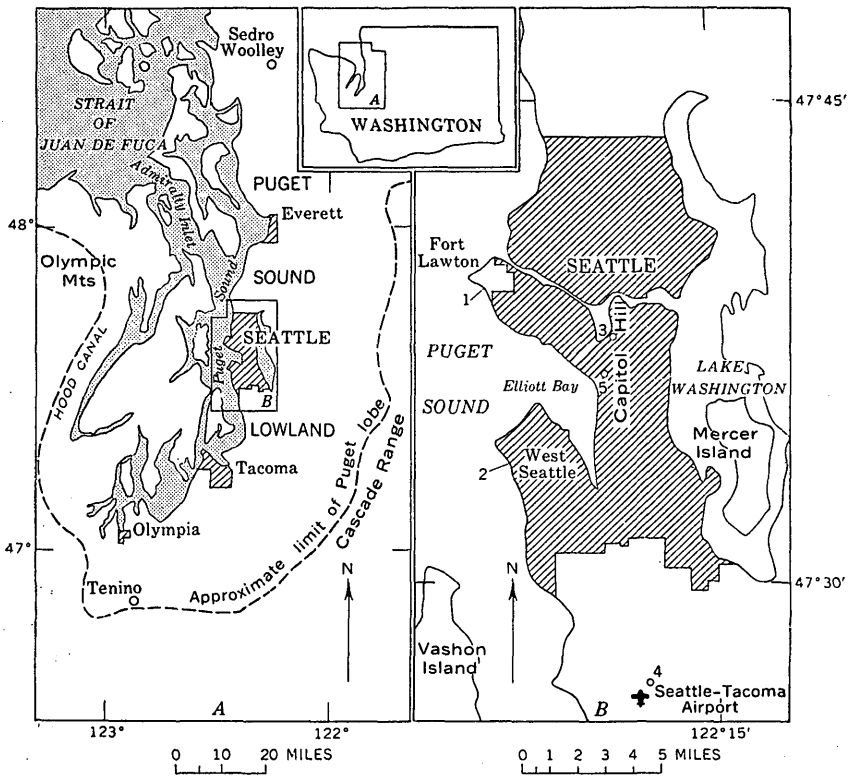

FIGURE 1.—Index maps of Puget Sound lowland and Seattle area, showing approximate maximum limit of the Puget glacier lobe during Vashon time and location of some dated wood and peat samples in and near Seattle: (1) W–1091, W–1181, and W–1186; (2) W–1182; (3) W–1227 and W–1305; (4) UW–8; and (5) W–1387.

[2] Stark and Mullineaux, op. cit.

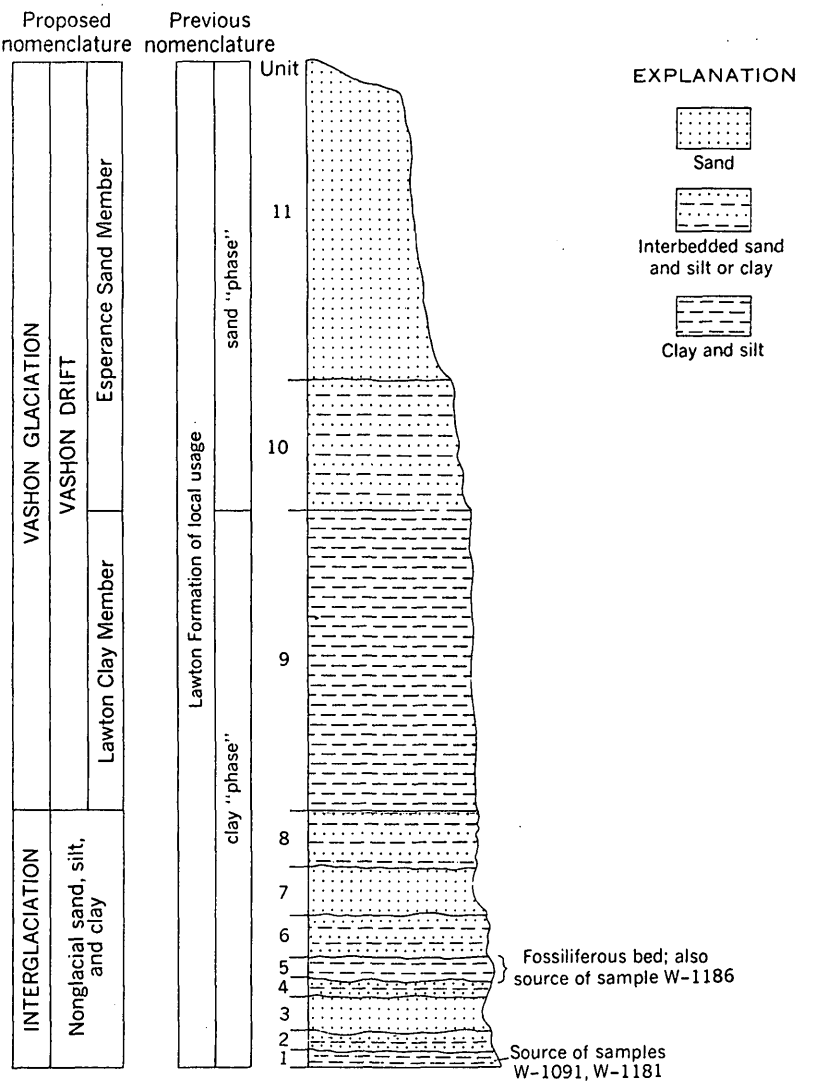

FIGURE 2.—Stratigraphy and subdivision of the nonglacial sediments and Vashon Drift exposed in sea cliff at Fort Lawton. (See measured section.)

unit of clay and silt about 80 feet thick; and an upper unit of sand more than 100 feet thick. The lower and middle units are distinguished on the basis of evidence of significant differences in their environments of deposition.

The lower unit shows evidence of having been deposited in a nonglacial environment of flood plains and shallow lakes. It is characterized by layers of silty clay and clayey silt interbedded with layers of sand that are locally crossbedded. Fibrous plant material com-

monly is concentrated along bedding surfaces, and wood fragments are scattered throughout the unit. Relatively abundant fragments of wood and some fossil pelecypod shells were found in a silty clay bed in the lower unit (USGS Cenozoic loc. 19024; fig. 2). These fossil shells previously were identified as *Anodonta* cf. *kennerlyi* Lea by E. J. Trumbull of the U.S. Geological Survey (Liesch and others, 1963), but now have been specifically identified by D. W. Taylor of the U.S. Geological Survey as *Anodonta oregonensis* Lea, a pelecypod that lives in shallow-water lakes and streams. Several pollen samples obtained from the lower unit (USGS Paleobot. loc. D1185) are dominated by pine and spruce (E. B. Leopold, written commun., 1957), suggesting that at the time of deposition the climate was cooler and moister than at present.

Stratigraphic sequence exposed at Fort Lawton, sec. 16, T. 25 N., R. 3 E.

[Nonglacial sediments and lower part of Lawton Clay Member measured in sea cliff approximately 2,500 ft southeast of West Point light; upper part of Lawton Member and Esperance Sand Member measured between 500 and 1,000 ft farther southeast. Section measured by hand level and tape]

	Thickness (feet)
Esperance Sand Member of Vashon Drift:	
11. Sand, chiefly medium, well-sorted, light-brown, mostly crossbedded; apparent dip of foreset beds is generally southeastward. Mostly loose and friable. Contains three thin silt beds and numerous rounded fragments of compact clay and peat	85
10. Sand, fine to medium, gray to brown, mostly horizontally bedded, interbedded with gray clayey silt layers; (these beds, which record a transition between the Lawton Clay Member and the relatively uniform medium sand above, are arbitrarily assigned to the Esperance Sand Member)	35
Lawton Clay Member of Vashon Drift:	
9. Clay, dark-gray, interbedded with light-gray silt. Upper part chiefly clayey silt; in part structureless, elsewhere laminated, locally ripple marked. Exposed clayey silt commonly fractures along conjugate joints spaced a few feet apart. Grades downward into finer grained beds typical of lower part. Lower part chiefly dark-gray clay containing thin light-gray silt layers. Strikingly laminated; laminations are somewhat similar to varves, but clay layers generally are thicker than silt layers, and persistent, regular alternation of clay and silt layers is not present. Exposed clay commonly fractures along conjugate joints, spaced only a few inches apart, and along bedding planes. A few thick beds contain contorted laminations suggesting deposition by subaqueous slumping. Characterized by flattish calcareous concretions apparently formed in thin silt layers. Contains thin beds of sand near base	82
Nonglacial sediments:	
8. Clay, silty, interbedded with thin beds of fine sand. Contains sparse tiny fragments of organic material. Unit appears to be transitional between nonglacial sediments and Lawton Clay Member; assigned to nonglacial beds because of organic material	14

Stratigraphic sequence exposed at Fort Lawton, sec. 16, T. 25 N., R. 3 E.—Con.

Nonglacial sediments—Continued	Thickness (feet)
7. Sand, fine, dark-brown; contains sparse organic material	12
6. Silt, clayey, gray to brown; contains thin fine to medium sand layers	12
5. Clay, silty, dark-gray to yellow-brown; upper part contains *Anodonta oregonensis* fossils (USGS Cenozoic loc. 19024); lower part contains small relatively abundant wood fragments (source of sample W–1186). Some organic material partly or wholly replaced by vivianite(?). Structureless, fractures conchoidally	6
4. Sand, fine, horizontally bedded; contains silt layers	4
3. Sand, medium, gray-brown, crossbedded, mostly loose, friable	10
2. Sand, medium, brown, crossbedded; contains thin clayey silt layers and fibrous organic debris concentrated along bedding surfaces	5
1. Silt, clayey, brown to gray, horizontally bedded, partly ripple marked; forms ribbed outcrop; contains scattered organic material (source of samples W–1091 and W–1181). More than 10 ft exposed elsewhere along bluff	5
Base of bluff.	

The middle unit, in contrast with the lower, consists almost entirely of clay and silt and is characterized by thin laminations of dark- and light-gray clay and silt that resemble varves. A few thin sand beds are common but only near the base or top; ripple marks also occur locally in the upper part. No organic matter or pollen has been found in this unit. The middle unit is interpreted as having been deposited rapidly in a relatively stable lacustrine environment. Such an environment probably occurred when the northward drainage of the lowland, which existed during interglacial time, was blocked at the mouth of Admiralty Inlet (fig. 1*A*) by the advancing Puget glacial lobe of Vashon age.

The upper unit of sand appears to be chiefly a proglacial fluvial and lacustrine deposit that was laid down after the lake was mostly filled with silt and clay. The streams that carried the sand are regarded as having come principally from the advancing Puget lobe (Crandell and others, 1965). Locally, the unit contains some lenses of gravel. In Seattle, this sand commonly is directly overlain by Vashon till, but in places it is overlain by outwash gravel.

Because the Lawton Formation is divisible into lithologic units that appear to record both nonglacial and diverse proglacial conditions, it seems desirable to redefine the formation. The term "Lawton Formation" will no longer be used, and the name Lawton will be restricted to the middle unit of glaciolacustrine clay and silt; it is here designated as the Lawton Clay Member of the Vashon Drift, and the sea-cliff exposures on the southwest side of Fort Lawton are designated as the type section (fig. 2). The upper unit of proglacial sand is here

correlated with the later outwash phase of the Esperance Sand Member of the Vashon Drift of Newcomb (1952). Newcomb recognized two major units within the Esperance Sand Member and stated: "The earlier phase of the sand member appears to be a coarser continuation of the horizontal Admiralty clay, whereas the later outwash phase is undoubtedly the advance outwash of the Vashon glacier." The two phases were combined for the ground-water study because of their hydrologic continuity and because of the difficulty involved in mapping them separately (Newcomb, 1952, p. 20). As anticipated by Newcomb, further study has made it advantageous to separate them, and the Esperance Sand Member is here restricted to the "later outwash phase" and its equivalents. The name is adopted for the sand "phase" of the Lawton Formation of previous usage (Mackin and others, 1950), and the outcrops on the southwest side of Fort Lawton (fig. 2) are designated as the reference locality of the Esperance Sand Member as restricted.

The nonglacial sediments of the lower unit are not formally named here; tentatively they are regarded as correlative in part to lithologically similar sediments that were deposited during the interglaciation in many other parts of the Puget Sound lowland and in southwestern British Columbia (Armstrong and others, 1965). Molenaar and others (1965) have used the name Kitsap Formation for such nonglacial sediments in the southern and central parts of the lowland.

CHRONOLOGY

Wood fragments from the nonglacial sediments under the Lawton Clay Member at the type section (figs. 1*B* and 2) have radiocarbon ages of 22,400±800 years (sample W–1181), 20,350±600 years (sample W–1091), and 18,100±700 years (sample W–1186). These dates indicate that the sediments represent a very late part of the interglaciation. Nonglacial deposits of this interglaciation were first dated from wood and peat in sediments on the east side of Vancouver Island in British Columbia, which John Fyles, of the Canadian Geological Survey, correlated with the Quadra sediments of Armstrong and Brown (1953). Radiocarbon dates from the Quadra sediments range from about 35,000 years to about 23,000 years ago (Fyles, 1963; Dyck and Fyles, 1963). Subsequently, John Noble and Dee Molenaar, of the Washington State Water Resources Division, and Grant Kimmel, of the U.S. Geological Survey, recognized similar nonglacial sediments in the southern part of the Puget Sound lowland. Radiocarbon dates from these sediments range from about 35,000 years to about 28,000 years ago (Dorn and others, 1962). The sediments just below the Lawton Member in Seattle represent a part of the interglaciation that

has not yet been identified in other parts of the Puget Sound lowland, and they may represent a time when Cordilleran ice had already entered the lowlands in southwestern British Columbia (Armstrong and others, 1965).

Additional radiocarbon samples obtained from nonglacial sediments under the Lawton Clay Member elsewhere in Seattle (fig. 1*B*) include peat (sample W–1182) from West Seattle whose age is 24,100±900 years, a wood sample (W–1387) from downtown Seattle whose age is 20,640±600 years, and two wood samples (W–1227 and W–1305) from Capitol Hill whose ages are 15,000±400 years and 15,100±300 years, respectively. The last two samples were collected from excavations made for the new freeway in Seattle, where as much as 80 feet of the Lawton Clay Member overlies the nonglacial sediments (Mullineaux and others, 1964). These dates indicate that nonglacial conditions at Seattle persisted until at least 15,000 years ago, and that the Puget glacial lobe did not advance southward far enough to form a proglacial lake in the vicinity of Seattle until after 15,000 years ago. Most of the Lawton Clay Member and the overlying Esperance Sand Member were deposited after about 15,000 years ago and before the ice overrode the locality.

Until recently, the Vashon generally has been regarded as possibly correlative with the "classical" Wisconsin ice advance of the Midwest (Waldron and others, 1957; Crandell, 1963), which apparently began some 25,000 or more years ago and reached a maximum about 18,000–20,000 years ago (Flint and Rubin, 1955; Flint, 1963). The dates from the Seattle area, however, suggest that nonglacial conditions prevailed in this part of the Puget Sound lowland throughout the advance and much of the retreat of the ice sheet in the Midwest. It is not known yet whether or not the whole of the lowland was ice free throughout all this time. It is known that some valley glaciers in the Cascade Range and Olympic Mountains reached their maximum extents and retreated before the Puget lobe reached its maximum extent in the lowland (Cary and Carlston, 1937; Mackin, 1941; Crandell, 1963; Heusser, 1964).

Radiocarbon ages of samples taken from basal post-Vashon peat provide a limiting date for the retreat of ice from this part of the lowland. The samples include peat from the vicinity of Seattle and from a bog near Sedro Woolley, about 45 miles north of Seattle (fig. 1*A*). These samples (indicated by parentheses) have radiocarbon ages of 14,000±900 years (L–330), 13,650±550 years (L–346A), 12,300±200 years (UW–8), and 12,900±330 years (W–398) (Broecker and Kulp, 1957; Dorn and others, 1962; Rubin and Alexander, 1958). Sample L–346A is from the same locality as sample L–330, but apparently its date was considered by Rigg and Gould (1957) and Gould and

Budinger (1958) to be more reliable; the sample was taken from basal peat in Lake Washington (fig. 1*B*) that overlies late- or post-Vashon glaciomarine(?) and glaciolacustrine clays.

On the basis of radiocarbon dates, the Puget glacial lobe of Vashon age advanced across the latitude of Seattle at some time after 15,000 years ago, and had retreated from the area by about 13,500 years ago. The time required for nonglacial sedimentation after deposition of the wood fragments on Capitol Hill is not known, but presumably it was brief. The time required for deposition of the Lawton Clay Member and Esperance Sand Member was also probably short, perhaps no more than a few hundred years. According to Rigg and Gould (1957, p. 357) and Gould and Budinger (1958, p. 190–191), a marine occupancy occurred between retreat of the ice and deposition of the peat in Lake Washington. Such evidence would indicate that some time also elapsed between these events. The radiocarbon dates suggest that the glacier occupied the Seattle area for no more than 1,500 years; and the events that are recorded between deposition of the sediments now dated by the radiocarbon method suggest that the actual term of occupancy by the ice may have been substantially shorter.

The limiting dates for ice occupancy at Seattle also establish approximate minimum rates of advance and retreat of the glacier in this part of the lowland. From Seattle, the ice advanced southward to its maximum extent in the vicinity of Tenino (fig. 1*A*), a distance of about 50 miles. If the glacier occupied the Seattle area for a total of 1,000–1,500 years, as suggested by the radiocarbon dates, the average rate of movement of the ice front was about 1 mile in every 10–15 years, or about 350–530 feet per year. These implied rates of ice movement, although seemingly large, are no greater than rates observed on existing glaciers, and they compare favorably with some of the rates calculated for the advance and retreat of the late Wisconsin continental glacier in the midwestern United States (Flint, 1955). In arriving at the above average rates of ice-front movement, we assumed that the movement was uninterrupted, no stillstands of the glacier occurring either at the terminus or during advance and retreat. The lack of a pronounced terminal moraine of the Puget glacial lobe and the absence of recessional moraines in the Vashon Drift, both of which have been noted by many observers, tend to substantiate the assumption that the movement of the ice front was uninterrupted.

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