NATURAL RESOURCES

Maps of the Surficial Geology and Depth to Bedrock of False Bay, Friday Harbor, Richardson, and Shaw Island 7.5-minute Quadrangles, San Juan County, Washington

by David P. Dethier, Daniel P. White, and Christopher M. Brookfield

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands
Kaleen Cottingham - Supervisor

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INTRODUCTION

The four 1:24,000-scale maps portray the distribution of surficial deposits that accumulated in the southwest San Juan Islands during the past 18,000 years (late Pleistocene and Holocene time), as well as outcrops of bedrock that formed more than 100 million years ago in Paleozoic and Mesozoic time. Our field mapping from 1992 to 1994 emphasized distinctions among different kinds of surficial deposits and the geologic processes that produced these materials. We use stratigraphic sections to portray vertical relations of glacial deposits where they are particularly well exposed along sea cliffs, in gravel pits, or described in well logs that we compiled and field checked during 1994. The depth-to-bedrock maps, based on geologic mapping and an analysis of well logs, portray the three-dimensional extent of surficial deposits, which locally cover bedrock with sediment more than 300 ft thick. We did not distinguish among the types of bedrock. Readers interested in bedrock geology of the San Juan Islands should consult Whetten and others (1988), Brandon and others (1988), and references in those reports.

Studies of surface- and ground-water hydrology of the areas (Russell, 1975; Whiteman and others, 1983) use surficial and bedrock geology, climatic data, and field measurements to analyze water availability and quality. Our detailed mapping and compilation are intended, in part, to provide additional basic information for studies concerned with water quantity and quality and patterns of land use.

LATE PLEISTOCENE AND HOLOCENE GEOLOGIC HISTORY

Our mapping and dating of surficial deposits and regional geologic relations (Pessl and others, 1988; Easterbrook, 1992) demonstrate that most of the sediment exposed in the San Juan Islands was deposited during the past 18,000 years, mainly during the Vashon Stade of the Fraser Glaciation. During this glaciation, continental ice flowed south into the Puget Lowland from source areas in Canada. Braided streams deposited large amounts of sediment as coalescing outwash fans in front of the advancing ice, smoothing topographic irregularities. Eventually the Fraser ice flowed over the outwash surface, depositing till and covering the highest points in the San Juan Islands some time after 18,000 ^{14}C years before present (18.0 ka).

Continental ice split into two lobes in the vicinity of the San Juan Islands and continued to flow south and west. The Juan de Fuca lobe terminated in tidewater west of Vancouver Island and the northern Olympic Peninsula, whereas the Puget lobe advanced south to near Olympia. Both lobes began to retreat between 15.0 and 14.5 ka in response to warming climate, globally rising sea level, and reduced accumulation of snow and ice in the source areas.

The Juan de Fuca lobe retreated by marginal calving, depositing sediment into marine waters as it alternately floated and grounded temporarily on topographic highs such as San Juan Island. Retreat of the Juan de Fuca lobe probably resulted in a deep embayment in the retreating Puget lobe, producing calving margins near Whidbey Island by about 13.6 ka. The continental ice margin retreated rapidly back to Canada through the San Juan Islands before about 13 ka (Dethier and others, 1995).

As the ice disappeared, marine waters invaded the area up to an elevation of about 300 ft, depositing marine sediment and shell assemblages in moderately deep to intertidal environments. The marine invasion, termed the Everson interval, resulted from the depression of the northern Puget Lowland by the weight of the massive continental ice sheet and from rising global sea level.

Between about 13.1 and 12.5 ka, most of the area rebounded rapidly (more than 0.4 ft per year), lifting the land through slowly rising sea level and eroding much of the recently deposited glacial, glaciomarine, and marine sediment. Waves cut into beach cliffs and deposited prominent beaches on such areas as Mount Finlayson on San Juan Island. Rebound slowed before 11 ka, and by about 8 ka local sea level was rising more rapidly than the rebounding land, producing slow submergence.

During Holocene time (the past 10,000 years), geologic processes have been dominated by coastal change produced by wave erosion and sediment transport, particularly in the vicinity of south-facing shores and other areas of high wave and current activity. Relative sea level has risen more than 150 ft in the Holocene, changing the locations of maximum erosion and gradually moving the shoreline inland. Shallow marine platforms composed of gravel, such as Salmon Bank, probably were part of San Juan Island until they were planed by erosion. Modern retreat rates of about 0.5 to 1.0 ft/yr (Keuler, 1988) along the cliffs near Cattle Point, for instance, could have produced Salmon Bank from a land mass in a couple of thousand years. Undercutting by waves has produced landslides locally.

In inland areas, slope and soil-forming processes acting at relatively slow rates modified the landscape, and as much as 7 m (ca. 22 ft) of organic and inorganic sediment has accumulated in both coastal lagoons and upland areas. Changes in landscape shape and drainage patterns have been rapid since European settlement, particularly during the past 30 years.

DESCRIPTIONS OF MAP UNITS

f Fill (Holocene)—Mixtures of earth materials, demolition debris, garbage, and other debris disposed of as solid waste; thickness generally more than 6 ft; overlies till, diamicton, or recessional deposits. Small areas of fill near roads are not shown.

Qd Dune deposits (Holocene)—Generally well-sorted medium to coarse sand containing layers of silt and fine sand; massive to planar cross-stratified; locally include one or more buried soil intervals; thickness generally 7-16 ft; occur adjacent to beaches exposed to strong onshore winds; overlies glaciomarine deposits in most areas; active and sparsely vegetated dunes most extensive near South Beach, San Juan Island.

Qb Beach deposits (Holocene)—Moderately well to well-sorted gravel and coarse sand along shorelines above high tide; planar and channel cross-stratified; locally massive; thickness more than 7 ft; overlies bedrock in most areas; forms elongate spits near Lopez and Flat Point on Lopez Island, and at Low Point and North Bay, San Juan Island. Numerous pocket beaches too small to show at this scale occur in shorelines mapped as bedrock, particularly along the southwest and northeast sides of San Juan Island, on Shaw Island, and along the south side of Lopez Island.

Qtf Tidal-flat deposits (Holocene)—Fine sand, sand, silt, and minor clay, generally water saturated, adjacent to active beach spits; massive; locally horizontally stratified; contain numerous burrows and remains of roots, particularly of eel grass; thickness and contact relations unknown; extends from high tide level to mean lower-low sea level. These deposits are most extensive near sheltered coves such as False Bay, San Juan Island, Fishermans Bay and west of Richardson, Lopez Island, and Squaw Bay, Indian Cove, and Blind Bay, Shaw Island.

Ql Landslide deposits (Holocene)—Heterogeneous mixtures of silt, sand, and diamicton transported downslope by sliding, slumping, or flowing and exposed in coastal bluffs; stratification discontinuous, reflecting original layers in the bluff or layers formed during sliding; thickness 7-20 ft; overlie fine Pleistocene sediments; deposit surfaces commonly hummocky and include closed depressions and

irregular low ridges; common along the west side of Lopez Island. Landslides too small to show at map scale are indicated by symbol.

Qm Marsh, bog, or swamp deposits (Pleistocene and Holocene)—Fine sand and silt mixed with decomposing vegetation; includes peat deposits and locally contains interlayered tephra; deposited in fresh or brackish water; stratification generally horizontal; thickness 7-27 ft; overlies Pleistocene deposits such as till and marine silt, or bedrock. Upland bogs and marshes fill local depressions on glacial deposits and bedrock, such as those near Sportsmans Lake, San Juan Island; salt marshes and swamps occur adjacent to lagoons, sand spits, and tidal flat deposits at Fishermans Bay, Lopez Island; small wetlands formed by dams and other impoundments are not shown.

Deposits of the Vashon Stade of Fraser Glaciation (Pleistocene)

Qvrm Recessional-marine deposits—Interbedded pebbly silt, sand and gravel, silt and sand containing lenses of diverse sediment types and sparse to locally abundant marine fossils; deposited in a glaciomarine or marine environment. Subdivided into:

Qvrme Emergence deposits—Moderately well sorted to well-sorted gravel and sand containing sparse boulders; fine to medium sand in a few places; beds massive to locally channel cross-stratified; thickness ranging from a boulder lag less than 1 ft thick to about 27 ft thick; common at elevations below about 200 ft; unconformably overlies other marine deposits or till; locally fills channels cut into underlying deposits; lies beneath or grades up into sandy eolian deposits rich in organic matter; buried soil profiles 0.7-2 ft thick in some gravelly deposits. Two deposits south of Friday Harbor have the morphology of beach deposits. This unit contains local concentrations of shell fragments, many highly leached, and molds (in sand) of *Protothaca staminae, Saxidomus giganteus, Chlamys* sp. and other species (see table). Age between about 12.8 and 12.3 ka.

Qvrms Marine subtidal deposits—Moderately well to well-sorted sand, silty sand, and silt containing local pods and lenses of gravel; laminated to thin-bedded, locally massive and cross-stratified; thickness generally 10-50 ft; generally lies above marine diamicton, till, and undifferentiated diamicton and can be distinguished from these units by the lack of clasts; lies beneath organic-rich soils or peat deposits; gray to bluish gray; preserved in topographic depressions below an elevation of 200 ft; most extensive near False Bay, San Juan and Beaverton valleys, San Juan Island, north of Lopez and northwest of Richardson on Lopez Island. Locally fossiliferous (see table). Age between about 12.9 and 12.5 ka.

Qvrmd Marine diamicton—Poorly to moderately well sorted pebbly silt and diamicton; contains lenses and discontinuous beds of silt, sand, and gravel; massive to poorly stratified; normally graded bedding common locally; unweathered matrix light olive gray to gray, locally bluish gray; olive to buff colors common in the upper 3 ft of oxidized diamicton; thickness generally 10-27 ft, but as great as 50 ft near Cattle Point and American Camp, San Juan Island; overlies marine outwash or Vashon till; generally lies beneath gravelly emergence deposits or marine subtidal deposits; locally mantles the landscape below elevations of about 200 ft, particularly in topographic depressions, where some marine diamicton is included with Vashon diamicton (unit Qvd); sparsely to highly fossiliferous (see table); fossils commonly in growth position; at other localities sedimentary structures and mixtures of fossils of different depths demonstrate the polygenetic origin of this unit. Age between about 13.1 and 12.8 ka.

Qvrmo Marine outwash—Moderately well to well-sorted gravel and sand, matrix-supported gravel and sand-rich diamicton, and lenses and beds of pebbly silt; generally well stratified in beds 1-7 ft thick; some beds massive to poorly stratified. Beds dip 5°-30° southeast, south, southwest, and west; planar crossbeds commonly extend 33-165 ft down dip; channels locally cut planar crossbeds. Pebbly marine silt most common in channels near the top and along margins of the deposit. Thickness ranges from 16 ft to more than 200 ft near Cattle Point, where deposits form an extensive moraine, and near Pear Point, San Juan Island, an area of extensive gravel mining. Marine outwash deposits overlie till, undifferentiated diamicton, or bedrock and lie beneath marine diamicton or marine emergence facies. The unit is locally collapsed or cut by thrust faults. Gravel units and beds of pebbly silt are locally fossiliferous (see table). Age about 13.2 ka.

Qvt Till—Poorly sorted, compact mixture of silt, sand, and clay containing 5-30 percent (by volume) pebble to boulder gravel; generally nonstratified, but subhorizontal layering, parting, and deformation structures present locally; contains lenses, pods, and thin discontinuous beds of sorted material, generally gravel, in some exposures; thickness variable, but generally ranging between 13 and 33 ft; matrix colors similar to those of the marine diamicton unit, mainly olive gray and gray where unoxidized and olive to buff in the upper 3-7 ft; clasts subangular to subround; rock types mainly local greenstones and graywackes, but granitic rocks derived from the Coast Range of British Columbia make up more than 10 percent of the larger clasts; generally rests on striated bedrock or on advance outwash and lies beneath marine diamicton or underlies the soil layer in most areas. Older than 13.2 ka.

Qvd Diamicton, undifferentiated—Poorly sorted, generally nonstratified till covered by 1.5-10 ft of marine diamicton; used as a map unit below an elevation of about 200 ft where till and marine diamicton cannot be differentiated at map scale; includes areas of marine diamicton; generally unfossilferous.

Qva Advance outwash deposits—Moderately well to well-sorted sand, gravel, and minor silt; mainly composed of well-stratified planar stratified, medium and coarse sand; contains lenses and thin beds of pebble gravel; channel-crossbedding also common; thin (less than 3 ft) beds of silty sand and silt common near the base of the section; lenses of fine material present throughout the section. Cross-beds indicate that paleocurrents flowed southeast, south, and southwest. Thickness ranges from 16 to more than 265 ft on Lopez Island; exposures absent on San Juan and southern Orcas Islands. The unit overlies deformed nonglacial deposits at Indian Cove on Shaw Island; base not exposed on Lopez Island. Well logs suggest outwash deposits overlie bedrock or fine-grained preglacial deposits in most locations. The unit lies beneath till or diamicton, undifferentiated.

Deposits of pre-Vashon Age

Qpfn Nonglacial deposits of pre-Fraser Glaciation age (Quaternary)—Interbedded silty sand, sand, silt, and clay overlying patches of diamicton; locally contains flattened woody fragments; massive to laminated and thin bedded; exposed on Shaw Island at Indian Cove where wood pieces gacea 14C age of 22.9 $\pm$ 0.2 ka (Beta 9495). Drill logs suggest the deposits may be more than 66 ft thick locally. The deposit base not exposed, but the unit probably lies on bedrock. Advance outwash (unit Qva) deposits unconformably overlie the nonglacial deposits.

br Bedrock (pre-Tertiary)—Abundant bedrock exposures mantled with thin (less than 10 ft) surficial deposits.

Table 1. Late Pleistocene fossil genera and radiocarbon ages, San Juan Islands, Washington

Location	Elevation (feet)	Stratigraphic unit	Abundant genera	^{14}C age (ka) (Lab., ID)
False Bay quadrangle				
DW-16d	95	Qvrms	*Mytilus, Macoma, Mya, Saxidomus, Hiatella*	
DW-16e	93	Qvrmd?	*Nuculana, Serripes, Mya, Hiatella*	
DW-83a	41	Qvrms?	*Mytilus, Clinocardium, Serripes, Macoma, Mya, Hiatella, Puncturella, Trichotropis, Serpula, Spirobis, Balanus*	
DW-83c	43	Qvrms?	*Saxidomus*	12.65±0.10 (Beta-73072)
DW-91	10	Qvrmd	*Nuculana, Clinocardium, Balanus*	
DW-91a	15	Qvrmd?	*Nuculana, Hiatella, Clinocardium*	12.77±0.44 (GX-19686)
Friday Harbor quadrangle				
DW-15	50	Qvrmo	*Mytilus, Macoma, Hiatella, Balanus*	13.24±0.07 (B-70971)
DW-30	92	Qvrmd	*Nuculana, Clinocardium, Hiatella, Mya, Balanus*	13.05±0.37 (B-73071)
DW-58	150	Qvrms	*Mytilus, Clinocardium, Macoma, Mya, Balanus, Strongylocentrotus*	12.64±0.21 (B-73071)
Richardson quadrangle				
DW-14[1]	21	Qvrmd	*Nuculana, Mytilus, Clinocardium, Serripes, Macoma, Mya, Hiatella, Serpula, Balanus, Strongylocentrus*	13.0±0.15 (B-73068)
DW-21[2]	11	Qvrms	*Macoma, Saxidomus, Mya, Trichotropis, Serpula, Balanus*	12.6+0.08 (B-73069)
DW-127a	0.5	Qvrmd	*Clinocardium, Mya*	13.07±0.13 (B-73073)
DW-127b	1.0	Qvrme	*Saxidomus, Protothaca, Chlamys*	12.74±0.15 (Beta-1717)
DW-127c	3.0	Qm/Qvrme?	*Heliosoma, Physa, Limnophysa*[3]	12.88±0.20 (Beta-1723)
UW-9791[4]	150	Qvrmd	*Hiatella, Tectum*	12.80+0.10 (B-73067)
Shaw Island quadrangle				
UW-A2688[4]	25	Qvrms?	*Mytilus, Clinocardium, Macoma, Saxidomus, Protothaca, Mya, Littorina, Serpula*	
UW-9778[4]	110	Qvrms?	*Hiatella*	12.60+0.38 (B-73064)
UW-9779[4]	107	Qvrme?	*Mytilus, Clinocardium, Macoma, Saxidomus, Protothaca, Heliosoma*[3], *Physa*[3]	12.62+0.13 (B-73065)
UW-9780[4]	40	Qvrme	*Chlamys, Saxidomus*	12.32+0.09 (B-73066)

1. Probably the same area as UW-9797, -9798, -9799 of Shaw (1972) and W-1214 of Easterbrook (1969), who reported an age of 12.35+0.33 (I-1469) for shell.
2. Near UW-9795, -9796 of Shaw (1972) and W-1212, -1213 of Easterbrook (1969), who reported an age of 11.9+0.17 (I-1256) for shell.
3. Fresh or brackish water genera.
4. Descriptions from Shaw (1972).

FOSSIL ASSEMBLAGES AND RADIOCARBON AGES

Fossil assemblages and radiocarbon age as listed in Table 1 fall into three categories: (1) genera such as *Nuculana, Serripes*, and *Clinocardium* that lived in moderately deep to subtidal water when calving ice was present before about 13.0 ka; (2) organisms such as *Saxidomus* that lived in shallow subtidal to intertidal water during the period of rapid emergence about 12.5 ka; and (3) fresh- or brackish-water gastropods such as *Lymnophysa* that lived in lagoons or coastal wetlands as the areas emerged after about 12.5 ka.

Radiocarbon ages in the table are from shell and have not been corrected for marine reservoir effects or to the calibrated time scale. Reservoir effects probably make the reported ages "too old" by about 600-800 years when compared, for instance, to wood that grew at the same time. Correction of marine shell ages to the calibrated time scale is not warranted because of uncertainty about the ^{14}C age of marine reservoirs in late Pleistocene time. However, calibrated ages likely would be more than 2,000 years older than the tabulated ages.

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SURFICIAL GEOLOGY OF THE FALSE BAY, FRIDAY HARBOR, RICHARDSON, AND SHAW ISLAND 7.5-MINUTE QUADRANGLES, SAN JUAN COUNTY, WASHINGTON

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November 1996

CORRELATION OF MAP UNITS

Qd	Qb	Qtf	Ql	Qm

QUATERNARY	Holocene		
	Pleistocene	Vashon stade, Fraser glaciation	Qvrms, Qvrme, Qvrmd, Qvrmo, Qvt, Qvd, Qva
			Qpfn
PRE-TERTIARY			br

DESCRIPTION OF MAP UNITS

- f Fill

- Qd Dune deposits
- Qb Beach deposits
- Qtf Tidal flat deposits
- Ql Landslide deposits
- Qm Marsh, bog, or swap deposits

Vashon Stade Deposits

- Qvrm Recessional marine deposits
  - Qvrme Emergence deposits
  - Qvrms Marine subtidal deposits
  - Qvrmd Marine diamicton
  - Qvrmo Marine outwash
- Qvt Till
- Qvd Diamicton, undifferentiated
- Qva Advance outwash deposits

Pre-Vashon Deposits

- Qpfn Nonglacial deposits
- br Bedrock

EXPLANATION

- x Landslide deposit, too small to show at map scale
- F Fossil locality (see table)
- C Location of radiocarbon-dated sample
- \+ Measured section
- J-5 ● Well-log location
- Striation or trough and direction of ice motion
- Drumlin, indicating orientation of long axis
- Uplifted beach deposit

CONTACTS AND SYMBOLS FOR GRAPHIC LOGS

- Conformable (surface exposures); or unknown (well log)
- Erosional
- Dropstone
- Diamicton, deformed (Qvt, Qvd, Qvrmd)
- Diamicton (Qvt, Qvd, Qvrmd)
- Gravel (Qva, Qvrmo, Qvrme)
- Fine gravel; coarse sand (Qva, Qvrmo, Qb)
- Fine to medium sand (Qva, Qvrms)
- Silty sand (Qva, Qvrms, Qm, Qtf)
- Silt and clayey silt (Qva, Qpfn)

Mapped by U. S. Coast and Geodetic Survey
Edited and published by the Geological Survey
Control by USC&GS
Topography from aerial photographs by multiplex methods
Aerial photographs taken 1949. Field check 1954
Hydrography compiled from USC&GS chart 6380 (1955)
Polyconic projection. 1927 North American datum
10,000-foot grid based on Washington coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 10, shown in blue

SCALE 1:24000
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
DEPTH CURVES IN FEET—DATUM IS MEAN LOWER LOW WATER
SHORELINE SHOWN REPRESENTS THE APPROXIMATE LINE OF MEAN HIGH WATER
THE AVERAGE RANGE OF TIDE IS APPROXIMATELY 4 FEET
UTM GRID AND 1954 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
ROAD CLASSIFICATION
Light-duty — Unimproved dirt

FALSE BAY, WASH.
N4822.5—W12300/7.5
1954
PHOTOINSPECTED 1972
AMS 1380 I NE—SERIES V891

RICHARDSON, WASH.
NW/4 RICHARDSON 15' QUADRANGLE
N4822.5—W12252.5/7.5
1977
AMS 1480 IV NW—SERIES V891

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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
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PLATE 1
OPEN FILE REPORT 96-7
MAPS OF THE SURFICIAL GEOLOGY AND DEPTH TO BEDROCK OF FALSE BAY, FRIDAY HARBOR, RICHARDSON, AND SHAW ISLAND 7.5-MINUTE QUADRANGLES SAN JUAN COUNTY, WASHINGTON

FRIDAY HARBOR QUADRANGLE
WASHINGTON—SAN JUAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

SHAW ISLAND QUADRANGLE
WASHINGTON—SAN JUAN CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)

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EXPLANATION

25 • Well finished in bedrock: thickness of Quaternary sediment, in feet, indicated at selected wells

>250 o Well finished in Quaternary sediment; minimum thickness of Quaternary sdiment, in feet, indicated at selected well sites

—20— Line connecting points of equal depth to bedrock, in feet; contour interval 20 ft; locally not shown or generalized where gradient is steep and values are uncertain near American Camp.

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PLATE 2
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UTM GRID AND 1954 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET
ROAD CLASSIFICATION
Light-duty ——— Unimproved dirt - - - - -
WASHINGTON
QUADRANGLE LOCATION

FALSE BAY, WASH.
N4822.5—W12300/7.5
1954
PHOTOINSPECTED 1972
AMS 1380 I NE—SERIES V891

RICHARDSON, WASH.
NW/4 RICHARDSON 15' QUADRANGLE
N4822.5—W12252.5/7.5
1977
AMS 1480 IV NW—SERIES V891