Map Unit Properties Table: San Juan Island National Historical Park

Colored map units are mapped within San Juan Island National Historical Park. Map numbers refer to Geologic Map Posters (in pocket).

Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
	San Juan Island Map 1	American Camp Map 2				
QUATERNARY (Holocene)	Artificial fill, including modified land (Qf)	Fill (Qf)	Riprap, soil, sediment, rock, demolition debris, solid waste material, and fill that has been added and reworked to modify topography; overlies till, diamicton, or recessional deposits. Generally more than 1.8 m (6 ft) thick. Mapped in American Camp.	None reported.	None reported.	**Modern Landscapes Shaped by Sea and Wind** In general, artificial fill is associated with construction or destruction activities. The Redoubt in American Camp was constructed on **Qf**.
	Alluvium (Qa)	Not mapped	Generally well-stratified and well-sorted, rounded cobble and pebble gravel, sand, silt, and clay. Grain size varies laterally and vertically due to stream migration.	None reported.	None reported.	**Modern Landscapes Shaped by Sea and Wind** Alluvium is deposited adjacent to streams, commonly during flood events.
	Beach deposits (Qb)	Beach deposits (Qb)	Moderately well-sorted gravel, coarse sand, and cobbles within the influence of the surf zone and along shorelines above high tide; planar and channel cross-stratified; locally massive; larger clasts in coarser deposits are generally well rounded and flat as a result of wave action; locally includes wave-worn shell fragments; overlies bedrock in most areas. Forms South Beach and numerous pocket beaches (too small to show on the map), particularly along the southwestern and northeastern sides of San Juan Island. May be more than 2 m (7 ft) thick. Mapped in American Camp.	**Beaches, Headlands, and Other Coastal Features** South Beach at American Camp is the longest public beach on San Juan Island.	**Global Climate Change** Rising sea levels may inundate beaches and other low-lying coastal areas. **Driftwood Impact to Coastline Features** Large woody debris may compact sediment and change sedimentation patterns.	**Modern Landscapes Shaped by Sea and Wind** Beach, dune, and marsh deposits (**Qb**, **Qd**, and **Qm**) represent recent processes. As post-glacial erosion has removed most glacial deposits along the coast, beach deposits (**Qb**) overlie bedrock in many areas. Pocket beaches have formed in protected shorelines. Strong onshore winds have produced dune deposits (**Qd**) adjacent to exposed beaches. Sea-level fluctuations resulted in the formation of estuarine wetlands (**Qp**, **Qm**) and lagoons along Griffin Bay.
	Dune sand (Qd)	Dune deposits (Qd)	Generally well-sorted, medium to coarse, wind-deposited sand containing layers of silt and fine sand; massive to planar cross-stratified; locally includes one or more paleosols; overlies glaciomarine deposits in most areas; most extensive adjacent to South Beach, which is exposed to strong onshore winds. Generally 1 m (3.3 ft) to more than 5 m (17 ft) thick. Mapped in American Camp.	**Aeolian Features** Occur adjacent to South Beach and Grandma's Cove due to strong onshore winds. Well-sorted, cross-bedded sand.	**Global Climate Change** Rising sea levels may drown beach areas, resulting in less sand for onshore winds to carry inland and replenish the dune system.	
	Peat deposits (Qp)	Marsh, bog, or swamp (Qm)	Fine sand and silt mixed with decomposing vegetation; locally contains interlayered tephra; deposited in fresh or brackish water; horizontal stratification; overlies Pleistocene deposits. Upland bogs and marshes fill local depressions; small wetlands formed by dams and other impoundments are not shown. Thickness: 2–8 m (7–27 ft). **Qp** and **Qm** mapped in American Camp.	**Estuaries and Wetlands** Jakles, Old Town, and Third lagoons are the only estuarine wetlands on San Juan Island. American Camp contains 26 freshwater wetlands and English Camp contains 9 freshwater wetland areas.	**Global Climate Change** Rising sea levels may inundate low-lying coastal areas, such as coastal lagoons, swamps, and estuaries. Jakles, Old Town, and Third lagoons are the only estuarine wetlands on San Juan Island and all are located on the northern shore of American Camp.	
	Not mapped	Tidal-flat deposits (Qtf)	Fine sand, silt, and minor clay, generally water-saturated, adjacent to active beach spits; massive to locally horizontally stratified; contain numerous burrows and remains of roots, particularly of eel grass; extend from high tide level to mean lower–low sea level. Extensive deposits near sheltered coves, such as False Bay, and adjacent to Cattle Point. Unknown thickness.	**Beaches, Headlands, and Other Coastal Features** During extreme low tide, extensive tidal flats are exposed in Garrison Bay at English Camp. Limited areas of **Qtf** may be within the American Camp boundary along Griffin Bay.	**Global Climate Change** Rising sea levels may inundate low-lying coastal areas.	**Modern Landscapes Shaped by Sea and Wind** Tidal flats (**Qtf**) are a function of tidal reach and form along the coast. Landslide deposits (**Ql**) develop along coastal bluffs when the bluffs are undercut by shoreline processes, such as wave action, high tides, or storm surges, and subsequently collapse.
	Not mapped	Landslide deposits (Ql)	Heterogeneous mixtures of silt, sand, and diamicton transported downslope by sliding, slumping, or flowing and exposed in coastal bluffs; discontinuous stratification may reflect original layers in the bluffs or layers formed during sliding; overlie fine Pleistocene sediments; surfaces commonly hummocky and include closed depressions and irregular low ridges. Thickness: 2–6 m (7–20 ft).	None reported.	**Coastal Erosion** Although landslide deposits are too small to map in the park at these scales, mass wasting and landslides are significant geologic issues, especially along the bluff facing the Strait of Juan de Fuca. The bluff collapses when its toe is undercut by wave action, further threatening Cattle Point Road.	

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Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
	San Juan Island Map 1	American Camp Map 2				
QUATERNARY (Pleistocene)	Not mapped	Recessional-marine deposits [undivided] (Qvrm)	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.	See **Qvrme**, **Qvrms**, **Qvrmd**, and **Qvrmo** units below.	See **Qvrme**, **Qvrms**, **Qvrmd**, and **Qvrmo** units below.	See **Qvrme**, **Qvrms**, **Qvrmd**, and **Qvrmo** units below.
	Glaciomarine drift (Qgdm)	Not mapped	Poorly sorted, weakly stratified to non-stratified, poorly compacted pebbly silt and clay with discontinuous layers of silty sand; weathers to a pseudo-columnar appearance on vertical sea-cliff faces; tan to gray, weathers to dark– to pale–yellowish brown; rare marine fossils. The age of the unit indicates that it was deposited during the interval established for the Everson Interstade of the Fraser Glaciation; however, whether the label "Everson" should be applied to deposits this far west of the Puget Lowland is not clear. **Qgdm** mapped in American Camp.	**Glacial Features** Poorly-sorted but stratified layers of pebbly silt, clay, and sand.	None reported.	**A Landscape Carved by Ice-Age Glaciers** Glaciomarine deposition in subtidal (**Qgdmes**), diamicton (**Qdgme**), and deltaic (**Qgome**) environments. A shell from the unit collected northwest of Sequim yielded a carbon-14 age of approximately 12,600 years before present.
	Not mapped	Recessional-marine deposits; emergence deposits (Qvrme)	Moderately well-sorted gravel and sand containing sparse boulders. Contains local concentrations of shell fragments. The beds are mostly massive, but locally cross-stratified due to deposition in channels that cut into underlying deposits. Common at elevations below about 60 m (200 ft). Unconformably overlies other marine deposits or till; lies beneath or grades up into sandy aeolian deposits rich in organic matter. Buried soils that are 0.2–0.6 m (0.7–2 ft) thick occur in some gravelly deposits. Two deposits south of Friday Harbor have beach deposit morphology. Thickness ranges from a boulder lag less than 0.3 m (1 ft) thick to about 8 m (27 ft) thick.	**Glacial Features** Cross-bedded channel sand and gravel represent emergent, fluvial deposition during the Everson Interstade. **Paleontological Resources** Bivalves: *Clinocardium*, *Mya*, *Protothaca staminae*, *Saxidomus giganteus*. Beetles: *Chlamys* sp. Snails: *Heliosoma*, *Limnophysa*, *Physa*.	None reported.	**A Landscape Carved by Ice-Age Glaciers** As the glacier receded, shallow subtidal, intertidal, and coastal wetlands developed on San Juan Island approximately 12,800 to 12,300 years before present. Sedimentary features in **Qvrme** suggest that fluvial systems also developed during this time.
	Glaciomarine drift, Everson Interstade and Sumas Stades [Qgdm(es)]	Recessional-marine deposits; subtidal deposits (Qvrms)	Moderately well-sorted sand, silty sand, and silt containing local pods and lenses of gravel; laminated to thinly bedded, locally massive or cross stratified; gray to bluish–gray; generally overlies marine diamicton, till, and undifferentiated diamicton [**Qgdm(e)**, **Qgt**, and **Qgd**] and can be distinguished from these units by the lack of clasts. Lies beneath **Qp**. Preserved in topographic depressions below 60 m (200 ft) elevation. Most extensive near False Bay, San Juan and Beaverton valleys, San Juan Island. Thickness: 3–15 m (10–50 ft).	**Glacial Features** Subtidal and intertidal deposits that lie beneath peat or bog deposits. **Paleontological Resources** Bivalves: *Clinocardium*, *Hiatella*, *Macoma*, *Mya*, *Mytilus*, *Protothaca*, *Saxidomus*, *Serripes*. Barnacles: *Balanus*. Worms: *Serpula*. Urchins: *Strongylocentrotus*. Snails: *Spirobis*, *Trichotropis*. Periwinkle: *Littorina*. Limpet: *Puncturella*.		**A Landscape Carved by Ice-Age Glaciers** Deposited in subtidal to intertidal marine environments approximately 12,900 to 12,500 years before present.
	Everson glaciomarine drift [Qgdm(e)]	Recessional-marine deposits; marine diamicton (Qvrmd)	Poorly to moderately sorted pebbly silt and diamicton with lenses and discontinuous beds of silt, sand, and gravel. Massive to poorly stratified. Olive to buff colors common in the upper 1 m (3 ft) of oxidized diamicton; locally bluish–gray. Sparsely to highly fossiliferous, with fossils commonly in growth position. Overlies marine outwash (**Qvrmo**) or Vashon till (**Qgt**); generally underlies marine subtidal deposits [**Qgdm(es)**, **Qvrms**] or emergence deposits [**Qvrm(e)**]; locally mantles the landscape below 60 m (200 ft) elevation. Thickness: 3–8 m (10–27 ft), but as great as 15 m (50 ft) near Cattle Point and American Camp. **Qgdm(e)** and **Qvrmd** mapped in American Camp.	**Glacial Features** Underlie the expansive prairies of American Camp. **Raised Beaches** Following the removal of the immense weight of glacial ice, San Juan Island rose (isostatic rebound), and former beaches became the terraces that are now well-developed at American Camp. **Paleontological Resources** Bivalves: *Clinocardium*, *Hiatella*, *Macoma*, *Mya*, *Mytilus*, *Nuculana*, *Serripes*. Barnacles: *Balanus*. Worms: *Serpula*. Urchins: *Strongylocentrotus*.	None reported.	**A Landscape Carved by Ice-Age Glaciers** Pebbly silt and diamicton were deposited in glaciomarine or marine environments approximately 13,100 to 12,800 years before present. The diamicton was capped by shallow-water clay or silt. **Modern Landscapes Shaped by Sea and Wind** Terrace formation following glacial retreat.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
	San Juan Island Map 1	American Camp Map 2				
QUATERNARY (Pleistocene)	Everson glaciomarine drift, marine outwash [Qgom(e)]	Not mapped	Loose, moderately well-sorted, subangular to sub-rounded gravel, gravelly sand, sand, and silt. Well-developed bedding. Forms high-angle foreset beds and trough cross-bedding commonly found in deltas. Foreset beds are usually tens of meters high, dip 15° to 40°, and are overlain by relatively horizontal topset beds that are 1–2 m (3–6 ft) thick. Clasts may contain phyllite and quartz-rich veins. Brown to gray, depending on oxidation state and lithologic content. Interfingers with **Qgdm(e)**. Thickness < 1 m (3 ft) to 70 m (230 ft).	**Glacial Features** Exposed on the peninsula southeast of Friday Harbor, this unit displays impressive foreset and topset beds, indicative of deltaic deposition.	None reported.	**A Landscape Carved by Ice-Age Glaciers** Well-sorted sand and gravel were deposited in deltas forming in front of the receding glacier. The age of unit is between 12,900 and 12,500 years before present in the western San Juan Islands. It may be as young as 11,990 years before present in this area.
	Continental glacial outwash, marine (Qgom)	Recessional-marine deposits; marine outwash (Qvrmo)	**Qvrmo**. Moderately well-sorted gravel and sand, matrix-supported gravel and sand-rich diamicton, and layers of pebbly silt; generally well stratified in southerly-dipping beds 0.3–2 m (1–7 ft) thick, with some massive to poorly stratified beds. Cross-beds commonly extend 10–50 m (33–165 ft) down dip; channels locally cut cross-beds. Pebbly marine silt is most common in channels near the top and along margins of the deposit. Overlies **Qvt**, **Qvd**, or bedrock and lies beneath **Qvrmd** or **Qvrme**. Locally collapsed or cut by thrust faults. Thickness ranges from 5 m (16 ft) to more than 60 m (200 ft) near Cattle Point, where deposits form an extensive moraine, and near Pear Point on San Juan Island, an area of extensive gravel mining. **Qgom**. Poorly to well-sorted, locally iron-stained gravel, sand, and silt. Thickness ranges from 2 to 10 m (7–33 ft), but valley fill is unusually thick [20–50 m (66–160 ft)] along major drainages. These deposits are associated with the following three principal depositional environments. *Ice-contact deposits*. Typically deposited in contact with masses of stagnant glacial ice; original stratification commonly dips 10° or less with local cut-and-fill structures; particle size and degree of sorting range widely. Forms hummocky topography with closed depressions and irregular ridges resulting from the collapse of the original sediment surface after buried glacial ice melted. Collapse structures such as steeply tilted, contorted, and faulted layers are common. Examples of ice-contact deposits are preserved near Ebey's Landing National Historical Reserve on Whidbey Island. *Outwash deposits*. Deposited downvalley from the zone of stagnant glacial ice. Sediments are horizontally stratified to gently dipping (5–10°) with channel cross-beds and cut-and-fill structures. Typically composed of medium- to well-sorted, pebble to- cobble gravel and coarse- to medium-grained sand. Local lenses of fine sand and silt. Except where modified by erosion, the deposits form smooth surfaces with gentle downvalley gradients of 3–5 m/km (10–50 ft/mi). Smith Prairie near Ebey's Landing National Historical Reserve on Whidbey Island is one example. *Alluvial fan deposits*. Poorly to moderately- well-sorted, pebble to-cobble gravel with boulders and lenses of finer materials deposited by streams flowing swiftly from upland areas. Boulders, cobbles, and pebbles are angular to subrounded and are commonly derived from local sources. Some fans have large-scale deltaic foreset beds. Most fan surfaces slope valleyward at angles less than 15°, but some individual layers dip as steeply as 30°. Fan deposits interfinger with and overlie the horizontally layered outwash deposits. Thickness: 20–40 m (66–130 ft). **Qgom** and **Qvrmo** mapped in American Camp.	**Glacial Features** American Camp: Mt. Finlayson is a glacial moraine composed of ice-contact marine fans. Glacial erratics occur on the surface of the unit. Forms part of the extensive prairie landscape. **Raised Beaches** Following the removal of the immense weight of glacial ice, San Juan Island rose (isostatic rebound), and former beaches became the terraces that are now well-developed at American Camp. **Paleontological Resources** Bivalves: *Hiatella*, *Macoma*, *Mytilus*. Barnacles: *Balanus*.	**Coastal Erosion** Wave action frequently generates landslides by undercutting the bluffs at American Camp that face the Strait of Juan de Fuca. Bluff erosion threatens the Cattle Point Road. The final environmental impact statement for the Cattle Point Road Realignment Project (WFLD-SJINHP 2012) indicates that the road will be realigned to the north. **Global Climate Change** Climate change is expected to exacerbate coastal erosion by increasing the rate of sea-level rise, precipitation, wave energy from storms, and storm frequency. Climate change will also influence recharge rates of groundwater aquifers as the frequency, intensity, and duration of precipitation change. **Groundwater Issues** Increased groundwater pumping may lower the water table in glacial outwash aquifers.	**A Landscape Carved by Ice-Age Glaciers** Late in the Vashon Stade and early in the Everson Interstade of the Fraser Glaciation, meltwater streams flowing from the front of the glacier deposited well-sorted sand and gravel outwash and alluvial fan deposits over San Juan Island. Unconsolidated glacial deposits were also deposited adjacent to the margin of the glacier (ice-contact deposits). Mapped unit **Qgom**, identified as a Vashon Stade deposit, is equivalent to mapped unit **Qvrmo**, which was deposited approximately 13,200 years ago, near the beginning of the Everson Interstade. **Modern Landscapes Shaped by Sea and Wind** Terrace formation following glacial retreat.

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Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
	San Juan Island Map 1	American Camp Map 2				
QUATERNARY (Pleistocene)	Continental glacial drift (Qgd)	Diamicton, undifferentiated (Qvd)	**Qvd**. Poorly sorted, generally nonstratified till covered by 0.5–3 m (1.5–10 ft) of marine diamicton; used as a map unit below an elevation of about 60 m (200 ft), where till and marine diamicton cannot be differentiated at map scale; includes areas of marine diamicton; generally unfossiliferous. **Qgd**. Undifferentiated till, sand, gravel, silt, and clay. Commonly forms hummocky topography. On southern San Juan Island (American Camp), consists of poorly sorted, generally nonstratified till covered by 0.5–3 m (1.5–10 ft) of marine diamicton [**Qgdm(e)**]; mapped below 60 m (200 ft) elevation, where till (**Qgt**) and marine diamicton [**Qgdm(e)**] cannot be differentiated at map scale. Generally unfossiliferous. **Qgd** and **Qvd** mapped in American Camp.	**Glacial Features** Glaciomarine drift deposited as the glacier receded during the Everson Interstade. Forms part of the extensive prairie landscape at American Camp.	**Coastal Erosion** Mass wasting and landslide hazard if undercut by wave erosion.	**A Landscape Carved by Ice-Age Glaciers** Glaciomarine drift deposited as the glacier receded. **Qgd** ranges in age from 19,000 years before present (Vashon Stade) to approximately 12,000 years before present (Everson Interstade).
	Continental glacial till (Qgt)	Not mapped	Unstratified, highly compacted mixture of poorly sorted clay, silt, sand, gravel, and boulders deposited directly by glaciers (lodgment till); gray where fresh and yellowish gray to light gray and tan where oxidized; locally includes ablation till (debris left in place as glaciers melted) of variable thickness and characterized by irregular hummocky topography. Subangular to subrounded clasts derived from local bedrock (greenstone, phyllite, schist, and gneiss) and from granitic rock types transported from southern British Columbia. Generally rests on striated bedrock or glacial-advance outwash and is overlain by marine diamicton [**Qgdm(e)**] or recessional outwash (advance and recessional outwash deposits are not mapped separately). In the Port Townsend quadrangle, thickness varies considerably, but typically ranges from a few meters to 40 m (130 ft) and probably averages between 3 m (10 ft) and 15 m (50 ft). Mapped in English Camp.	**Glacial Features** Deposited and compacted directly beneath the base of the glacier.	None reported.	**A Landscape Carved by Ice-Age Glaciers** Glacial debris (till) deposited at the base of the advancing glacier (lodgment till). The age of the unit is bracketed by carbon-14 ages from Vashon advance outwash near Sequim of about 17,500 to 18,500 years ago and a carbon-14 date of about 14,500 years ago from a bog on Vashon Drift near the western margin of the Strait of Juan de Fuca.
	Not mapped	Till (Qvt)	Poorly sorted, compact mixture of silt, sand, and clay containing 5% to 30% (by volume) pebble to boulder gravel. Generally nonstratified, but subhorizontal layering, parting, and deformation structures are present locally. Some exposures contain lenses, pods, and thin discontinuous beds of sorted material, generally gravel. Matrix colors are similar to those of **Qvrmd**, mainly olive gray and gray where unoxidized and olive to buff in the upper 1–2 m (3–7 ft). Subangular to subrounded clasts consist mainly of local greenstones and graywackes, but granitic rocks derived from the Coast Range of British Columbia make up more than 10% of the larger clasts. Generally rests on striated bedrock or advance outwash and lies beneath marine diamicton or the soil layer in most areas. Thickness varies, but generally ranges from 4 to 10 m (13–33ft).	**Glacial Features** Some granitic clasts have been transported from the Coast Range of British Columbia.	None reported.	**A Landscape Carved by Ice-Age Glaciers** Represents glacial deposits late in the Vashon Stade. The unit is older than 13,200 years.

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	San Juan Island Map 1	American Camp Map 2				
PRE-TERTIARY	See individual map units below.	pre-Tertiary bedrock (pTbr)	Abundant bedrock exposures mantled with thin [less than 3 m (10 ft)] surficial deposits. Variety of ages. See individual map units below. Mapped in American Camp.	See individual units below.	See individual map units below.	See individual map units below.
CRETACEOUS–JURASSIC	Lopez Structural Complex, Lummi Formation derivative [KJm(ll)]	pre-Tertiary bedrock (pTbr)	Foliated graywacke-argillite flysch with minor chert, greenstone, and conglomerate. Highly deformed. Part of the Late Cretaceous San Juan Thrust System. May contain fossils.	**Tectonic Features** Imbricated fault slices that have been thrust over the Constitution Formation (**KJmmc**) in the southeastern corner of American Camp. **Beaches, Headlands, and Other Coastal Features** Forms the headland at Cattle Point. **Paleontological Resources** Early Cretaceous bivalve (*Buchia*), Jurassic radiolarians, and a Late Jurassic or Early Cretaceous belemnite.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes.	**Assembling the West Coast of North America** *Upper Half of the San Juan Thrust System* Displaced and deformed by thrust faults and high-pressure metamorphism associated with the Late Cretaceous San Juan Thrust System approximately 100 million to 84 million years ago. The sedimentary units contain evidence of submarine slumping and turbidite flows (density currents). **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.
CRETACEOUS–JURASSIC	Constitution Formation, Decatur terrane, marine metasedimentary rocks [KJmm(c)]	pre-Tertiary bedrock (pTbr)	Poorly to moderately sorted volcaniclastic sandstone, cherty sandstone, mudstone, and conglomerate with lesser amounts of ribbon chert, green tuff, pillow lava, and rare limestone. Clastic rocks (sandstone, mudstone, conglomerate) are generally tan- to-gray. Sandstone, deposited as turbidites (submarine density flows), contains volcanic detritus with lesser chert, non-volcanic quartz, and epidote grains. Mudstone is commonly massive with minor sand-sized grains and local blocks of limestone and metavolcanic boulders 1–2 m (3–7 ft) in diameter. Conglomerate contains rounded to angular volcanic, chert, metaplutonic, and schistose clasts in a siltstone matrix. Clasts are thought to be derived from underlying units [**JTRmc(o)**, **pDi**, and **pPsh**] and average 5 cm (2 in) in diameter. Light to dark green and locally red-green ribbon chert, rhythmically bedded every 3–4 cm (1.2–1.6 in). Interbedded with clastic rocks throughout the entire section, but more abundant near the base. Green tuff occurs near the base of the section and is commonly fine grained and indurated. Mudstone and chert in the tuff give it a layered appearance. Light to dark green and locally red-green pillow lava ranges in composition from ocean-floor basalt to possibly arc-derived dacite and is interlayered with clastic rocks. Whether the pillow lava occurs as transported and/or in situ blocks is unclear. Light-gray limestone occurs as isolated pods near the base. Local deformation is especially apparent toward the base of the section, where many underlying lithologies are tectonically interleaved within the formation. Includes metamorphic minerals. Mapped in English and American camps.	**Tectonic Features** Forms the hanging wall of the Rosario Thrust, the dominant fault zone on San Juan Island and one of four major thrust sheets in the Late Cretaceous San Juan Thrust System. Forms the summit and flanks of Young Hill at English Camp. Metamorphic minerals include albite, quartz, chlorite, calcite/aragonite, white mica lawsonite, and prehnite. **Glacial Features** At American Camp, striations indicate that the most recent glacier flowed in a southwesterly direction. **Beaches, Headlands, and Other Coastal Features** Exposed headlands protect Friday Harbor. Tidepools. **Paleontological Resources** Late Jurassic to Early Cretaceous radiolaria from chert beds. Late Triassic conodonts recovered from a displaced block of limestone at Eagle Cove.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes.	**Assembling the West Coast of North America** *Upper Half of the San Juan Thrust System* Displaced and deformed by thrust faults and high-pressure metamorphism associated with the Late Cretaceous San Juan Thrust System approximately 100 million to 84 million years ago. Bounded by the Rosario and Lopez thrust faults. Rock types suggest deposition within a volcanic-arc terrane. The unit's age is poorly constrained, but it is probably no older than Middle or Late Jurassic (table 2). **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.

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	San Juan Island Map 1	American Camp Map 2				
TRIASSIC–JURASSIC	Orcas Chert, Deadman Bay terrane [JTRmc(o)]	pre-Tertiary bedrock (pTbr)	Metamorphosed gray or white ribbon chert with minor marble; locally contains quartzite, metamorphosed argillite and pillow basalt, basaltic tuff, greenstone, and phyllitic slate. Commonly highly folded and locally chaotically disrupted. Bedding is commonly contorted where preserved; ribbon chert is well bedded with shaly interbeds; pillow basalt and mafic tuff are interbedded with chert; limestone is recrystallized into aragonite marble and occurs as interbeds in chert and as transported blocks; interbedded mudstone and mafic tuff are locally abundant. Mapped in English and American camps.	**Tectonic Features** Forms the footwall of the Rosario Thrust, the dominant fault zone on San Juan Island and one of four major thrust sheets in the Late Cretaceous San Juan Thrust System. Exposed at the base of Young Hill at English Camp and along the southwestern coastline of the island. Contains metasedimentary and metavolcanic rocks. **Glacial Features** At American Camp, striations indicate that the most recent glacier flowed in a southwesterly direction. **Beaches, Headlands, and Other Coastal Features** Exposed along the southwestern coast of San Juan Island. Protects Grandma's Cove. Tidepools. **Paleontological Resources** Triassic to Jurassic radiolaria. Triassic conodonts.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes. At English Camp, the Commissary, blockhouse, Formal Garden, and Officers' Hill were constructed adjacent to the thrust contact between this unit and the underlying **pDi**.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* The Orcas Chert and Deadman Bay Volcanics are related stratigraphic units that compose the distinct Deadman Bay terrane. The presence of Tethyan fusulinid limestones in the Deadman Bay terrane suggests that it traveled far from its origin. The origin of the terrane and history of its accretion to North America are not well understood. The presence of radiolarians and conodonts indicates that the unit is Triassic to Early Jurassic in age (Table 2). **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.
TRIASSIC	Haro Formation (TRn)	pre-Tertiary bedrock (pTbr)	Andesitic and dacitic siltstone, sandstone, tuff, conglomerate, breccia, and limestone at Davidson Head on the northern end of San Juan Island; metamorphosed to the zeolite facies.	**Tectonic Features** Exposed at Davidson Head, north of English Camp. Contains the metamorphic mineral zeolite, indicative of low-temperature, low-pressure metamorphism. This unit was not involved in the Late Cretaceous San Juan Thrust System. **Beaches, Headlands, and Other Coastal Features** The Davison Head headland, northern tip of San Juan Island. **Paleontological Resources** Bivalves: *Halobia* cf., *Halobia inortissima*. Late Triassic radiolaria.	None reported.	**Assembling the West Coast of North America** *Marine Rocks Deposited in Front of the San Juan Thrust System* The nearshore sedimentary rocks of **TRn** suggest shallow marine deposition in front of the leading edge of the San Juan Thrust System. Radiolaria and clams from the unit suggest a Late Triassic or Early Jurassic age, but potassium-argon analysis of whole rocks yielded an Early Cretaceous age of 141 million years (table 2).
TRIASSIC–PERMIAN	Deadman Bay Volcanics (TRPv)	pre-Tertiary bedrock (pTbr)	Metavolcanic rocks. Metamorphosed pillow basalt, breccia, tuff breccia, mafic tuff, and chert; contains metamorphic aragonite; contains minor fusulinid limestone.	**Tectonic Features** Exposed in the footwall of the Rosario Thrust along the western coastline of the island. **Paleontological Resources** Early Permian conodonts. Late Permian fusulinids from the Tethys Sea. Algae.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* Late Permian fusulinids indicate that the unit formed in the Tethys Sea, which developed between present-day North Africa and Asia when rifting broke apart the supercontinent Pangaea. This is the only unit in the San Juan Islands to contain Tethyan fusulinids, indicating that this terrane traveled a great distance before accreting to North America.
PERMIAN–DEVONIAN	East Sound Group, metasedimentary and metavolcanic rocks (PDmt)	pre-Tertiary bedrock (pTbr)	Metasedimentary and metavolcanic rocks, undivided. Metamorphosed, well-bedded argillite and volcanic sandstone with basalt to rhyolite breccia, tuffs, and flows, as well as igneous rocks formed at shallow depth. Contains local pebble conglomerate, non-Tethyan fusulinid limestone, gabbro, and rare chert.	**Tectonic Features** Metasedimentary and metavolcanic rocks. Found in the footwall of the Orcas Thrust, one of four major thrust sheets in the Late Cretaceous San Juan Thrust System.	None reported.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* A Devonian to Early Permian stratigraphic sequence of volcanic-arc rocks and limestone. Separated from the Orcas–Deadman Bay sequence by fault slices of the Turtleback Complex (**pDi**).

Colored map units are mapped within San Juan Island National Historical Park. Map numbers refer to Geologic Map Posters (in pocket).

Age	Map Unit (Symbol)		Geologic Description	Geologic Features and Processes	Geologic Resource Management Issues	Geologic History
	San Juan Island Map 1	American Camp Map 2				
PRE–PERMIAN	Garrison Schist (pPsh)	pre-Tertiary bedrock (pTbr)	Well-foliated amphibolite, greenschist, blueschist, micaceous quartzite (metachert), mica-quartz (± garnet) schist, and rare marble. Underlies Bell Point, a prominent topographic high at English Camp. Mapped in English Camp.	**Tectonic Features** Found in the Rosario Fault Zone as fault slices and clasts caught up in KJmm(c). Contains the metamorphic minerals prehnite, epidote, and actinolite and rock types schist and quartzite, which document an episode of high-grade metamorphism. Contains amphibolites, greenschist, blueschist, quartzite, and marble. **Beaches, Headlands, and Other Coastal Features** Forms the headland at Bell Point. Tidepools.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* Described as "exotic" because the unit has no relationship to adjacent rock units in the Rosario Fault Zone. May have been part of the basement rocks underlying **KJmm(c)**. High-grade metamorphism occurred in the Permian to Triassic, about 256 million to 228 million years ago, and "reset" the isotopic clock. **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.
PRE–DEVONIAN	Turtleback Complex, undivided intrusive rocks (pDi)	pre-Tertiary bedrock (pTbr)	Metamorphosed gabbro, quartz diorite, tonalite, trondhjemite, diabase, and rare pyroxenite; local orthogneiss and metamorphosed basaltic to silicic dikes; veins of calcite, aragonite, and prehnite; metamorphosed to greenschist and amphibolite facies.	**Tectonic Features** Metamorphosed igneous rocks in the footwall of the Orcas Thrust. Contains metamorphic aragonite and prehnite. Metamorphosed to greenschist and amphibolite mineral assemblages. **Beaches, Headlands, and Other Coastal Features** Exposed headlands on islands in Westcott Bay, northern San Juan Island.	**Earthquakes and Tsunamis** Potential movement along previously active fault planes.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* Plutonic and volcanic rocks suggest a volcanic-arc tectonic setting, but whether this volcanic terrane was attached to a continent or formed as oceanic islands is not known. On Orcas Island, a plutonic igneous rock yielded a uranium-lead date of approximately 405 million years ago (Early Devonian). **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.
	Turtleback Complex, tonalite [pDit(t)]	pre-Tertiary bedrock (pTbr)	Unit mapped as part of the Lopez terrane. This unit is cataclastic, contains the metamorphic minerals aragonite, lawsonite, pumpellyite, and epidote, and is cut by metabasaltic dikes. Includes exotic blocks of metamorphosed quartz diorite dated to the Devonian.		None reported.	**Assembling the West Coast of North America** *Lower Half of the San Juan Thrust System* Uranium-lead analysis of zircon yielded an age of 398 million years (Devonian). Fission-track dating of zircon yielded a much younger age of 265 million to 294 million years (Permian), probably representing the metamorphic event that "reset" the isotopic clock (Table 2). **Modern Landscapes Shaped by Sea and Wind** Waves and surf continue to shape coastal exposures.

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