Northwest Geological Society

Society Field Trips in Pacific Northwest Geology

The Geology of San Juan and Lopez Islands

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Darrel Cowan
University of Washington
and
Donn Charnley
Shoreline Community College

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Northwest Geological Society Field Trip, Spring 1997

The Geology of San Juan and Lopez Islands, San Juan Islands, Wa

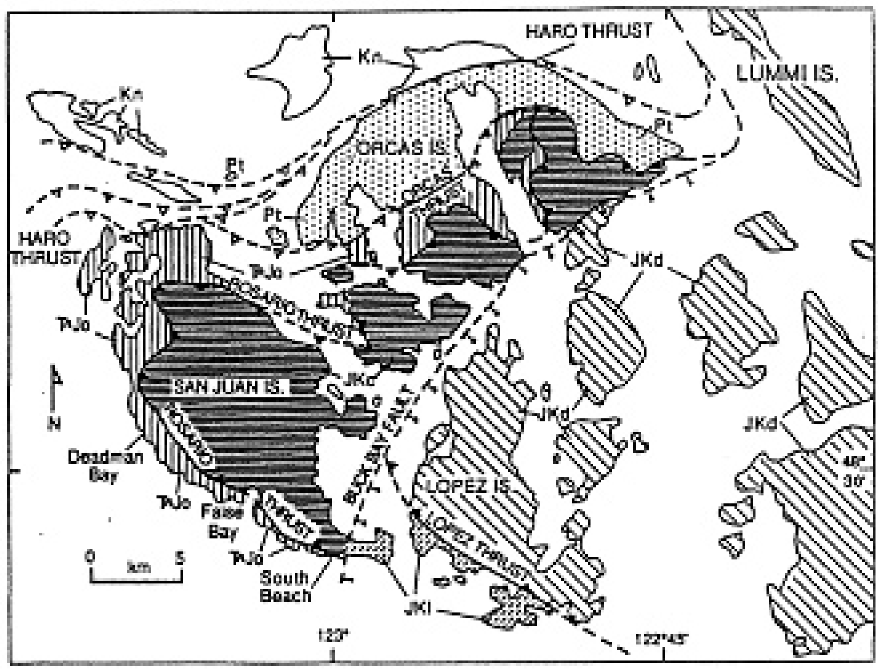
Trip Leaders:

Darrel Cowen, University of Washington
Donn Charnley, Shoreline Community College

Introduction

Rock units in the San Juan Islands fall into two groups.- Those north of the Haro thrust are well bedded and lack evidence for mid-Cretaceous metamorphism and deformation.

South of this fault, the geology is characterized by stacked nappes. Each nappe is dominated by a stratigraphically related group of rock units. At present, the nappes are shaped into broad folds that trend and plunge gently to the southeast, and have wavelengths of about 12 km. These folds are inferred to be early Tertiary in age because they are similar both in style and orientation to folds in the upper Cretaceous Nanaimo Group and the Eocene Chuckanut Group exposed on the mainland east of the San Juan Islands.



Generalized geology of the San Juan Islands showing the major large-slip thrusts: Haro. Orcas, Rosario, and Lopez. JKd = rocks of the Decarur terrane, constituting the hanging wall of the Lopez thrust. JK1 = Lopez Structural Complex, composed of diverse structural slices within the Lopez fault zone. JKc = Constitution Formation, a nappe bounded above by the Lopez Complex and below by the Rosario thrust. TRJo = Orcas Chert and Deadman Bay Volcanics (Deadman Bay terrane) which collective make up the footwall of the Rosario thrust. Pt = Paleozoic Turtleback Complex and related rocks. Kn = Upper Cretaceous Nanaimo Croup. The Buck Bay fault, which is inferred to dip to the southeast, may represent a younger normal fault. Map adapted from figures 3 and 5 in Brandon and others (1988).

Because the faults at the boundaries of the thrust nappes juxtapose unrelated tectonostratigraphic units, we conclude that they have accommodated large amounts of slip, probably in excess of tens of kilometers.

We interpret the the orogenic history of the San Juan nappes consisted of: [1] juxtaposition of nappes along the Rosario, Lopez, and related large-slip fault zones; [2] high-pressure metamorphism; [3] formation of cleavage; and [4] erosional exumation. All of these events took place within a 16 m.y. interval (100 to 84 Ma), during which time the nappes traversed a roundtrip distance of about 36 km, at an avarage vertical rate of about 2 km/m.y. Brandon and others (1988) favor the interpretation that these events are collectively related to the accre-tion of the San Juan nappes at a depth of about 18km beneath an actively advancing orogenic wedge.

During the NWGS fieldtrip, we will examine representative outcrops of several of the rock units, and one of the major large-slip brittle fault zones, the Rosario thrust. We will spend the first day on S'an Juan Island in nappes of Constitution Formation and Deadman Bay Ter-rane, separated by the Rosario thrust. The second day, on Lopez Island, we will be in structurally higher units constituting parts of the Lopez complex and the Decatur terrane. We will also see examples of Pleistocene glacial erosion and deposition, and shoreline features built after the last glacial ice retreated, (less than 11,000 years ago) .

SAN JUAN ISLAND

South Beach; **Mesoscale structures and fault rocks in brittle shear zones in the Rosario thrust.**

This stop encompasses shoreline exposures extending approximately 400 m west of South Beach. The entire stop is in San Juan National Historic Park, administered by the National Park Service. Although this is public land, collecting samples without a special permit is illegal and prohibited - Leave your rock hammers in the car.

The outcrops here lie at the southest end of the trace of the Rosario thrust zone, which extends offshore beyond this point. The thrust dips northeast here, placing the massive sandstones of the Constitution Formation over a structurally complex assortmant of mudstone, green volcanic rock (locally pillowed), green tuff, and ribbon chert, which are collectively assigned to the Orcas Deadman Bay terrane.

The best evidence for large thrust displacements across the fault is the presence of exotic slices of Garrison Schist lying within the fault zone. The Garrison is a throughly recrystallized rock that was metamorphosed under greenschist and amphibolite conditions during the Permian and Triassic, long before its tectonic emplacement along the Late Cretaceous Rosario thrust.

Deadman Bay;

Here, the Deadman Bay Volcanics are well exposed along the coast on the rocky headlands between the bay and the lighthouse to the north. The unit is dominated by red and green pillow basalt, breccia, and tuff with subordinate interbedded limestone. It is disrupted in many places by faults, but it generally has a persistant easterly strike and, in this area, a near vertical dip. Geopetal structures indicate younging to the north.

Limestones in the unit are massive and gray, and they contain small amounts of intercalculated green tuff. Bedding, where present in the limestones, is typically contorted and appears to have been deformed by soft-sediment slumping. Carbonate material occurs interstitially in the pillow flows and might have been sucked into the pillowed framework by rapidly convecting currents generated by the cooling submarine flows or by a churning as the lavas flowed across carbonate accumulations. Some of the limestones were converted into aragonite marble during Late Cretaceous high-pressure metamorphism. Crinoid debris and fragments of other fossils can be found in many limestone beds.

Davidson Head:

If time and tide permit, we will stop on the southwest shore of this headland on the northernmost tip of San Juan Island to examine one of the units which does not record the mid-Cretaceous deformation and high-P, low-T metamorphism that characterizes all of the other units visited on this trip. Exposed here are well-bedded Upper Triassic dacitic and andesite breccia and volcaniclastic sand¬stone and mudstone of the Haro Formation. Thin-shelled pelecypods of Habobia or Monotis are present locally.

LOPEZ ISLAND

There are three types of bed rock on Lopez:

1. Greenstones -primarily metamorphosed gabbros, diorite, diabase, etc, whose minerals have been altered to greenish chlorite, epidote, and actinolite. This phase of metamorphism proceeded shearing, as these minerals display considerable deformation (ie: bending). Some volcanics and sediments are found in the greenstones, but they were most likely added during the shearing event(s).

2. Sedimentary Rocks - composed primarily of flysch-type marine muds, sands, and coarser fragments - these units most common characteristic is graded bedding. Individual beds vary from a few mm to over 20 cm in thickness. Basal fragments are the largest, and quite angular indicating a relatively short transportation distance, possibly by massive submarine turbidity currents. Ribbon cherts are also found below and above these rocks. The chert layers range from 5 to 30+ mm, with thinner alternating of less resistant mudstones.

These rocks have been subjected to high-P, low-T metamorphism, and a subsequent event of strong shearing. The age of these units is late Jurassic to Cretaceous, based on a belemnite found at the base of one of the turbidity current deposits on the north side of Otter Cove, and the radiolarians which make up the chert beds.

3. Pillow Basalts. These are seen in a remarkable unit of vesicular pillows (ranging from 0.2 to 2+ m in size), at least 150 m thick. The volumes of these units suggest their origin either at an oceanic (spreading) ridge or in a massive marine plateau paleoenvironment. Ted Banner, UBC, has found latest-early K microfossils in sediments interbedded within the pillows at Richardson. Pillow lavas found on Johns Point (to the east) are Jurassic. These rocks also display some metamorphism, and are sheared.

4. Plant-bearing Sandstones and Conglomerates. Different from the flysch-type sediments described above, these sediments contain rounded grains, ranging up to 10cm in size, and are quite poorly sorted. Their paleoenvironment could be near-shore non-marine, or a marine basin located very close to a continent; in either case the sediments were rapidly 'dumped'. Their lithologies include quartz, volcanic, chert, andesites, limestones and a few metamorphic rocks. There appearence suggests a deltaic deposit of mudflows into a relatively deep basin. While these rocks also display faulting and folding, they do not appear to have experienced any metamorphic nor shearing conditions.

Watmough Head (& Otter Cove):

Bedrock: Vertical graded beds of black mudstones, and grey sand to small, angular conglomerates in rhythmic, alternating beds. The belemnite fossil can be seen on the cliff at the north side of Otter Cove (best seen at lower tides!). Otter cove MAY represent the site of an east-west fault zone.

Pleistocene: All of the small eastward-pointing points on Watmough Head display excellent glacial polish on their north sides, and are 'plucked and quarried' on their south sides. This denotes the southward movement of the ice sheets which repeatedly moved over this region. The points are glacial 'rock knobs' ('rouche moutonee' to the oldtimers!), grooved and polished on their stoss ('upstream sides') and plucked on their downstream sides. Numerous erratics of granites, diorites, and many other NON-San Juan Island lithologies can be seen scattered about on the beaches, points, and upland surfaces.

Watmough Bay (Bight):

Bedrock: The rocks exposed at the south end of the beach are steeply dipping black marine mudstones, probably from a deep, mid-ocean pelagic paleoenvironment. The rock at the bay's north side is over 150 m of slightly altered, pillow basalts. The (devitrified) rims and numberous vesicles are easily seen on close examination. The pillows also display the classic downward 'V in their shapes, formed as each subsequet pillow was formed upon the earlier pillows. The 100+ m-wide bay is possiblly the site of a major (transverse?) fault zone; it apparently extends to the west through McCardle Bay, Alec Bay, and across the Richardson area.
Pliestocene: Boulder Island, seen to the east, is a fine example of a glacial rock knob, with its grooved, streamlined north end, and its rough, cliffy south end. Its name comes from the granitic errat¬ics seen scattered about its surface. Across Rosario Strait you will see Mt Erie (on Fidalgo Island); it also is a glacial rock knob, but the diorite which makes it up was more resistant. It does have a spectacular south-facing 'plucked' face, (a favorite for rock climbers), but lacks the smoothed-off north side more common with knobs.

Watmough's beach is a mid-bay bar, built by longshore currents over the past 10.000 years (post-ice age). Its lithology is made up of less than 20% of the local bedrock. It dammed up the much deeper bay left by the glaciers; the cattail lake to west is now entirely fresh water.

Richardson; (former site of the best 'country store1 in Wash.)

Bedrock: at the NE side of the turn-around is a remarkable exposure of marine, radiolarian-rich volcanic sediments. The reason(s) for the dramatic change in color is a matter of some debate. On the south side of and below the road, are pillow basalts and pillow breccias, apparently stratigraphicaly below the volcanic sediments, The pillows extend to the west across the small bay at your right - but do not appear to be as massive (thick) as the Watmough Bay pillows. These pillows lavas are the youngest pre-Nanaimo Group rocks found so far in the San Juans.

Shark Reef;

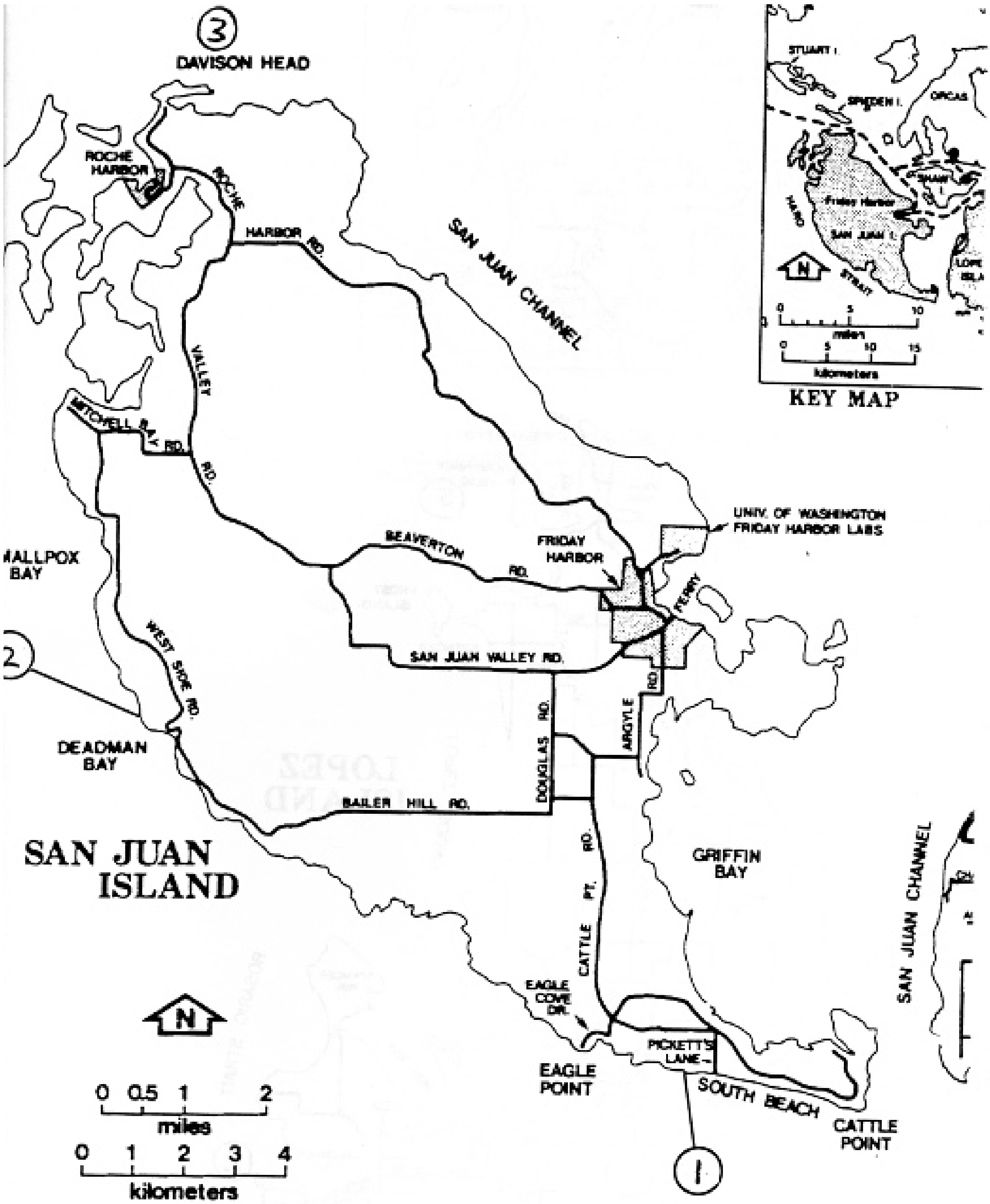
The rocks exposed on the shore of Shark Reef Park form a coherent sequence of turbidite sandstone, mudstone, and subordinate chert-pebble conglomerate. ALthough you cannot see them without a thin-section, the high-P, low-T metamorphic minerals lawsonite, pum-pellyite, and aragonite are present. Note the evicence for brittle deformation in the form of filled, sigmoidal tension fracture, and zones populated by small faults. This is a good place to examine the strong pressure-solution cleavage, present in most of the Lopez Complex. By the way - is the sequence here right-side up or upside-down?

Humphrey Head Quarry/(Ferry dock): Quarry: PRIVATE PROPERTY - We are here with the owners' permission: DO NOT CLIMB!!

Bedrock: Do you believe in Terranes?? (Carefully) examine this outcrop. Does this rock resemble any of the units we examined at the south end of Lopez? This is an example of the 'Plant-bearing' Sedimentary Rocks described in the introduction. Consider the massive deposit of muds, sands, and rather well rounded gravels. What was the paleoenvironment of its origin? Marine or non-marine? Slow or rapid accumulation? Into what kind of depositional basin? Etc? Consider also the apparent lack of an overprint of high-P, low-T metamophisim seen in the southern rocks. This exposure also displays some excellent jointing - compressional or extensional? - and a vertical fault plane with slickensides. Note: if time does not allow us to visit the quarry, this rock unit will also be seen on the east side of the parking lot at the ferry dock, (without the fault, however).

Lopez Island Vineyards

The winery has been constructed from 'field rocks' - in other words: erratics. Examine them: they display a fine accumulation of the many rock units found to the north in southwestern and midwestern British Columbia!



3
DAVISON HEAD
ROCHE HARBOR
ROCHE
HARBOR RD.
SAN JUAN CHANNEL
VALLEY
RD.
MITCHELL BAY RD.
SMALLPOX BAY
BEAVERTON
RD.
FRIDAY HARBOR
UNIV. OF WASHINGTON FRIDAY HARBOR LABS
FERRY
2
WEST SIDE RD.
SAN JUAN VALLEY RD.
DOUGLAS RD.
ARGYLE RD.
DEADMAN BAY
BAILER HILL RD.
SAN JUAN ISLAND
CATTLE PT. RD.
GRIFFIN BAY
SAN JUAN CHANNEL
EAGLE COVE DR.
EAGLE POINT
PICKETT'S LANE
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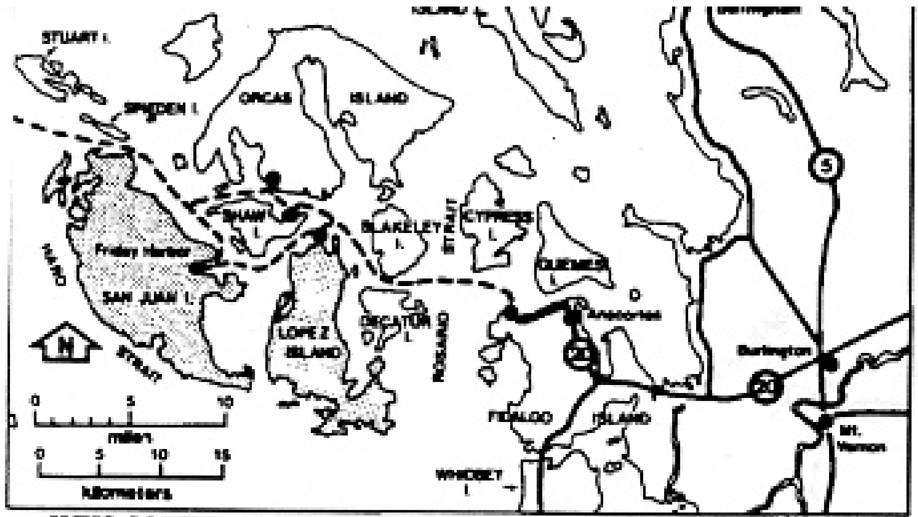
KEY MAP



STUART I.
SPIEDEN I.
ORCAS
ISLAND
SHAW I.
BLAKELEY I.
STRAIT
CYPRESS I.
GUEMES I.
Friday Harbor
SAN JUAN I.
LOPEZ ISLAND
DECATUR I.
ROSARIO
Anacortes
Burlington
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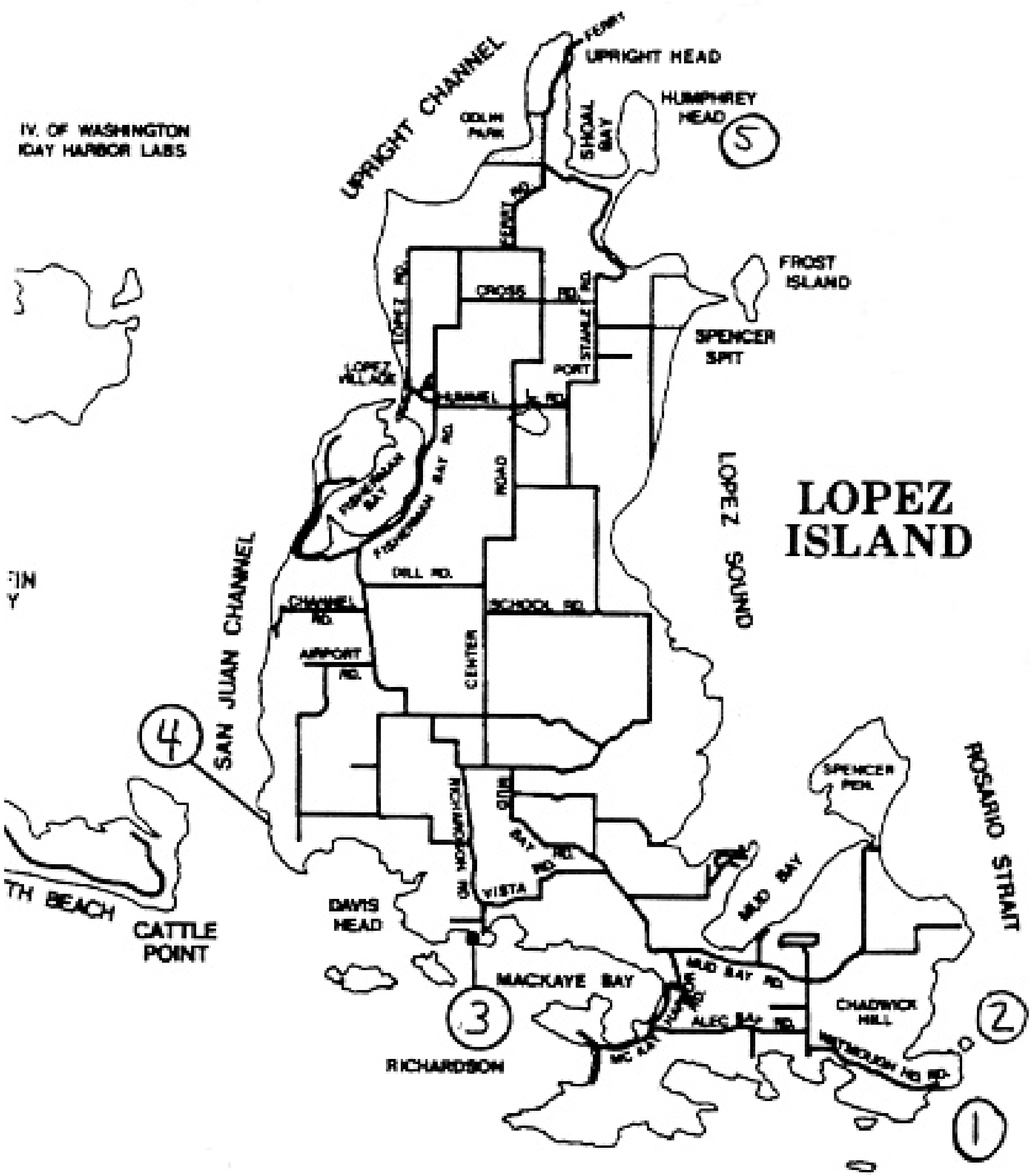
KEY MAP



FERRY
UPRIGHT HEAD
UPRIGHT CHANNEL
ODLIN PARK
SHOAL BAY
HUMPHREY HEAD
5
IV. OF WASHINGTON
IDAY HARBOR LABS
FERRY RD.
FROST ISLAND
CROSS RD.
STARK RD.
SPENCER SPIT
PORT
LOPEZ RD.
LOPEZ VILLAGE
HUMMEL RD.
FISHERMAN BAY
FISHERMAN BAY RD.
ROAD
LOPEZ SOUND
LOPEZ ISLAND
SAN JUAN CHANNEL
DILL RD.
CHANNEL RD.
SCHOOL RD.
AIRPORT RD.
CENTER
4
SPENCER PEN.
ROSARIO STRAIT
VISTA RD.
MUD BAY
DAVIS HEAD
CATTLE POINT
MACKAYE BAY
MUD BAY RD.
CHADWICK HILL
2
3
ALEC BAY RD.
RICHARDSON
1

Selected References

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