The San Juan Islands Thrust System: New Perspectives from LIDAR and Sonar Imagery

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Abstract: New LIDAR (Light Detection and Ranging) and sonar imagery have revealed remarkable geomorphic details never seen before and not visible by any other means. Numerous faults and other geologic structures are plainly visible on LIDAR and sonar images. Many previously unknown faults criss-cross the islands and large fault scarps are visible on sonar imagery along the margins of the larger islands. Sonar images of sea floor morphology show many submerged faults as long linear scarps with relief up to 300m (1,000 ft), some of which visibly truncate geologic structures. The San Juan Lopez fault, the largest fault in the islands, extends for at least 65 km (40 mi) from Stuart Island to Rosario strait with a scarp up to 330m (1,000 ft) high. Since 1975, the basic structural framework of the San Juan Islands has been considered to consist of five stacked thrust faults, the Rosario, Orcas, Haro, Lopez, and Buck Bay faults, constituting the San Juan Thrust (Nappe) System that has shuffled together far distant terranes. However, the new LIDAR and sonar imagery shows that most of the mapped extent of these postulated faults are actually segments of high angle, dipslip faults and are not thrust faults at all. Thus, the San Juan Thrust (Nappe) System does not exist. The age of these faults is not accurately known and more than one period of high angle faulting may have occurred. Faults shown on LIDAR images of the surface of the islands appear as visible gashes, etched out by erosion of fault zones with few fault scarps. However, the sea floor faults have bold relief and high scarps. A late Pleistocene moraine lies undisturbed across the San Juan Lopez fault.

Key words: San Juan Thrust System, San Juan Islands, LIDAR, sonar, faults.

1. Introduction

The San Juan Islands consist of an archipelago in the northern Puget Lowland of NW Washington (Figs. 1 and 2). The islands represent the highest points of a submerged mountainous area that extends across the Puget Lowland from the mainland to Vancouver Island. For the most part, the larger islands have rugged topography with fifteen peaks above 1,000 feet, typically rising precipitously from the water’s edge. Channels between islands attain depths of 200 meters (~600 feet) and in places exceed 300 meters (~1,000 feet). The highest point is Mount Constitution with an altitude of 2,409 feet. The deepest water in the San Juan Islands is 1,356 feet below sealevel, giving a relief of about 3,800 feet.

1.1 Previous Work

The first geologic map and comprehensive study of the geology of the islands was by McClellan [1]. For more than 30 years, this remained the only source of geologic information on the San Juan Islands until 1957 when Danner completed a PhD thesis at the University of Washington on fossils and stratigraphy of the rocks in the islands [2]. He continued working on fossils and stratigraphy for many years thereafter [3, 4].

In 1958, a group of geology graduate students and faculty from the University of Washington mapped the eastern part of Orcas Island, making significant revisions to McClellan’s work, including (1) recognition that the Turtleback Crystalline Complex was a basement complex of ancient rocks [5], not igneous intrusions as mapped by McClellan, (2) revision of much of the stratigraphy [5], and (3) recognition of several new rock units [5].
The San Juan Islands Thrust System: New Perspectives from LIDAR and Sonar Imagery

Fig. 1  The San Juan Islands, Washington.

Fig. 2  The San Juan Islands, Washington.
The San Juan Islands Thrust System: New Perspectives from LIDAR and Sonar Imagery

Another 17 years passed before new geologic maps and reports of the San Juan Islands were published by Vance [6] and Whetten [7]. These papers postulated five major, single-plane thrust sheets in the islands that constituted the San Juan Island Thrust (Nappe) System. This hypothesis has remained unchallenged for 40 years and forms the basic structural framework for many published papers [9-21].

For the past five years, I've been using new technology of laser, sonar, and satellite imagery to study the geology of the San Juan Islands. To my great surprise, these new techniques have shown that interpretation of the primary geologic structure of the islands as five extensive thrust faults is, in fact, not valid.

1.2 The San Juan Islands Thrust (Nappe) System

Since 1975, the structural framework of the San Juan Islands has been postulated to be multiple thrust sheets stacked successively one upon another. Each thrust sheet was mapped as a single, discrete, named fault that extended over a wide area in the islands (Fig. 3) and was thought to bound rock terrains from far distant sources [6-8]. Although minor differences exist between published geologic maps of the islands, the general structural framework on each map is essentially the same. However, new laser, sonar, and satellite imagery now shows that these thrust faults do not exist—the postulated thrust faults of the San Juan Thrust System are actually segments of younger, high-angle faults.

1.2.1 Postulated Thrust Faults of the San Juan Thrust (Nappe) System

(1) Rosario Thrust

The postulated Rosario thrust (Fig. 3) is mapped as a single, low-angle thrust fault that extends from easternmost Orcas Island across East Sound and SW
Orcas Island; along the SW coast of Shaw Island; across San Juan channel to San Juan Island; then loops across northern San Juan Island and southward along most of the SW coast to the southeastern tip of the island at Cattle Point (Fig. 3). The overriding block of the thrust sheet consists mostly of Constitution greywacke and volcanic rocks.

(2) Orcas Thrust

The postulated Orcas thrust (Fig. 3) is mapped as a single, low-angle thrust fault that extends from Point Lawrence on eastern Orcas Island across Mt. Constitution, East Sound, central and western Orcas Island, and across San Juan channel to the north end of San Juan Island. The overriding block of the thrust fault has been mapped as mostly Orcas Chert with slices of Turtleback Crystalline Complex.

(3) Haro Thrust

The postulated Haro thrust (Fig. 3) is mapped as a low–angle thrust that extends east-west across the sea floor north of San Juan Island, across San Juan Channel to the NW coast of Orcas Island, across northern Orcas, and along the entire NE coast of the island. The overriding block of the thrust sheet has been mapped as bringing the Turtleback Crystalline Complex and Paleozoic and Mesozoic marine rocks over the Haro and Spieden marine beds.

(4) Lopez Thrust

The Lopez thrust (Fig. 3) is mapped as a single, low-angle thrust fault that extends across the southern end of Lopez Island. The overriding block is mapped as rocks of the Fidalo Ophiolite Complex.

(5) Buck Bay Thrust

The Buck Bay thrust (Fig. 3) is mapped as a single, low-angle thrust that extends from southeastern Orcas Island southward down the entire length of Upright Channel and southern San Juan Channel to Cattle Point.

2. Materials and Methods

2.1 LIDAR and Sonar Imagery

New LIDAR imagery (Fig. 4) has revealed remarkable morphological details not visible by any other means. Faults and other geologic structures are clearly visible because LIDAR doesn’t “see” vegetation. Fractures show up exceptionally well on LIDAR imagery as linear gashes in the topography made by etching out of weak rock in fault zones and as long, straight scarps that cut geologic structures. The straightness of the faults cutting across areas of topographic relief indicates that they dip steeply. Sonar imagery reveals numerous, previously unknown submerged fault scarps.

One of the more remarkable things common to all of the geologic maps of the San Juan Islands is that all of the maps show multiple thrust faults, but very few of them show high-angle faults. This would perhaps not be surprising if the region has undergone only strongly compressive deformation, but are high-angle faults really rare in the islands? LIDAR and sonar data now provides a definitive answer—the San Juan Islands are riddled with numerous high-angle faults.

3. Results and Discussion

3.1 Orcas Island

Several long, linear, high-angle faults cutting across Orcas Island are apparent on LIDAR images (Fig. 5). None of these faults has been previously mapped. Many smaller faults are also apparent on the images.

3.1.1 Central Orcas Fault

The Central Orcas fault (Fig. 5) shows up as a continuous, straight, topographic feature that extends from Point Lawrence across the entire width of the island. The straightness of the fault trace across rugged topography indicates that it dips at high angle.

3.1.2 Olga Fault

The Olga fault (Fig. 5) parallels the Central Orcas Island fault and extends from Doe Bay on the east coast of Orcas Island to West Sound. The straightness of this fault trace indicates that it has a high dip.

3.1.3 Northern Orcas Fault

The north shore of Orcas Island consists of Nanaimo marine beds that consistently strike NW-SE
and dip to the southeast toward the main part of the island. The contact with the older Paleozoic beds to the south is covered by Pleistocene glacial deposits and is not exposed. Because Nanaimo beds dip into older rocks, a fault must cross the northern part of the island, separating the Nanaimo sandstone from the older Paleozoic beds (Fig. 5). This fault has been shown on previous geologic maps as the Haro thrust. Because of the mantle of glacial deposits covering the bedrock, the dip of the fault is uncertain, but all of the other faults that cut the Nanaimo sandstone are high-angle faults.

3.2 San Juan Island

Many long, high-angle faults that cross San Juan Island are apparent on LIDAR imagery (Figs. 6 and 7). Some of the faults trend east-west while others trend NW-SE to NS along coastal areas. These faults have not been mapped previously.

3.2.1 Friday Harbor Fault

The Friday Harbor fault (Figs. 6 and 7) crosses the entire width of San Juan Island from Friday Harbor to Limekiln Point before disappearing below sea level. The straightness of the fault across rugged topography indicates that the fault dips steeply.
Numerous other smaller, high-angle faults that are also apparent on LIDAR images criss-cross the island (Figs. 6 and 7). Segments of some of these faults make up what has been shown on geologic maps as the Rosario thrust fault.

3.3 Shaw Island

The western end of the Olga high-angle fault crosses the northwestern part of Shaw Island (Fig. 8). This fault trends at a right angle to what has been mapped as part of the Rosario thrust. The previously mapped Rosario thrust has no trace on LIDAR images.

3.4 Lopez Island

Southern Lopez Island is crossed by several high-angle, NW-SE trending faults (Figs. 9 and 10) and the rocks have been intensely sheared. The northernmost of these faults has been mapped as the Lopez thrust fault, but the linear straightness of the trace of the fault across topographic relief indicates that it is really a high-angle fault, not a thrust fault. The straightness of several other fault traces to the south (Figs. 11 and 11) indicates that they are also high-angle faults. Relief on these fault scarps suggests that they are dip slip faults (Fig. 11). High angle shear zones also occur on southern Lopez (Fig. 12).

3.5 New Data from Sonar Imagery

Until recently, the geology of the sea floor in the San Juan Islands remained virtually unknown. Some subsurface geophysical surveys had been made, but the relationship of the sea floor geology to the geology of the islands remained obscure. With new sea floor images, we can now see that most of islands are the tops of more extensive submerged geologic structures. Most of the islands rest on broad subsurface platforms, many of which are bounded by large faults (Fig. 13).

Interpretation of the sea floor geology from the NOAA images depends largely on the sea floor geomorphology. Many of the submerged faults show up as long linear gashes on the sea floor. Other faults truncate geologic structures that would otherwise continue across the sea floor. These geologic structures are evident from submerged ridges of the same resistant rocks that make up the northern islands.
Fig. 6  LIDAR image of San Juan Island showing major faults (red).
Fig. 7  Topographic map of San Juan Island showing major faults (red).
Fig. 8  Faults (red) shown on LIDAR image of Shaw Island.

Fig. 9  LIDAR image showing high-angle faults on southern Lopez Island.
Fig. 10  High-angle faults on southern Lopez Island.

Fig. 11  High-angle fault scarp, southern Lopez Island.
Fig. 12  High-angle fault zone, southern Lopez Island.

Fig. 13  Sonar image of high-angle faults in the San Juan Islands. Not all faults are shown—see detail maps for more precise locations (Base map by NOAA).
3.5.1 San Juan-Lopez Fault

The southwest margins of San Juan and Lopez Islands below sea level consist of a long, relatively straight escarpment, suggestive of a fault scarp (Figs. 14 and 15). However, since not all escarpments are made by faults, the question of what other geologic processes might create the scarp must be addressed. Although other geologic processes can produce straight escarpments, they rarely do so for long distances. A critical point here is that the San Juan-Lopez escarpment occurs well below sea level where normal subaerial surfaces processes are inoperative. The scarp is nearly at right angles to the direction of flow of the Cordilleran Ice sheet so it cannot be of glacial origin.

The San Juan-Lopez fault is the largest fault in the
islands. It is at least 65 km (40 miles) long, extending from the northern end of Stuart Island to the SE corner of Lopez Island (Figs. 14 and 15), where it disappears beneath what appears to be a submerged glacial moraine in Rosario Strait. It may (or may not) continue eastward through Deception Pass and into the North Cascade foothills as the Devil’s Mt. fault. The fault scarp reaches heights up to 340 m (1,100 ft) at the north end near Stuart Island and 90 m (300 ft) at the southeastern corner of Lopez Island (Figs. 14 and 15).

The age of the fault is not accurately known. The topographic freshness of the scarp suggests that it is quite young. Pleistocene continental ice sheets over a mile thick crossed the islands more than half a dozen times, but the scarp is not severely eroded, attesting to the youthfulness of the scarp. The topographic relief on the scarp indicates that this is a dipslip fault. At Rosario Strait, a prominent end moraine is draped over the fault (Figs. 16 and 17).

3.5.2 Point Caution Fault

The Pt. Caution fault extends at least 20 km (12 miles) from just north of Stuart Island to Point Caution on the NE coast of San Juan Island (Fig. 18). It may be even longer, but the bottom topography becomes complex southeastward. The height of the fault scarp reaches more than 300 m (1,000 ft) at its northern end. The topographic relief on the scarp indicates that this is a high-angle, dipslip fault.

3.5.3 Shaw Island Fault

The Shaw Island fault scarp (Fig. 18) makes the NE side of San Juan Channel between Shaw and San Juan Island, extending NW from Shaw Island to the west end of the Wasp Islands. The height of the scarp is generally about 300 feet.

3.5.4 Point Lawrence Fault

A linear fault scarp extends along the entire northeast shoreline of Orcas Island from Point Lawrence to Point Thompson, a distance of 13 km (8 miles) (Figs. 19-21). The base of the scarp is ~350 ft below sea level and rises to ~400 ft above sea level NW of Point Lawrence. The southeast end of the scarp abruptly truncates the southern end of two sea floor ridges that are probably beds of resistant Nanaimo or Chuckanut sandstone (Fig. 19). Because of the relief along the scarp, the Point Lawrence fault appears to be a dipslip fault with a displacement of at least several hundred feet.
Fig. 17  End moraine draped across the San Juan-Lopez fault. The outside of the moraine at Lawson Reef is about 500 feet high (Base map by NOAA).

Fig. 18  Point Caution and Shaw Island fault scarps (Base map by NOAA).
3.5.5 West Beach Fault
The West Beach fault makes the coastline along the NW shore of Orcas Island (Fig. 22). The subaerial scarp along the coast continues several hundred feet below sea level.

3.5.6 Sea Floor Faults in the Northern San Juan Islands
Numerous fault scarps criss-cross the sea floor in the San Juan Islands north of the major central islands (Fig. 23). Some of the linear scarps are 300 m (1,000 ft) high. Many of the sea floor faults truncate geologic structures.

(1) Sucia Fault
The Sucia fault makes a long, prominent, east-west trending gash on the sea floor between Sucia and Skipjack Islands (Figs. 24 and 25). It truncates beds on the SE flank of the Sucia syncline and north of Skipjack Island (Fig. 24). I first recognized this fault while working on a seismic hazard project about 2,000 and named it the Sucia fault. It lies on the same trend as the Vedder Mt. fault, a major fault that extends across the mainland northeast of Bellingham and into southwestern BC. Although these faults aren’t visibly connected, their alignment suggests that they may be the same fault.

“Vedder-Sucia fault. We have identified two large faults, the Vedder Mt. Fault (citation-Moen) and the Sucia Island fault that are directly on strike with one another and seem to connect as single fault buried beneath glacial deposits of western Whatcom County. The Vedder Mt. Fault has a prominent, linear, northeast-trending scarp that can be traced for many km. Bedrock on the northwest block of the fault has been downdropped several thousand feet beneath Quaternary unconsolidated deposits. We have recently recognized the Sucia Island fault in the San Juan Islands to the west from a prominent, linear scarp below sea level that truncates the Sucia Island syncline and adjacent structures.”

(2) Other Faults near Sucia
The Echo Bay fault truncates beds of the SE end of the Sucia syncline at the mouth of Echo Bay at Sucia Island (Fig. 25). It is a relatively short fault transverse to the main structures in this part of the northern islands. The southern terminus of the fault intersects the Sucia fault SE of Finger Islands. The northern end of the fault extends to the south end of the deep basin north of Sucia Island.
The San Juan Islands Thrust System: New Perspectives from LIDAR and Sonar Imagery

Fig. 20  Point Lawrence high-angle fault scarp, northeastern Orcas Island.

Fig. 21  Cross section of the Point Lawrence fault, northeastern Orcas Island.

Fig. 22  West Beach high-angle fault scarp, northwestern Orcas Island (Base map by NOAA).
A fault extends NW from the northern arm of the Sucia syncline toward Patos Island (Fig. 25). Evidence of the fault consists of off-setting of the outer beds of the greater Sucia syncline. Another fault truncates beds at the eastern end of the Nanaimo sandstone on Patos Island (Fig. 25) and truncates the westward continuation of the north-dipping beds that make Clements Reef.

3.6 Relationship of High-angle Faults to Mapped Thrust Faults

Underlying the concept of the San Juan Islands Thrust (Nappe) System is that five single-plane thrust sheets have moved very long distances (Fig. 31).
However, as shown by lidar and sonar imagery, most of the postulated, discrete thrust sheets of the “San Juan Thrust System” are not thrust faults, but rather multiple segments of high-angle faults. The implications of the new LIDAR and sonar imagery are very significant because they invalidate the five thrust faults which form the basis for the concept of the San Juan Thrust System.

3.6.1 Validity of the Rosario Thrust Fault

The Rosario thrust fault has been mapped as a single, continuous, thrust fault that extends in a contorted path from the eastern tip of Orcas Island at Point Lawrence across Orcas and Shaw Islands and adjacent waterways, across the length and breadth of San Juan Island to Cattle Point at the southeastern-most part of San Juan Island (Figs. 3 and 27). The thrust fault is postulated to have a very large horizontal displacement along a single fault plane from a far distant source.

The portion of the Rosario thrust mapped on Orcas Island follows segments of several high-angle faults apparent on LIDAR images for many kilometers. Fig. 27 shows the relationship between the postulated Rosario/Orcas thrust sheet and high angle faults and lithologic contacts between Pt. Lawrence and Mt. Constitution. The LiDAR image shows that the lithologic contacts have been incorrectly mapped, are offset along high-angle faults, and most of the Rosario/Orcas thrust sheet between Pt. Lawrence and Mt. Constitution consists of high angle-faults, rather than a thrust fault.

A portion of the Rosario thrust is mapped crossing West Sound, bending around Crane Island at a sharp angle, and trending southeastward along the west shore of Shaw Island where it crosses several high-angle faults at right angles (Fig. 28). It intersects a high-angle fault at the southern end of Shaw Island, makes a sharp bend to briefly follow the high-angle fault, and crosses San Juan Channel. It then follows the Stuart Island-Pt. Caution high-angle fault along...
Fig. 26  Long travel distances for postulated thrust sheets of the San Juan Island Thrust System, which are assumed to have move great distances from the North Cascades. However, LIDAR and sonar imagery shows that the Orcas, Rosario, and Lopez thrusts are not thrust faults but are actually high-angle faults. The red line is the San Juan-Lopez high-angle fault, which lines up with the fault to the east (Based on Brown, 2012).

Fig. 27  Portions of the Rosario and Orcas mapped thrust faults that are actually segments of high-angle faults.
The San Juan Islands Thrust System: New Perspectives from LIDAR and Sonar Imagery

the east coast of San Juan Island before diverging westward across San Juan Island where it follows the trace of several high-angle faults. Thus, much of this portion of the mapped Rosario thrust really consists of segments of high-angle faults and is not a thrust fault.

3.6.2 Validity of the Orcas Thrust Fault

The Orcas thrust has been mapped across Orcas Island from Point Lawrence to West Sound and is shown on geologic maps extending westward across San Juan Channel between Orcas and San Juan Island (Figs. 3 and 29). However, the trace of much of the mapped thrust follows a linear trend across topographic relief on lidar imagery, indicating that it is actually a high-angle fault rather than a low-angle thrust fault.

The Orcas thrust has been mapped as merging with the Rosario thrust between Mt. Constitution and Pt. Lawrence, so the same issues as discussed for the Rosario thrust above also apply to the Orcas thrust, i.e., its trace from Mt. Constitution to Pt. Lawrence is not a thrust fault, but rather segments of high-angle faults. Geologic maps show the trace of the Orcas thrust crossing the island between East Sound and the westernmost part of the island then across San Juan channel to the northern tip of San Juan Island.

Fig. 29 shows the trace of the mapped Orcas thrust fault across western Orcas Island and San Juan Channel to San Juan Island. The Orcas thrust is mapped across the peninsula between East Sound and West Sound along the trace of a high-angle fault just north of the Central Orcas fault parallel to several other high-angle faults (Fig. 30). It then is shown

![Map of San Juan Islands showing mapped Rosario and Orcas thrust faults.](image)

Fig. 28  The mapped Rosario thrust follows the trace of the Pt. Caution high-angle faults and crosses several high-angle faults (Base map by NOAA).
Fig. 29  The Orcas thrust fault as mapped consists of several segments of high-angle faults. The mapped Orcas thrust fault is shown in blue and high-angle faults are shown in red. The postulated Orcas fault from East Sound to West Sound is actually a segment of a high-angle fault (Fig. 30). The western portion of the postulated Orcas thrust crosses several high-angle faults.

crossing West Sound and following the prominent high-angle Central Orcas fault across the peninsula between West Sound and Deer Harbor (Fig. 30). The remainder of the Orcas thrust is mapped almost entirely on the sea floor as crossing the high-angle fault west of Jones Island, crossing San Juan Channel, and crossing the Point Caution high-angle fault on the east coast of San Juan Island (Fig. 30). Thus, the

Fig. 30  This segment of the Orcas thrust fault (blue) is actually a high-angle fault (top red) and not a thrust fault. Several other high-angle faults parallel the high-angle fault that follows the postulated Orcas thrust.
Orcas thrust fault does not exist.

3.6.3 Validity of the Haro Thrust Fault

The Haro thrust is mapped as a low-angle thrust fault that extends eastward from north of San Juan Island across about 25 km of the sea floor in President Channel, circumscribes the entire northern coast of Orcas Island (Figs. 3 and 31) and swings sharply around Clark and Barnes Islands. Geologic maps show the western part of the postulated Haro fault as three separate faults, all following sea floor fault scarps, but these are all scarps of high-angle faults, not thrust faults. The three branches of the postulated Haro thrust fault are shown merging as they cross President Channel to the northwest shore of Orcas Island where the thrust is shown following the trace of three high-angle faults, the West Beach fault, the northern Orcas fault, and the Point Lawrence fault. Because almost all of the postulated Haro thrust lies along the path of these high-angle faults, it is not a thrust fault at all.

3.6.4 Validity of the Lopez Thrust Fault

The Lopez thrust fault is shown on geologic maps as extending across southern Lopez Island (Figs. 3 and 32). Brown et al. show multiple smaller thrust faults in the islands south of the Lopez thrust (Fig. 32). However, all of these faults exhibit high, straight, parallel, scarps and are high-angle faults, not thrust faults.

3.6.5 Validity of the Buck Bay Thrust

The Buck Bay thrust is mapped as a single, low-angle, thrust fault that extends southward from northeast of Orcas Island down the entire length of Upright and San Juan Channels to Cattle Point (Figs. 3 and 33). However, the northeastern portion of the mapped Buck Bay thrust follows the prominent Olga high-angle fault (Fig. 33), the middle portion follows the scarp of a high-angle fault along the east coast of Shaw Island, and the southern portion is submerged with no evidence of its existence. Thus, the Buck Bay thrust does not exist.

3.7 Age of the High-Angle Faults

So many high-angle faults cutting rocks of different ages are apparent on LIDAR images that generalizing about a single age range of the faulting is difficult. However, several lines of evidence suggest that two periods of high-angle faulting occurred. High-angle faults shown on LIDAR on the islands above sea level appear to be older than the high-angle faults shown on sonar imagery because few of the faults shown on LIDAR have topographic scarps. Almost all of faults

![Fig. 31 The trace of the mapped Haro thrust (blue) follows several segments of high-angle faults (red), including the Pt. Lawrence fault, the north Orcas fault, the West Beach fault, and several faults between San Juan and Stuart Islands (Base map by NOAA).](image-url)
obvious on lidar consist of linear fractures etched out by erosion, rather than scarps offsetting the land surface. At one point along the central Orcas fault, a mass of rock appears to cross the fault with no disruption, suggesting that the fault is older than the rock mass. Although this doesn’t mean that other high-angle faults are not young, but it is consistent with the lack of surface offsetting and erosional etching out of the fault zones on land.

The seafloor faults and island-bounding faults, however, are marked by high, prominent linear fault scarps that cut across geologic structures and have not been affected by Ice Age glaciations even where they are transverse to the direction of ice flow of the mile-thick Cordilleran Ice Sheet. The Point Lawrence fault scarp shows morphological evidence of landslides off the fault scarp (Fig. 19) that were not affected by glaciation, suggesting (but not proving) that the scarp is very young. The landslides could have occurred any time after faulting, but both the scarp and the landslides appear to be unaffected by erosion. Thus, the age of the faulting appears to be younger than the glacial maximum of the last Ice Age (i.e., about 17,000 years).

However, a prominent, well-developed moraine at the south end of Rosario Strait is draped across the San Juan-Lopez fault, the longest and highest fault scarp in the islands. The morphology of the moraine is not offset by the fault so no movement has occurred on that fault since the moraine was deposited. The age of the moraine is not directly dated but must be slightly older than Everson glaciomarine drift (11,700 14C yrs BP) and slightly younger than the retreat of the Cordilleran Ice Sheet (~14,000 14C yrs BP). Thus, the age of the faulting seems to be confined to a short period of time after the last glacial maximum but before the deposition of the Rosario moraine.
4. Conclusions

LIDAR and sonar imagery clearly indicates that all five of the mapped large thrust sheets, the Rosario, Orcas, Haro, Lopez, and Buck Bay thrusts, actually consist of segments of high-angle faults and are not thrust faults. That is not to say that thrust faulting and shearing have not occurred, it simply means that shearing has been distributed throughout the pre-late Cretaceous rocks rather than along postulated large, single, discrete thrust sheets of large displacement (Nappes).

- Almost no high-angle faults have been mapped in the San Juan Island for 50 years.
- LIDAR imagery shows the traces of numerous high-angle faults on the islands.
- Sonar imagery reveals many prominent, linear, high-angle fault scarps on the sea floor, many of which truncate geologic structures.
- Most of the mapped Rosario thrust follows the trace of high-angle faults and is not a thrust fault.
- Most of the mapped Orcas thrust follows the trace of high-angle faults and is not a thrust fault.
- Most of the mapped Haro thrust follows the trace...
of high-angle faults and is not a thrust fault.
  • Most of the mapped Lopez thrust follows the trace of high-angle faults and is not a thrust fault.
  • Most of the Buck Bay thrust follows the trace of high-angle faults and is not a thrust fault.

Because all of five mapped thrust faults making up the San Juan Islands Thrust (Nappe) System are actually segments of high-angle faults, rather than thrust faults, the San Juan Islands Thrust (Nappe) System does not exist and the stacked thrust (Nappe) concept in the San Juan Islands is not valid.

References


