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SEISMOTECTONIC MAP OF THE PUGET SOUND REGION, WASHINGTON

By Howard D. Gower, James C. Yount, and Robert S. Crosson[1]

INTRODUCTION

The Puget Sound region is a seismically active area with hundreds of earthquakes occurring each year (Crosson, 1974, 1975, Crosson and Millard, 1975, Crosson and Noson, 1978a, 1978b, 1979). Most of the earthquakes are so small that they can be detected only by sensitive seismographs such as those operated by the University of Washington. Not all of the earthquakes have been small, however, for several damaging ones have occurred in historic time. Little is known about the geologic structures responsible for generating these earthquakes, and knowledge of the causative structures is fundamental to an adequate evaluation of the earthquake risks for the Puget Sound region. The purpose of this map is to summarize the current knowledge about tectonic deformation, seismicity, and the tectonic framework of the Puget Sound region in order to provide a basis for detailed geologic and geophysical studies that will lead to better understanding of the structures and forces responsible for generating earthquakes in the area.

This map is a compilation of all known and inferred faults, including what is known about their age of movement. Also shown are some deformed deposits of Quaternary age and earthquake epicenters. Few of the faults have been studied in sufficient detail to establish whether or not they have been active or inactive during late Tertiary or Quaternary time, but most of the faults are the result of tectonic forces that were active during early and middle Tertiary time. These faults may or may not be related to the tectonic forces responsible for the current seismicity. Approximately 5 percent of the earthquakes recorded in the Puget Sound region originated at depths of 40 Km or more (Crosson, 1972, fig. 11), and these are probably not directly related to exposed or near-surface structures. Most of the earthquakes occur at shallower depths and may be associated with near-surface structures, but no earthquakes have been definitely identified with mapped faults.

The faults and other tectonic features shown on this map are compiled from the work of others or were discovered or inferred through our own reconnaissance and local detailed field studies, interpretation of subsurface well data, and analysis of geophysical data consisting of aeromagnetic and gravity anomalies and marine seismic reflection profiles. The locations of the principal sources of information on bedrock structures are shown on figure 1, but in some instances modifications and additions have been made by the authors. While the location of structures resulting from Cenozoic tectonic activity is the principal purpose of this map, older structures are also shown where mapped in the pre-Tertiary terranes of the San Juan Islands and the northern Cascade Range.

Faults are classified as to type of displacement and age of movement. A minimum age of the most recent movement is given for a few of the faults that have been studied in detail. The locations of deformed Quaternary deposits, including large-scale deformation such as faulting, folding, and tilting, are shown on the map and described in table 1. Only deformation which is considered to be of possible tectonic origin is listed in table 1. Soft-sediment deformation that could best be explained by glacial processes or features that appear to be related to slope failure are not shown. It should be recognized, however, that the forces resulting from the thick ice that overrode the Puget Sound Lowland several times during the Pleistocene epoch could have formed structures not readily distinguishable from those formed by tectonic forces. Many of the deformed Quaternary deposits shown on the map may owe their origin to causes other than tectonic activity.

Major structures inferred from interpretation of linear gravity and aeromagnetic anomalies are shown on the seismotectonic map and figure 2 and are described in table 2. These geophysical anomalies, subject to various interpretations, may have been formed by geologic processes other than faulting. Gravity anomalies result from juxtaposition of rocks of differing density and thickness, and magnetic anomalies result from juxtaposition of rocks of different magnetic intensity. Such relationships, although commonly formed by faulting, can also be formed by steep folding or nontectonic means such as abrupt changes of thickness.

The hundreds of shallow earthquakes recorded each year by the University of Washington regional seismograph network may be related to surface and near-surface faults. The location of earthquakes recorded for the period July 1970 through December 1978 with hypocenters shallower than 35 km are shown on the seismotectonic map. Deeper earthquakes with hypocenters of 40 km or more are probably related to the deep-seated regional crustal structures shown schematically on figure 4. The epicenters and focal depths of these deeper earthquakes are shown on figure 3.

Map users should keep in mind that fault lines, though located as accurately as possible on a map of this scale, are intended only as guides for more detailed work in the field.

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[1]Geophysics Program, University of Washington, Seattle, Washington

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TABLE 1.—Localities of Quaternary deformation[1]

Map number	Description of deformation	Age of deformed sediment[2]	Reference[3]
1	Anticlinal fold in stratified clay and silt underlying undisturbed Vashon Drift exposed in sea cliffs between Point Whitehorn and Neptune Beach. Limbs of fold dip 7°.	Pre-Fraser	Easterbrook, 1963
2	Anticlinal fold in probable glacial outwash deposits, interpreted from offshore high-resolution seismic profiles.	Pleistocene	Snavely and others, 1976
3	Tilted stratified clay and silt cut by numerous small normal faults with as much as 40 cm displacement.	Pre-Fraser	Fred Pessl, oral commun., 1978
4	Steep, up to 87°, south-dipping stratified clay, silt, and iron-stained gravel exposed in valley of Tumwater Creek about 650 m south of Highway 101. Clay gouge at south end of exposure may be along inferred south-dipping thrust fault. To the north strata dip 10° S. Tilted strata are overlain by apparently undeformed Vashon Drift.	Pre-Fraser	
5	Tilted stratified clay, silt, and sand dipping 13° S. Tilted strata appear to be overlain by undeformed Vashon Drift.	Pre-Fraser	
6	Overturned glacial drift in fault contact with Oligocene siltstone along south-dipping thrust fault exposed in roadcut along US 101 on east side of Morse Creek.	Pre-Fraser	P.D. Snavely, Jr. oral commun.. 1977
7	Gentle arching of stratified Vashon glacial outwash along Swamp Creek anticline near mouth of Swamp Creek.	Post-Fraser	Brown and others, 1960
8	Normal fault striking N. 50° W. and dipping 68° NE. Offsets glacial outwash gravel and sand about 2 m, down on northeast side.	Post-Fraser(?)	
9	Gentle arching of iron-stained early(?) Pleistocene gravel and sand overlain by undeformed outwash deposits of Fraser Glaciation.	Pre-Fraser	P.D. Snavely, Jr., oral commun., 1978
10	Marine high-resolution seismic reflection profiles show evidence of faulting of Holocene deposits.	Holocene	Wagner and Wiley, 1980
11	Several east-striking, north-dipping thrust faults in stratified glacial deposits.	Fraser or Post-Fraser	Gerald W. Thorson oral commun., 1980
12	East-striking, steeply north-dipping thrust fault in stratified glacial deposits.	Fraser or Post-Fraser	Gerald W. Thorson oral commun., 1980
13	Numerous normal faults in stratified sand and silt exposed in lower part of sea cliff. Faults trend east-west and have displacements as much as 5.5 m. Strata in upper part of sea cliff do not appear to have been deformed.	Pre-Fraser	Gerald W. Thorson oral commun., 1980
14	Several west-trending folds in stratified sand and silt exposed in wave cut bench and lower part of sea cliff. Limbs of folds dip up to 7°; overlying Fraser glacial deposits in upper part of sea cliff appear to be undeformed.	Pre-Fraser	Gower, 1978, 1980
15	Stratified silt, clay, grit, and small pebble gravel tilted 55° SE., exposed in ditch along east side of road and overlain by undeformed glacial outwash.	Pre-Fraser	
16	Laminated to very thin-bedded silt and sandy gravel, and till dipping 52° N., exposed in roadcut 50 m north of Beaver Valley.	Pre-Fraser	

TABLE—1 (continued)

Map number	Description of deformation	Age of deformed sediment[2]	Reference[3]
17	Thin-bedded, laminated silt, clay, sand, and iron-stained gravel striking N. 30° W. and dipping as much as 33° NE. Beds are contorted locally. Section cut by small high-angle reverse faults striking N. 35° W. and dipping 62° NE., east side upthrown about 30 cm	Pre-Fraser	
18	Peat, 15 cm thick, interbedded with clay, silt, and very fine grained sand striking N. 82° W. and dipping 17° S.	Pre-Fraser	
19	Steeply dipping to vertical glacial outwash gravels. May have been deformed by ice rather than by tectonic forces.	Pleistocene	
20	Stratified sand tilted 24° to the west and cut by several small faults with up to 30 cm displacement.	Pleistocene	
21	High-angle reverse fault exposed in trench. Cuts Salmon Springs Drift. East side upthrown. Presence of scarp which presumably would have been obliterated by glaciation suggests some post-Fraser movement.	Post-Fraser(?)	Wilson and others, 1979
22	Saddle Mountain East fault, a left-lateral oblique-slip fault striking N. 22° E., dipping 75° SE. In trench at locality 22 apparent dip-slip displacement is 3.5 m, with the early and middle Eocene Crescent Volcanics in fault contact with glacial drift. Movement along fault presumably raised the level of Price Lake and formed a small lake north of Saddle Mountain. Radiocarbon dating of stumps of drowned trees in Price Lake and the small lake to the north yielded ages of 1,315±80 and 1,155±85 yr B.P., respectively.	Holocene	Wilson and others, 1979; Carson, 1973
23	High-angle reverse fault. In trench at locality 23 fault strikes N. 50° W., dips 59° NE., and appears to offset Salmon Springs Drift 1.7 m.	Pre-Fraser	Wilson and others, 1979; Carson and Wilson, 1974;
24	1,100-m-long linear "rift" valley that may have been formed by late Quaternary fault.	Fraser or Holocene	Carson and Wilson, 1974; Wilson and others, 1979
25	Folded stratified Salmon Springs Drift, including varved lacustrine silt and clay. Limbs of folds dip up to 42°.	Pre-Fraser or younger	
26	Apparent movement along fault during earthquake in 1948. This may have been landsliding rather than tectonic movement along the fault.	Historic(?)	Pease and Hoover, 1957
27	Possible fault scarp on bottom of Puget Sound off the Nisqually Delta associated with magnetic anomaly.	Holocene(?)	Univ. of Washington, Dept. of Geol Sci., unpubl. report on the Nisqually Delta
28	Faulted and slightly tilted gravel at east end of Fox Island.	Pre-Fraser	Bretz, 1913, p. 227
29	Folded pre-Salmon Springs Drift cut by many normal faults with displacements up to 0.6 m. Limbs of folds dip up to 38°. Overlying Vashon(?) Drift is not deformed	Pre-Fraser	Smith, 1972
30	Steeply dipping "fault" contact between sheared clay on the east and crossbedded sand on the west. Strike of contact varies from N. 10° E. to N. 70° W. Dip of sand steepened owing to drag along contact. Interpreted as diapiric intrusion of clay into sand. Overlying Vashon(?) Drift appears to be undeformed.	Pre-Fraser	

TABLE—1 (continued)

Map number	Description of deformation	Age of deformed sediment[2]	Reference[3]
31	In sea bluff exposures in N½ sec. 29, south of Saltwater State Park, lacustrine deposits of Salmon Springs Drift dip about 14° N.	Pre-Fraser or younger	Waldron, 1961
32	Fault in Salmon Springs Drift in NE¼ sec. 14. Downthrown on north. Amount of displacement is unknown but is believed to be no more than a few tens of feet.	Pre-Fraser or younger	Waldron, 1961
33	Several normal faults in Vashon Drift, striking N. 40° E. and dipping northwest. Displacements are all less than 65 m.	Fraser	Waldron, 1961
34	Salmon Springs drift and Puyallup Formation in fault contact along nearly vertical northeast-trending fault, downdropped on the northwest.	Pre-Fraser	Waldron, 1961
35	North-trending fault in Vashon Drift. Apparent scarp suggests possible Holocene movement. Vertical displacement estimated to be 6 to 9 m.	Holocene	Allan Fiksdal, oral commun., 1977
36	Northwest-striking, nearly vertical, normal fault exposed in bluff at northwest outskirts of Sumner. Vashon Drift has been downdropped about 24 m on the southwest.	Fraser	Crandell, 1963
37	Two faults offset the Lilly Creek Formation, exposed in the valley of Kings Creek in the SW¼ sec. 34. One fault strikes N. 60° W. and dips 50° SW. The other strikes N. 5° E. and dips 55 W. Both faults have plastic-clay gouge zones 15 cm to 60 cm wide.	Pre-Fraser	Crandell, 1963
38	Prominent lineation identified by photointerpretation and field investigations may be fault-related to July 1973 earthquake and aftershocks.	Holocene(?)	Crosson and Frank, 1975
39	Near-vertical north-trending fault in glaciolacustrine and fluvial deposits of the Orting(?) Drift. East side downdropped about 9 m.	Pre-Fraser	Mullineaux, 1970
40	Uplifted shallow-water marine sand and gravel deposits containing Holocene (3,260±80 B.P.) mollusks and some wood. Mollusk shells collected 4.9 m above present sea level yielded radiocarbon date of 3,260±80 B.P. Wood from about 2.4 m above sea level was radiocarbon dated at 4,530±90 B.P.		
41	Sand in Magnolia Bluff is "somewhat bowed up" just south of West Point.	Pre-Fraser	Bretz, 1913, p. 227

[1]Age and stratigraphic divisions are shown in map explanation (symbols for age of faulting).

[2]Term "Fraser" used here refers to the Fraser Glaciation.

[3]Descriptions of deformation not referenced are the result of observations by the authors during reconnaissance field studies.

REGIONAL TECTONIC SETTING AND PROPOSED SEISMOTECTONIC MODEL OF PUGET SOUND REGION

The current tectonics and seismicity of the Puget Sound region are the result of stresses imposed by the interaction of three lithospheric plates; the Pacific, American, and Juan de Fuca plates (fig. 4). The movement between the two largest plates is right lateral, that is the American plate is moving south relative to the Pacific plate. This movement has been taking place at an estimated rate of 5.8 cm per year (Atwater, 1970) along the Queen Charlotte fault northwest of Vancouver Island and the San Andreas fault zone in California. In the vicinity of Oregon and Washington the interaction between these two major plates is complicated by the presence of the Juan de Fuca plate, a small oceanic plate that has spread eastward from the Juan de Fuca Ridge. During late Cenozoic time the Juan de Fuca plate was being actively subducted beneath western Washington at

TABLE 2.—Structures inferred from interpretation of linear geophysical anomalies.
[Structures are shown on the seismotectonic map and figure 2]

Inferred structure	Description	Reference
A	Southern boundary of a high-amplitude magnetic anomaly. Considered to be the westward continuation of the Devils Mountain fault separating highly magnetic ophiolite on the north from weakly magnetic metamorphic rocks on the south. Youthful appearance of topographic lineations along the fault west of Lake Cavanaugh suggest that this structure may have been active in late Quaternary time; however, no geologic units younger than Oligocene(?) are definitely known to have been offset by the Devils Mountain fault.	U.S. Geological Survey, 1977; J. T. Whetten, oral commun., 1977
B	Sharp east-trending gravity nose bounding the north side of a large gravity low to the southeast. Coincides with linear alinement of series of small magnetic lows that may be related to the inferred fault zone. Considered to be westward and eastward continuation of the northern Whidbey Island fault. This anomaly appears to bound pre-Tertiary metamorphic rocks at or near the surface on northern Whidbey Island from a thick section of unconsolidated Quaternary deposits on the south. It may also form the northern boundary of basin of Tertiary sedimentary rocks to the south. Faulting of sediments deposited prior to the Fraser Glaciation (locality 3) occurs along the strike of this inferred structure. Overlying Fraser glacial deposits are apparently not deformed along this structure.	Rogers, 1970; U.S. Geological Survey, 1977; MacLeod and others, 1977; Gower, 1980
C and D	A pronounced linear magnetic high extending southeast from near Victoria on Vancouver Island. Has been interpreted as a northeast-dipping slab of the lower and middle Eocene Metchosin Volcanics of Clapp (1917), a correlative of the Crescent Formation, bounded on both sides by faults (structures C and D). MacLeod and others (1977) consider C to be the offshore continuation of the Leech River fault of Vancouver Island.	MacLeod and others, 1977
E	Northeast side of linear magnetic anomaly probably reflecting a fault in lower and middle Eocene basement rocks.	MacLeod and others, 1977
F	Northern edge of a high-amplitude magnetic anomaly bounding Eocene volcanic rocks; in part overlain by a thin section of Tertiary sedimentary rocks on the south and a thick section of Tertiary sedimentary rocks on the north. Interpreted as a fault with the north side down.	MacLeod and others, 1977; U.S. Geological Survey, 1977; Gower, 1980
G	Linear magnetic high and southern boundary of a pronounced gravity low. Interpreted as northwest-trending fault, the southern Whidbey Island fault, of probable Quaternary age. Evidence for Quaternary displacement includes the large difference (1,374 ft) in depth to bedrock in wells on opposite sides of fault and apparent Holocene faulting observed on high-resolution seismic reflection profiles crossing the northwest end of this structure (map location 10).	U.S. Geological Survey, 1974, 1978; Gower, 1980; Wagner and Wiley, 1980
H	An east-trending gravity high interpreted as an east-plunging anticlinal fold. Bedrock at shallow depth along its axis suggests that it has had Quaternary movement.	Gower and Yount, 1985

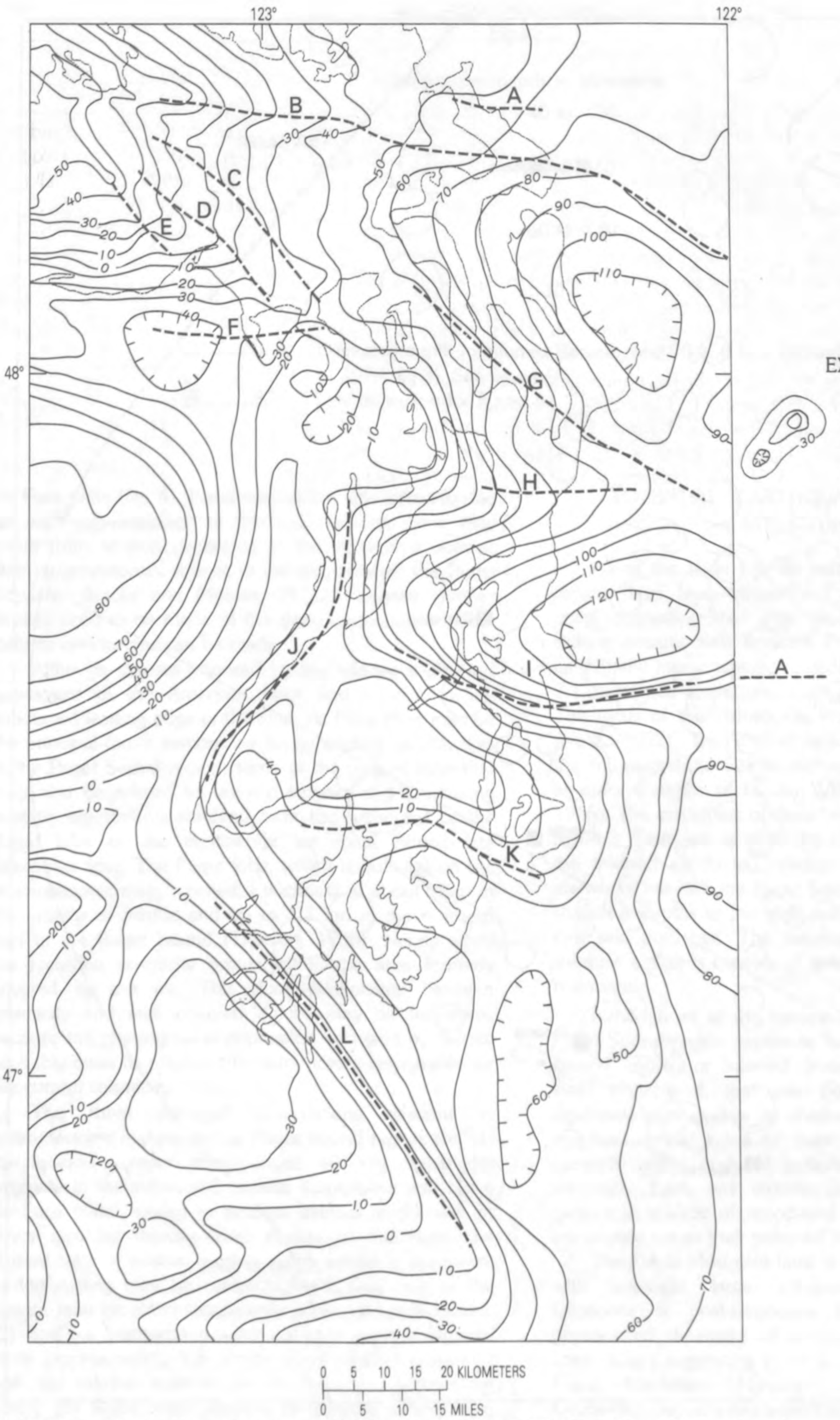
TABLE—2 (continued)

Inferred structure	Description	Reference
I	The anomaly associated with this feature is one of the steepest gravity anomalies in the United States and is interpreted as a major fault zone, down to the north. It also coincides with the northern boundary of a large magnetic high and is associated with steeply dipping Tertiary strata. Danes and others (1965) calculated a total of about 11 km of displacement along two parallel faults to account for this large gravity anomaly. The possible Quaternary fault mapped to the north may be the location of Quaternary faulting associated with this anomaly. It has been estimated that the area to the north of this possible fault is underlain by more than 1,100 m of unconsolidated deposits, suggesting possible large movements during the Quaternary. In addition, at map locality 40, immediately south of the possible fault, uplifted shallow water marine deposits indicate more than 4.9 m of uplift in past few thousand years. The position of the possible Quaternary fault shown on the seismotectonic map is drawn north of steeply dipping upper Cenozoic sedimentary rocks at or near the surface on Bainbridge Island and north of Lake Sammanish State Park near Eastgate.	Rogers, 1970; Danes and others, 1965; U.S. Geological Survey 1974, 1977; Hall and Othberg, 1974. Gower and Yount, 1985
J	Eastern boundary of a northeast-trending gravity high underlain by thick, steeply dipping section of the Crescent formation. This may be the fault against which the east-west structure I terminates.	Danes and others, 1965
K	Southern boundary of pronounced gravity and magnetic highs. Interpreted as fault or steep monoclinal fold, down to the south.	Danes and others, 1965 Rogers, 1970; U.S. Geological Survey 1974, 1977
L	Northeast side of prominent northwest-trending positive gravity anomaly. May represent northeast dipping homocline of Eocene basalt.	Danes and others, 1965

a rate estimated at 5.8 cm per year (Silver, 1971; Atwater, 1970). Areas of active subduction throughout the world are associated with pronounced active Benioff zones, seismic zones typically inclined approximately 45° along which earthquakes occur to depths of 600 km or more. The absence of such a distinct Benioff zone beneath western Washington and Oregon suggests that subduction may now be occurring at a slower rate or may even have ceased. Atwater (1970) and Riddihough and Hyndman (1976) have suggested that the lack of a well-defined Benioff zone may be the result of the Juan de Fuca plate having been so young, thin, and hot that it readily reheated as it descended beneath western Washington. Thus, because of its elevated temperature and resultant lack of strength, the plate is incapable of producing deep earthquakes.

Recent strain measurements in the vicinity of Seattle by Savage and others (1981) indicate an east-northeast contraction although at a rate so low as to be barely detected. This may be consistent with oblique convergence between the Juan de Fuca and American plates. Earthquake data, however, are inconsistent with these strain measurements.

Earthquakes in the Puget Sound region occur in two separate depth zones separated by a nearly aseismic interval (fig. 5). Most of the recorded earthquakes occur in the upper seismic zone, which reaches a depth of approximately 30 km. Hypocenters for the lower seismic zone form an eastward-deepening zone ranging in depth from 40 km on the west to more than 70 km on the east. The focal-mechanism solutions available suggest that the two seismic zones belong to separate and different stress regimes. Focal mechanisms for the upper zone show north-south compression (Crosson, 1972) and are consistent with, and presumably related to, the regional stress field associated with the right-lateral movement between the Pacific and American plates. Even though the lower seismic zone lacks the high seismicity or very deep earthquakes of typical active subduction zones, it probably defines the top of the subducted lithosphere of the Juan



EXPLANATION

Gravity contours—Showing Bouguer gravity anomaly in milligals relative to arbitrary datum. Hachured to indicate closed areas of lower Bouguer gravity. Contour interval 10 milligals

Inferred structure—Letter refers to same structure on map sheet and in table 2

FIGURE 2.—Regional gravity map and inferred structures. Modified from MacLeod and others (1977). Structures B, C, D, E from Rogers (1970); structures G, H, I, K from Bonini and others (1974)

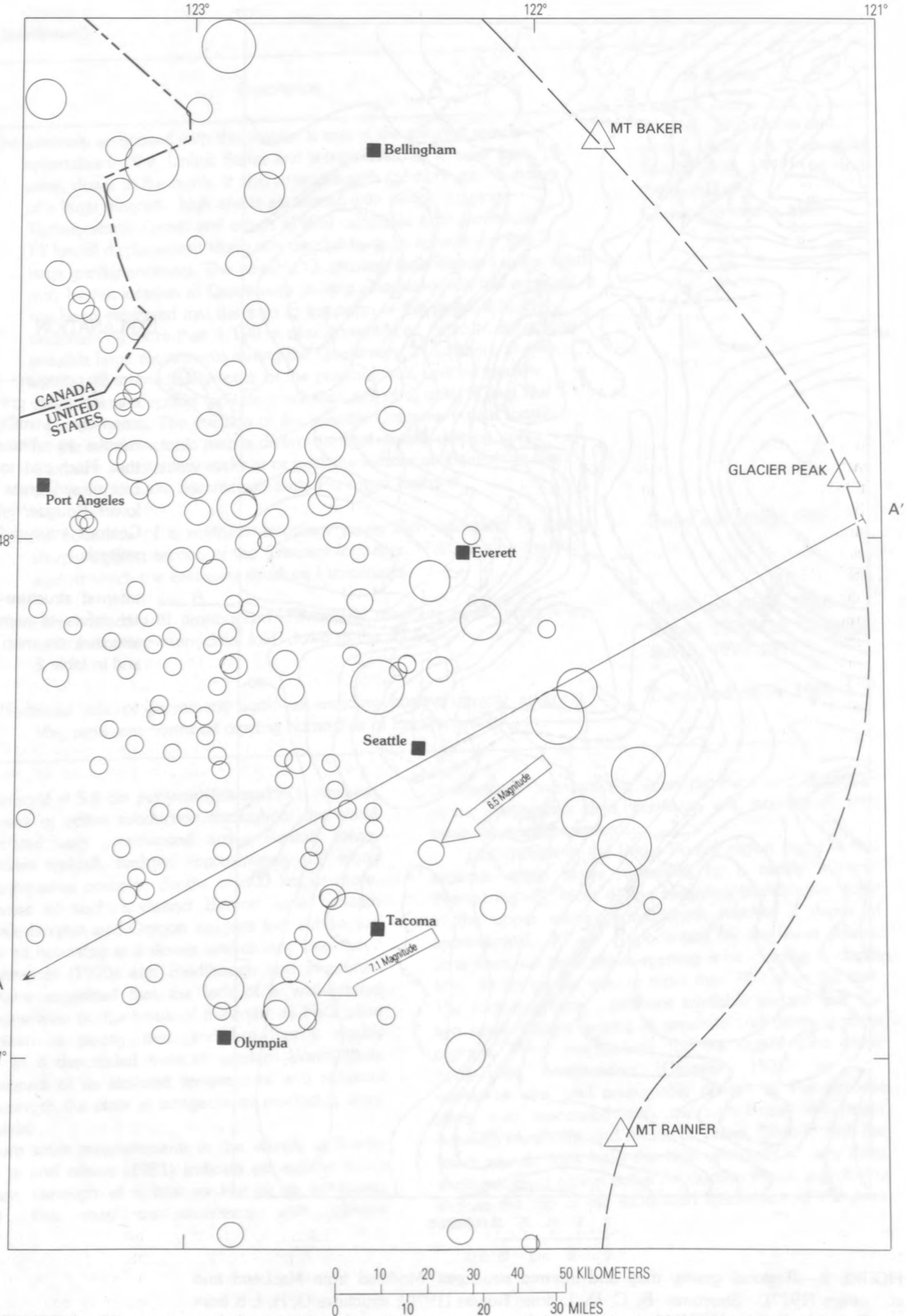


FIGURE 3.—Hypocenters of deep earthquakes. Section in figure 5 begins about 30 km southwest of map edge.

EXPLANATION
Figure 3

Earthquake depth in kilometers

40 to <50

50 to <60

60 to <70

≥70

— —— — Estimated depth to inferred Benioff zone 90-150 km (Dickinson, 1970, fig 3). See figure 5

A ____ A′ Line of section for figure 5

de Fuca plate (fig. 4). Focal-mechanism solutions showing an east-west extension in this lower seismic zone may result from tension generated in the subducted oceanic slab by gravitational sinking of the slab beneath the Puget Lowland (Isacks and Molnar, 1971); however, further studies need to be made of the deep earthquakes before definite conclusions can be made.

Although stresses imposed by the relative southward movement of the American plate and tension in the subducted leading edge of the Juan de Fuca plate may be the principal forces responsible for generating earthquakes in the Puget Sound region, some of the current seismicity may also be related to residual stresses and continuing isostatic adjustments resulting from the withdrawl of the Puget lobe of the continental ice sheet during late Wisconsin time. The Puget lobe, which is outlined on the seismotectonic map, reached a thickness of about 1 km in the vicinity of Seattle and up to 1.3 km in the northern part of the Puget Sound (Thorson, 1980). Nearly all of the recorded seismicity occurs within the area formerly covered by the ice. This close relationship between seismicity and area covered by ice may be fortuitous, because the physiographic depression occupied by the ice probably owes its origin to the same forces responsible for the current seismicity.

The three principal observations relevant to seismotectonic features in the Puget Sound region are: (1) Earthquakes deeper than about 40 km apparently originate in the subducted oceanic lithospheric slab (Juan de Fuca plate), owing to residual stresses in the slab or stress resulting directly from sinking of the slab. The current state of relative motion of the system is unknown; underthrusting may be continuing at a slow rate or the system may be either temporarily or permanently locked. (2) Shallow earthquakes seem to arise from a regional stress (approximately N-S compression) which is consistent with the relative motions of the Pacific and American plates. (3) Some small shallow earthquake activity may result from adjustment to residual stresses imposed by advance and withdrawl of the Puget lobe of the continental ice sheet.

POTENTIAL EARTHQUAKE-GENERATING STRUCTURES

All of the large historic earthquakes for which focal depths have been determined appear to be relatively deep, suggesting that they are related to the inferred sinking oceanic slab beneath Puget Sound. The largest earthquake instrumentally recorded in the region was the 7.1-magnitude earthquake northeast of Olympia in 1949. The focus of this earthquake was at a depth of 70 km (Nuttli, 1952). The second largest recorded earthquake, the 6.5-magnitude Seattle earthquake in 1965, occurred at a focal depth of 60 km (Algermissen and Harding, 1965). The epicenters of these earthquakes are plotted on figure 3. Earthquakes of similar magnitude associated with the inferred subducted oceanic slab may be expected elsewhere beneath the Puget Sound region, presumably at shallower depths to the west and at greater depths to the east and northeast. The maximum depth at which the subducting slab is capable of generating large earthquakes is uncertain.

Although all of the historic large earthquakes in the Puget Sound region appear to have been deep, there are several known or inferred faults, described below and listed in table 2, that may be capable of generating significant earthquakes at shallow depths. It should be emphasized that none of these faults is known to be currently active and the potential hazard they pose is uncertain. Each will require detailed geophysical and geological studies of associated Quaternary deposits to adequately assess their potential hazard.

The Devils Mountain fault, a major west-trending fault with apparent large left-lateral movement during Oligocene or post-Oligocene time, is marked by a pronounced alinement of physiographic depressions and linear ridges suggesting possible movement following the Fraser Glaciation. However, no definite offset of Quaternary deposits has been identified with this fault.

The northern Whidbey Island fault, inferred structure B on the seismotectonic map, appears to bound bedrock on the north and a thick section of Quaternary deposits.

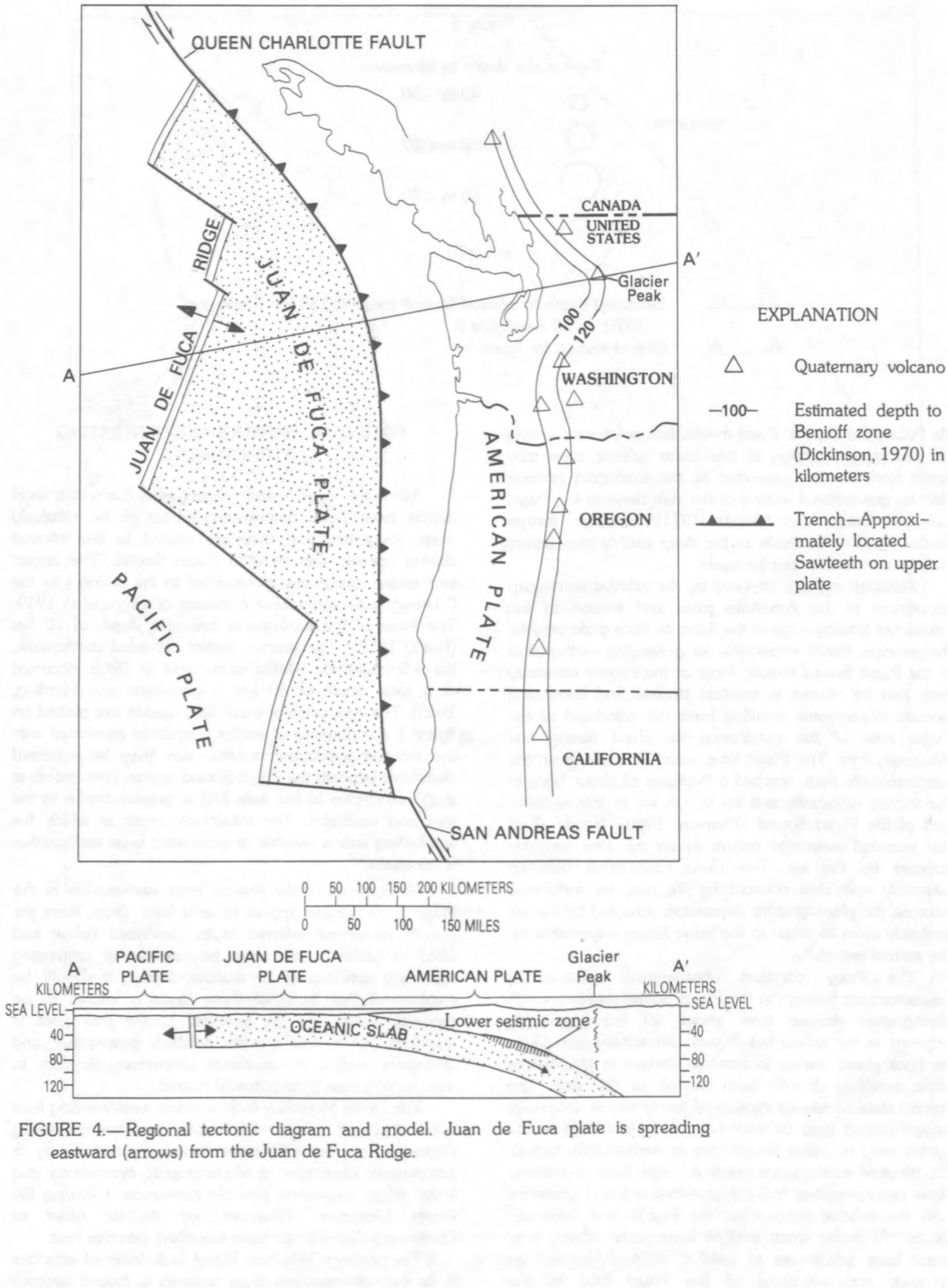


FIGURE 4.—Regional tectonic diagram and model. Juan de Fuca plate is spreading eastward (arrows) from the Juan de Fuca Ridge.

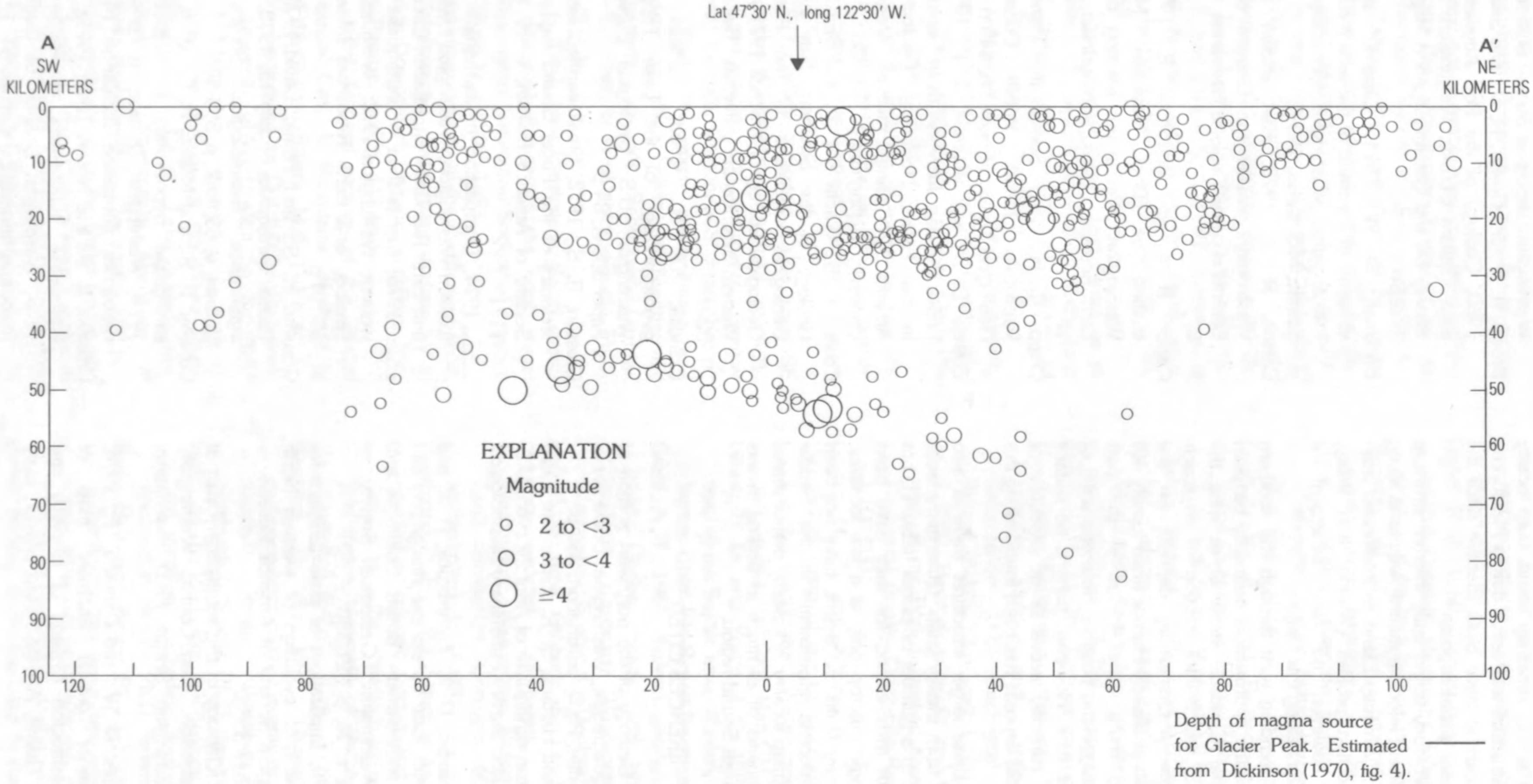


FIGURE 5.—Section of earthquake hypocenters. Only earthquakes of magnitude 2.0 or greater are shown. Location of section shown on figure 3.

on the south (Gower, 1980). Faulting of pre-Fraser glacial deposits on the east side of Whidbey Island, map locality 3, indicate that this structure was active during Pleistocene time. The fault appears to have been inactive since the deposition of the Fraser glacial deposits.

The southern Whidbey Island fault, inferred structure G, shows possible offset Holocene marine sediments along its trend northwest of Whidbey Island as interpreted from marine seismic reflection profiles (Wagner and Wiley, 1980). There is, however, no clear alinement of earthquake hypocenters along this feature.

The fault zone trending west through the southern part of Seattle marks the approximate boundary between steeply dipping upper Cenozoic strata at or near the surface on the south and a thick section of as much as 1,000 m of probable Quaternary deposits on the north. Marine deposits at Blakely Harbor (map locality 40) have been uplifted more than 4.9 m in the past 3,260 ± 80 years, suggesting possible Holocene uplift of the south side of the fault. However, there is no surface indication that it is currently active as no evidence of displaced Fraser glacial deposits has been found along this structure.

In addition to these larger structures there is also potential seismic risk from smaller faults. Quaternary faults have been observed in a number of places (table 1), but little is known about their extent, for they have been traced beyond a single outcrop only at a few localities. Many other Quaternary faults, no doubt, have not been recognized. The Holocene movement on the Saddle Mountain East fault (map locality 22) clearly demonstrates that surface displacements of as much as several meters are possible in the Puget Sound region.

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