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WELLBORE BREAKOUT ANALYSIS FOR DETERMINING TECTONIC STRESS ORIENTATIONS IN WASHINGTON STATE

by

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ABSTRACT

This report presents the results from a detailed analysis of wellbore breakouts from petroleum exploration well logs in the state of Washington. Principal horizontal stress directions are inferred from the measured azimuths of borehole breakouts and are used to place constraints on the style of faulting and regional deformation within the state. Our results indicate mean maximum horizontal stress directions (S_{Hmax}) of about N20°E near the south-central Washington coast, N5°-10°E within the Puget Sound, and approximately NW on the Olympic peninsula. These stress data are consistent with horizontal stress directions inferred from earthquake focal mechanisms in the Puget Sound basin (Ma and others, 1991) and with directions inferred from mapped cinder cone alignments in the Cascade Range of Washington and Oregon (Magee, in prep.), but are inconsistent with geodetic data in the Puget Sound basin and the Olympic Peninsula which indicate ENE maximum horizontal strain accumulation (Savage and others, 1991). Enigmatically, the breakout orientations observed in several wells appear to be dominated by local stresses in the vicinity of actively deforming folds or faults.

INTRODUCTION

The state of Washington, and much of the Pacific Northwest region, is situated landward of the Cascadia subduction zone where oceanic crust of the Juan de Fuca plate is being overridden by the North American plate in a N67°E direction at a rate of 4 cm/year (Riddihough, 1984; DeMets and others, 1990). Subduction of oceanic crust younger than 10 Ma might be expected to result in strong shear coupling along the plate boundary and evidence of ENE compression directed roughly parallel to plate convergence (Molnar and Atwater, 1978). However, previous stress data in the Puget Sound region were sparse and only weakly defined a N-S directed compressive stress regime (Zoback and Zoback, 1989).

Orientations of in-situ horizontal stresses can be inferred from oriented elliptical borehole cross-sectional enlargements which are often observed in petroleum exploration wells. Several recent studies have demonstrated that these borehole enlargements, commonly referred to as wellbore breakouts, develop parallel to the least principal horizontal stress direction in response to stress concentration around the borehole wall due to unequal horizontal stresses (Gough and Bell, 1981; Zoback and others, 1985; Hickman and others, 1985). Stress-induced wellbore breakouts can be inexpensively and straightforwardly identified through the analysis of high resolution, 4-arm caliper, non-computed dipmeter logs routinely recorded in petroleum industry wells (Plumb and Cox, 1987).

In order to define the tectonic stress field in Washington more precisely, we attempted to acquire non-computed dipmeter logs for all 67 petroleum exploration wells drilled in the state after 1970 when the high-resolution caliper tool became widely used. Table A-1 (Appendix 1) lists specific well names, year and total depth drilled (McFarland, 1983), as well as comments concerning the availability of dipmeter logs. We were able to acquire and analyze dipmeter logs for only 22 of these 67 wells, nearly all of which were located in western Washington. Unfortunately, all offshore and most coastal wells were drilled before 1970 and dipmeter logs were either not run in them, or are from the 3-arm caliper tool and therefore inappropriate for this analysis. Petroleum companies have recently drilled a few wells in eastern Washington; researchers at Princeton University analyzed logs for two of these wells (V. Mount, 1989, written communication) but logs for the other wells in eastern Washington were not available at the time of this study.

METHOD

The dipmeter tool consists of two orthogonal pairs of caliper arms oriented with respect to magnetic north; these caliper arms record hole diameter as well as measure electrical conductivity of the formation around the borehole through four electrode pads situated on the arms. Due to cable torque during logging the tool normally rotates as it is pulled up the hole. If the tool encounters an elongated section of the hole, two of the oriented caliper arms lock into the elongation direction and record a hole diameter larger than bit size while the other pair records the orthogonal diameter close to bit size (about 9 to 11 inches). Depending on how continuous and well developed the breakouts are, the caliper arms remain locked along a fairly constant azimuth until the borehole becomes circular again, at which point the caliper arms resume their normal rotation. The field dipmeter log records the two orthogonal hole diameters, the azimuth of hole deviation, and the azimuth of one of the caliper arms.

Four general criteria have been established in the use of non-computed dipmeter logs for identification of wellbore breakouts (Plumb and Hickman, 1985). The requirements are: 1) the tool must rotate above and below the elongated section, 2) normal tool rotation must stop within the elongated section, 3) only one caliper pair can significantly exceed the borehole diameter with respect to bit size, and 4) the direction of elongation must not coincide with the azimuth of the hole deviation.

As the interpretation of borehole elongations can be complicated to varying degrees by hole conditions, the following log characteristics were evaluated to determine whether azimuths measured over an elongated interval should be included in our statistical analysis:

a) The shape of a high quality breakout is recorded on one caliper pair trace with an abrupt beginning and end. Although azimuths for breakouts that depart from this ideal shape (described herein as "poorly shaped") were included in the analysis, they were considered less reliable.

b) Azimuths of breakouts that occur within wash-out zones (where both caliper arms record borehole diameters significantly larger than bit size) are recorded but are not included in the statistical analysis.

c) Normal tool rotation was found to vary in rate and direction depending on hole conditions and logging procedures. In some cases, minor tool rotation occurs through elongated sections where breakouts are irregularly shaped and larger than the maximum tool diameter. But if the tool did not "lock in" to a consistent orientation (±10°) over that interval, the measured azimuths were considered unreliable and not included in the statistics.

d) Because the azimuth of hole deviation tends to be random for non-deviated boreholes (vertical deviation < 3°), the computed breakout azimuth may coincide with the azimuth of hole deviation. The measured breakout azimuths were considered valid for those near vertical wells in this study and were included in the statistical analysis. However, if there was significant vertical deviation throughout the hole and the breakout azimuth coincided with the azimuth of hole deviation (indicating preferential wear of the wellbore walls by the caliper tool in the direction of hole deviation), then that interval was described as a "key seat" and not included in the determination of the mean breakout direction.

RESULTS

A summary of individual log analyses for the 22 available wells is given in Table 2A (Appendix 1) which tabulates well location, breakout lengths, measured azimuth, comments on breakout quality and tool rotation, as well as the statistical results for each well computed using standard circular statistics for directional data (Mardia, 1972). We assigned a quality rating to the inferred directions based on standard deviation, number of breakouts, and total length of breakout intervals using the quality ranking criteria of Zoback and Zoback (1989). The detailed record of enlargements observed on the logs and of the statistical analysis are in Appendix 2.

Inferred directions of maximum horizontal stress (S_{Hmax}) were statistically significant for eight wells. Regionally consistent orientations were inferred from three additional wells, although only a small number of breakouts were observed on the logs from these wells. Results for all 11 wells are summarized in Table 1 and described in detail below. The inferred S_{Hmax} azimuths for these wells (keyed to the location numbers in Table 1) are plotted on the maps in Figures 1-5 along with rose diagrams for each well which illustrate the number weighted means and standard deviations.

No breakouts were observed on the logs from nine coastal wells (marked by asterisks on the map in Figure 2). In addition, the logs from two remaining wells were not interpretable and their locations are not shown on any figures.

The inferred S_{Hmax} directions plotted in Figure 1 indicate a complex pattern. The maximum horizontal stress appears to be directed N to NE near the south-central Washington coast and near the Canadian border, N to NNE or EW in the Puget Sound basin near Seattle, and approximately NW on the Olympic Peninsula. We interpret these inferred S_{Hmax} directions to indicate a generally N to NE directed compression in western Washington and suggest that the complexities in the stress directions inferred within the Puget Sound region may be evidence of shallow secondary stresses acting locally in the vicinity of the wellbore, possibly in response to young deformation. Our data only poorly constrains the NW S_{Hmax} direction on the Olympic Peninsula. The results of all wells are discussed in detail by region below with reference to Figure 2 for the fourteen southwest Washington coastal wells, Figure 3 for the single well near the Canadian border, Figure 4 for the three Puget Sound basin wells, and Figure 5 for the two wells on the Olympic Peninsula.

Southwestern Coastal Washington

The data in this region come from 5 wells and are of mixed quality but consistently indicate a N to NNE S_{Hmax} direction. An S_{Hmax} direction of N28°E ± 7° was inferred for Amoco-Weyerhauser #1-29 (well **#5**, Figure 2 and Table 1), the deepest well for which dipmeter logs were available. This well was drilled to a total depth of 3.75 km with less than 1° of vertical deviation. It is located north of and along trend of N- to NNW-trending, lower to middle Miocene folds (Rau, 1967). Most breakouts were observed in the deeper section of the hole; and analysis of their shape, quality, and orientations were unambiguous.

Although Luse #1-23 (well **#8**, Figure 2 and Table 1) is a shallow well with a total depth of only 1.1 km, we are able to infer a consistent S_{Hmax} direction of N178°E ± 9° from 4 small and short breakouts observed in the deeper section of the well.

Another shallow well, Sampson Johns #1-15 (well **#9**, Figure 2 and Table 1) was drilled to a total depth of 0.85 km with less than 3° of hole deviation. A total of 4 short elongations were observed on this well's logs, but all were in directions within ±10-15° of the azimuth of hole deviation and may indicate preferential wear of the borehole walls. A poorly constrained S_{Hmax} of N168°E is inferred for this well.

Only 3 poorly shaped elongations were observed on logs from LHA #1-15 (well **#10**, Figure 2 and Table 1) which was drilled to a total depth of less than 0.50 km. Each elongation is in a different direction causing large standard deviations for both the length and number weighted means. But the inferred S_{Hmax} direction of N24°E ± 30° from this well is generally consistent with inferred directions from the other wells in west central Washington.

Data from Montesano #1 (well **#11**, Figure 2 and Table 1) yielded an S_{Hmax} direction of N167°E ± 8° from 5 long intervals of small, poorly shaped breakouts. The total length of breakouts is 213 m over a 1500 m depth range with hole deviation generally less than 2°. The well is located near the Chehalis River in unconsolidated alluvium overlying lower to middle Miocene sedimentary rocks on trend with the crest of the north-striking Melbourne anticline which deforms middle Tertiary and older strata (Gower and Pease, 1965).

Although the breakout data are of mixed quality, the modern S_{Hmax} direction inferred from the breakout analysis consistently trends N to NE.This is in contrast to geologic evidence of probable Miocene age E-W compression in the southwest coastal region of Washington (Rau, 1967) and episodic Quaternary compressional deformation along the continental slope offshore consistent with oblique subduction and approximate E-W shortening (Snavely, 1987; Snavely and Wells, 1991).

Canadian border region

An S_{Hmax} direction of N5°E ± 19° was inferred from analysis on breakouts in Birch Bay #1 (well #1, Figure 3 and Table 1) which is located about 2 km east of Birch Bay, near the Canadian border in the far northern part of Puget Sound. The well was drilled to a total depth of 2.78 km and was situated on the north flank of a broad, generally E-trending fold (Easterbrook, 1976). A total of 17 breakouts were observed over a 1.80 km depth interval in the hole. Each enlargement interpreted as a breakout generally had an abrupt beginning and end, with clear tool rotation above and below the enlarged wellbore interval. The hole was logged in two runs; the log from the deeper section (1.996-2.585 km) shows the hole to be increasingly deviated from the vertical by 3° to 7° with the tool encountering more hole problems and getting stuck with a consequent loss of recorded azimuths. This is the only well for which a lithology log was acquired. Rocks penetrated by the well are predominantly a mix of sandstones, shales, and siltstones with the exception of a 138 m thick igneous sill at 0.70 km depth. There is no obvious correlation of breakout shape or orientation with lithology.

Puget Sound Basin

Stress orientations were obtained from three wells (#2-4, Figure 4), the breakouts occurred in consolidated Tertiary bedrock consisting of conglomerates, sandstones, shales, and some volcanic rocks (Gower et al, 1985) which underlie the shallow unconsolidated Quaternary basin fill as interpreted from a variety of geophysical and geological data (Yount and others, 1985; Danes and others, 1965). The S_{Hmax} orientations inferred from breakouts observed in these wells are shown in Figure 4 along with two major tectonic features identified by Gower and others (1985) in the Puget Sound region. On the basis of gravity and magnetic anomalies as well as mapped Quaternary deformation, Gower and others (1985) have identified the NW-trending Whidbey Island fault and an E-W-trending, E-plunging anticline, these structures are identified as active in Cenozoic time, although the details of their timing and sense of movement are largely unresolved. No surface fault exposures have been described in the literature for the Puget Sound basin region; much of the near surface deformation appears related to broad folding and warping. Bucknam (1991) has described 7m of warping and uplift of a marine terrace dated at less than about 1500 cal yr B.P. on Bainbridge Island located to the south of the area shown in Figure 4. This warping has been ascribed to compressional deformation associated with an approximately E-W trending buried reverse fault.

An S_{Hmax} orientation of N15°E ± 10° is inferred at Whidbey #1 (well #2, Figure 4 and Table 1). This well is located on the northern, down-dropped side of the inferred WNW-trending southern Whidbey Island fault. Although the actual fault trace and sense of slip are poorly constrained, possible offset Holocene marine sediments have been interpreted from seismic reflection profiles near its northwestern termination (Wagner and Wiley, 1980; Gower and others, 1985). Drilled to a total depth of 2.04 km, a large portion of the well is washed out. Twenty-two elongations occur over the depth range of 0.335-2.042 km but only 9 are considered to be high quality breakouts and these occur in a single interval between 1.531 and 1.794 km. A second, subsidiary set of breakout orientations with a mean direction of N110°E ± 21° occurs in the shallow portion of the well between 0.353 and 0.774 km depth. This subsidiary set consists of 5 generally lower quality breakout zones; one of which exhibits slow tool rotation throughout its 201 m length.

The Whidbey #1 well and the Birch Bay #1 well in the Canadian border region indicate a generally NNE-directed S_{Hmax}, consistent with mapped geologic structures (Wagner and Wiley, 1980; Gower and others, 1985; Easterbrook, 1976). However, two wells directly south of the Whidbey #1 well give contrasting results. These two wells, Kingston #1 and Schroeder #1 (well #3 and #4, Figure 4 and Table 1), indicate roughly E-W trending S_{Hmax} directions. Both were drilled near an E-trending gravity high interpreted to be an E-trending, E-plunging anticline with possible Quaternary movement (Gower and others, 1985).

A mean S_{Hmax} azimuth of N115° ± 16° was inferred for Kingston #1 (well #3), located near the axis of the anticline. Kingston #1 was drilled to total depth of 2.64 km with less than 2° vertical deviation and a randomly varying azimuth of hole deviation, but good quality breakouts were observed over only a relatively shallow interval of 0.50 to 1.52 km. From a summary of the lithology log (R. Dart, 1990, personal communication) elongations were observed predominantly in sandy claystones and siltstones, with the exception of an 8 m interval of volcanic tuff. Measured breakout azimuths are not correlated with the reported lithologies.

Schroeder #1 (well #4), drilled to total depth of 2.95 km, is located on the southern limb of the inferred anticline as shown in Figure 4. Two distinct breakout sets were observed on the logs from this well, but only the dominant S_{Hmax} orientation of N88°E ± 15° which was inferred from the deeper section of the well is plotted in Figures 1 and 4. Although the means for the two sets of breakout orientations are internally consistent, these two sets have orientations which are 60° apart and the change in azimuth occurs near casing between logging runs 2 and 3. The shallow trend is defined by 9 poorly shaped breakouts with a total length of only 150 m while the deeper trend is defined by 13 good quality breakouts with a total length of over 400 m. Also, in the shallow interval of the hole the average azimuth of hole deviation is approximately equal to the elongation azimuth; although the recorded azimuth of hole deviation may not reflect a preferential orientation for wellbore wear because the borehole deviates less than 2° from the vertical.

The N to NNE S_{Hmax} directions inferred from Birch Bay #1 and Whidbey #1 wells are in good agreement with the regional maximum compression direction inferred from focal mechanisms (Ma, 1988; Ma and others, 1991; Zoback and Zoback, 1989) and numerous other EW-trending folds and reverse faults, as well as NW- and NE-trending faults which have been mapped in the Puget sound region; (see summary of these features in Gower and others, 1985). The E-trending anticline and other E-W structural trends in Puget Sound (Bucknam, 1991; Gower and others, 1985) are also consistent with a N to NNE compressive stress within the basin. However, S_{Hmax} directions inferred from analysis of breakouts in the Kingston #1 and Schroeder #1 wells are approximately perpendicular to this regional stress direction. In detail, the inferred S_{Hmax} directions from Kingston #1 and Schroeder #1 parallel the axis of the anticlinal fold into which they were drilled, suggesting that the inferred stress directions may be dominated by this neotectonic structure.

It is interesting to note that there is considerable complexity in the regional gravity map of the Puget Sound basin. It may be that these scattered and inconsistent SHmax directions are due to local perturbations of the regional stress field caused by lateral density variations beneath the basin. Another possibility is that extensional flexural stresses in the uppermost layers of an actively deforming fold above a buried fault are relatively large. Thus, the orientations of the borehole elongations from these two wells are indicating local extensional stresses perpendicular to the trend of the fold at its crest, analogous to the extensional fractures observed at the surface above the 17 October 1989 Loma Prieta, California rupture (Cotton and others, 1990; Zoback and Reches, 1990).

Olympic Peninsula

Due to a lack of availability, logs were analyzed for only two Olympic Peninsula wells. Shearing #1 (well #6, Figure 5 and Table 1) was drilled to a total depth of 1.5 km on the crest of the Mosquito Creek anticline. The well was sited close to a change in anticlinal trend from generally NNW to more WNW and adjacent to the cross-cutting NE-trending Oil City fault, a possibly reverse or strike-slip fault that offsets the mid-Tertiary fold (Rau, 1979). The wellbore is deviated about 4° from the vertical over most of it depth, and azimuths of observed elongations in the upper part of the well coincide with the azimuth of hole deviation. Only 4 small well-shaped breakouts were observed on the logs and the total length of breakouts is short, only about 42 m. Thus, although the length and number weighted mean directions of the 4 breakouts are consistent, the S_{Hmax} direction of N110°E ± 7° is considered to be marginally reliable.

The other Olympic peninsula well, State #1-30 (well #7, Figure 5 and Table 1), was drilled to total depth of 2.01 km in a complex structural setting where folded sedimentary rocks pinch out against an EW-striking fault with an undetermined sense of slip due to poor exposures and structurally complex bedrock relationships (Brown and others, 1960; Tabor and Cady, 1978). Elongations occur over the depth range of 0.67 km to total depth, but the well deviates from the vertical by 2° to as much as 7° at depth and the azimuths of the elongations measured in the deeper section coincide with the azimuth of hole deviation. Only 4 well shaped breakouts with a total length of 52 m are observed over a 300 m section of the hole. The length and number weighted means are again consistent but because of the short breakout length the inferred S_{Hmax} direction of N155°E ± 10° is considered to be only marginally reliable.

As discussed above, the S_{Hmax} directions for the Olympic Peninsula inferred from wells #6 and #7 may not be significant because so few breakouts were observed in each well over a relatively short interval. Although the inferred directions are consistent within each well as indicated by the low standard deviations and similar length-weighted and number-weighted means, they differ from each other by 45° and only weakly constrain the S_{Hmax} direction to lie in the NW quadrant. Breakouts observed in both wells are from reasonable depth ranges, on the order of 1 km, but the state of stress in this region remains poorly constrained.

DISCUSSION

The orientation of S_{Hmax} as inferred from breakouts throughout the Puget Sound basin presents a puzzling pattern that could interpreted to imply either E-W or N-S directed compression. However, as described below the inferred E-W S_{Hmax} directions appear to be a shallow effect that is locally associated with an E-W trending gravity high. This ridge-like high on the regional Bouguer gravity anomaly map is located south of the Whidbey fault and has been interpreted as an E-trending, E-plunging anticline (Gower and others, 1985) as shown in Figure 4.

To illustrate the apparent association of inferred E-W S_{Hmax} directions with shallow depth in the vicinity of the plunging anticline, rose diagrams of length-weighted means and graphs of breakout azimuth with depth are plotted. Figure 6 shows the data for those well which indicate a generally E-W breakout orientation (implying an approximate N-S S_{Hmax}) and Figure 7 shows the data for those wells with generally N-S oriented breakouts (implying an approximate E-W S_{Hmax}). North of the Whidby fault, breakout orientations from below 1.5 km depth in Whidbey #1 are consistent with NNE directed compression. While south of the Whidby fault, the S_{Hmax} inferred from oriented breakouts between 0.5 km and 2.9 km depths at Kingston #1 and Schroeder #1 (both shallow and deep trends) scatter about N 116° E ± 30° as do the breakouts in the shallow (less than 1.5 km) section of the Whidbey #1 well. The only well drilled deeper than 3 km, Amoco-Weyerhauser #1, located outside the Puget Basin in southwestern Washington, yielded a well resolved breakout orientations that implies an S_{Hmax} consistent with the deeper Whidbey #1 orientation. North of the Puget Sound basin, breakouts in the Birch Bay #1 well, are also consistent with a generally NS S_{Hmax} direction.

Additional constraints on the stress field within the Puget Sound basin have been inferred from earthquake focal mechanisms. Ma and others (1991) inverted 76 focal mechanisms from M>1 crustal earthquakes in the depth range of 3 to 30 km for the state of stress in the crust beneath the Puget Sound. They found the maximum principal compressive stress, σ_1, to be subhorizontal and directed generally N-S. Their composite plot of P and T axes for all 76 crustal earthquakes suggests that the intermediate principal stress, σ_2, is comparable in magnitude to the minimum principal compressive stress,σ_3, implying an uniaxial state of stress, a combination strike-slip/thrust faulting stress regime. Only the deep breakout orientations from the Amoco-Weyerhauser #1 well in southwestern Washington occur below 3 km depth and sample the upper part of the depth range where the crustal earthquakes occur; however, the inferred S_{Hmax} direction from Amoco-Weyerhauser #1, Birch Bay #1, and the deeper section of the Whidbey #1, and the 4 coastal wells (Shell Luse #1-23, Sampson John's #1-15, Gray's Harbor LHA #1-15, and Montesano #1-X) are all generally consistent with the stress field inferred from the earthquake focal mechanisms.

Regionally, the crustal stress field as inferred from our breakout analysis suggests a N20°E oriented maximum horizontal compression near the southwestern Washington coast that becomes more northerly within the Puget Sound basin. As noted above, this N to NNE maximum horizontal compression is consistent with focal mechanisms of crustal earthquakes beneath Puget Sound (Yelen, 1982; Ma, 1988; Ma and other, 1991) and is also consistent with generally N-trending S_{Hmax} directions in western Oregon inferred from wellbore breakouts and volcanic alignments (Werner and others, 1991). This state of stress is also consistent with the stress state in the eastern portions of the state Zoback and Zoback (1989, 1991). Spence (1989) suggested that this N to NNE compression was due to the Pacific plate colliding with the Juan de Fuca offshore plate system, with much of the resulting compression transferred into the continental plate. His conclusion was based on finite element modeling of stresses due to plate motion displacements however, much of his predicted stress pattern appears to be strongly influenced by an artificial E-W boundary forming the northern edge of his model. Previously, Sbar (1982) and Zoback and Zoback (1989, 1991) have suggested that the generally northerly compression observed throughout the Pacific Northwest is related to a broad zone of NW oriented, right-lateral shear arising from Pacific-North American relative plate motion.

Interestingly, the N to NNE compression along southwestern coastal Washington and in the Puget Sound is **inconsistent** with NE to ENE compression which would be inferred from strong coupling with the obliquely subducting Juan de Fuca plate. Geodetic strain data suggest maximum horizontal strain accumulation in a N68°E direction near Seattle and N59°E on the Olympic Peninsula (Savage and others, 1991). Both strain measurements are consistent with uniaxial contraction in the direction of plate convergence (approximately N68°E, DeMets and others 1990). While strain may be accumulating at depth on this subduction zone, the state of stress in the crust beneath Puget Sound both at shallow levels (upper few kilometers from breakouts and geologic structure) and deeper levels (18-28 km, depth of most earthquakes) appears unrelated to shear tractions due to this convergence. The available stress data throughout Washington state indicate a regional uniaxial compression directed N to NNE and a strike-slip/thrust stress regime. The apparent orthogonal rotation of the regional N to NNE uniaxial compression locally within the Puget Sound basin suggests that the local stress perturbation is large compared to the regional horizontal stress magnitudes at these depths (Zoback, 1992).

CONCLUSIONS

Our analysis of non-computed dipmeter logs for petroleum wells in the western part of Washington state indicates that the maximum horizontal stress is directed about N20°E near the south-central Washington coast, N to NNE within Puget Sound basin, and generally NW on the Olympic peninsula. This stress state is consistent with geophysical and geologic evidence of young generally E- to ENE-trending compressional structures including folds and probable reverse faults throughout the Puget Sound basin. That the maximum horizontal compressive stress directions inferred from breakouts in two wells drilled within the Puget Sound basin are orthogonal to the regional trend is problematic, but appears to be a local shallow effect. We suggest that these inferred S_{Hmax} directions may be due to local perturbations to the regional stress field active in the vicinity of the wellbore, possibly in response to the effects of young deformation or lateral density contrasts.

Within western Washington, the regional crustal stress field is inconsistent with the geodetic strain measured on the Olympic Peninsula, where the deformation rates are interpreted as ENE uniaxial contraction consistent with the direction of subduction of the Juan de Fuca plate. While strain may be accumulating on the subduction zone beneath the Puget Sound region, upper crustal earthquake focal mechanisms, wellbore breakouts, and young geologic structures are all consistent with the N to NNE S_{Hmax} direction. Potential seismicity related to this N to NNE compression and ongoing deformation of the upper crust must not be ignored in the assessment of earthquake hazard of the Puget Sound-Seattle region.

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TABLE 1

Wellbore Breakout Analysis--Washington State

Well Number	Well Name	S_{Hmax} orientation ± Standard Deviation	Number of BO Intervals	Total Length (m)	Depth Range (km)	Structural Setting
1	Birch Bay #1	N 5° E ± 19°	17	211	0.366-2.166	on north limb of broad E-trending anticlinal fold
2	Whidbey #1					on north, down-dropped side of NW-striking Whidbey Is. fault
	1st set	N 15° E ± 10°	9	184	1.532-2.047	
	2nd set	N101° E ± 25°	5	359	0.353-0.774	
3	Kingston #1	N113° E ± 16°	14	560	0.506-1.328	on axis of gravity high interpreted as E-striking, E-plunging anticline
4	Schroeder #1					on south limb, near nose of inferred E-striking, E-plunging anticline
	1st set	N 89° E ± 15°	13	465	2.137-2.861	
	2nd set	N146° E ± 13°	9	153	0.650-2.024	
5	Amoco-Weyerhauser #1	N 28° E ± 7°	19	205	1.731-3.741	north of NW-striking syncline
6	Shearing #1	N110° E ± 7°	4	42	1.158-1.251	on axis of NNW-WNW trending anticline, near end cut by NE-striking fault
7	State #30-1	N155° E ± 9°	4	52	0.939-1.225	on N limb of E-trending syncline where beds pinch out against E-striking fault
8	Luse #1-23	N175° E ± 10°	4	36	0.556-0.845	shallow well no structural info
9	Sampson Johns #1-15	N168° E	2	21	0.386-0.463	shallow, coastal well no structural info
10	LHA #1-15	N 14° E ± 30°	3	41	0.165-0.471	shallow, coastal well no structural info
11	Montesano #1-X	N167° E ± 8°	5	296	0.213-1.688	on trend with axis of N-trending anticline

FIGURE CAPTIONS

Figure 1: Map of western Washington showing S_{Hmax} orientations inferred from wellbore breakout analysis. Boxes outline the approximate areas included in Figures 2 through 5. The length of the oriented lines for stress directions are proportional to quality. The geodetically measured strain (as reported by Savage and others, 1991) is also shown with the direction of principal contraction indicated by the lined inward pointing arrow and the direction of principal extension indicated by the thin outward pointing arrows. The large black arrow offshore indicates the direction of plate convergence between the Juan de Fuca and North American plates along the Cascadia subduction zone as determined by DeMets and others (1990). Major volcanoes of the Cascade range are indicated by gray asterisks. These are designated Ba - Mt. Baker, Gl - Glacier Peak, Ra - Mt. Rainier, Ti - Tieton Peak, Sa - Mt. St. Helens, Ad - Mt. Adams, and Gi - Gifford Peak.

Figure 2: Map of coastal Washington in the vicinity of Gray' Harbor showing S_{Hmax} orientations inferred from breakouts in wells #5, #8, #9, #10, and #11. Asterisks mark the approximate locations of wells which yielded no breakout information. The azimuth of each breakout orientation is drawn in the rose diagrams for each well (keyed to the map by the location numbers in Table 1). The radius (r) of each rose diagram and the total number of breakouts (n) are indicated for each well along with the inferred directions of S_{Hmin} and S_{Hmax}.

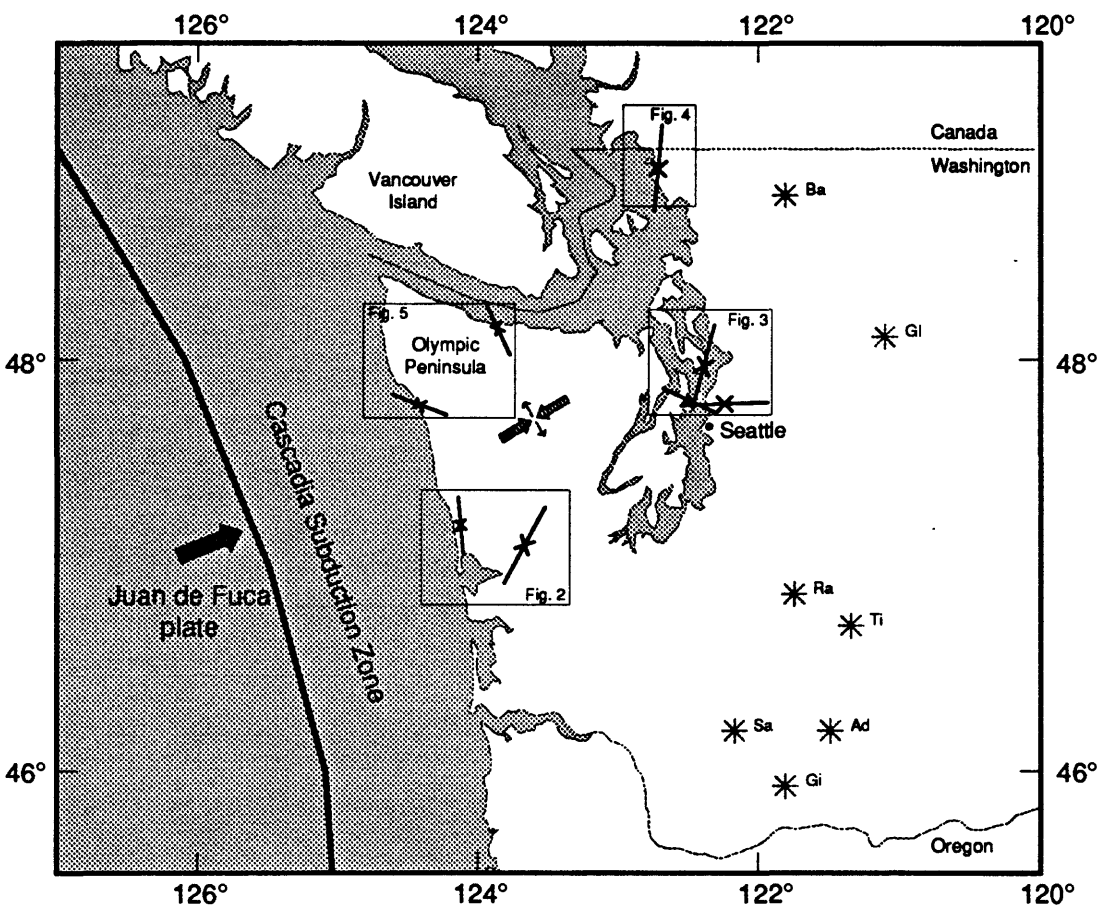
Figure 3: Map of the Washington-Canadian border north of Puget Sound showing the S_{Hmax} orientation inferred from breakouts in wells #1. Rose diagrams and statistical information as in Figure 2.

Figure 4: Map of Puget Sound region showing S_{Hmax} orientations inferred from breakouts in wells #2, #3, and #4. The Whidbey Island fault (identified from gravity, aeromagnetic, and geologic data) and an EW-trending anticline (associated with an E-trending gravity high) are also shown. Rose diagrams and statistical information as in Figure 2.

Figure 5: Map of the Olympic Peninsula showing S_{Hmax} orientations inferred from breakouts in wells #6 and #7. Rose diagrams and statistical information as in Figure 2.

Figure 6: The azimuth of wellbore elongations are plotted with respect to depth for the three wells which yielded well constrained NS S_{Hmax} directions. The rose diagrams illustrate the azimuthal variations associated with breakout length as the radius (r) of the rose diagrams are scaled by the length in meters indicated; total length (len) of elongations, and the length weighted means and standard deviations for the inferred S_{Hmin} and S_{Hmax} are also listed.

Figure 7: The azimuth of wellbore elongations are plotted with respect to depth for the three wells which yielded well-constrained EW S_{Hmax} directions. The rose diagrams illustrate the azimuthal variations associated with breakout length as the radius (r) of the rose diagrams are scaled by the length in meters indicated; total length (len) of elongations, and the length weighted means and standard deviations for the inferred S_{Hmin} and S_{Hmax} are also listed.



scale 1:6,000,000
mercator projection

Figure 1

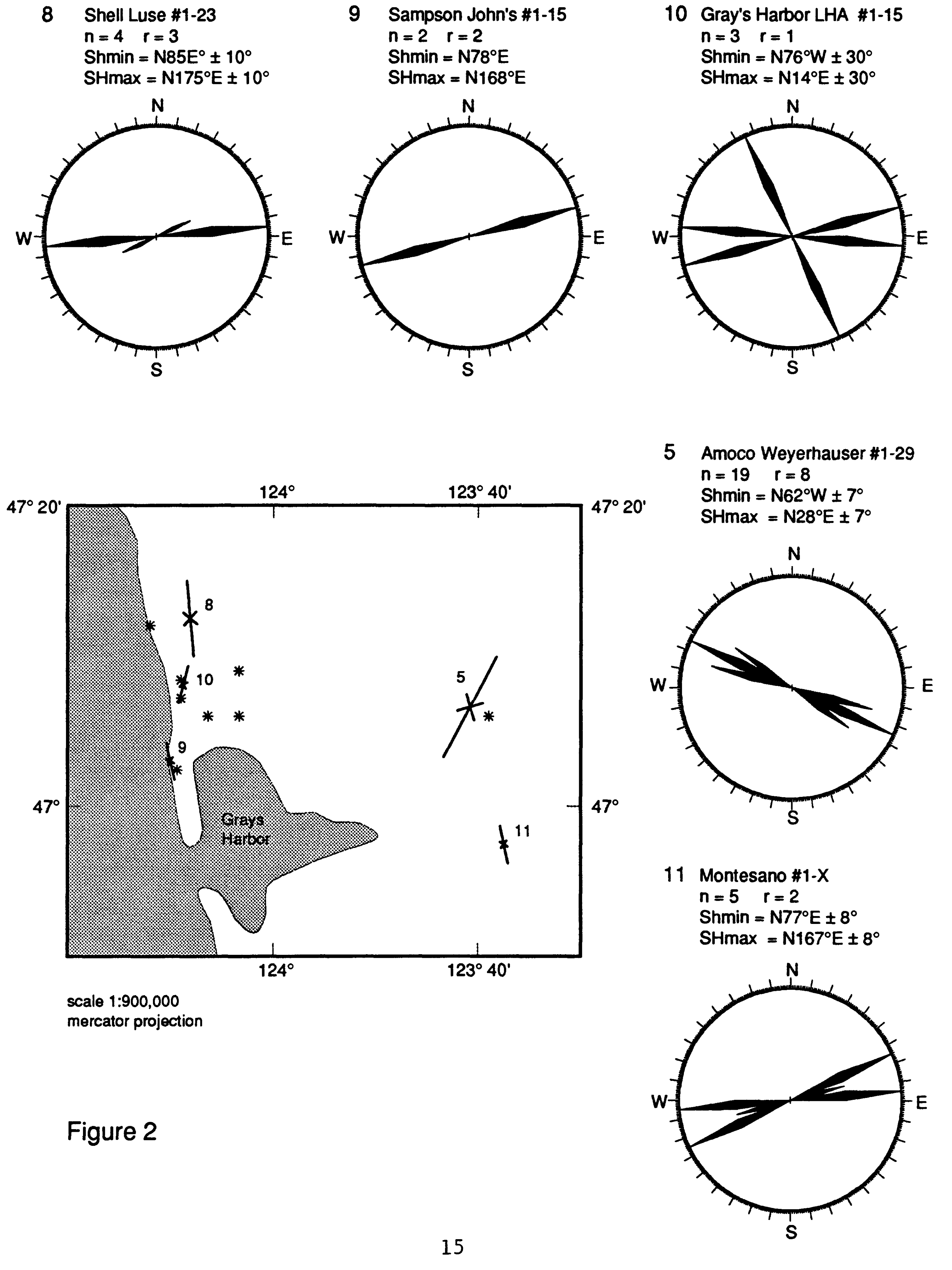

8 Shell Luse #1-23
n = 4 r = 3
Shmin = N85E° ± 10°
SHmax = N175°E ± 10°
9 Sampson John's #1-15
n = 2 r = 2
Shmin = N78°E
SHmax = N168°E
10 Gray's Harbor LHA #1-15
n = 3 r = 1
Shmin = N76°W ± 30°
SHmax = N14°E ± 30°
5 Amoco Weyerhauser #1-29
n = 19 r = 8
Shmin = N62°W ± 7°
SHmax = N28°E ± 7°
11 Montesano #1-X
n = 5 r = 2
Shmin = N77°E ± 8°
SHmax = N167°E ± 8°
N
S
E
W
124°
123° 40'
47° 20'
47°
Grays Harbor
8
10
9
5
11
scale 1:900,000
mercator projection

Figure 2

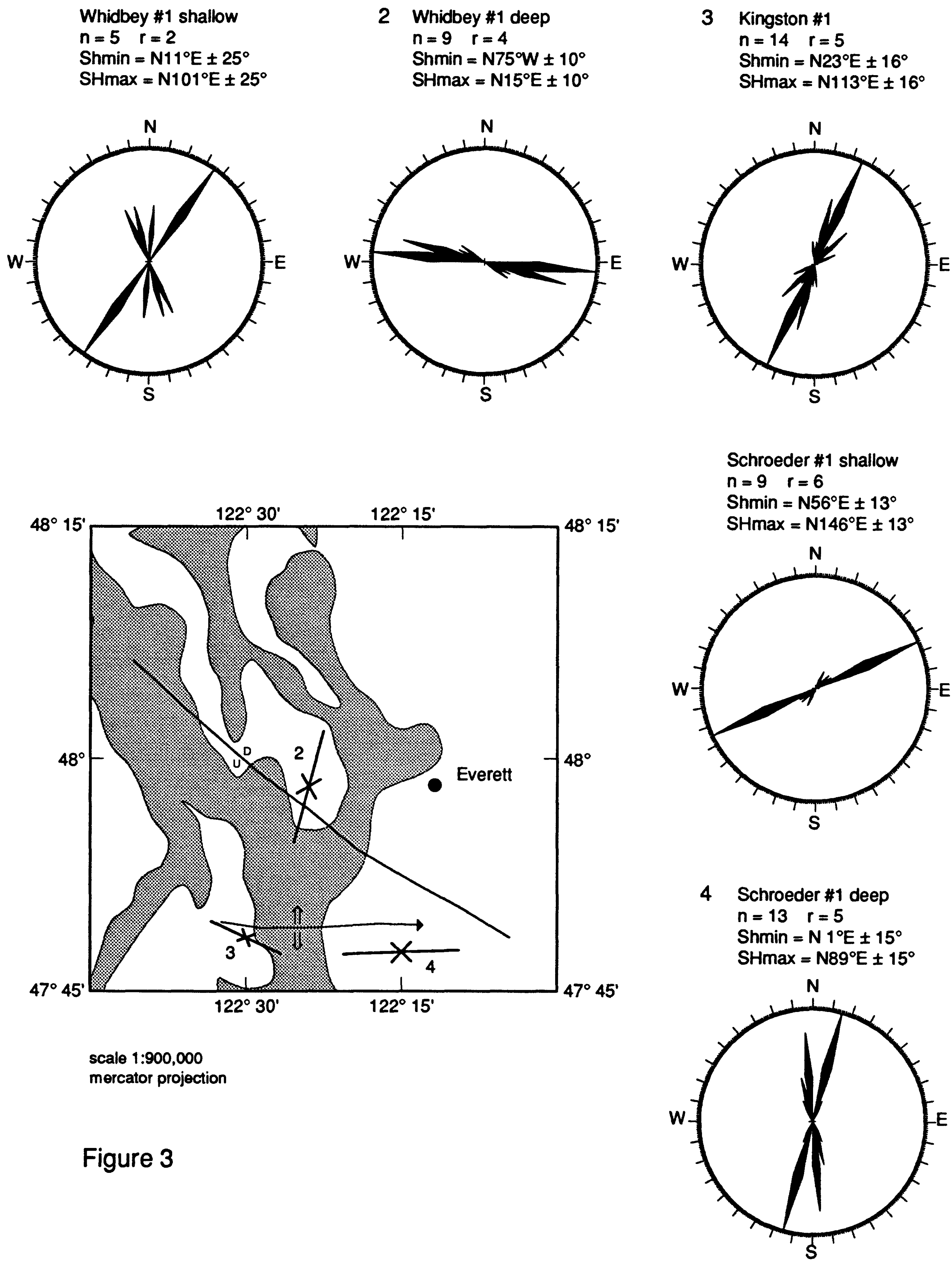
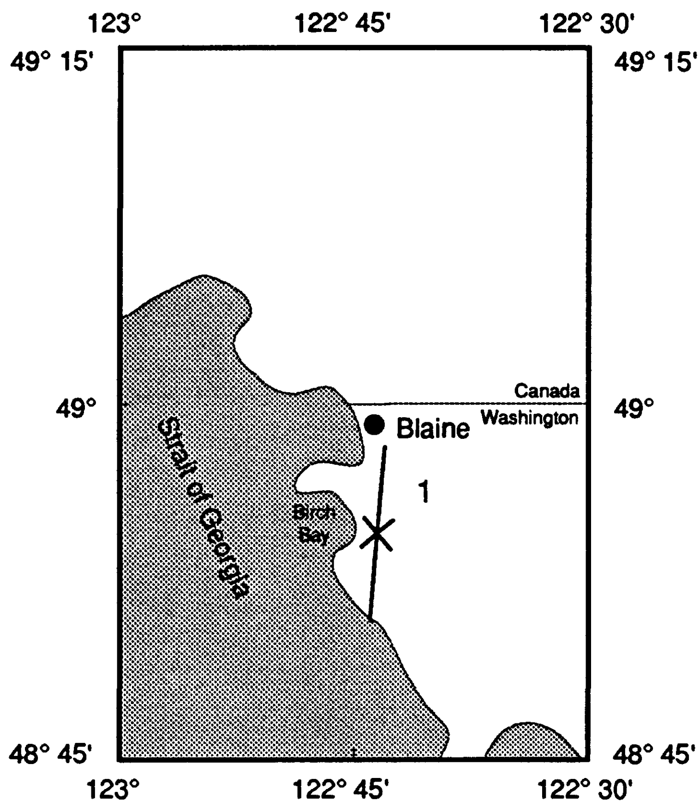

Whidbey #1 shallow
n = 5 r = 2
Shmin = N11°E ± 25°
SHmax = N101°E ± 25°
2 Whidbey #1 deep
n = 9 r = 4
Shmin = N75°W ± 10°
SHmax = N15°E ± 10°
3 Kingston #1
n = 14 r = 5
Shmin = N23°E ± 16°
SHmax = N113°E ± 16°
Schroeder #1 shallow
n = 9 r = 6
Shmin = N56°E ± 13°
SHmax = N146°E ± 13°
4 Schroeder #1 deep
n = 13 r = 5
Shmin = N 1°E ± 15°
SHmax = N89°E ± 15°
N
E
S
W
48° 15'
122° 30'
122° 15'
48°
47° 45'
D
U
2
3
4
Everett
scale 1:900,000
mercator projection

Figure 3



scale 1:900,000
mercator projection

1 Birch Bay #1
n = 17 r = 6
Shmin = N85°W ± 19°
SHmax = N 5°E ± 19°

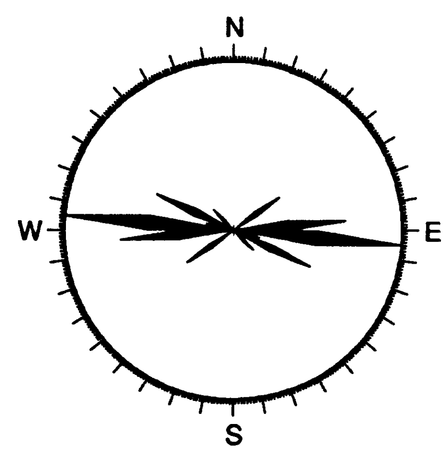


Figure 4

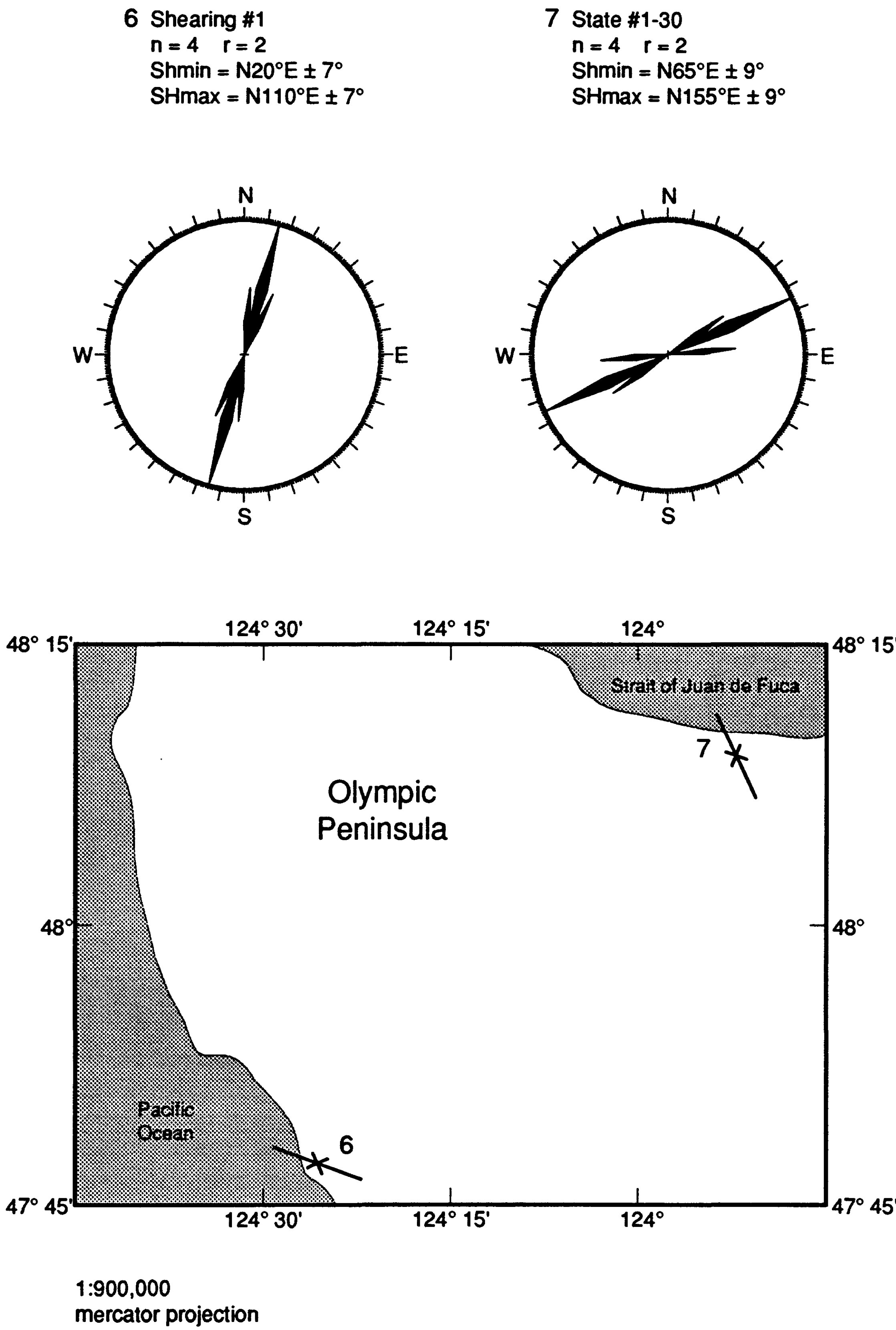
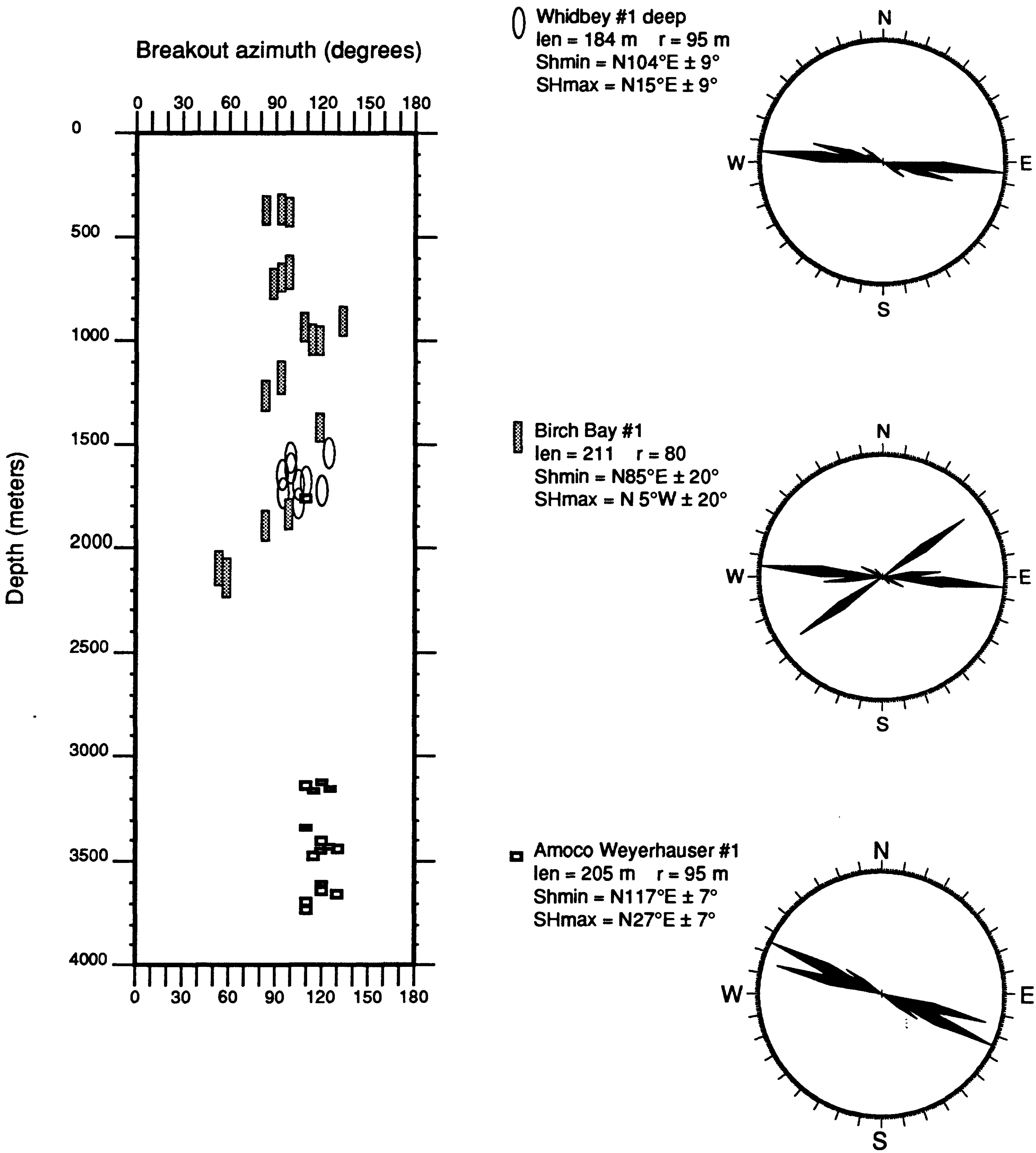

6 Shearing #1
n = 4 r = 2
Shmin = N20°E ± 7°
SHmax = N110°E ± 7°
7 State #1-30
n = 4 r = 2
Shmin = N65°E ± 9°
SHmax = N155°E ± 9°
N
W
E
S
N
W
E
S
124° 30'
124° 15'
124°
48° 15'
48° 15'
Strait of Juan de Fuca
7
Olympic
Peninsula
48°
48°
Pacific
Ocean
6
47° 45'
47° 45'
124° 30'
124° 15'
124°
1:900,000
mercator projection

Figure 5



Breakout azimuth (degrees)
0 30 60 90 120 150 180
Depth (meters)
0
500
1000
1500
2000
2500
3000
3500
4000
Whidbey #1 deep
len = 184 m r = 95 m
Shmin = N104°E ± 9°
SHmax = N15°E ± 9°
Birch Bay #1
len = 211 r = 80
Shmin = N85°E ± 20°
SHmax = N 5°W ± 20°
Amoco Weyerhauser #1
len = 205 m r = 95 m
Shmin = N117°E ± 7°
SHmax = N27°E ± 7°
N
S
E
W

Figure 6

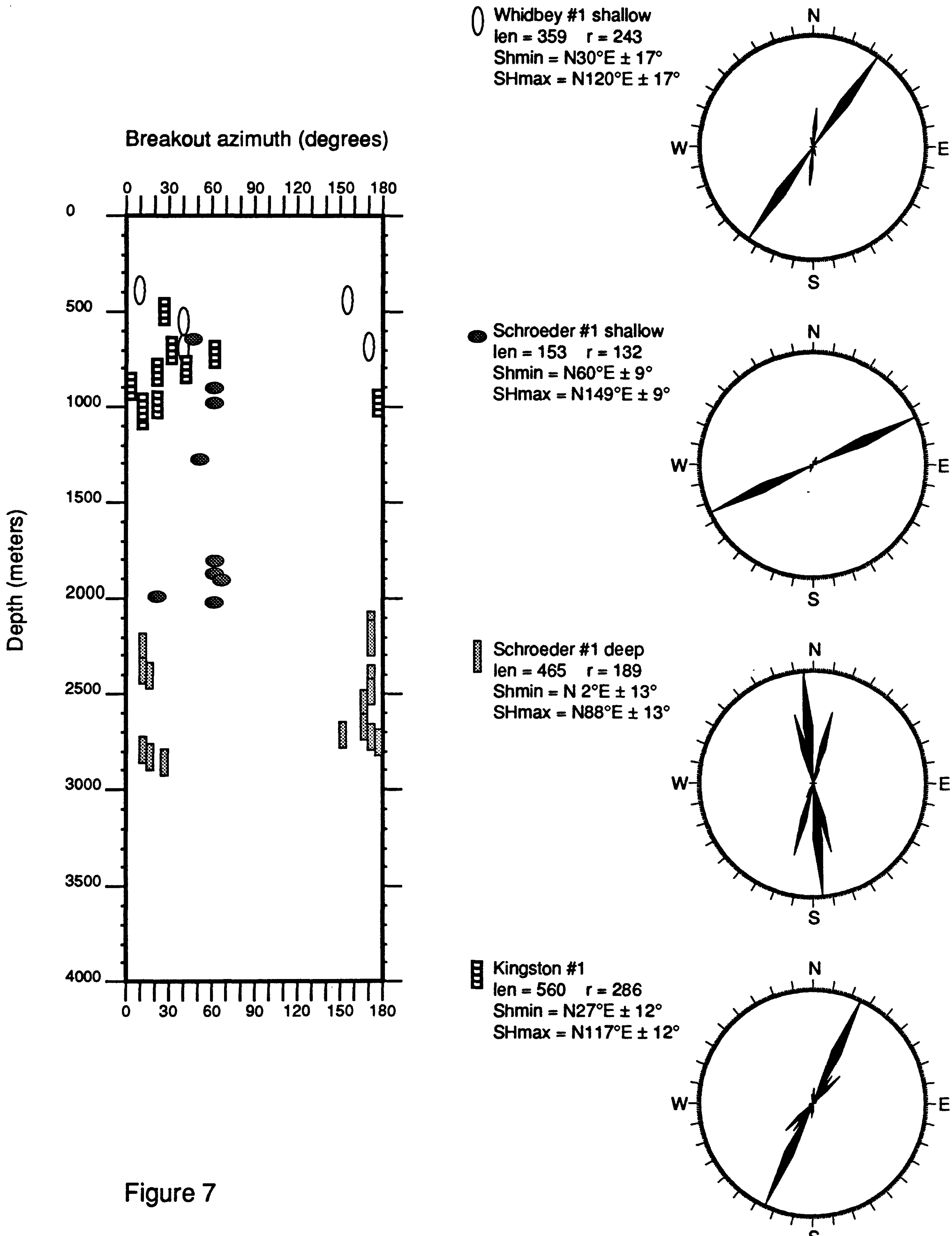

Breakout azimuth (degrees)
0 30 60 90 120 150 180
Depth (meters)
0
500
1000
1500
2000
2500
3000
3500
4000
Whidbey #1 shallow
len = 359 r = 243
Shmin = N30°E ± 17°
SHmax = N120°E ± 17°
Schroeder #1 shallow
len = 153 r = 132
Shmin = N60°E ± 9°
SHmax = N149°E ± 9°
Schroeder #1 deep
len = 465 r = 189
Shmin = N 2°E ± 13°
SHmax = N88°E ± 13°
Kingston #1
len = 560 r = 286
Shmin = N27°E ± 12°
SHmax = N117°E ± 12°
N
S
E
W

Figure 7

APPENDIX 1

Table A-1: Status and availability of logs for all wells drilled in Washington state after 1970.

Table A-2: Summary of wellbore breakout analysis.

TABLE A-1: WASHINGTON STATE PETROLEUM WELLS
completed in 1970 or later

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
Benton	Moon #1 046-005-00035 Columbia Hydrocarbon	501	1982	Dip log not run
Clallum	Soleduck #1 046-009-00048 Eastern Petroleum	472	1973	Company out of business or unknown
	Sniffer-Forks #1 046-009-00049 Eastern Petroleum	943	1973	Company out of business or unknown
	State #1 046-009-00050 Fairview Oil & Gas	2182	1982	Dip log not run
	State #1-30 046-009-00051 Twin River Oil & Gas Inc.	2012	1986	Logs acquired
Grant	Moses Lake #1A 046-025-00005 Snowbird Resources Ltd.	2125	1981	Company out of business or unknown
	BN #1-9 046-025-00006 Shell Oil Co.	5339	1984	Logs requested, but not available
Grays Harbor	Hogan #1-13 046-027-00106 Shell Oil Co.	891	1970	3-arm dip
	Hogan #1-8 046-027-00107 Shell Oil Co.	425	1970	Logs acquired
	Grays Harbor #1-11 046-027-00110 Shell Oil Co.	988	1970	Logs requested, but not available
	Grays Harbor LHA #1-15 046-027-00111 Shell Oil Co.	619	1970	Logs aquired
	Sampson Johns #1-15 046-027-00113 Shell Oil Co.	852	1970	Logs acquired

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
Grays Harbor	McCleave #1-33 046-027-00115 Shell Oil Co.	410	1970	Logs acquired
	Minard #1-34 046-027-00116 Shell Oil Co.	1402	1970	Logs acquired
	Sampson Johns #2-15 046-027-00117 Shell Oil Co.	728	1970	Logs acquired
	Trambitas #1-28 046-027-00118 Shell Oil Co.	951	1970	Logs acquired
	Ocean City Land Co. *et al* #1-14 046-027-00120 Shell Oil Co.	1301	1970	Logs acquired
	Grays Harbor #1-35 046-027-00121 Shell Oil Co.	770	1970	Logs acquired
	Luse #1-23 046-027-00122 Shell Oil Co.	1098	1970	Logs acquired
	M.A. Baker #1-30 046-027-00123 Developmental Associates, Inc.	1280	1970	Company out of business or unknown
	Carlisle #1-23 046-027-00124 Developmental Associates, Inc.	1250	1970	Logs acquired
	Grays Harbor Co. #35-1 046-027-00125 El Paso Products Co.	760	1970	Logs requested, but not available
	Montesano #1-X 046-027-00127 El Paso Products Co.	2112	1974	Logs acquired
	Grays Harbor Co. #36-1 046-027-00128 El Paso Products Co.	807	1974	Logs requested, but not available

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
Grays Harbor	Grays Harbor #27-1 046-027-00129 El Paso Products Co.	1432	1975	Logs requested, but not available
	Caldwell Creek #1 046-027-00130 El Paso Products Co.	914	1975	Logs acquired
	Grays Harbor Co. #27-2 046-027-00131 El Paso Products Co.	954	1976	Logs requested, but not available
	Grays Harbor Co. #28-1 046-027-00129 El Paso Products Co.	1116	1976	Logs requested, but not available
	Diane #1 046-027-00133 Exploration International	337	1978	Company out of business or unknown
	Amoco-Weyerhauser #1-29 046-027-00136 AMOCO Production Co.	3747	1985	Logs acquired
Island	Socal-Whidbey #1 046-029-00004 Standard Oil Co.of California	2040	1972	Logs acquired
Jefferson	Lacey #22-1 046-031-00026 El Paso Products Co.	1744	1975	Logs requested, but not available
	Pyramid-Shearing #1 046-031-00027 Pyramid Petroleum Inc.	1501	1979	Logs acquired
	Sunburst #1 046-031-00028 Sunburst Petroleums, Ltd.	2286	1981	Company out of business or unknown
	Black Diamond #4-13 046-031-00028 Voyager Petroleums	2216	1983	Company out of business or unknown
King	WC-83-2 046-033-00028 AMOCO Production Co.	847	1983	Dip log not run
	WC-83-1 046-033-00029 AMOCO Production Co.	457	1983	Dip log not run

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
King	WC-83-10 046-033-00030 AMOCO Production Co.	346	1984	Dip log not run
	WC-83-14 046-033-00033 AMOCO Production Co.	534	1984	Dip log not run
Kitsap	WC-83-17 046-033-00037 AMOCO Production Co.	529	1984	Dip log not run
	WC-83-21 046-033-00041 AMOCO Production Co.	462	1984	Dip log not run
	Kingston #1 046-035-00010 Mobil Oil Co.	2636	1972	Logs acquired
	Pope & Talbot #18-1 046-035-00011 Union Oil Co.	1225	1972	3-arm dip log
Kittitas	Yakima Mineral Co. #2-33 046-037-00007 Shell Oil Co.	1707	1982	Logs requested, but not available
Lewis	Forest Strat Test #1 046-041-00144 Northwest Pipeline Co.	676	1975	Logs requested, but not available
	Forest Strat Test #2 046-041-00145 Northwest Pipeline Co.	905	1975	Logs requested, but not available
	Ethel Strat Test #1 046-041-00146 Northwest Pipeline Co.	487	1975	Logs requested, but not available
	Forest Strat Test #3 046-041-00149 Northwest Pipeline Co.	752	1975	Logs requested, but not available
	Forest Strat Test #5 046-041-00150 Northwest Pipeline Co.	711	1975	Logs requested, but not available
	WC-83-5 046-041-00158 Amoco Production Co.	609	1983	Dip log not run

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
Mason	Weyerhauser #C-1 046-045-00006 Amoco Production Co.	763	1985	Logs requested, but not available
Pierce	Orting #2 046-053-00012 Concept Resources	614	1976	Company out of business or unknown
	WC-83-6 046-053-00016 Amoco Production Co.	609	1984	Dip log not run
	WC-83-27 046-053-00019 Amoco Production Co.	610	1984	Dip log not run
King	WC-83-29 046-053-00023 Amoco Production Co.	312	1984	Dip log not run
	Kerryn BN #34-11 046-053-00029 L.B. Petroleum	1485	1986	Logs requested, but not available
	Wilexco-Carbonado #1-17 046-053-00035 Wilexco, Inc.	417	1986	Company out of business or unknown
	Carbon River #2-20 046-053-00042 Carbon River Energy Partnership	1829?	1986	Logs requested, but not available
	Carbon River #3-29 046-053-00043 Carbon River Energy Partnership	1829?	1986	Logs requested, but not available
	Carbon River #5-20 046-053-00044 Carbon River Energy Partnership	1829?	1986	Logs requested, but not available
	Carbon River #4-20 046-053-00046 Carbon River Energy Partnership	1829?	1986	Logs requested, but not available
	Plum Creek #23-2 046-053-000047 Meridian Oil & Gas Inc.	1402	1988	CDP log acquired
Snohomish	Socal-Schroeder #1 046-061-00013 Standard Oil Co. of California	2949	1988	Logs acquired

COUNTY	WELL API number Company	TOTAL DEPTH (m)	YEAR COMPLETED	STATUS
Stevens	Hague #1 046-065-00008 Sonex Resources Unlimited	427	1980	Company out of business or unknown
Walla Walla	Darcell-Western #1 046-071-00003 Shell Western E&P Inc.	2608	1988	Logs requested, but not available
Whatcom	Birch Bay #1 046-073-00095 American Hunter Exploration	2782	1988	Logs acquired

TABLE A-2

Summary of Wellbore Breakout Analysis

Well Name	Latitude °N Longitude °W	Depth Range of BO's	Total Length Number of BO	Length Weighted Mean SH azi	Standard Deviation	Number Weighted Mean SH azi	Standard Deviation	Quality	Comments
Birch Bay #1	48.914 122.723	366-2166 m	211 m 17	175°	20°	5°	19°	B	Increasing tool problems and hole deviation with depth
Socal-Whidbey #1	48.070 122.400	1532-2047 m	184 m 9	15°	9°	15°	10°	B	Deep, primary trend
		353-774 m	359 m 5	120°	17°	101°	25°	D	Shallow, secondary trend
Kingston #1	47.808 122.500	506-1328 m	560 m 14	117°	12°	113°	15°	B	
Socal-Schroeder #1	47.792 122.251	2137-2861	465 m 13	88°	13°	89°	15°	B	Deep, primary trend
		650-2024 m	153 m 9	149°	9°	146°	13°	D	Shallow, secondary trend
Amoco-Weyerhauser #1-29	47.110 123.680	1731-3741 m	205 m 19	27°	7°	28°	7°	B	"perfectly" shaped breakouts
Shearing #1	47.787 124.428	1158-1251 m	42 m 4	110°	6°	110°	7°	C	

Well Name	Latitude °N Longitude °W	Depth Range of BO's	Total Length Number of BO	Length Weighted Mean SH azi	Standard Deviation	Number Weighted Mean SH azi	Standard Deviation	Quality	Comments
State #30-1	48.150 123.870	939-1225 m	52 m 4	154°	8°	156°	10°	C	Hole deviates with depth
Luse #1-23	47.208 124.135	556-845 m	36 m 4	178°	6°	5°	9°	C	
Sampson John's #1-15	47.050 124.167	386-463 m	21 m 2	168°		168°		D	Small, short breakouts
LHA #1-15	47.135 124.146	165-471 m	41 m 3	14°	30°	34°	30°	D	Short, poorly shaped breakouts
Montesano #1-X	46.958 123.625	213-1688 m	296 m 5	166°	8°	168°	8°	D	Small, poorly shaped breakouts
Plum Creek #23-2	47.050 122.044	201-304 m	103 m 1	179°		179°		D	Inferred from computed dip log
Sampson John's #OC 2-15	47.040 124.150	428 m	0					E	No breakouts, location approx.
McCleave #1-33	47.200 124.200	302 m	0					E	No breakouts, location approx.
Ocean City Land #1-14	47.120 124.150	1188 m	0					E	No breakouts, location approx.
Grays Harbor Co. #1-35	47.140 124.150	543 m	0					E	No breakouts, location approx.

Well Name	Latitude °N Longitude °W	Depth Range of BO's	Total Length Number of BO	Length Weighted Mean SH azi	Standard Deviation	Number Weighted Mean SH azi	Standard Deviation	Quality	Comments
Trambitas #1-28	47.140 124.150	543 m	0					E	No breakouts, location approx.
Minard #1-34	47.120 124.150	779 m	0					E	No breakouts, location approx.
Shell OCA #1-11(7)	47.100 124.100	558 m	0					E	No breakouts, location approx.
Carlisle #1-23	47.100 124.050	718 m	0					E	No breakouts, location approx.
Shell Hogan #1-8	47.150 124.050	355 m	0					E	No breakouts, location approx.
Caldwell Creek #1	47.100 123.650	507 m	0					E	No breakouts, location approx.
Darcell-Western #1-10	46.300 118.650	2546 m	0					E	6-arm dip log, unable to interpret, location approx.

APPENDIX 2

Details of log observations for each of 12 wells with wellbore enlargements.

Summary statistical analysis for each of 12 wells with wellbore enlargements.

RECORD OF LOG OBSERVATIONS

****

WASHINGTON STATE DATA
BIRCH BAY #1
2 WA294 DECL=23.0 LAT=48.914 LON=-122.723
WHATCOM CO., WASHINGTON, AMERICAN HUNTER EXPL.

****

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	1202.	1212.	250.	205.	0.5	45.	2	ONE OF SERIES OF SHRT BO W/IN GOOD ROT
01	1216.	1228.	240.	193.	0.75	47.	2	DITTO
01	1242.	1264.	255.	210.	0.75	45.	2	DITTO
02	1386.	1460.	330.	278.	1.0	52.	2	GOOD ROT ABV, BLW, OK SHAPE
01	1464.	1486.	310.	260.	1.0	50.	4	WOBBLY TOOL, DOESN'T LOCK IN
02	1488.	1550.	325.	275.	1.0	50.	4	LOUSY SHAPE; LOSE RB, AHD BELOW
02	2170.	2270.	345.	295.	0.0	50.	2	GOOD SHAPE, ROT; NO RB, AHD SO FAKED
01	2274.	2290.	250.	200.	0.0	50.	2	GOOD SHAPE, ROT; NO RB, AHD SO FAKED
02	2362.	2422.	155.	205.	0.75	310.	2	GOOD SHAPE, ROT; AHD, RB RTN AT MID
02	2440.	2496.	190.	215.	1.0	335.	4	OK SHAPE, SOME ROT THRU, BLW WO ZONE
01	2846.	2888.	90.	115.	0.0	335.	4	INCL 4 BO'S; PR ROT ABV, GD BLW
02	2914.	2970.	130.	95.	0.5	35.	2	OK SHAPE, GD ROT ABV, TOOL FLPS BLW
01	2970.	2992.	110.	75.	0.75	35.	2	GOOD SHAPE AND ROTATION ABV, BLW
02	3066.	3080.	355.	310.	0.75	45.	2	GD SHAPE; FLIPS ABV, BLW;
02	3142.	3150.	240.	200.	2.0	40.	4	V.SHORT; GD SHAPE, ROT; ?LOCKED IN?
01	3206.	3258.	275.	230.	2.0	45.	3	PR SHAPE TILL END; GOOD ROT ABV, BLW
02	3260.	3282.	180.	140.	1.75	40.	1	GOOD SHAPE; TOOL FLIPS ABV, BLW
01	3284.	3300.	275.	235.	2.0	40.	1	GOOD SHAPE AND ROTATION
01	3300.	3370.	250.	210.	2.0	40.	4	POOR SHAPE W/ ROTATION THRU
01	3390.	3400.	250.	225.	2.0	25.	3	V SHORT, GOOD SHAPE AND ROTATION
02	3550.	3560.	160.	140.	1.5	20.	3	SHORT; ROT ABV, BLW;
01	3562.	3572.	190.	170.	2.0	10.	5	KS; AHD WOBBLY
01	3676.	3690.	260.	240.	1.5	20.	3	BELOW WO, SHAPE POOR, ROT BLW
01	3816.	3896.	250.	245.	1.8	5.	2	NUM SHRT BO'S; GOOD SHAPE,ROT
01	3900.	3968.	275.	270.	2.0	5.	4	POOR SHAPE, SOME TOOL ROT;
01	4008.	4018.	260.	250.	2.0	10.	4	GOOD SHAPE, POOR ROT; UNREAD AZI.
01	4100.	4144.	280.	270.	1.5	10.	4	POOR SHAPE; GOOD ROT ABV, BLW
01	4144.	4170.	240.	220.	1.5	20.	2	GOOD SHAPE, ROTATION
01	4280.	4340.	270.	265.	2.0	5.	3	5 SHRT SHRP BO'S, GOOD ROT
02	4646.	4658.	185.	175.	3.0	10.	2	SHRT, PEAKY; GOOD ROT; CONS AZI;
02	4678.	4686.	190.	180.	3.0	10.	3	SHORT, NOT LOCKED IN??
01	4924.	4936.	360.	340.	2.5	20.	4	GD SHP, SOME ROT ABV, STUCK BELOW
01	4990.	5038.	310.	290.	3.0	20.	4	R THRU U.SECT; GD R ABV, BLW;PR SHAPE
01	5102.	5170.	230.	205.	3.0	25.	4	OK SHP, TOOL STICK IN MIDL, PR ROT BLW
02	5352.	5366.	280.	255.	3.5	25.	4	GD SHP, DOESN'T LOCK IN, GD ROT
02	5534.	5568.	280.	245.	3.0	35.	4	TOOL STUCK BELOW, OK ROT ABV; GD SHAPE
02	5590.	5610.	290.	250.	3.0	40.	4	TOOL STUCK ABV. GD ROT BLW, PR SHAPE
02	5950.	5975.	195.	180.	2.5	15.	4	SOME ROT ABV, BLW; SHRT PEAKY
02	6004.	6040.	165.	150.	3.0	15.	2	GOOD SHAPE, ROTATION
01	6114.	6126.	35.	25.	3.0	10.	4	GD SHP, ROT ABV, STUCK BLW, HRD 2 READ
02	6202.	6230.	330.	320.	3.5	10.	2	GD ROT ABV, SOME BLW, PEAKY SHAPE
02	6350.	6400.	360.	345.	4.0	15.	4	SHRT PEAKY; STUCK BLW, ROT ABV
01	6550.	6742.	47.	57.	3.0	350.	3	CASING ABV, ROT BLW; 10' WO IN MID
02	6755.	6838.	320.	340.	2.8	340.	4	GD ROT ABV, BLW; NUM SHRT BO'S, PR SHP
01	6842.	6920.	210.	220.	2.5	350.	2	GOOD ROT ABV, BLW
02	6968.	7106.	305.	320.	2.0	345.	2	GOOD ROT, OK SHAPE; IGNEOUS SILL
02	7550.	7664.	125.	135.	2.5	350.	4	BETW WO ZONES, POOR ROT
01	7712.	7770.	40.	60.	2.75	340.	4	TOOL STUCK, WO ABV N BLW, NO ROT
01	7814.	7900.	50.	65.	2.8	345.	3	WO ABOVE, GOOD ROT BELOW
02	8004.	8070.	320.	350.	2.25	330.	3	GOOD ROT ABV, NONE BLW; RB FLIPS
02	8074.	8106.	345.	15.	2.5	330.	3	OK SHAPE, ROT
02	8110.	8170.	310.	345.	3.5	325.	3	SOME ROT ABV N BLW
02	8302.	8390.	330.	20.	5.5	310.	3	OK SHAPE, KS ABV N BLW
02	8410.	8480.	325.	25.	6.5	300.	4	KS ABV, BLW, POOR SHAPE

WASHINGTON STATE DATA
SOCAL-WHIDBEY #1
0 WA25 20.0 48.07 -122.40
ISLAND CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	6656.	6692.	010.0	050.0	2.500		3	BOTTOM OF HOLE, NOISY TOOL
02	6622.	6636.	110.0	150.0	2.500		3	NOISY TOOL
01	6612.	6622.	205.0	255.0	2.750		3	HARD TO READ DUE TO SLOW ROTATION
02	6584.	6590.	190.0	230.0	2.750		3	DITTO
02	6572.	6580.	200.0	245.0	2.250		3	DITTO
01	6504.	6514.	125.0	180.0	1.500		3	DOESN'T LOCK IN
02	6232.	6238.	005.0	015.0	0.000		3	SMALL QUESTIONABLE B.O.--DON'T USE
01	5960.	5990.	070.0	230.0	0.000		4	WASHED OUT
01	5728.	5885.	265.0	050.0	1.000		1	GOOD ROTATION ABOVE AND BELO
02	5696.	5712.	345.0	135.0	0.500		1	DITTO
02	5645.	5690.	010.0	150.0	0.500		1	SMALL
02	5548.	5560.	175.0	325.0	1.250		1	
02	5510.	5524.	180.0	335.0	1.000		1	
02	5470.	5510.	165.0	315.0	1.000		1	
01	5384.	5450.	255.0	040.0	1.000		1	
02	5120.	5310.	170.0	310.0	1.750		1	
02	5026.	5090.	195.0	340.0	2.000		1	
02	4984.	5008.	155.0	310.0	1.750		4	WASHED OUT
02	4838.	4848.	220.0	010.0	2.000		3	QUESTIONABLE
02	4824.	4830.	185.0	000.0	2.500		3	MAY BE KEY SEAT
02	4602.	4698.	045.0	210.0	3.000		3	AT END OF WO
02	4515.	4558.	120.0	270.0	4.000		3	MAYBE KEY SEAT
01	4130.	4514.	130.0	280.0	4.000		4	WASH OUT
01	4064.	4130.	230.0	000.0	4.500		3	MAY BE KEY SEAT
02	3950.	4050.	310.0	095.0	4.500		3	MAYBE KEY SEAT
01	3822.	3950.	035.0	180.0	4.500		4	WASH OUT
02	3760.	3822.	085.0	245.0	4.500		4	WASHED OUT
02	3664.	3750.	050.0	225.0	4.500		4	WASHED OUT
02	3600.	3614.	050.0	220.0	4.500		4	PART OF WO
01	3572.	3582.	210.0	015.0	4.000		3	DITTO
01	3476.	3490.	020.0	200.0	3.750		3	
02	3444.	3458.	120.0	285.0	3.500		3	
02	3426.	3440.	165.0	335.0	3.500		3	
02	3392.	3408.	110.0	270.0	3.500		3	MAY BE KEY SEAT
01	3382.	3392.	150.0	000.0	4.000		3	MAY BE KEY SEAT
01	3375.	3382.	150.0	000.0	4.000		3	MAY BE KEY SEAT
01	3356.	3375.	160.0	000.0	4.000		3	MAY BE KEY SEAT
01	3130.	3225.	020.0	200.0	4.000		4	WASHED OUT
01	3066.	3130.	040.0	185.0	5.000		3	?KEY SEAT
02	2998.	3066.	120.0	280.0	5.000		3	?KEY SEAT
	[illegible]984.	2996.	150.0	310.0	5.000		3	
02	2948.	2964.	160.0	330.0	5.000		3	
02	2884.	2940.	140.0	310.0	5.000		4	?WASHOUT
02	2846.	2873.	140.0	300.0	4.500		4	?WASHOUT
01	2538.	2400.	020.0	220.0	4.500		3	NOT GOOD SHAPE
02	2338.	2380.	060.0	270.0	4.500		2	TOOL ROTATION ABOVE AND BELOW
01	2264.	2330.	150.0	310.0	4.250		2	DITTO
02	1600.	2260.	110.0	315.0	4.250		3	TOOL LOCKS THEN ROTATES OUT
02	1442.	1475.	045.0	200.0	2.250		2	
01	1160.	1440.	170.0	290.0	2.250		3	NOT GOOD SHAPE

WASHINGTON STATE DATA
SOCAL-WHIDBEY #1 SHALLOW
0 WA282 20.0 48.07 -122.40
ISLAND CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	2538.	2400.	020.0	220.0	4.500		3	NOT GOOD SHAPE
02	2338.	2380.	060.0	270.0	4.500		2	TOOL ROTATION ABOVE AND BELOW
01	2264.	2330.	150.0	310.0	4.250		2	DITTO
02	1600.	2260.	110.0	315.0	4.250		3	TOOL LOCKS THEN ROTATES OUT
02	1442.	1475.	045.0	200.0	2.250		2	
01	1160.	1440.	170.0	290.0	2.250		3	NOT GOOD SHAPE

WASHINGTON STATE DATA
KINGSTON 1
0 WA284 22.0 47.808 -122.500
KITSAP CO., WASHINGTON, MOBIL OIL CO.
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	5000.	5006.	130.0	310.0	2.000		3	NEVER LOCKS IN
01	4914.	4980.	170.0	350.0	2.000		3	
02	4780.	4890.	265.0	095.0	2.000		4	WASHOUT
01	4596.	4712.	345.0	180.0	2.000		3	
01	4310.	4358.	350.0	195.0	2.000		2	BOTH ARMS > BIT SIZE
02	4226.	4234.	080.0	300.0	2.000		2	SMALL
02	4206.	4216.	080.0	300.0	2.000		2	SMALL
01	3984.	4054.	360.0	210.0	2.000		1	
01	3584.	3737.	360.0	210.0	2.000		1	
01	3516.	3534.	360.0	210.0	2.000		1	
01	3434.	3510.	335.0	080.0	2.000		1	
02	3310.	3434.	070.0	290.0	2.000		1	
02	3275.	3290.	110.0	340.0	2.000		2	
01	3214.	3260.	180.0	050.0	2.000		1	
02	2910.	3214.	290.0	150.0	2.000		1	
02	2670.	2706.	310.0	170.0	2.000		2	
02	2370.	2650.	280.0	150.0	2.000		2	NOISY
01	1660.	2310.	185.0	125.0	2.000		1	DEPTH RANGE INFERRED FROM REPEAT SECTIO

WASHINGTON STATE DATA
SOCAL-SCHROEDER #1
0 WA23 22.0 47.792 -122.251
SNOHOMISH CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
02	9420.		170.0	110.0	3.000		4	TROUBLE LOCKING IN
01	9300.	9365.	185.0	160.0	2.000		2	
01	9250.	9296.	175.0	155.0	2.000		2	
02	9178.	9232.	260.0	255.0	1.500		2	
02	9036.	9041.	065.0	055.0	1.500		2	SHORT
02	8920.	8970.	060.0	045.0	1.500		2	
02	8896.	8920.	040.0	010.0	1.500		2	
02	8394.	8770.	235.0	205.0	3.000		1	EXCELLENT, CONSISTENT
02	8352.	8366.	235.0	205.0	2.750		1	SMALL
01	8240.	8316.	325.0	290.0	2.750		3	UNUSUAL SHAPE
01	7930.	8185.	330.0	250.0	3.000		1	LARGE, CONSISTENT
01	7880.	7900.	355.0	265.0	3.000		2	
02	7594.	7820.	260.0	170.0	3.000		2	
01	7390.	7450.	350.0	240.0	2.500		2	

02	7010.	7320.	240.0	220.0	2.000		2	
02	6840.	6950.	320.0	220.0	2.000		3	SERIES OF SMALL, SHARP ENLARGEMENTS, JU
01	6550.	6640.	040.0	320.0	1.000		3	
02	6520.	6550.	090.0	360.0	1.250		3	
02	6346.	6352.	000.0	300.0	1.000		4	WASHED OUT
02	6252.	6274.	135.0	060.0	1.750		3	
02	6176.	6184.	310.0	230.0	1.750		3	SHORT
02	5920.	5936.	130.0	050.0	1.750		3	ROTATING THROUGH
02	5542.	5620.	320.0	100.0	1.000		5	KEY SEAT
02	5130.	5240.	310.0	260.0	1.250		5	KEY SEAT
01	4648.	4740.	050.0	185.0	2.100		5	KEY SEAT
01	4186.	4210.	030.0	270.0	1.000		3	SHORT
02	3334.	3950.	280.0	090.0	1.750		5	KEY SEAT
01	3270.	3330.	260.0	075.0	1.750		4	DOESN'T LOCK IN
02	2990.	3260.	310.0	120.0	1.750		3	SIX B.O.'S, APPROX. 20' LONG
01	2830.	2940.	025.0	360.0	1.500		5	PROBABLE KEY SEAT
01	2676.	2830.	030.0	350.0	1.500		5	PROBABLE KEY SEAT
01	2650.	2676.	050.0	350.0	1.500		5	PROBABLE KEY SEAT
01	2240.	2260.	065.0	280.0	0.500		5	KEY SEAT
01	2160.	2186.	040.0	280.0	0.750		3	
01	2134.	2150.	025.0	295.0	0.750		3	
01	1910.	2054.	000.0	360.0	1.250		5	KEY SEAT
01	1580.	1840.	000.0	170.0	1.000		5	KEYSEAT

WASHINGTON STATE DATA
SOCAL-SCHROEDER #1 SHALLOW
0 WA2 22.0 47.792 -122.251
SNOHOMISH CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
02	6840.	6950.	320.0	220.0	2.000		4	SERIES OF SMALL, SHARP ENLARGEMENTS, JU
01	6550.	6640.	040.0	320.0	1.000		3	
02	6520.	6550.	090.0	360.0	1.250		3	
02	6346.	6352.	000.0	300.0	1.000		4	WASHED OUT
02	6252.	6274.	135.0	060.0	1.750		3	
02	6176.	6184.	310.0	230.0	1.750		3	SHORT
02	5920.	5936.	130.0	050.0	1.750		3	ROTATING THROUGH
02	5542.	5620.	320.0	100.0	1.000		5	KEY SEAT
02	5130.	5240.	310.0	260.0	1.250		5	KEY SEAT
01	4648.	4740.	050.0	185.0	2.100		5	KEY SEAT
01	4186.	4210.	030.0	270.0	1.000		3	SHORT
02	3334.	3950.	280.0	090.0	1.750		5	KEY SEAT
01	3270.	3330.	260.0	075.0	1.750		4	DOESN'T LOCK IN
02	2990.	3260.	310.0	120.0	1.750		3	SIX B.O.'S, APPROX. 20' LONG
01	2830.	2940.	025.0	360.0	1.500		5	PROBABLE KEY SEAT
01	2676.	2830.	030.0	350.0	1.500		5	PROBABLE KEY SEAT
01	2650.	2676.	050.0	350.0	1.500		5	PROBABLE KEY SEAT
01	2240.	2260.	065.0	280.0	0.500		5	KEY SEAT
01	2160.	2186.	040.0	280.0	0.750		3	
01	2134.	2150.	025.0	295.0	0.750		3	
01	1910.	2054.	000.0	360.0	1.250		5	KEY SEAT
01	1580.	1840.	000.0	170.0	1.000		5	KEYSEAT

WASHINGTON STATE DATA
AMOCO WEYERHAUSER 1-29
0 WA283 20.0 47.110 -123.680
WASHINGTON, GRAYS HARBOR CO., AMOCO

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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	12202.	12274.	270.0	140.0	1.000		2	TOO SMALL
01	12124.	12167.	270.0	150.0	1.000		1	
01	11970.	11994.	290.0	160.0	1.000		1	
01	11940.	11956.	280.0	160.0	1.000		1	
01	11860.	11940.	280.0	160.0	1.000		2	TOO SMALL
01	11382.	11430.	275.0	135.0	1.000		1	
02	11328.	11340.	010.0	225.0	1.000		1	
02	11292.	11308.	020.0	240.0	1.000		1	
02	11260.	11286.	020.0	235.0	1.000		1	
02	11240.	11260.	015.0	225.0	1.000		1	
02	11220.	11240.	010.0	215.0	1.000		1	
02	11170.	11220.	010.0	215.0	1.000		2	TOO SMALL
01	10964.	10980.	270.0	110.0	1.000		2	SLIGHT ROTATION
01	10948.	10964.	320.0	160.0	1.000		3	TOOL STILL ROTATING, MAX READ
01	10590.	10680.	345.0	170.0	0.500		5	KEY SEAT
02	10545.	10570.	050.0	240.0	0.500		3	SMALL & TOOL STILL ROTATING
02	10370.	10434.	185.0	025.0	0.500		1	
02	10350.	10370.	195.0	035.0	0.500		2	SMALL
01	10300.	10335.	270.0	100.0	0.500		1	
02	10254.	10264.	010.0	185.0	0.500		2	QUESTIONABLE
01	10174.	10210.	160.0	340.0	0.500		3	V.SMALL AND TOOL STILL ROTATING
02	10060.	10154.	270.0	105.0	0.500		3	V.SMALL AND TOOL ROTATING
01	9990.	10022.	000.0	160.0	0.500		3	V.SMALL, BELOW CASING, AND TOOL ROTATIN
01	5780.	5820.	270.0	060.0	1.000		1	FROM RUN2, HIGH ANGLE TOOL
01	5680.	5740.	270.0	060.0	1.000		1	DITTO

WASHINGTON STATE DATA
SHEARING 1
0 WA286 20.0 47.792 -124.425
JEFFERSON CO., WASHINGTON, PYRAMID PETROLEUM CORP.

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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	4082.	4104.	010.0	130.0	4.000		1	
01	4040.	4070.	170.0	305.0	4.000		1	
01	3850.	3906.	000.0	110.0	4.000		1	
02	3800.	3850.	090.0	220.0	4.000		1	
01	3180.	3370.	240.0	010.0	4.000		4	WASHOUT
01	3080.	3120.	270.0	030.0	4.000		4	WASHOUT
01	2960.	2985.	080.0	200.0	4.[illegible]		3	TOOL ROTATING THRU BO
01	2880.	2930.	220.0	360.0	4.[illegible]		5	KEY SEAT
02	2790.	2880.	330.0	085.0	4.000		5	KEY SEAT
01	0910.	2790.	060.0	180.0	4.000		5	KEY SEAT

WASHINGTON STATE DATA
STATE #1-30
2 WA303 22.0 48.100 -123.800
CLALLUM CO., WASHINGTON, TWIN RIVERS
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PAD	TOP	BOT	AZ1	RB	VD	AHD	Q COMMENTS
01	5730.	6600.	185.0	000.0	7.500	015.04	NO ROTATION
01	5580.	5660.	185.0	000.0	7.500	015.04	NR
02	5550.	5580.	115.0	000.0	7.500	015.03	ROT ABOVE
01	5210.	5545.	200.0	000.0	7.500	015.03	ROT BELOW
01	5030.	5190.	200.0	000.0	7.000	015.03	ROT BELOW
02	4850.	4970.	120.0	000.0	6.000	015.05	END OF RUN; CONSISTENT REPEAT SECTION
01	4090.	4345.	195.0	0.0	3.000	015.03	3 SMALL BO'S--MAY SPLIT THIS LATER
01	3994.	4020.	060.0	0.0	2.500	015.01	GOOD SHAPE; ROT ABOVE & BELOW
01	3750.	3770.	035.0	0.0	2.250	005.02	
01	3590.	3620.	120.0	0.0	1.750	005.03	GOOD ROT; POOR SHAPE
02	3520.	3550.	300.0	0.0	1.670	000.03	DITTO
02	3220.	3400.	100.0	0.0	1.500	000.04	WO
02	3165.	3220.	130.0	0.0	2.000	005.02	ENDS IN WO BELOW
01	3080.	3150.	220.0	0.0	2.000	005.02	
01	2980.	3080.	180.0	0.0	2.000	010.03	POOR SHAPE
01	2832.	2900.	250.0	0.0	2.000	010.03	POOR SHAPE
01	2800.	2832.	255.0	0.0	2.000	010.03	drifts-but use as mode 2, 1bo
02	2440.	2700.	220.0	0.0	1.500	025.03	POOR SHAPE
01	2310.	2420.	280.0	0.0	1.500	040.03	poor shape
02	2190.	2240.	080.0	0.0	1.750	035.03	POOR SHAPE

WASHINGTON STATE DATA
SHELL LUSE 1-23
0 WA285 20.0 46.208 -124.135
GRAYS HARBOR CO., WASHINGTON, SHELL
****

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
02	3322.	3400.	075.0	210.0	2.000		3	TOOL ROTATING
02	2760.	2772.	320.0	150.0	2.000		2	
02	2722.	2738.	340.0	170.0	2.000		2	SMALL
02	2480.	2524.	095.0	280.0	2.000		3	SMALL
01	2394.	2460.	000.0	200.0	2.000		3	SMALL
02	1970.	1996.	340.0	200.0	2.000		2	
01	1825.	1890.	250.0	120.0	2.000		2	

WASHINGTON STATE DATA
SAMPSON JOHN'S 1-15
0 WA287 20.0 47.100 -124.300
GRAYS HARBOR CO., WASHINGTON, SHELL
****

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
02	1512.	1520.	325.0	070.0	2.000		1	
02	1485.	1500.	325.0	080.0	2.000		5	KEYSEAT
01	1410.	1450.	010.0	140.0	2.000		3	V. SMALL
01	1346.	1410.	040.0	170.0	2.000		5	KEYSEAT
01	1268.	1330.	060.0	200.0	2.000		1	

WASHINGTON STATE DATA
GRAYS HARBOR LHA 1-15
0 WA288 20.0 47.135 -124.146
GRAYS HARBOR CO., WASHINGTON, SHELL
****

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	1545.	1565.	055.0	115.0	0.000		3	V.SMALL, POOR SHAPE
01	1235.	1300.	135.0	195.0	0.000		2	
01	540.	590.	080.0	065.0	0.000		2	

WASHINGTON STATE DATA
MONTESANO 1-X
0 WA24 20.0 46.958 -123.625
GRAYS HARBOR, WASHINGTON, EL PASO PRODUCTS
****

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
02	5472.	5540.	160.0	315.0	1.000		2	VERY SMALL
02	5220.	5450.	290.0	100.0	1.200		2	VERY SMALL, KEY SEAT
02	5190.	5220.	320.0	140.0	1.200		2	SMALL
02	5120.	5180.	260.0	070.0	1.500		3	SMALL
02	5015.	5106.	220.0	040.0	2.000		3	SMALL
01	2954.	2992.	235.0	030.0	4.000		2	SMALL AND GRADUAL
01	2410.	2930.	230.0	030.0	6.500		2	LONG, SMALL, AND GRADUAL
02	2150.	2410.	145.0	080.0	6.000		4	SLOWLY ROTATING OVER LENGTH
02	700.	1015.	335.0	115.0	5.000		2	LARGE, ENDS IN WASHOUT

WASHINGTON STATE DATA
PLUM CREEK 23-2
2 WA289 0.0 47.135 -122.146
****
PIERCE CO., WASHINGTON, MERIDIAN OIL CO., READ FROM CPD LOG

PAD	TOP	BOT	AZ1	RB	VD	AHD	Q	COMMENTS
01	3330.	3380.	231.0		13.0	237.	5	KEY SEAT
01	3050.	3180.	230.0		13.0	238.	5	KEY SEAT
01	1580.	1608.	234.0		7.0	264.	4	WASHOUT
01	660.	1000.	268.9		3.0	252.	3	QUESTIONABLE ROTATION

BIRCH BAY #1

LATITUDE = 48.9140 LONGITUDE =-122.7230 DECLINATION = 23.0
WHATCOM CO., WASHINGTON, AMERICAN HUNTER EXPL.

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	10.0	1.0	2	-87.0	68.0	0.5	1202.0	1212.0
2	12.0	1.0	2	83.0	70.0	0.8	1216.0	1228.0
3	22.0	1.0	2	-82.0	68.0	0.8	1242.0	1264.0
4	74.0	1.0	5	83.0	75.0	1.0	1386.0	1460.0
5	22.0	1.0	4	-27.0	73.0	1.0	1464.0	1486.0
6	62.0	1.0	5	78.0	73.0	1.0	1488.0	1550.0
7	100.0	1.0	2	-82.0	73.0	0.0	2170.0	2270.0
8	16.0	1.0	2	-87.0	73.0	0.0	2274.0	2290.0
9	60.0	1.0	2	88.0	333.0	0.8	2362.0	2422.0
10	56.0	1.0	4	-57.0	358.0	1.0	2440.0	2496.0
11	42.0	1.0	4	-67.0	358.0	0.0	2846.0	2888.0
12	56.0	1.0	5	63.0	58.0	0.5	2914.0	2970.0
13	22.0	1.0	2	-47.0	58.0	0.8	2970.0	2992.0
14	14.0	1.0	2	-72.0	68.0	0.8	3066.0	3080.0
15	8.0	1.0	4	-7.0	63.0	2.0	3142.0	3150.0
16	52.0	1.0	3	-62.0	68.0	2.0	3206.0	3258.0
17	22.0	1.0	1	-67.0	63.0	1.8	3260.0	3282.0
18	16.0	1.0	1	-62.0	63.0	2.0	3284.0	3300.0
19	70.0	1.0	4	-87.0	63.0	2.0	3300.0	3370.0
20	10.0	1.0	3	-87.0	48.0	2.0	3390.0	3400.0
21	10.0	1.0	3	-87.0	43.0	1.5	3550.0	3560.0
22	10.0	1.0	5	33.0	33.0	2.0	3562.0	3572.0
23	14.0	1.0	3	-77.0	43.0	1.5	3676.0	3690.0
24	80.0	1.0	2	-87.0	28.0	1.8	3816.0	3896.0
25	68.0	1.0	4	-62.0	28.0	2.0	3900.0	3968.0
26	10.0	1.0	4	-77.0	33.0	2.0	4008.0	4018.0
27	44.0	1.0	4	-57.0	33.0	1.5	4100.0	4144.0
28	26.0	1.0	2	83.0	43.0	1.5	4144.0	4170.0
29	60.0	1.0	3	-67.0	28.0	2.0	4280.0	4340.0
30	12.0	1.0	2	-62.0	33.0	3.0	4646.0	4658.0
31	8.0	1.0	3	-57.0	33.0	3.0	4678.0	4686.0
32	12.0	1.0	4	23.0	43.0	2.5	4924.0	4936.0
33	48.0	1.0	4	-27.0	43.0	3.0	4990.0	5038.0
34	68.0	1.0	4	73.0	48.0	3.0	5102.0	5170.0
35	14.0	1.0	4	33.0	48.0	3.5	5352.0	5366.0
36	34.0	1.0	4	33.0	58.0	3.0	5534.0	5568.0
37	20.0	1.0	4	43.0	63.0	3.0	5590.0	5610.0
38	25.0	1.0	4	-52.0	38.0	2.5	5950.0	5975.0
39	36.0	1.0	2	-82.0	38.0	3.0	6004.0	6040.0
40	12.0	1.0	4	58.0	33.0	3.0	6114.0	6126.0
41	28.0	1.0	2	83.0	33.0	3.5	6202.0	6230.0
42	50.0	1.0	4	-67.0	38.0	4.0	6350.0	6400.0
43	192.0	1.0	3	70.0	13.0	3.0	6550.0	6742.0
44	83.0	1.0	4	73.0	3.0	2.8	6755.0	6838.0
45	78.0	1.0	2	53.0	13.0	2.5	6842.0	6920.0
46	138.0	1.0	2	58.0	8.0	2.0	6968.0	7106.0
47	114.0	1.0	4	58.0	13.0	2.5	7550.0	7664.0
48	58.0	1.0	4	63.0	3.0	2.8	7712.0	7770.0
49	86.0	1.0	3	73.0	8.0	2.8	7814.0	7900.0
50	66.0	1.0	3	73.0	353.0	2.3	8004.0	8070.0

51	32.0	1.0	3	-82.0	35[illegible].0	2.5	8074.0	8106.0
52	60.0	1.0	3	63.0	348.0	3.5	8110.0	8170.0
53	88.0	1.0	3	83.0	333.0	5.5	8302.0	8390.0
54	70.0	1.0	4	78.0	323.0	6.5	8410.0	8480.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 50 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 17 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 84.2 E +- 23.9 DEGREES	SHmin = N 84.7 E +- 20.4 DEGREES
SHmax = N 5.8 W +- 23.9 DEGREES	SHmax = N 5.3 W +- 20.4 DEGREES
STANDARD ERROR = 1.0 DEGREES	STANDARD ERROR = 1.5 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 87.1 W +- 26.9 DEGREES	SHmin = N 84.7 W +- 18.6 DEGREES
SHmax = N 2.9 E +- 26.9 DEGREES	SHmax = N 5.3 E +- 18.6 DEGREES
STANDARD ERROR = 7.4 DEGREES	STANDARD ERROR = 9.9 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 21.8 E +- 26.6 DEGREES
STANDARD ERROR = 1.1 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 70.5 +- 30.6 DEGREES
STANDARD ERROR = 1.2 DEGREES

WHIDBEY #1

LATITUDE = 48.0700 LONGITUDE =-122.4000 DECLINATION = 20.0
ISLAND CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA, WHIDBEY #1

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	36.0	1.0	3	30.0	340.0	2.5	6656.0	6692.0
2	14.0	1.0	3	40.0	340.0	2.5	6622.0	6636.0
3	10.0	1.0	3	45.0	330.0	2.8	6612.0	6622.0
4	6.0	1.0	3	-60.0	340.0	2.8	6584.0	6590.0
5	8.0	1.0	3	-50.0	335.0	2.3	6572.0	6580.0
6	10.0	1.0	5	-35.0	325.0	1.5	6504.0	6514.0
7	6.0	1.0	3	-65.0	10.0	0.0	6232.0	6238.0
8	30.0	1.0	4	90.0	220.0	0.0	5960.0	5990.0
9	157.0	1.0	1	-75.0	235.0	1.0	5728.0	5885.0
10	16.0	1.0	1	-85.0	230.0	0.5	5696.0	5712.0
11	45.0	1.0	1	-60.0	240.0	0.5	5645.0	5690.0
12	12.0	1.0	1	-75.0	230.0	1.3	5548.0	5560.0
13	14.0	1.0	1	-70.0	225.0	1.0	5510.0	5524.0
14	40.0	1.0	1	-85.0	230.0	1.0	5470.0	5510.0
15	66.0	1.0	1	-85.0	235.0	1.0	5384.0	5450.0
16	190.0	1.0	1	-80.0	240.0	1.8	5120.0	5310.0
17	64.0	1.0	1	-55.0	235.0	2.0	5026.0	5090.0
18	24.0	1.0	4	85.0	225.0	1.8	4984.0	5008.0
19	10.0	1.0	3	-30.0	230.0	2.0	4838.0	4848.0
20	6.0	1.0	3	-65.0	205.0	2.5	4824.0	4830.0
21	96.0	1.0	3	-25.0	215.0	3.0	4602.0	4698.0
22	43.0	1.0	5	50.0	230.0	4.0	4515.0	4558.0
23	384.0	1.0	4	-30.0	230.0	4.0	4130.0	4514.0
24	66.0	1.0	5	70.0	250.0	4.5	4064.0	4130.0
25	100.0	1.0	5	60.0	235.0	4.5	3950.0	4050.0
26	128.0	1.0	5	55.0	235.0	4.5	3822.0	3950.0
27	62.0	1.0	4	15.0	220.0	4.5	3760.0	3822.0
28	86.0	1.0	4	-20.0	205.0	4.5	3664.0	3750.0
29	14.0	1.0	4	-20.0	210.0	4.5	3600.0	3614.0
30	10.0	1.0	3	50.0	215.0	4.0	3572.0	3582.0
31	14.0	1.0	3	40.0	200.0	3.8	3476.0	3490.0
32	14.0	1.0	3	50.0	215.0	3.5	3444.0	3458.0
33	14.0	1.0	3	-85.0	210.0	3.5	3426.0	3440.0
34	16.0	1.0	5	40.0	220.0	3.5	3392.0	3408.0
35	10.0	1.0	5	-10.0	170.0	4.0	3382.0	3392.0
36	7.0	1.0	5	-10.0	170.0	4.0	3375.0	3382.0
37	19.0	1.0	5	0.0	180.0	4.0	3356.0	3375.0
38	95.0	1.0	4	40.0	200.0	4.0	3130.0	3225.0
39	64.0	1.0	5	60.0	235.0	5.0	3066.0	3130.0
40	68.0	1.0	5	50.0	220.0	5.0	2998.0	3066.0
41	12.0	1.0	3	80.0	220.0	5.0	2984.0	2996.0
42	16.0	1.0	3	90.0	210.0	5.0	2948.0	2964.0
43	56.0	1.0	4	70.0	210.0	5.0	2884.0	2940.0
44	27.0	1.0	4	70.0	220.0	4.5	2846.0	2873.0
45	138.0	1.0	3	40.0	180.0	4.5	2538.0	2400.0
46	42.0	1.0	5	-10.0	170.0	4.5	2338.0	2380.0
47	66.0	1.0	2	-10.0	220.0	4.3	2264.0	2330.0
48	660.0	1.0	3	40.0	175.0	4.3	1600.0	2260.0
49	33.0	1.0	2	-25.0	225.0	2.3	1442.0	1475.0
50	280.0	1.0	3	10.0	260.0	2.3	1160.0	1440.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 38 BREAKOUTS)	FOR DATA OF QUALITY 1 OR BETTER (INCLUDES 9 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 27.1 E +- 37.5 DEGREES	SHmin = N 75.4 W +- 9.2 DEGREES
SHmax = N 62.9 W +- 37.5 DEGREES	SHmax = N 14.6 E +- 9.2 DEGREES
STANDARD ERROR = 1.4 DEGREES	STANDARD ERROR = 0.7 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 85.2 W +- 35.9 DEGREES	SHmin = N 74.6 W +- 10.3 DEGREES
SHmax = N 4.8 E +- 35.9 DEGREES	SHmax = N 15.4 E +- 10.3 DEGREES
STANDARD ERROR = 11.4 DEGREES	STANDARD ERROR = 8.4 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 34.6 E +- 27.1 DEGREES
STANDARD ERROR = 1.0 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 60.1 +- 31.0 DEGREES
STANDARD ERROR = 1.1 DEGREES

WHIDBEY #1 SHALLOW

LATITUDE = 48.0700 LONGITUDE =-122.4000 DECLINATION = 20.0
ISLAND CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA, WHIDBEY #1

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	138.0	1.0	3	40.0	180.0	4.5	2538.0	2400.0
2	42.0	1.0	5	-10.0	170.0	4.5	2338.0	2380.0
3	66.0	1.0	2	-10.0	220.0	4.3	2264.0	2330.0
4	660.0	1.0	3	40.0	175.0	4.3	1600.0	2260.0
5	33.0	1.0	2	-25.0	225.0	2.3	1442.0	1475.0
6	280.0	1.0	3	10.0	260.0	2.3	1160.0	1440.0

FOR DATA OF QUALITY 3 OR BETTER
(INCLUDES 5 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

SHmin = N 29.9 E +- 17.2 DEGREES
SHmax = N 60.1 W +- 17.2 DEGREES
STANDARD ERROR = 1.0 DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

SHmin = N 11.4 E +- 24.9 DEGREES
SHmax = N 78.6 W +- 24.9 DEGREES
STANDARD ERROR = 34.6 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 4.2 E +- 29.8 DEGREES
STANDARD ERROR = 1.7 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 56.6 +- 0.0 DEGREES
STANDARD ERROR = 0.0 DEGREES

KINGSTON 1

LATITUDE = 47.8080 LONGITUDE =-122.5000 DECLINATION = 22.0
KITSAP CO., WASHINGTON, MOBIL OIL CO.

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	6.0	1.0	3	-28.0	202.0	2.0	5000.0	5006.0
2	66.0	1.0	5	12.0	202.0	2.0	4914.0	4980.0
3	110.0	1.0	5	17.0	192.0	2.0	4780.0	4890.0
4	116.0	1.0	5	7.0	187.0	2.0	4596.0	4712.0
5	48.0	1.0	2	12.0	177.0	2.0	4310.0	4358.0
6	8.0	1.0	2	12.0	162.0	2.0	4226.0	4234.0
7	10.0	1.0	2	12.0	162.0	2.0	4206.0	4216.0
8	70.0	1.0	1	22.0	172.0	2.0	3984.0	4054.0
9	153.0	1.0	1	22.0	172.0	2.0	3584.0	3737.0
10	18.0	1.0	1	22.0	172.0	2.0	3516.0	3534.0
11	76.0	1.0	1	-3.0	277.0	2.0	3434.0	3510.0
12	124.0	1.0	1	2.0	162.0	2.0	3310.0	3434.0
13	15.0	1.0	2	42.0	152.0	2.0	3275.0	3290.0
14	46.0	1.0	1	22.0	152.0	2.0	3214.0	3260.0
15	304.0	1.0	1	42.0	162.0	2.0	2910.0	3214.0
16	36.0	1.0	2	62.0	162.0	2.0	2670.0	2706.0
17	280.0	1.0	2	32.0	152.0	2.0	2370.0	2650.0
18	650.0	1.0	1	27.0	82.0	2.0	1660.0	2310.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 15 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 14 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 26.9 E +- 12.5 DEGREES	SHmin = N 27.0 E +- 12.2 DEGREES
SHmax = N 63.1 W +- 12.5 DEGREES	SHmax = N 63.0 W +- 12.2 DEGREES
STANDARD ERROR = 0.6 DEGREES	STANDARD ERROR = 0.6 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 20.4 E +- 19.0 DEGREES	SHmin = N 22.8 E +- 15.8 DEGREES
SHmax = N 69.6 W +- 19.0 DEGREES	SHmax = N 67.2 W +- 15.8 DEGREES
STANDARD ERROR = 10.9 DEGREES	STANDARD ERROR = 9.5 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 35.3 W +- 34.6 DEGREES
STANDARD ERROR = 1.6 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 70.2 +- 34.8 DEGREES
STANDARD ERROR = 1.6 DEGREES

SCHROEDER #1

LATITUDE = 47.7920 LONGITUDE =-122.2510 DECLINATION = 22.0
SNOHOMISH CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA, SCHROEDER #1

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	60.0	1.0	4	-78.0	82.0	3.0	9420.0	9480.0
2	85.0	1.0	2	27.0	47.0	2.0	9300.0	9385.0
3	46.0	1.0	2	17.0	42.0	2.0	9250.0	9296.0
4	54.0	1.0	2	12.0	27.0	1.5	9178.0	9232.0
5	5.0	1.0	2	-3.0	32.0	1.5	9036.0	9041.0
6	50.0	1.0	2	-8.0	37.0	1.5	8920.0	8970.0
7	24.0	1.0	2	-28.0	52.0	1.5	8896.0	8920.0
8	376.0	1.0	1	-13.0	52.0	3.0	8394.0	8770.0
9	14.0	1.0	1	-13.0	52.0	2.8	8352.0	8366.0
10	76.0	1.0	3	-13.0	57.0	2.8	8240.0	8316.0
11	255.0	1.0	1	-8.0	102.0	3.0	7930.0	8185.0
12	20.0	1.0	2	17.0	112.0	3.0	7880.0	7900.0
13	226.0	1.0	2	12.0	112.0	3.0	7594.0	7820.0
14	60.0	1.0	2	12.0	132.0	2.5	7390.0	7450.0
15	310.0	1.0	2	-8.0	42.0	2.0	7010.0	7320.0
16	110.0	1.0	3	72.0	122.0	2.0	6840.0	6950.0
17	90.0	1.0	3	62.0	102.0	1.0	6550.0	6640.0
18	30.0	1.0	3	22.0	112.0	1.3	6520.0	6550.0
19	6.0	1.0	4	-68.0	82.0	1.0	6346.0	6352.0
20	22.0	1.0	3	67.0	97.0	1.8	6252.0	6274.0
21	8.0	1.0	3	62.0	102.0	1.8	6176.0	6184.0
22	16.0	1.0	3	62.0	102.0	1.8	5920.0	5936.0
23	78.0	1.0	5	72.0	242.0	1.0	5542.0	5620.0
24	110.0	1.0	5	62.0	72.0	1.3	5130.0	5240.0
25	92.0	1.0	5	72.0	247.0	2.1	4648.0	4740.0
26	24.0	1.0	3	52.0	142.0	1.0	4186.0	4210.0
27	616.0	1.0	5	32.0	212.0	1.8	3334.0	3950.0
28	60.0	1.0	4	-78.0	207.0	1.8	3270.0	3330.0
29	270.0	1.0	3	62.0	212.0	1.8	2990.0	3260.0
30	110.0	1.0	5	47.0	47.0	1.5	2830.0	2940.0
31	154.0	1.0	5	52.0	62.0	1.5	2676.0	2830.0
32	26.0	1.0	5	72.0	82.0	1.5	2650.0	2676.0
33	20.0	1.0	5	87.0	167.0	0.5	2240.0	2260.0
34	26.0	[illegible]	3	62.0	142.0	0.8	2160.0	2186.0
35	16.0	[illegible]	3	47.0	112.0	0.8	2134.0	2150.0
36	144.0	1.0	5	22.0	22.0	1.3	1910.0	2054.0
37	260.0	1.0	5	22.0	212.0	1.0	1580.0	1840.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 27 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 13 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 7.7 E +- 30.1 DEGREES	SHmin = N 2.4 W +- 12.5 DEGREES
SHmax = N 82.3 W +- 30.1 DEGREES	SHmax = N 87.6 E +- 12.5 DEGREES
STANDARD ERROR = 1.2 DEGREES	STANDARD ERROR = 0.6 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 24.8 E +- 33.3 DEGREES	SHmin = N 1.3 E +- 14.9 DEGREES
SHmax = N 65.2 W +- 33.3 DEGREES	SHmax = N 88.7 W +- 14.9 DEGREES
STANDARD ERROR = 13.4 DEGREES	STANDARD ERROR = 9.4 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 63.7 E +- 31.3 DEGREES
STANDARD ERROR = 1.3 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 71.4 +- 32.8 DEGREES
STANDARD ERROR = 1.3 DEGREES

SCHROEDER #1 SHALLOW

LATITUDE = 47.7920 LONGITUDE =-122.2510 DECLINATION = 22.0
SNOHOMISH CO., WASHINGTON, STANDARD OIL CO. OF CALIFORNIA, SCHROEDER #1

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	110.0	1.0	4	72.0	122.0	2.0	6840.0	6950.0
2	90.0	1.0	3	62.0	102.0	1.0	6550.0	6640.0
3	30.0	1.0	3	22.0	112.0	1.3	6520.0	6550.0
4	6.0	1.0	4	-68.0	82.0	1.0	6346.0	6352.0
5	22.0	1.0	3	67.0	97.0	1.8	6252.0	6274.0
6	8.0	1.0	3	62.0	102.0	1.8	6176.0	6184.0
7	16.0	1.0	3	62.0	102.0	1.8	5920.0	5936.0
8	78.0	1.0	5	72.0	242.0	1.0	5542.0	5620.0
9	110.0	1.0	5	62.0	72.0	1.3	5130.0	5240.0
10	92.0	1.0	5	72.0	247.0	2.1	4648.0	4740.0
11	24.0	1.0	3	52.0	142.0	1.0	4186.0	4210.0
12	616.0	1.0	5	32.0	212.0	1.8	3334.0	3950.0
13	60.0	1.0	4	-78.0	207.0	1.8	3270.0	3330.0
14	270.0	1.0	3	62.0	212.0	1.8	2990.0	3260.0
15	110.0	1.0	5	47.0	47.0	1.5	2830.0	2940.0
16	154.0	1.0	5	52.0	62.0	1.5	2676.0	2830.0
17	26.0	1.0	5	72.0	82.0	1.5	2650.0	2676.0
18	20.0	1.0	5	87.0	167.0	0.5	2240.0	2260.0
19	26.0	1.0	3	62.0	142.0	0.8	2160.0	2186.0
20	16.0	1.0	3	47.0	112.0	0.8	2134.0	2150.0
21	144.0	1.0	5	22.0	22.0	1.3	1910.0	2054.0
22	260.0	1.0	5	22.0	212.0	1.0	1580.0	1840.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 12 BREAKOUTS)	FOR DATA OF QUALITY 3 OR BETTER (INCLUDES 9 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

SHmin = N 65.0 E +- 14.7 DEGREES	SHmin = N 59.5 E +- 9.4 DEGREES
SHmax = N 25.0 W +- 14.7 DEGREES	SHmax = N 30.5 W +- 9.4 DEGREES
STANDARD ERROR = 1.1 DEGREES	STANDARD ERROR = 0.8 DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

SHmin = N 64.1 E +- 20.5 DEGREES	SHmin = N 56.1 E +- 12.6 DEGREES
SHmax = N 25.9 W +- 20.5 DEGREES	SHmax = N 33.9 W +- 12.6 DEGREES
STANDARD ERROR = 13.6 DEGREES	STANDARD ERROR = 10.3 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 63.6 E +- 38.1 DEGREES
STANDARD ERROR = 2.9 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 21.2 +- 40.1 DEGREES
STANDARD ERROR = 3.0 DEGREES

AMOCO WEYERHAUSER 1-29

LATITUDE = 47.1100 LONGITUDE =-123.6800 DECLINATION = 20.0
WASHINGTON, GRAYS HARBOR CO., AMOCO WEYERHAEUSER 1-29

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	72.0	1.0	2	-70.0	150.0	1.0	12202.0	12274.0
2	43.0	1.0	1	-70.0	140.0	1.0	12124.0	12167.0
3	24.0	1.0	1	-50.0	150.0	1.0	11970.0	11994.0
4	16.0	1.0	1	-60.0	140.0	1.0	11940.0	11956.0
5	80.0	1.0	2	-60.0	140.0	1.0	11860.0	11940.0
6	48.0	1.0	1	-65.0	160.0	1.0	11382.0	11430.0
7	12.0	1.0	1	-60.0	165.0	1.0	11328.0	11340.0
8	16.0	1.0	1	-50.0	160.0	1.0	11292.0	11308.0
9	26.0	1.0	1	-50.0	165.0	1.0	11260.0	11286.0
10	20.0	1.0	1	-55.0	170.0	1.0	11240.0	11260.0
11	20.0	1.0	1	-60.0	175.0	1.0	11220.0	11240.0
12	50.0	1.0	2	-60.0	175.0	1.0	11170.0	11220.0
13	16.0	1.0	2	-70.0	180.0	1.0	10964.0	10980.0
14	16.0	1.0	3	-20.0	180.0	1.0	10948.0	10964.0
15	90.0	1.0	5	5.0	195.0	0.5	10590.0	10680.0
16	25.0	1.0	3	-20.0	190.0	0.5	10545.0	10570.0
17	64.0	1.0	1	-65.0	180.0	0.5	10370.0	10434.0
18	20.0	1.0	2	-55.0	180.0	0.5	10350.0	10370.0
19	35.0	1.0	1	-70.0	190.0	0.5	10300.0	10335.0
20	10.0	1.0	2	-60.0	205.0	0.5	10254.0	10264.0
21	36.0	1.0	3	0.0	200.0	0.5	10174.0	10210.0
22	94.0	1.0	3	20.0	185.0	0.5	10060.0	10154.0
23	32.0	1.0	3	20.0	220.0	0.5	9990.0	10022.0
24	40.0	1.0	1	-70.0	230.0	1.0	5780.0	5820.0
25	60.0	1.0	1	-70.0	230.0	1.0	5680.0	5740.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 24 BREAKOUTS) — FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 19 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 24 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 19 BREAKOUTS)
SHmin = N 58.1 W +- 25.8 DEGREES	SHmin = N 63.5 W +- 6.5 DEGREES
SHmax = N 31.9 E +- 25.8 DEGREES	SHmax = N 26.5 E +- 6.5 DEGREES
STANDARD ERROR = 1.7 DEGREES	STANDARD ERROR = 0.5 DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

FOR DATA OF QUALITY 4 OR BETTER	FOR DATA OF QUALITY 2 OR BETTER
SHmin = N 55.7 W +- 22.6 DEGREES	SHmin = N 61.6 W +- 7.0 DEGREES
SHmax = N 34.3 E +- 22.6 DEGREES	SHmax = N 28.4 E +- 7.0 DEGREES
STANDARD ERROR = 9.7 DEGREES	STANDARD ERROR = 3.5 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 5.4 W +- 25.1 DEGREES
STANDARD ERROR = 1.7 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 36.4 +- 29.2 DEGREES
STANDARD ERROR = 1.9 DEGREES

SHEARING

LATITUDE = 47.7920 LONGITUDE =-124.4250 DECLINATION = 20.0
JEFFERSON CO., WASHINGTON, PYRAMID PETROLEUM CORP.

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	22.0	1.0	1	30.0	260.0	4.0	4082.0	4104.0
2	30.0	1.0	1	10.0	245.0	4.0	4040.0	4070.0
3	56.0	1.0	1	20.0	270.0	4.0	3850.0	3906.0
4	50.0	1.0	1	20.0	250.0	4.0	3800.0	3850.0
5	190.0	1.0	5	80.0	250.0	4.0	3180.0	3370.0
6	40.0	1.0	4	-70.0	260.0	4.0	3080.0	3120.0
7	25.0	1.0	3	-80.0	260.0	4.0	2960.0	2985.0
8	50.0	1.0	5	60.0	240.0	4.0	2880.0	2930.0
9	90.0	1.0	5	80.0	265.0	4.0	2790.0	2880.0
10	1880.0	1.0	5	80.0	260.0	4.0	910.0	2790.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 6 BREAKOUTS)	FOR DATA OF QUALITY 1 OR BETTER (INCLUDES 4 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 21.8 E +- 31.1 DEGREES	SHmin = N 19.5 E +- 5.7 DEGREES
SHmax = N 68.2 W +- 31.1 DEGREES	SHmax = N 70.5 W +- 5.7 DEGREES
STANDARD ERROR = 4.1 DEGREES	STANDARD ERROR = 0.9 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 25.0 E +- 33.2 DEGREES	SHmin = N 20.0 E +- 7.0 DEGREES
SHmax = N 65.0 W +- 33.2 DEGREES	SHmax = N 70.0 W +- 7.0 DEGREES
STANDARD ERROR = 38.2 DEGREES	STANDARD ERROR = 12.9 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 78.3 E +- 8.6 DEGREES
STANDARD ERROR = 1.1 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 53.7 +- 31.5 DEGREES
STANDARD ERROR = 4.1 DEGREES

STATE #1-30

LATITUDE = 48.1000 LONGITUDE =-123.8000 DECLINATION = 22.0
CLALLUM CO., WASHINGTON, TWIN RIVERS

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	870.0	1.0	5	27.0	37.0	7.5	5730.0	6600.0
2	80.0	1.0	5	27.0	37.0	7.5	5580.0	5660.0
3	30.0	1.0	5	47.0	37.0	7.5	5550.0	5580.0
4	335.0	1.0	5	42.0	37.0	7.5	5210.0	5545.0
5	160.0	1.0	5	42.0	37.0	7.0	5030.0	5190.0
6	120.0	1.0	5	52.0	37.0	6.0	4850.0	4970.0
7	255.0	1.0	5	37.0	37.0	3.0	4090.0	4345.0
8	26.0	1.0	1	82.0	37.0	2.5	3994.0	4020.0
9	20.0	1.0	2	57.0	27.0	2.3	3750.0	3770.0
10	30.0	1.0	3	-38.0	27.0	1.8	3590.0	3620.0
11	30.0	1.0	3	52.0	22.0	1.7	3520.0	3550.0
12	180.0	1.0	5	32.0	22.0	1.5	3220.0	3400.0
13	55.0	1.0	2	62.0	27.0	2.0	3165.0	3220.0
14	70.0	1.0	2	62.0	27.0	2.0	3080.0	3150.0
15	100.0	1.0	5	22.0	32.0	2.0	2980.0	3080.0
16	68.0	1.0	3	-88.0	32.0	2.0	2832.0	2900.0
17	32.0	1.0	3	-83.0	32.0	2.0	2800.0	2832.0
18	260.0	1.0	3	-28.0	47.0	1.5	2440.0	2700.0
19	110.0	1.0	3	-58.0	62.0	1.5	2310.0	2420.0
20	50.0	1.0	3	12.0	57.0	1.8	2190.0	2240.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 11 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 4 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 54.2 W +- 35.1 DEGREES	SHmin = N 64.3 E +- 7.5 DEGREES
SHmax = N 35.8 E +- 35.1 DEGREES	SHmax = N 25.7 W +- 7.5 DEGREES
STANDARD ERROR = 2.5 DEGREES	STANDARD ERROR = 1.1 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 80.2 E +- 33.2 DEGREES	SHmin = N 65.6 E +- 9.5 DEGREES
SHmax = N 9.8 W +- 33.2 DEGREES	SHmax = N 24.4 W +- 9.5 DEGREES
STANDARD ERROR = 23.4 DEGREES	STANDARD ERROR = 17.4 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 41.8 E +- 12.7 DEGREES
STANDARD ERROR = 0.9 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 71.8 +- 29.4 DEGREES
STANDARD ERROR = 2.1 DEGREES

SHELL LUSE 1-23

LATITUDE = 46.2080 LONGITUDE =-124.1350 DECLINATION = 20.0
GRAYS HARBOR CO., WASHINGTON

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	78.0	1.0	3	5.0	245.0	2.0	3322.0	3400.0
2	12.0	1.0	2	70.0	190.0	2.0	2760.0	2772.0
3	16.0	1.0	2	90.0	190.0	2.0	2722.0	2738.0
4	44.0	1.0	5	25.0	195.0	2.0	2480.0	2524.0
5	66.0	1.0	3	20.0	180.0	2.0	2394.0	2460.0
6	26.0	1.0	2	90.0	160.0	2.0	1970.0	1996.0
7	65.0	1.0	2	90.0	150.0	2.0	1825.0	1890.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 6 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 4 BREAKOUTS)
STATISTICS WEIGHTED BY BREAK OUT LENGTHS	
SHmin = N 40.0 E +- 35.2 DEGREES	SHmin = N 88.1 E +- 5.9 DEGREES
SHmax = N 50.0 W +- 35.2 DEGREES	SHmax = N 1.9 W +- 5.9 DEGREES
STANDARD ERROR = 4.3 DEGREES	STANDARD ERROR = 1.1 DEGREES
STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS	
SHmin = N 72.0 E +- 31.0 DEGREES	SHmin = N 85.2 E +- 8.6 DEGREES
SHmax = N 18.0 W +- 31.0 DEGREES	SHmax = N 4.8 W +- 8.6 DEGREES
STANDARD ERROR = 35.6 DEGREES	STANDARD ERROR = 15.8 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 1.1 W +- 32.4 DEGREES
STANDARD ERROR = 3.9 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 63.5 +- 31.6 DEGREES
STANDARD ERROR = 3.8 DEGREES

SAMPSON JOHN'S 1-15

LATITUDE = 47.1000 LONGITUDE =-124.3000 DECLINATION = 20.0
GRAYS HARBOR CO., WASHINGTON, SHELL

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	8.0	1.0	1	75.0	275.0	2.0	1512.0	1520.0
2	15.0	1.0	5	75.0	265.0	2.0	1485.0	1500.0
3	40.0	1.0	3	30.0	250.0	2.0	1410.0	1450.0
4	64.0	1.0	5	60.0	250.0	2.0	1346.0	1410.0
5	62.0	1.0	1	80.0	240.0	2.0	1268.0	1330.0

FOR DATA OF QUALITY 1 OR BETTER
(INCLUDES 2 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

SHmin = N 77.2 E +- DEGREES
SHmax = N 12.8 W +- DEGREES
STANDARD ERROR = DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

SHmin = N 77.5 E +- DEGREES
SHmax = N 12.5 W +- DEGREES
STANDARD ERROR = DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 65.9 E +- 9.1 DEGREES
STANDARD ERROR = 1.7 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 2.2 +- 27.1 DEGREES
STANDARD ERROR = 5.1 DEGREES

GRAYS HARBOR LHA 1-15

LATITUDE = 47.1340 LONGITUDE =-124.1460 DECLINATION = 20.0
GRAYS HARBOR CO., WASHINGTON, SHELL

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	20.0	1.0	3	75.0	320.0	0.0	1545.0	1565.0
2	65.0	1.0	2	-25.0	320.0	0.0	1235.0	1300.0
3	50.0	1.0	2	-80.0	35.0	0.0	540.0	590.0

FOR DATA OF QUALITY 4 OR BETTER
(INCLUDES 3 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

SHmin = N 55.8 W +- 30.0 DEGREES
SHmax = N 34.2 E +- 30.0 DEGREES
STANDARD ERROR = 5.1 DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

SHmin = N 76.2 W +- 30.4 DEGREES
SHmax = N 13.8 E +- 30.4 DEGREES
STANDARD ERROR = 92.4 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 24.5 W +- 32.4 DEGREES
STANDARD ERROR = 5.5 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 39.2 +- 30.9 DEGREES
STANDARD ERROR = 5.2 DEGREES

MONTESANO 1-X

LATITUDE = 46.9580 LONGITUDE =-123.6250 DECLINATION = 20.0
GRAYS HARBOR, WASHINGTON, EL PASO PRODUCTS, MONTESANO 1-X

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	68.0	1.0	2	90.0	225.0	1.0	5472.0	5540.0
2	230.0	1.0	5	40.0	210.0	1.2	5220.0	5450.0
3	30.0	1.0	2	70.0	200.0	1.2	5190.0	5220.0
4	60.0	1.0	3	10.0	210.0	1.5	5120.0	5180.0
5	91.0	1.0	3	-30.0	200.0	2.0	5015.0	5106.0
6	38.0	1.0	2	75.0	225.0	4.0	2954.0	2992.0
7	520.0	1.0	2	70.0	220.0	6.5	2410.0	2930.0
8	260.0	1.0	5	75.0	85.0	6.0	2150.0	2410.0
9	315.0	1.0	2	85.0	240.0	5.0	700.0	1015.0

FOR DATA OF QUALITY 4 OR BETTER (INCLUDES 7 BREAKOUTS)	FOR DATA OF QUALITY 2 OR BETTER (INCLUDES 5 BREAKOUTS)

STATISTICS WEIGHTED BY BREAK OUT LENGTHS

SHmin = N 76.6 E +- 21.1 DEGREES	SHmin = N 76.4 E +- 7.7 DEGREES
SHmax = N 13.4 W +- 21.1 DEGREES	SHmax = N 13.6 W +- 7.7 DEGREES
STANDARD ERROR = 1.2 DEGREES	STANDARD ERROR = 0.5 DEGREES

STATISTICS WEIGHTED BY NUMBER OF BREAK OUTS

SHmin = N 77.0 E +- 29.6 DEGREES	SHmin = N 78.0 E +- 8.1 DEGREES
SHmax = N 13.0 W +- 29.6 DEGREES	SHmax = N 12.0 W +- 8.1 DEGREES
STANDARD ERROR = 29.6 DEGREES	STANDARD ERROR = 11.2 DEGREES

STATISTICS FOR HOLE AZIMUTH

HOLE ORIENTATION = N 43.4 E +- 12.1 DEGREES
STANDARD ERROR = 0.7 DEGREES

STATISTICS FOR RELATIVE BEARING

RELATIVE BEARING = 26.9 +- 19.6 DEGREES
STANDARD ERROR = 1.1 DEGREES

PLUM CREEK 23-2

LATITUDE = 47.1000 LONGITUDE =-122.1000 DECLINATION = 20.0
PIERCE CO., WASHINGTON, MERIDIAN OIL CO.

HORIZONTAL AZIMUTHS ARE MEASURED CLOCKWISE WITH RESPECT TO TRUE NORTH

NO.	LENGTH (FEET)	NUMBER OF B.O.	QUALITY FACTOR	B.O. AZIM.	DEV. AZIM.	HOLE DEV.	INT. TOP	INT. BOTTOM
1	50.0	1.0	5	71.0	257.0	13.0	3330.0	3380.0
2	130.0	1.0	5	70.0	258.0	13.0	3050.0	3180.0
3	28.0	1.0	4	74.0	284.0	7.0	1580.0	1608.0
4	340.0	1.0	3	-71.1	272.0	3.0	660.0	1000.0

FOR DATA OF QUALITY 4 OR BETTER
(INCLUDES 2 BREAKOUTS)