A COMPILATION OF REFLECTION AND REFRACTION SEISMIC DATA FOR WESTERN WASHINGTON AND ADJACENT OFFSHORE AREAS

William S. Lingley, Jr., Linden Rhoads,
Stephen P. Palmer, and Carl F. T. Harris

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Brian Boyle - Commissioner of Public Lands
Art Stearns - Supervisor

Division of Geology and Earth Resources
Raymond Lasmanis, State Geologist

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PLATE

Plate 1: Index map of some public-record seismic data for western Washington and adjacent offshore areas.

Optional Enclosure: Data Exchange File (DXF) or AutoCad®-compatible version of Plate 1 is available on 5½″ disk upon request.

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INTRODUCTION

This is a progress report on the continuing effort of the Washington Division of Geology and Earth Resources (DGER) to build a library of public-record seismic data. Mylar or paper copies of more than 8,000 km of reflection seismic data and some refraction seismic data have been acquired and are now available on a limited basis for research or commercial purposes. DGER also holds reproducible, statewide, 1:250,000-scale Bouguer gravity compilations of Finn and others (1984). Other geophysical data are listed in Manson (1984, 1991).

More than 9,000 line kilometers of reflection and refraction seismic data have been acquired in Washington and adjacent marine areas with the support of public funds. Most of the reflection profiles are marine: approximately 7,000 km have been acquired on the continental margin, 350 km in the Strait of Juan de Fuca, and 1,000 km in Puget Sound (Plate 1). Data quality varies mainly as a function of near-surface conditions: Scripps Institution of Oceanography acquired excellent single-channel marine reflection data across the continental margin (Silver, 1972), whereas Geophysical Services, Inc., was unable to record coherent reflectors with multi-fold reflection data shot across Columbia River Basalt Group outcrops (Donaldson, 1963).

All these public-record data sets share one detrimental aspect—inaccessibility. Public access to these data varies; the studies by Mann and Snavely (1984), McClellan and Snavely (1987, 1988), and Harding and others (1988a) were included in timely USGS open-file reports, but some analogue tapes have been stored for long periods in an unheated, open warehouse a few feet from salt water in Seattle. An effect of restricted accessibility is that various studies of tectonics, petroleum potential, and structure have been published without benefit of these data.

The authors request that users of the DGER reflection and refraction seismic data cite the original publications when referring to these data.

REFLECTION SEISMIC DATA

Seismic data have been acquired in Washington for various tectonic and earthquake-risk mitigation studies (cited below) and for petroleum exploration purposes. The areas covered by data now on file at the DGER are shown on Plate 1.

While seismic records acquired by private companies for exploration purposes comprise the vast majority of line-kilometers, most of these lines are currently classified as proprietary. Our efforts to obtain samples of these records were, understandably, unsuccessful. Strata Search, Inc., allowed publication of a Chehalis basin line in Ise (1985). This line was part of a survey which may be available for purchase[1].

Information about the locations of some onshore proprietary seismic profiles acquired after 1982 is contained in State Environmental Policy Act declarations on file at the DGER. However, the confidentiality of the data is

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1 From Lauren Geophysical, Inc., Denver, Colo.

permanently protected by various state and federal statutes. Important proprietary surveys were carried out in the Columbia Basin, mainly by Shell Western Exploration and Production, Inc., but also by Mobil Oil Corp., Exxon Corp., Arco, Inc., and Chevron USA, Inc. A few of these lines are reported as having coherent reflectors on the gentle southern limbs of the major Yakima Fold Belt structures, but most have no coherent events. In the central Puget basin, Shell and Chevron have been most active and have produced lines in several interesting locations. Because most of these data were acquired prior to 1975 and in rough terrain that has a wide range of near-surface velocities, the record quality is reported to be poor. From 1978 to 1983, Amoco shot or vibrated an extensive multi-channel program in south-central Washington in order to evaluate Weyerhaeuser Corporation lands. More recently, Canadian Hunter Exploration, Ltd., acquired multi-channel data on a grid covering much of the Bellingham basin.

Public-record onshore reflection data consist of several surveys designed to evaluate the potential of shallow horizons at the proposed Hanford nuclear waste repository (Donaldson, 1963; Brown and Raymond, 1965) and U.S. Department of Energy surveys, which were part of the Deep Crustal Gas study. The Hanford data image only the Hanford and Ringold Formations, which are Pliocene and younger fluvial/flood deposits. No coherent reflectors are present at two-way-times (T.W.T.) that indicate horizons within the Columbia River Basalt Group. In contrast, the Department of Energy lines (Gwilliam and others, 1990) acquired in mountainous parts of the easternmost Chehalis basin have frequency content and coherency adequate for interpretation. These 624-channel records represent the first useful public seismic profiles recorded in the Cascade foothills where commercial natural gas accumulations are possible (Anderson, 1959; Armentrout and Suek, 1985; Walsh and Lingley, 1991). Elsewhere, Berg and others (1966a, 1966b) and Carson and McManus (1969) used reflection data to analyze Pleistocene stratigraphy.

Proprietary data acquired in marine waters under federal jurisdiction (outside the 3-mile limit of Washington's jurisdiction) are held as confidential for a period defined in federal rule. Initially, that period was 25 years, but amendment of the rule during 1987 extended the confidentiality period. As a result, no data will be made public until 2012. Federal proprietary data include lines across the continental shelf acquired by Shell Western Exploration and Production, Inc., Pan American Company (Exxon), and Union Oil Company for use in locating wildcat wells. Also included is a GECO, Inc., "spec shoot" survey comprising a comprehensive 6-km grid covering much of the continental shelf [2].

Public-record reflection data on the continental margin have been acquired mainly for use in petroleum and tectonic studies. Most of the data were acquired during the 1976, 1977, and 1980 cruises of the RV *S. P. Lee,* which were directed by Parke Snavely. The data were published in Mann and Snavely (1984) and McClellan and Snavely (1987, 1988). These are 12- and 24-channel data for the continental shelf that have fair frequency content and coherency to about 2 seconds T.W.T., which approximates the top of the pre-middle Miocene melange sections. On the continental slope, some records have 4.0 seconds of useable data, and the top of the oceanic basement is imaged. Parke Snavely (USGS, 1989, oral commun.) has reprocessed some of these data and kindly provided us with a copy. As noted above, single-channel data collected by Scripps Institution of Oceanography (Silver, 1972) are of remarkably good quality owing to good weather during acquisition. The high quality of these data suggests that the Washington continental margin is generally a good record area to depths approximately equivalent to 2.0 seconds T.W.T. and, consequently, future seismic stratigraphic and direct hydrocarbon detection studies should be fruitful.

Other reflection surveys of the continental margin are described in Barnard (1973), Carson and others (1974), Kulm and Peterson (1984), and Lewis (1984). Surveys of the continental margin were performed by the RV *Thomas G. Thompson* and *Oceaneer* for the Office of Naval Research (Bennett and others, 1969a, 1969b; Bennett and Henry, 1967; Snavely and Wagner, 1982a) and the University of Washington. Many of these lines

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2 During the GECO survey, a number of crab pots were inadvertently disturbed. Shortly thereafter, public concern resulted in strong new regulations for proprietary data acquisition within the 3-mile limit. These were established by the State Legislature and are administered by the Department of Ecology. The statute (RCW 90.51) exempts surveys performed for public-record research.

were recorded to 250 milliseconds and may have limited utility for commercial or tectonic studies. Lynn and Larner (1989) describe an experimental survey shot off the Strait of Juan de Fuca.

Many single-channel records have been acquired in Puget Sound and Lake Washington. Reports of these surveys and/or interpretations of the data are included in Harding and others (1988a, 1988b, 1989), Holmes and others (1982), Lankston and others (1985), Snavely and Tiffin (1980), Snavely and others (1976, 1978a, 1978b), Wagner and Wiley (1983), and Whetten (1966). These records depict the post-Fraser glacial stratigraphic section in good detail. Older Pleistocene strata and the underlying Tertiary sections have only discontinuous reflectors.

None of the public-record marine data were acquired in a rectilinear grid. Many lines are curved; one line in Puget Sound was recorded along an oddly circular path when the seismic vessel rescued the crew of a burning boat with the detection streamer remaining deployed. Many lines have been plotted with seemingly random scale changes to adjust for bathymetric variation. These scale changes are not labeled on many of the profiles. As a result, structure cannot be correlated nor can lines be reliably tied. Therefore, these surveys are easily misinterpreted and are of limited value. Some interpretations of these records are summarized in Seely (1977), Palmer and Lingley (1989), Snavely (1987), Snavely and Kvenvolden (1989), Snavely and Wagner (1982b), and Wagner and others (1986).

REFRACTION SEISMIC DATA

Seismic refraction data are included in various reports catalogued in the DGER research library. Hubert (1979), McClain (1981), Taber (1983), Yorath and others (1985a, 1985b), and Taber and Lewis (1986) describe refraction or acoustic velocity data. They also provide cross sections of the Olympic Peninsula and/or the accretionary wedge, which are based on these data. In eastern Washington, Catchings and Mooney (1988) and Cotton and Catchings (1988) have had remarkable success in analyzing the Columbia Basin. Jarchow and others (1991) have used refraction data to image the base of the Columbia River Basalt Group, pre-basalt sedimentary rocks, and a crystalline basement uplift east of Ellensburg. Hill (1972), Glover (1985), and Wagstaff (1986) also recorded refraction lines in the Columbia Basin. These data indicate that a large, northwest-trending graben or rift basin may be present between Pasco and Yakima.

In the Cascade Range and northeastern Washington, Tanaka (1975), Hurich and others (1985), Potter and others (1986), Sanford and others (1988), and Stanley and others (1990) have recorded refraction data for various purposes.

Additionally, numerous portable refraction surveys have been performed for hydrologic studies (Crosby, 1966; Robinette, 1979, Schwarz, 1988); to assess geohazards (Sylwester and others, 1971; Youngs and others, 1985); for coal exploration (Dobecki and Bartel, 1981); and to evaluate construction sites (see Selected References). These data have not been included in the seismic data collection because they were recorded to only a few milliseconds T.W.T. However, reports of these surveys are available through the DGER library.

NAVIGATION AND CARTOGRAPHY

Plate 1 is a composite of various seismic track and shot-point maps for both marine and land reflection-seismic data. The original track and shot-point index maps were drafted at different scales on various projections. Even the shot-point recording systems vary: the Scripps data (Silver, 1972), for example, are located on the basis of Greenwich Mean Time during each day's cruise rather than by geographic position. Many marine track maps were not available on scale-stable bases.

Analyses of line ties for many marine profiles and velocity surveys for offshore wells indicate that many lines are inaccurately located. The mis-ties are relative to both seismic profiles and offshore exploratory wells. Presumably the lines are misplaced relative to the coastline as well. Palmer and Lingley (1989) determined that the accuracy of any given shot-point location on most Washington public-record marine seismic data is no better than a 2-mile radius. One exception is the experimental survey described in Lynn and Larner (1989); this

is accurately located. Onshore data, on the other hand, are accurately located because adverse topography and dense vegetation required that most lines were laid out along existing highways.

We have assumed that the navigational data for each survey shown on Plate 1 are internally correct and have plotted the data accordingly. This assumption should be verified by users through review of the original cruise or acquisition reports for each individual survey.

The base map for Plate 1 is an Arc/Info geographic information system (GIS) product supplied by the Washington Department of Natural Resources, Division of Lands and Minerals. This product was converted to AutoCad@ computer drafting format via a drawing-exchange file (DXF). This base map consists of the outline of the state and adjacent areas, an up-to-date township and range grid, and 15-minute tics, all of which have been mathematically projected into the Pacific Ocean. Individual track or shot-point index maps were photographically enlarged or reduced to conform as closely as possible to the 1:500,000-scale base. Each enlarged or reduced track or shot point map was registered to a 1:500,000-scale mylar plot of the Arc/Info base map using the 15-minute tics and geographic references. Direct transfer of original data to the 1:500,000-scale Arc/Info base map was not possible owing to projection distortion, paper stretch, and/or prior cartographic error. Therefore, a best fit was produced by manually adjusting each map. The manually transferred data were then digitized and are presented on Plate 1 and on the optional DXF or AutoCad@-compatible disks. We chose not to utilize expensive "rubber-sheeting" technology because of probable uncertainty in all of the original marine navigation.

PRODUCTS AVAILABLE FROM DGER

In addition to this report, the DGER can produce different products for research and other purposes, generally at cost. Availability is limited by support personnel and other DGER priorities. These products include:

1. Additional paper or sepia reproducible copies of Plate 1
2. Individual reflection or refraction lines, on film or paper
3. Track maps showing the seismic lines on paper, at any reasonable scale
4. Digital track maps in AutoCad drawing format (*.DWG) and/or in DXF format for down-loading into other software programs

We recommend that users make arrangements to reproduce these data at our Olympia office using their own technical staff.

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SELECTED REFERENCES

Anderson, J. Q., 1959, Puget Sound area has several prospective oil and gas basins: Washington Division of Mines and Geology Reprint 5, 4 p.

Armentrout, J. M.; Suek, D. H., 1985, Hydrocarbon exploration in western Oregon and Washington: American Association of Petroleum Geologists Bulletin, v. 69, no. 4, p. 627-643.

Barnard, W. D., 1973, Late Cenozoic sedimentation on the Washington continental slope: University of Washington Doctor of Philosophy thesis, 255 p.

Bartel, L. C.; Dobecki, T. L., 1981, High-resolution reflection seismics at potential in-situ coal gasification test site [abstract]: American Association of Petroleum Geologists Bulletin, v. 65, no. 5, p. 896.

Bennett, L. C., Jr.; Bostrom, R. C.; Burk, R.; Carver, G. A.; Coombs, H. A.; Frost, B. R.; Hales, P.; Johnson, D.; Leo, R.; Markham, D.; and others, 1972, Nisqually Delta; a report [abstract]: Geological Society of America Abstracts with Programs, v. 4, no. 3, p. 126-127.

Bennett, L. C., Jr.; Henry, M., 1967, Preliminary report, RV *Oceaneer* Cruise 10, continental shelf survey, 10 June to 18 June, 1967: U.S. Geological Survey Contract 14-08-0001-10924, unpaginated.

Bennett, L. C., Jr.; Henry, M.; Lewis, L., 1969a, Preliminary report, RV *Thomas G. Thompson* Cruise 13, continental shelf survey, 17 March to 25 March, 1967: U.S. Navy Office of Naval Research Contract No-447(37), Project NR 083 012, unpaginated.

Bennett, L. C., Jr.; Henry, M.; Lewis, L., 1969b, Preliminary report, RV *Thomas G. Thompson* Cruise 24, continental shelf survey, 8 December to 15 December, 1967: U.S. Navy Office of Naval Research Contract Nonr-447(37), Project NR 083 012, unpaginated.

Berg, J. W., Jr.; King, J. M.; Carlson, P. R., 1966a, Seismic reflection studies of buried channels off the Columbia River: Ore Bin, v. 28, no. 8, p. 145-150.

Berg, J. W., Jr.; Trembly, Lynn; Emilia, D. A.; Hutt, J. R.; King, J. M.; Long, L. T.; McKnight, W. R.; Sarmah, S. K.; Souders, R. P.; and others, 1966b, Crustal refraction profile, Oregon coast range: Seismological Society of America Bulletin, v. 56, no. 6, p. 1357-1362.

Brown, R. E.; Raymond, J. R., 1965, Geophysical seismic evaluation study at Hanford: Battelle Pacific Northwest Laboratory BNWL-47, 40 p.

Carson, Bobb; McManus, D. A., 1969, Seismic reflection profiles across Juan de Fuca canyon: Journal of Geophysical Research, v. 74, no. 4, p. 1052-1060.

Carson, Bobb; Yuan, J. W.; Myers, P. B., Jr.; Barnard, W. D., 1974, Initial deep-sea sediment deformation at the base of the Washington continental slope—A response to subduction: Geology, v. 2, no. 11, p. 561-564.

Catchings, R. D.; Mooney, W. D., 1985, Crustal structure of the Columbia Plateau [abstract]: Earthquake Notes, v. 56, no. 1, p. 22.

Catchings, R. D.; Mooney, W. D., 1988, Crustal structure of the Columbia Plateau—Evidence for continental rifting: Journal of Geophysical Research, v. 93, no. B1, p. 459-474.

Clowes, R. M.; Brandon, M. T.; Green, A. G.; Yorath, C. J.; Sutherland-Brown, A.; Kanasewich, E. R.; Spencer, C. J., 1987, LITHOPROBE—Southern Vancouver Island—Cenozoic subduction complex imaged by deep seismic reflections: Canadian Journal of Earth Sciences, v. 24, no. 1, p. 31-51.

Cotton, J. A.; Catchings, R. D., 1988, Data report for the 1984 U.S. Geological Survey central Columbia Plateau seismic refraction experiment, Washington–Oregon: U.S. Geological Survey Open-File Report 88-226, 56 p.

Couch, R. W.; Kienle, C. F., Jr.; Connard, Gerry, 1978, The continental margin of the Pacific Northwest—A summary of the geological and geophysical data: Oregon State University [under contract to the U.S. Department of State], 96 p.

Crosby, J. W., III, 1966, Ground-water research in the Pullman–Moscow basin. *In* Engineering Geology and Soils Engineering Symposium, 4th Annual, Proceedings: Idaho Department of Highways, p. 215-236.

Dobecki, T. L.; Bartel, L. C., 1981, Applications of reflection seismics to mapping coal seam structure and discontinuities. *In* Peng, S. S., editor, Proceedings of the first conference on ground control in mining: West Virginia University, p. 160-166.

Donaldson, J. A., 1963, Seismic survey, Hanford Atomic Productions Operation, Richland, Benton County, Washington: Geophysical Services, Inc. [Dallas, TX.], 79 p., 20 plates.

Finn, Carol; Phillips, W. M.,; Williams, D. L., 1984, Gravity maps of the State of Washington and adjacent areas (scale 1:250,000): U.S. Geological Survey Open-File Report 84-416, 5 p., 18 plates, scale 1:250,000.

Fuller, B. N., 1987, Seismic reflection data acquisition problems in the Columbia River Plateau and Snake River Plain: University of Wyoming Master of Science thesis, 87 p.

Glover, D. W., 1985, Crustal structure of the Columbia Basin, Washington from borehole and refraction data: University of Washington Master of Science thesis, 71 p.

Grim, M. S.; Bennett, L. C., Jr., 1969, Shallow sub-bottom geology of the Washington shelf off Grays Harbor [abstract]: Eos (American Geophysical Union Transactions), v. 50, no. 2, p. 63-64.

Gwilliam, W. J.; Stanley, W. D.; Latham, G. V.; Westhusing, J. K., 1990, Deep seismic surveys of a dormant subduction zone in the Pacific Northwest, United States [abstract]: American Association of Petroleum Geologists Bulletin, v. 74, no. 5, p. 667-668.

Harding, S. T.; Agena, W.; Nichols, D.; Lee, M., 1989, Small-boat, multi-channel, high-resolution seismic reflection survey in Puget Sound and the Strait of Juan de Fuca: Offshore Technology Conference, 21st, Proceedings, v. 1, p. 593-598.

Harding, S. T.; Barnhard, T. P.; Urban, T. C., 1988a, Preliminary data from the Puget Sound multichannel seismic-reflection survey: U.S. Geological Survey Open-File Report 88-698, 7 p., 17 plates.

Harding, S. T.; Urban, T. C.; Barnhard, T. P., 1988b, Preliminary evidence of possible Quaternary faulting in Puget Sound, Washington, from a multichannel marine seismic reflection survey. *In* Hays, W. W., editor, Workshop on "Evaluation of earthquake hazards and risk in the Puget Sound and Portland areas"; Proceedings of conference XLII: U.S. Geological Survey Open-File Report 88-541, p. 178-193.

Hill, D. P., 1972, Crustal and upper mantle structure of the Columbia Plateau from long range seismic-refraction measurements: Geological Society of America Bulletin, v. 83, no. 6, p. 1639-1648.

Hill, D. P., 1978, Seismic evidence for the structure and Cenozoic tectonics of the Pacific Coast States. *In* Smith, R. B.; Eaton, G. P., editors, Cenozoic tectonics and regional geophysics of the western cordillera: Geological Society of America Memoir 152, p. 145-174.

Holmes, M. L.; MacQueen, J. D.; Sylwester, R. E., 1982, Marine geophysical measurements in central Puget Sound, Washington [abstract]: American Association of Petroleum Geologists Bulletin, v. 66, no. 10, p. 1690-1691.

Hubert, K. A., 1979, Physical properties of selected basalt and graywacke and the inferred seismic structure of the Olympic Peninsula, Washington: University of Washington Master of Science thesis, 96 p.

Hurich, C. A.; Smithson, S. B.; Fountain, D. M.; Humphreys, M. C., 1985, Seismic evidence of mylonite reflectivity and deep structure in the Kettle dome metamorphic core complex, Washington: Geology, v. 13, no. 8, p. 577-580.

Ise, F. T., 1985, Washington and Oregon—Are there other rocks to explore?: Oil and Gas Journal, v. 83, no. 32, p. 112-115.

Iyer, H. M.; Hitchcock, T., 1989, Upper-mantle velocity structure in the continental U.S. and Canada. *In* Pakiser, L. C.; Mooney, W. D., editors, Geophysical framework of the continental United States: Geological Society of America Memoir 172, p. 681-710.

Jarchow, C. M.; Catchings, R. D.; Lutter, W. J., 1991, How Washington crew got good, thrifty seismic in bad data area: Oil and Gas Journal, v. 89, no. 24, p. 54-55.

Johnson, S. Y.; Brandon, M. T.; Stewart, R. J.; McClain, K. J.; Lewis, B. T. R.; Taber, J. J., Jr.; Crosson, R. S., compilers, Cross section D-D'-D", western Washington. *In* Kulm, L. D.; and others, editors, Western North American continental margin and adjacent ocean floor off Oregon and Washington: Marine Science International [Woods Hole, Mass.] Ocean Drilling Program, Regional Atlas Series 1, p. 22.

Johnson, S. H.; Couch, R. W., 1970, Crustal structure in the north Cascade Mountains of Washington and British Columbia from seismic refraction measurements: Seismological Society of America Bulletin, v. 60, no. 4, p. 1259-1269.

Kulm, L. D.; Embley, R. W., 1988, Nature of the deformation front along the Oregon–Washington subduction zone. *In* Shearer, C. F., editor, Minutes of the National Earthquake Prediction Evaluation Council, April 2 and 3, 1987: U.S. Geological Survey Open-File Report 88-37, p. 185-195.

Kulm, L. D.; Fowler, G. A., 1974, Cenozoic sedimentary framework of the Gorda–Juan de Fuca Plate and adjacent continental margin—A review. *In* Dott, R. H., Jr.; Shaver, R. H., editors, Modern and ancient geosynclinal sedimentation: Society of Economic Paleontologists and Mineralogists Special Publication 19, p. 212-229.

Kulm, L. D.; Peterson, C. P., compilers, 1984, Multichannel seismic records of northern Washington and central Oregon margin. *In* Kulm, L. D.; and others, editors, Western North American continental margin and adjacent ocean floor off Oregon and Washington: Marine Science International [Woods Hole, Mass.] Ocean Drilling Program, Regional Atlas Series 1, p. 28.

Lankston, R. W.; Lankston, M. M.; West, L. M., 1985, Seismic reflection profiling in the Cedar River basin, western Washington. *In* National Water Well Association, NWWA Conference on surface and borehole geophysical methods in ground water investigations: National Water Well Association, p. 146-164.

Lewis, B. T. R., compiler, 1984, Deep-tow seismic reflection experiment, Washington margin. *In* Kulm, L. D.; and others, editors, Western North American continental margin and adjacent ocean floor off Oregon and Washington: Marine Science International [Woods Hole, Mass.] Ocean Drilling Program, Regional Atlas Series 1, p. 27.

Lingley, W. S., Jr.; Walsh, T. J., 1986, Issues relating to petroleum drilling near the proposed high-level nuclear waste repository at Hanford: Washington Geologic Newsletter, v. 14 no. 3, p. 10-19.

Lynn, W.; Larner, K., 1989, Effectiveness of wide marine seismic source arrays: Geophysical Prospecting, v. 37, no. 2, p. 181-207.

Manson, C. J., compiler, 1984, Index to geologic and geophysical mapping of Washington, 1899-1983: Washington Division of Geology and Earth Resources Information Circular 77, 56 p., 14 plates.

Manson, C. J., compiler, 1991, Geologic and geophysical mapping of Washington, 1984 through 1990, and, Theses on the geology of Washington, 1984 through 1990: Washington Division of Geology and Earth Resources Open File Report 91-1, 39 p.

Mayers, I. R., 1971, An analysis of continuous seismic profiles from the Strait of Juan de Fuca: University of Washington Master of Science thesis, 123 p.

McClain, K. J., 1981, A geophysical study of accretionary processes on the Washington continental margin: University of Washington Doctor of Philosophy thesis, 141 p.

McClain, K. J.; Peper, J. S.; Holmes, M. L., compilers, 1984, Single channel seismic reflection records of western Washington margin and Cascadia basin. *In* Kulm, L. D.; and others, editors, Western North American continental margin and adjacent ocean floor off Oregon and Washington: Marine Science International [Woods Hole, Mass.] Ocean Drilling Program, Regional Atlas Series 1, p. 26.

McClellan, P. H.; Snavely, P. D., Jr., 1987, Multichannel seismic-reflection profiles collected in 1976 off of the Washington–Oregon coast: U.S. Geological Survey Open-File Report 87-607, 2 p., 1 plate.

McClellan, P. H.; Snavely, P. D., Jr., 1988, Multichannel seismic-reflection profiles collected in 1980 off of the Washington and northern Oregon coast: U.S. Geological Survey Open-File Report 88-205, 4 p., 1 plate.

Mann, D. M.; Snavely, P. D., Jr., 1984, Multichannel seismic- reflection profiles collected in 1977 in the eastern Pacific Ocean off of the Washington/Oregon coast: U.S. Geological Survey Open-File Report 84-5, 3 p., 1 plate.

Palmer, S. P.; Lingley, W. S., Jr., 1989, An assessment of the oil and gas potential of the Washington outer continental shelf: University of Washington, Washington Sea Grant Program, Washington State and Offshore Oil and Gas, 83 p., 12 plates.

Potter, C. J.; Sanford, W. E.; Yoos, T. R.; Prussen, E. I.; Keach, R. W., II; Oliver, J. E.; Kaufman, Sidney; Brown, L. D., 1986, COCORP deep seismic reflection traverse of the interior of the North American Cordillera, Washington and Idaho—Implications for orogenic evolution: Tectonics, v. 5, no. 7, p. 1007-1025.

Robinette, M. S., 1979, Geophysical investigations of the Pullman, Washington–Moscow, Idaho ground-water basin. *In* Engineering Geology and Soils Engineering Symposium, 17th Annual, Proceedings: Idaho Department of Highways, p. 197-217.

Sanford, W. E.; Potter, C. J.; Oliver, J. E., 1988, Detailed three-dimensional structure of the deep crust based on COCORP data in the Cordilleran interior, north-central Washington: Geological Society of America Bulletin, v. 100, no. 1, p. 60-71.

Schwarz, S. D., 1988, Application of geophysical methods to groundwater exploration in the Tolt River basin, Washington State. *In* Proceedings of the symposium on the application of geophysics to engineering and environmental problems: Society of Engineering and Mineral Exploration Geophysicists, p. 652-657.

Seely, D. R., 1977, The significance of landward vergence and oblique structural trends on trench inner slopes. *In* Talwani, Manik; Pitman, W. C., III, editors, Island arcs, deep sea trenches, and back-arc basins: American Geophysical Union Maurice Ewing Series 1, p. 187-198.

Silver, E. A., 1972, Pleistocene tectonic accretion of the continental slope off Washington: Marine Geology, v. 13, no. 4, p. 239-249.

Snavely, P. D., Jr., 1987, Tertiary geologic framework, neotectonics, and petroleum potential of the Oregon-Washington continental margin. *In* Scholl, D. W.; Grantz, A.; Vedder, J. G., editors, Geology and resources potential of the continental margin of western North America and adjacent ocean basins—Beaufort Sea to Baja California: Circum-Pacific Council for Energy and Mineral Resources, Earth Science Series, v. 6, p. 305-335.

Snavely, P. D., Jr.; Gower, H. D.; Yount, J. C.; Pearl, J. E.; Tagg, A. R.; Lee, J. W., 1976, High resolution seismic profiles adjacent to Whidbey and Fidalgo Islands, Washington: U.S. Geological Survey Open-File Report 76-187, 1 p., 1 roll microfilm, 1 plate.

Snavely, P. D., Jr.; Gower, H. D.; Tagg, A. R.; Lander, D. L.; Novak, R. L., 1978a, High-resolution seismic profiles in southern Strait of Georgia, Washington: U.S. Geological Survey Open-File Report 78-1061, 1 p., 1 plate, scale 1:62,500.

Snavely, P. D., Jr.; Gower, H. D.; Yount, J. C.; Pearl, J. E.; Tagg, A. R.; Lee, J. W.; Lander, D. L., 1978b, Notes of acquisition of high-resolution seismic profiles in southern Puget Sound, Washington: U.S. Geological Survey Open-File Report 78-328, 1 p.

Snavely, P. D., Jr.; Kvenvolden, K. A., 1989, Geology and hydrocarbon potential. Chapter A *In* Preliminary evaluation of the petroleum potential of the Tertiary accretionary terrane, west side of the Olympic Peninsula, Washington: U.S. Geological Survey Bulletin 1892, p. 1-17, 1 plate.

Snavely, P. D., Jr.; Tiffin, D. L., 1980, Seismic reflection profiles from cooperative investigations in the Strait of Juan de Fuca by the U.S. Geological Survey and Geological Survey of Canada aboard the Canadian Survey ship *Parizeau* between May 15 and June 3, 1972: U.S. Geological Survey Open-File Report 80-239, 4 p.

Snavely, P. D., Jr.; Wagner, H. C., 1982a, Geophysical data collected on the southern Washington continental shelf along line 12, USGS RV *S.P. Lee* cruise 3-76: U.S. Geological Survey Open-File Report 82-424, 1 sheet.

Snavely, P. D., Jr.; Wagner, H. C., 1982b, Geologic cross section across the continental margin of southwestern Washington: U.S. Geological Survey Open-File Report 82-459, 10 p., 1 sheet.

Snavely, P. D., Jr.; Wagner, H. C., 1983, Geophysical data collected across the continental margin between Washington and Oregon along line 16, USGS RV *S.P. Lee* cruise 11-80: U.S. Geological Survey Open-File Report 83-20, 1 sheet.

Stanley, W. D.; Mooney, W. D.; Fuis, G. S., 1990, Deep crustal structure of the Cascade Range and surrounding regions from seismic refraction and magnetotelluric data: Journal of Geophysical Research, v. 95, no. B12, p. 19,419-19,438.

Sylwester, R. E.; Bennett, L. C., Jr.; Sherif, M. A.; Bostrom, R. C., 1971, The determination of active fault zones in Puget Sound, Washington, by means of continuous seismic profiling. *In* Proceedings of the International symposium on the engineering properties of sea-floor soils and their geophysical identification: University of Washington, p. 360-374.

Taber, J. J., Jr., 1983, Crustal structure and seismicity of the Washington continental margin: University of Washington Doctor of Philosophy thesis, 159 p.

Taber, J. J., Jr.; Lewis, B. T. R., 1986, Crustal structure of the Washington continental margin from refraction data: Seismological Society of America Bulletin, v. 76, no. 4, p. 1011-1024.

Tanaka, H. H., 1975, Seismic profile lines in the Spokane area [abstract]: U.S. Geological Survey Professional Paper 975, p. 115.

von Huene, Roland; Kulm, L. D., 1973, Tectonic summary of Leg 18. *In* Kulm, L. D.; von Huene, Roland; and others, Initial reports of the Deep Sea Drilling Project: U.S. Government Printing Office, v. 18, p. 961-976.

Wagner, H. C.; Batatian, L. D.; Lambert, T. M.; Tomson, J. H., 1986, Preliminary geologic framework studies showing bathymetry, locations of geophysical tracklines and exploratory wells, sea floor geology and deeper geologic structures, magnetic contours, and inferred thickness of Tertiary rocks on the continental shelf and upper continental slope off southwestern Washington between latitudes 46 degrees N and 48 degrees 30 minutes N and from the Washington coast to 125 degrees 20 minutes W: Washington Division of Geology and Earth Resources Open File Report 86-1, 8 p., 6 plates.

Wagner, H. C.; Wiley, M. C., 1983, Offshore Quaternary geology of the northern Puget Sound–eastern Strait of Juan de Fuca region, Washington. *In* Yount, J. C.; Crosson, R. S., editors, Proceedings of workshop XIV, Earthquake hazards of the Puget Sound region, Washington: U.S. Geological Survey Open-File Report 83-19, p. 178-267.

Wagstaff, M. D., 1986, Three-dimensional velocity structure of the lithosphere beneath the Hanford array in Washington State: University of North Carolina at Chapel Hill Master of Science thesis, 119 p.

Walsh, T. J.; Lingley, W. S., Jr., 1991, Coal maturation and the natural gas potential of western and central Washington: Washington Division of Geology and Earth Resources Open File Report 91-2, 26 p.

Whetten, J. T., 1966, Lake Washington's third dimension: Pacific Search, v. 1, no. 3, Technical insert 66-7, 2 p.

Yorath, C. J.; Clowes, R. M.; Green, A. G.; Sutherland-Brown, A.; Brandon, M. T.; Massey, N. W. D.; Spencer, C.; Kanasewich, E. R.; Hyndman, R. D., 1985a, LITHOPROBE—Phase 1—Southern Vancouver Island—Preliminary analyses of reflection seismic profiles and surface geological studies: Geological Survey of Canada Paper 85-1A, p. 543-554.

Yorath, C. J.; Green, A. G.; Clowes, R. M.; Sutherland-Brown, A.; Brandon, M. T.; Kanasewich, E. R.; Hyndman, R. D.; Spencer, C., 1985b, LITHOPROBE, southern Vancouver Island—Seismic reflection sees through Wrangellia to the Juan de Fuca plate: Geology, v. 13, no. 11, p. 759-762.

Youngs, R. R.; Coppersmith, K. J.; Power, M. S.; Swann, F. H., III, 1985, Seismic hazard assessment of the Hanford region, eastern Washington State. *In* Proceedings—DOE natural phenomena hazards mitigation conference: Lawrence Livermore National Laboratory, p. 169-176.

WASHINGTON DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES
Raymond Lasmanis, State Geologist

A Compilation of Reflection and Refraction Seismic Data for Western Washington and Adjacent Offshore Areas

Open File Report 91-5

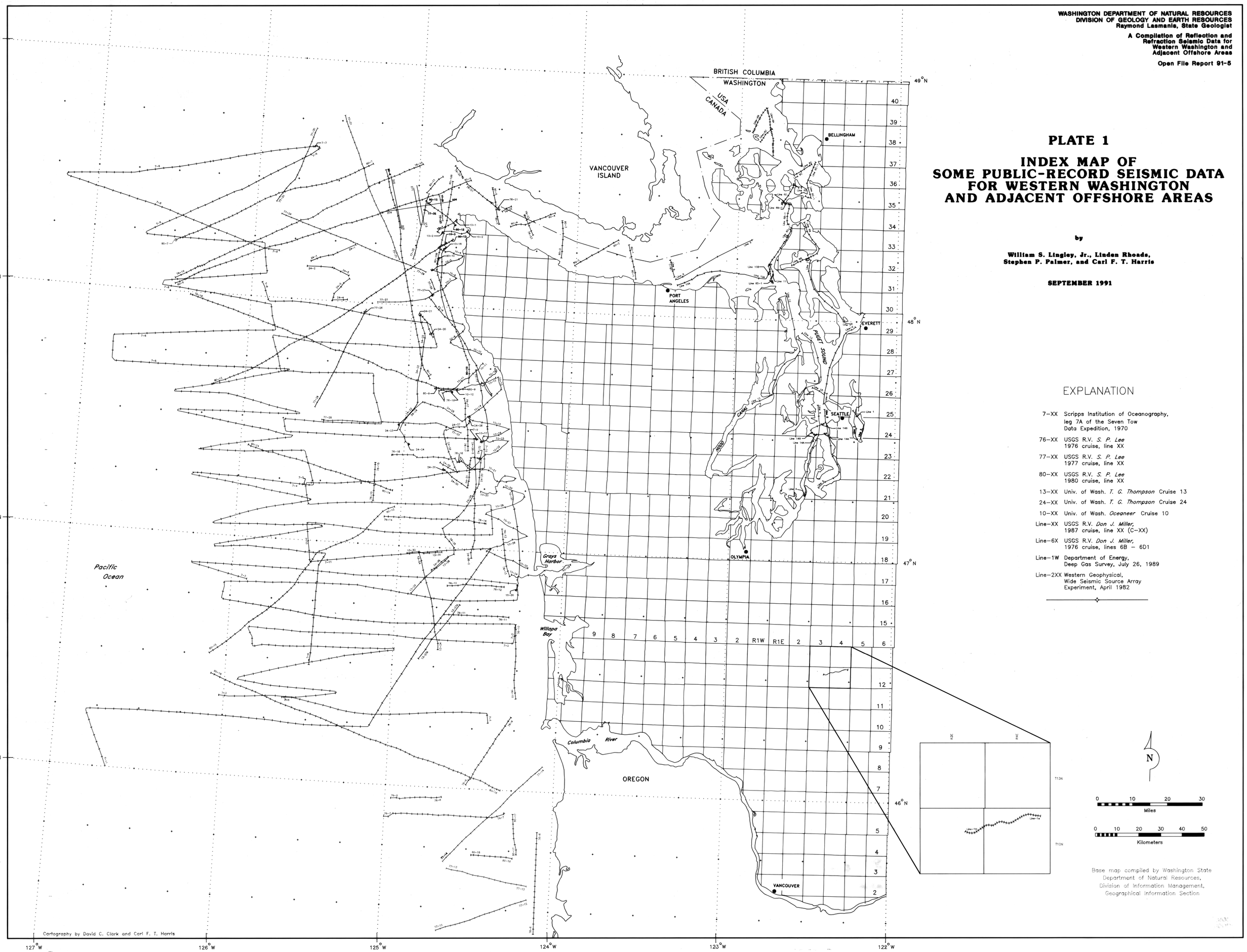
PLATE 1

INDEX MAP OF SOME PUBLIC-RECORD SEISMIC DATA FOR WESTERN WASHINGTON AND ADJACENT OFFSHORE AREAS

by

William S. Lingley, Jr., Linden Rhoads, Stephen P. Palmer, and Carl F. T. Harris

SEPTEMBER 1991



EXPLANATION

7–XX	Scripps Institution of Oceanography, leg 7A of the Seven Tow Data Expedition, 1970
76–XX	USGS R.V. *S. P. Lee* 1976 cruise, line XX
77–XX	USGS R.V. *S. P. Lee* 1977 cruise, line XX
80–XX	USGS R.V. *S. P. Lee* 1980 cruise, line XX
13–XX	Univ. of Wash. *T. G. Thompson* Cruise 13
24–XX	Univ. of Wash. *T. G. Thompson* Cruise 24
10–XX	Univ. of Wash. *Oceaneer* Cruise 10
Line–XX	USGS R.V. *Don J. Miller*, 1987 cruise, line XX (C–XX)
Line–6X	USGS R.V. *Don J. Miller*, 1976 cruise, lines 6B – 6D1
Line–1W	Department of Energy, Deep Gas Survey, July 26, 1989
Line–2XX	Western Geophysical, Wide Seismic Source Array Experiment, April 1982

Base map compiled by Washington State Department of Natural Resources, Division of Information Management, Geographical Information Section

Cartography by David C. Clark and Carl F. T. Harris