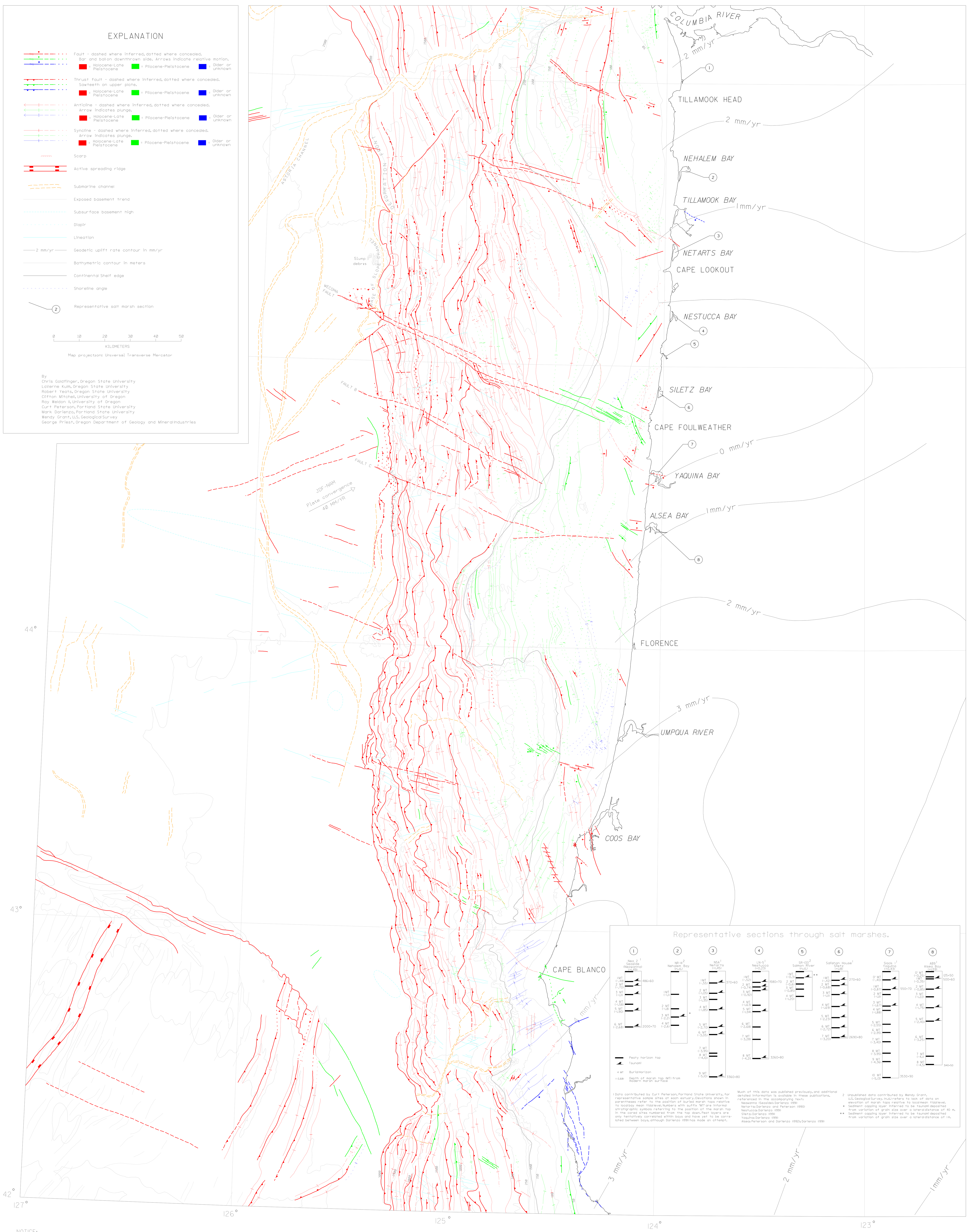
State of Oregon
Department of Geology
and Mineral Industries
Donald A. Hull, State Geologist

Neotectonic Map of the Oregon Continental Margin and Adjacent Abyssal Plain

1992

Open File Report O-92-4
By C. Goldfinger
and others

Plate 1



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Publication and compilation of this map was supported by U.S. Geological Survey Cooperative Agreement Number 14-08-0001-A0512 under the auspices of the National Earthquake Hazards Reduction Program.

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Locations of track lines for offshore geophysical data

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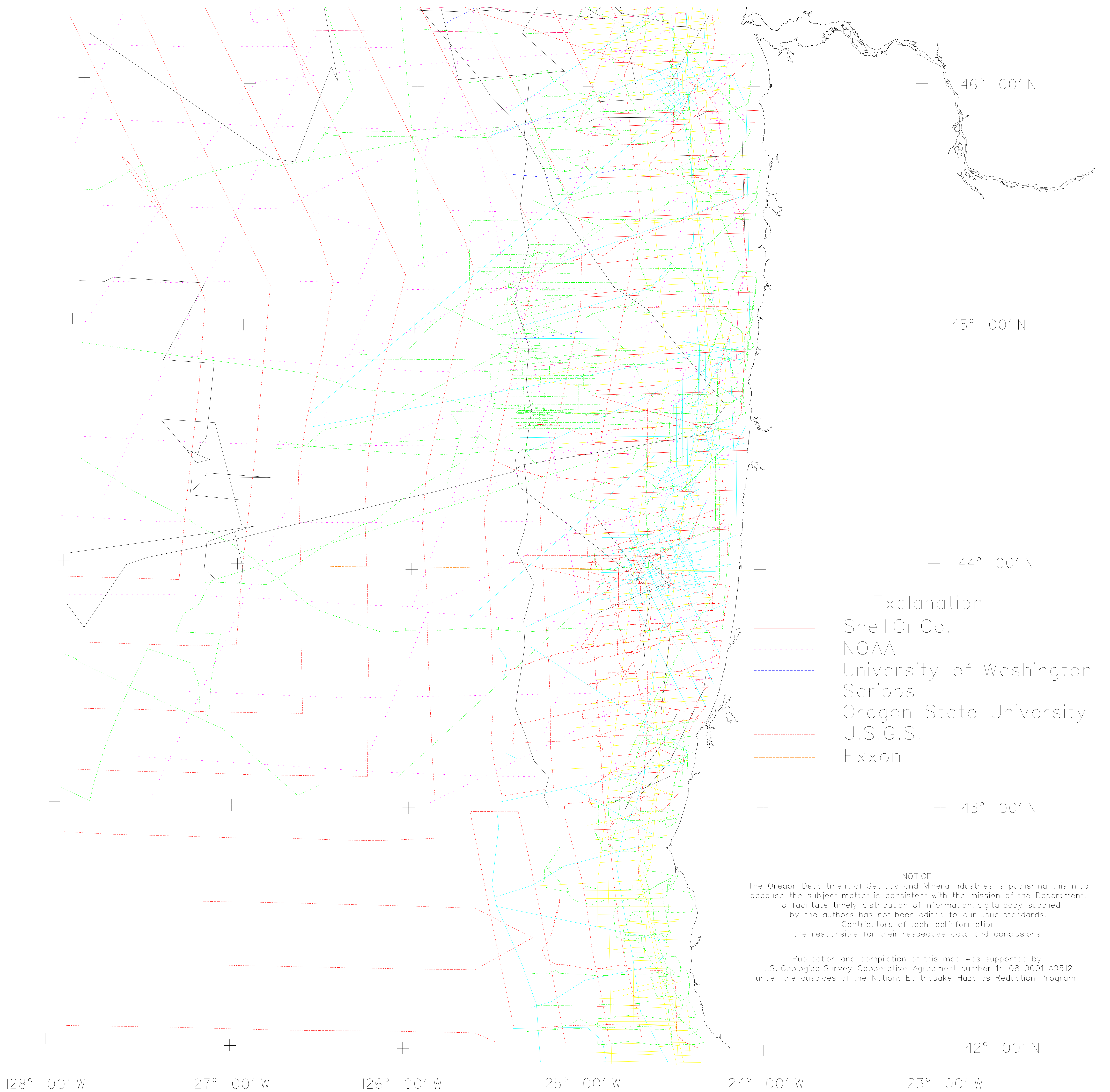
Plate 2



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STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
800 N.E. Oregon Street # 28
Suite 965
Portland, Oregon 97232

OPEN-FILE REPORT 0-92-4

NEOTECTONIC MAP OF THE OREGON CONTINENTAL MARGIN AND ADJACENT ABYSSAL PLAIN

By

Chris Goldfinger, Department of Geosciences, LaVerne D. Kulm, College of Oceanography, and Robert S. Yeats, Department of Geosciences, Oregon State University, Corvallis, OR 97331;

Clifton Mitchell and Ray Weldon II, Geological Sciences Department, University of Oregon, Eugene, OR 97403;

Curt Peterson and Mark Darienzo, Department of Geology, Portland State University, Portland, OR 97207;

Wendy Grant, U.S. Geological Survey, University of Washington, Seattle, WA 98195; and

George R. Priest, Oregon Department of Geology and Mineral Industries, Portland, OR 97232

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DETAILED EXPLANATION OF MAP SYMBOLS ON PLATE 1

CONTOURS OF GEODETIC UPLIFT RATE

Absolute coastal uplift rates are in mm per year and are relative to an unchanging far field reference surface, approximately equivalent to the geoid. Data are from Clifton E. Mitchell and Ray Weldon II of the University of Oregon and are a modification of very similar contours presented by Mitchell and others (1991), based on analysis of benchmarks resurveyed over a 70-year time span and on changes in the monthly mean records of sea level from tide gauges. Note that eustatic (global) sea level rise is approximately 1.8 mm per year, so these uplift rates provide a guide to coastal areas that are rising or falling relative to global sea level rise. The uplift rates are additional evidence of ongoing strain in the North American Plate that may be related to a locked interface on the Cascadia subduction zone. The uplift contours were contributed by Ray Weldon II and Clifton Mitchell of the University of Oregon.

STRATIGRAPHIC COLUMNS SHOWING SALT MARSH BURIAL EVENTS

Stratigraphic columns from representative sample sites at salt marshes in each bay show dark stripes that are believed to represent the depths to the tops of peaty layers that are buried salt marshes. These peats are overlain by muds typical of salt water bays and indicate episodic, virtually instantaneous inundation of the marshes by sea water, the inundation persisting for tens or hundreds of years after each submergence. Some peat layers are overlain by sandy sediment (sediment capping layer) possibly deposited by a seismic sea wave (tsunami) arriving shortly after submergence. Those peats with a sediment capping layer have a symbolic wave symbol on top of the stripe. Peats buried by bay mud are considered good physical evidence that the coast may have experienced great (M 8-9) subduction zone earthquakes that are commonly associated with instantaneous coseismic subsidence or uplift of coastal areas. Data sources and other details are given in the footnotes. Where available, some representative radiocarbon ages (in radiocarbon years) for uppermost and lowermost buried peat layers are listed. The salt marsh subsidence data were contributed by Curt Peterson and Mark Darienzo of Portland State University and Wendy Grant of the U.S. Geological Survey.

GEOLOGIC STRUCTURES AND PHYSIOGRAPHY

As a convention used in this map, we show offsets across faults only where they can be demonstrated with existing data. Other offsets that might be expected, but that have not been demonstrated, are not shown. This may cause some ambiguity where sea floor features are most probably offset by a fault but do not appear so on this map. We considered this preferable to the greater ambiguity caused by inferring offsets where insufficient data exist.

We emphasize young structures (i.e., those that offset and/or deform the sea floor) on the neotectonic map in order to evaluate regional structural trends under the present oblique subduction environment. Young structures are also the easiest to map, as they generally deform the sea floor or appear in the more easily interpretable uppermost portion of seismic reflection profiles. We used a color coding scheme to represent the estimated age of youngest demonstrated activity on folds and faults. Structures active in the latest Pleistocene and Holocene are shown in red; structures active in the Pliocene-Pleistocene are shown in green; all older structures are shown in blue. The youngest estimated age of continuous structures may vary along strike; this is represented on the map by along-strike color changes. A color change on the map could indicate either an actual along-strike change in the motion history of a structure or it could be an artifact created by the variability in quality or distribution of the seismic data. In some areas, younger structures can be seen to overlap older (usually NE-trending) structures. This occurs where erosional unconformities vertically juxtapose structures of widely differing ages. In some cases, the older structural trends have remained active despite unfavorable orientation in the present stress field. In a few cases, coeval structures cross each other. These occurrences are associated with active strike-slip faults cutting other, sometimes active structures. Some of these faults have associated flower structures and fault-parallel folding that is active, while other folds of different orientations also remain active. This can occur because both sets of structures are compatible with a single greatest principal stress orientation.

Age determinations for structures other than active structures that cut or deform the present sea floor generally have a large and undefined error bar and should be considered relative ages for general use. Active structures are difficult to confirm in areas of older surface exposure; thus some active faults have probably been missed in these areas (i.e., inshore areas of southern Oregon south of Coos Bay and inshore areas between Cape Falcon and Cape Foulweather). Structures in these areas that are shown as active have generally been confirmed as active by sidescan sonar imaging or submersible dives. A number of other suspected active structures have been ground truthed in this manner. Ages are constrained by biostratigraphy in industry drill holes, Deep-Sea Drilling Program (DSDP) drill holes, dart cores and dredges from sedimentary rock outcrops on the sea floor, and piston and gravity cores from unconsolidated sediments.

DISCUSSION OF MAP FEATURES AND SYMBOLS

The physiography of the Oregon margin and abyssal plain is presented in Figure 1 to show the relationship of the structures to the main physiographic features of the region. The continental shelf extends from the shoreline to the shelf break (i.e., a significant increase in bottom slope), at a water depth from 180 to 200 m. The shelf break is highly sinuous in Oregon, and its distance from the coast varies from 25 to 75 km. The widest shelf areas correspond to the Nehalem, Heceta, and Coquille submarine banks. The continental slope extends from the shelf break to a water depth of about 3,000 m, seaward of which is the relatively flat abyssal plain of the Juan de Fuca Plate. In northern and central Oregon, the slope is further subdivided morphologically into an upper and lower slope, based upon the occurrence of upper and lower structural terraces, respectively (see below). Various named and unnamed submarine channels are indicated on the continental slope and abyssal plain. On the abyssal plain, most of these channels are distributary channels of the Astoria submarine fan, the apex of which is at the mouth of Astoria canyon in the northwestern quadrant of the map. The Blanco Fracture Zone, a transform fault, connects the southern end of the spreading Juan de Fuca Ridge with the northern end of the spreading Gorda Ridge. The Juan de Fuca Plate is converging with the North American Plate off central Oregon along a vector oriented at 062° and at a rate of 40 mm/yr (calculated from the poles of DeMets and others (1990) at 45°00' N latitude along the deformation front).

DATA SOURCES AND MAPPING METHODOLOGY -- OFFSHORE GEOLOGIC STRUCTURES AND BATHYMETRY

DATA COLLECTION AND SOURCES

The geology and physiography were contributed by Vern Kulm, Chris Goldfinger, and Robert Yeats of Oregon State University. This part of the map represents the compilation and interpretation of about 30,000 km of seismic reflection profiles, SeaBeam swath bathymetry, and side-scan sonar mosaics of the sea floor morphology. The primary data sets used in constructing the map include (1) single-channel sparker and airgun reflection profiles shot by Oregon State University and the University of Washington; (2) single and multi-channel airgun profiles shot by the U. S. Geological Survey; (3) migrated multi-channel airgun reflection profiles shot by Digicon for Oregon State University; (4) single-channel sparker profiles made by Shell Oil Corporation; (5) single and multi

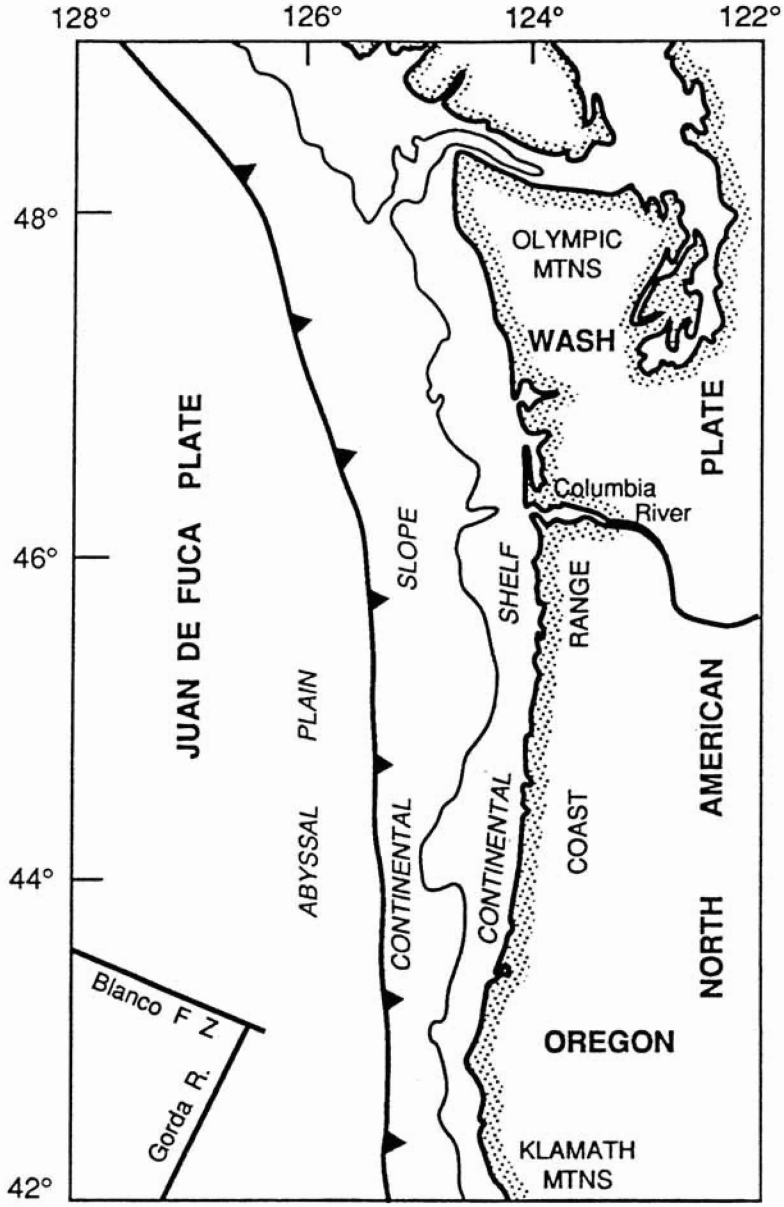

Figure 1. Geomorphic and geologic features of the Oregon and Washington continental margin. Gorda R. refers to the Gorda Ridge, an area of active spreading apart of oceanic plates. The tooth pattern marks the Cascadia subduction zone where the Juan de Fuca Plate plunges beneath the North American Plate. Blanco F.Z. refers to the Blanco Fracture Zone, a right-lateral transform fault.

channel profiles acquired by Chevron Oil Co. (mostly shot by Gulf Oil); (6) SeaBeam swath bathymetry obtained by NOAA/National Ocean Survey and Oregon State University; (7) GLORIA long-range side-scan sonar acquired by the U.S. Geological Survey; (8) 50-kHz Klein sidescan sonar and and associated DELTA submersible observations; and (9) SeaMARC 1A high-resolution side-scan sonar acquired by Oregon State University. Several of these data sets were used in conjunction with one another to identify and map the active structures of the continental margin (shelf and slope) and adjacent abyssal plain. Table 1 lists the sources and navigation methods for the various data sets (see also discussion below). Locations of ships tracks for the data used in this study are on Plate 2.

Seismic reflection profiles made on the Oregon margin and abyssal plain were acquired using a variety of sources, including various sized air gun and sparker arrays, and a variety of digital and analog recording systems. The single- and multi-channel seismic reflection data vary widely in type of source signal, record quality, depth of penetration, and navigational accuracy. They include unmigrated single-channel sparker records navigated with Loran-A and Loran-C, as well as migrated 144-channel digital profiles navigated with GPS (Global Positioning System). Some multi-channel reflection profiles were navigated with GPS, and the position information from these lines is used as the datum for mapping that portion of the study area. Navigational accuracy was more variable with older single-channel seismic profiles. Loran-A navigated profiles have maximum errors about 1-3 km, Loran-C errors are approximately 0-1.5 km, and Transit satellite errors range from near zero up to several hundred meters. An exception is the Shell Oil Company lines. Although these profiles were shot in 1961-62, their navigational accuracy rivals the TRANSIT navigated lines due to the use of a company SHORAN radio navigation system. Horizontal errors with this system are approximately 50 m. The dense coverage of reflection profiles allowed readjustment of older lines where crossed by satellite-navigated lines.

Table 1. Data sources used in this study and approximate navigational accuracy. MCS = multichannel seismic profiles, SCS = single channel seismic profiles, Multibeam = SeaBeam swath bathymetry.

Data Source	**Navigation System**	**Approx. Nav. Error**
U.S.G.S MCS/GLORIA	Transit/Loran C	0-500 m
OSU-U/W Sparker SCS	Loran A	1000-3000 m
OSU/Digicon MCS	GPS	100 m
NOAA/NOS Multibeam	ARGO	50 m
OSU Multibeam	TRANSIT/GPS/Loran C	100 m
OSU 50-kHz sidescan	GPS	100 m
OSU SeaMarc 1A	TRANSIT/GPS/Loran C	100 m
Chevron Oil MCS	Transit/Loran C	0-500 m
Shell Oil Sparker SCS	SHORAN	50 m

The SeaBeam bathymetric survey system is a 12-kHz multibeam echo sounder developed by the General Instrument Corporation to produce near-real-time high-resolution contoured swath charts of the sea floor morphology. Full coverage digital SeaBeam swath bathymetry was acquired on the abyssal plain and continental slope from water depths extending from about 3,000 m to about 200 m on the upper continental slope by NOAA/NOS. These bathymetry data were contoured at a 20-m interval and used as a base map for the Oregon neotectonic map. The bathymetry is accurate to within 1% of the water depth across the swath. The NOAA/NOS multibeam surveys were navigated with an ARGO system that was placed in towers positioned along the shoreline; navigational accuracy is 50 m. The partial coverage academic SeaBeam surveys completed in 1987 and 1988 were utilized initially in this study before the NOAA/NOS data were declassified by the U. S. Navy in 1991. The academic SeaBeam surveys were generally navigated with a combination of GPS and Transit satellite navigation, with Loran-C tracking used between satellite fixes.

The regional sea floor morphology of the abyssal plain and continental slope was imaged with the GLORIA system, a side-scan sonar instrument that uses a frequency of 6.8 kHz on the port side array and 6.2 kHz on the starboard side array. It images a 45-km swath width (i.e., 22.5 km either side of the ship's track), with spatial resolution of about 50 m in the across-track direction and 125 m in the along-track direction (see EEZ-SCAN 84 Staff, 1986, for details). This relatively low-resolution GLORIA system is designed to image the relatively large-scale features of the sea floor, such as mid-ocean ridges, fracture zones, abyssal hills and ridges, deep-sea channels, and lineaments. Higher resolution side-scan sonar data were collected with a SeaMARC 1A deep-towed vehicle, which uses a frequency of 27 kHz on the port array and 30 kHz on the starboard array. It is capable of imaging a 2-km or a 5-km swath width (i.e., 1 km and 2.5 km on either side of the ship's track, respectively), with spatial resolutions of 1 and 2.5 m, respectively (see Appelgate, 1988, for details). The side-scan sonar surveys were navigated with a combination of GPS and Transit satellite navigation, with Loran-C tracking used between satellite fixes. Navigation of the deep-towed SeaMARC-IA side-scan fish was done by the method described by Appelgate (1988). Where spatial misfits occur, we have adjusted the side-scan and single-channel seismic reflection data to best fit the TRANSIT and GPS navigated multi-channel seismic reflection lines or the SeaBeam bathymetry where appropriate. The highest resolution side-scan sonar data were collected with a Klein 50-kHz sidescan sonar unit on the Oregon Shelf in July/August 1992. This system imaged details of shelf faults with 30-cm resolution. Ten areas of particular interest were surveyed, and dives were made with the submersible DELTA on active shelf faults to ground truth the sonar data.

MAPPING PROCEDURES

The structural geology and physiography were mapped utilizing a Geographical Information System (GIS) with several layers consisting of the different data sets. The GLORIA side-scan sonar mosaics were used as a base layer at a scale of 1:500,000. Large features such as the major submarine channels, the Blanco Fracture Zone, and the deformation front were mapped primarily from this data set. The GLORIA side-scan mosaics were selected for the base map because of their wide coverage of the Exclusive Economic Zone (EEZ) off the Pacific Northwest. At the time this mapping project was initiated in 1990, full SeaBeam coverage was not yet available for the Oregon margin from NOAA/NOS. (SeaBeam bathymetry coverage remains classified for the entire Washington margin and abyssal plain, where a new neotectonic map is being compiled by us in the same manner as described here.) Preliminary copies of the SeaBeam swath bathymetry charts were provided by NOAA/NOS as soon as they became available and were scaled to 1:500,000 on transparent media. Together, these contour charts and GLORIA mosaics were used to map faults and fold axes between seismic reflection profiles, allowing nearly continuous mapping of individual structures from the abyssal plain to the outer continental shelf. The accurately navigated SeaBeam bathymetry provided another means of correcting position information from older Loran-A navigated seismic profiles, structural information from which was shifted to match the high-resolution bathymetry as needed. In the Coos Bay area, our mapping is modified from Clarke and others (1985), who mapped the structures of Coos Bay basin using closely spaced and well-navigated single channel reflection profiles. We incorporated and modified this earlier mapping using SeaBeam bathymetry and industry reflection profiles.

DESCRIPTION OF THE OFFSHORE STRUCTURAL GEOLOGY AND PHYSIOGRAPHY

The neotectonic structures of the Oregon margin, abyssal plain, and Blanco Fracture Zone are shown on the accompanying map. A brief description of the structure is presented here to acquaint the reader with the main structural elements. The reader is referred to the following publications for a detailed description of these structures: Appelgate and others, 1992; Goldfinger and others, 1992, 1992a; and MacKay and others, 1992. Additional background information on the structural and tectonic setting of this portion of the northeast Pacific Ocean is given in the Cited and General References.

The primary structural feature is the North American-Juan de Fuca Plate boundary at about 3,000-m water depth. The deformation front is characterized by a seaward-vergent thrust fault from the Gorda Plate off northern California north to 44°51' N latitude off southern and south-central Oregon. North of 44°51' N latitude into Washington, the basal thrust is landward-vergent, with one minor exception (Goldfinger and others, 1992). The plate boundary is complex in detail, highly sinuous in many seaward-vergent areas, offset by oblique structures, and commonly distributed over many splay thrusts. Many small and several large slumps are mapped on the lowermost slope and abyssal plain, notably a very large debris pile and arcuate scarp at 44°00' N and a smaller one at 45°21' N latitude.

In central and northern Oregon, the continental slope is characterized by upper and lower terraces separated by a major landward-dipping thrust and a coincident break in slope (labeled SB for slope break on the map) at about 1,000-m water depth. Seaward of this fault, thrusts and folds of the accretionary wedge trend north-south, sub-parallel to the continental margin. Landward of the fault, folds of the upper slope and shelf trend mostly north-northwest to west-northwest, oblique to the margin. In southern Oregon, the terraces become one steep escarpment, and this boundary becomes indistinguishable as a bathymetric feature, but the two domains of structural orientations remain distinct south into California (Clarke, 1992). Thrust faulting within the accretionary wedge occurs in both landward and seaward vergent styles, with landward vergence common off northern Oregon and rare off southern Oregon. Out of sequence thrusting follows a similar pattern, being common, if not typical, in the north and less so in the south.

Many second-order features of particular tectonic significance are also apparent on the map. On the continental slope and abyssal plain of northern and central Oregon, detailed investigations using sidescan sonar surveys, SeaBeam bathymetry and single/multichannel seismic records show three confirmed and three probable WNW- trending left-lateral strike-slip faults between 43°20' N and 45°12' N latitude. The three northernmost structures (Wecoma fault, faults B, and C) between 44°40°N and 45 12' N latitude offset the basaltic crust and overlying sedimentary section (Goldfinger and others, 1992, 1992a; Appelgate and others, 1992). The best-known fault (Wecoma fault) extends 18 km seaward of the deformation front and offsets sub-bottom reflectors and basaltic basement approximately 100 m (NE block up). Late Pleistocene to Holocene sea floor channels are offset 150-400 m in a left-lateral sense. Strike-slip faulting is also indicated by flower structures, mismatched stratigraphy, and reversals of vertical separation along trend. These structures are inferred to be active from direct ALVIN submersible observation of bedding attitudes, fresh scarps, and fluid venting (Tobin and others, 1991). Faults B and C are associated with left offsets of the deformation front and/or left offsets of fold axes on the continental slope. Fault B intersects the base of the continental slope at 44°51' N latitude, the point at which regional thrust vergence reverses, being seaward-vergent to the south and landward-vergent to the north. On the continental slope, these structures are characterized by deformation zones composed of WNW-trending linear scarps, en-echelon NW- to WNW-trending folds, and left-stepping and sigmoidally bent folds. Oblique folds are commonly fault-propagation and fault-bend folds developed above high-angle faults. Some of these active NNW- to WNW-striking faults and folds are refolding somewhat older or coeval north- and NNE-trending folds. Deformation in these zones is consistent with a left-lateral sense of shear (see Goldfinger and others, 1992, 1992a and Appelgate and others, 1992, for a detailed discussion of these structures). Detailed mapping and submersible observations of fault B in the area of Daisy Bank confirmed the presence of the active left-lateral fault there and suggest that Daisy Bank itself may be a pressure ridge uplift across a compressional step in fault B. We have added selected Quaternary and suspected Quaternary structures mapped onshore by other investigators that are probable correlatives of offshore structures, including the following: South Slough syncline and other Coos Bay area structures from McInelly and Kelsey, 1990, and references therein; Cape Blanco anticline and Port Orford area faults from Kelsey, 1990; all other southern Oregon structures from Dott, 1971; Yaquina Bay fault from Kelsey and others, 1992; Happy Camp fault and other Netarts Bay area structures from Parker, 1990, and Wells and others, 1992; Tillamook Bay fault from Wells and others, 1983.

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* Now at School of Earth Sciences and Technology, University of Hawaii, Honolulu, HI.

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