

Regional Hydrogeology of the Willamette Valley

Compiled By

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**Derived from Gannet and Caldwell (1998); Yeats and
Others (1991)**

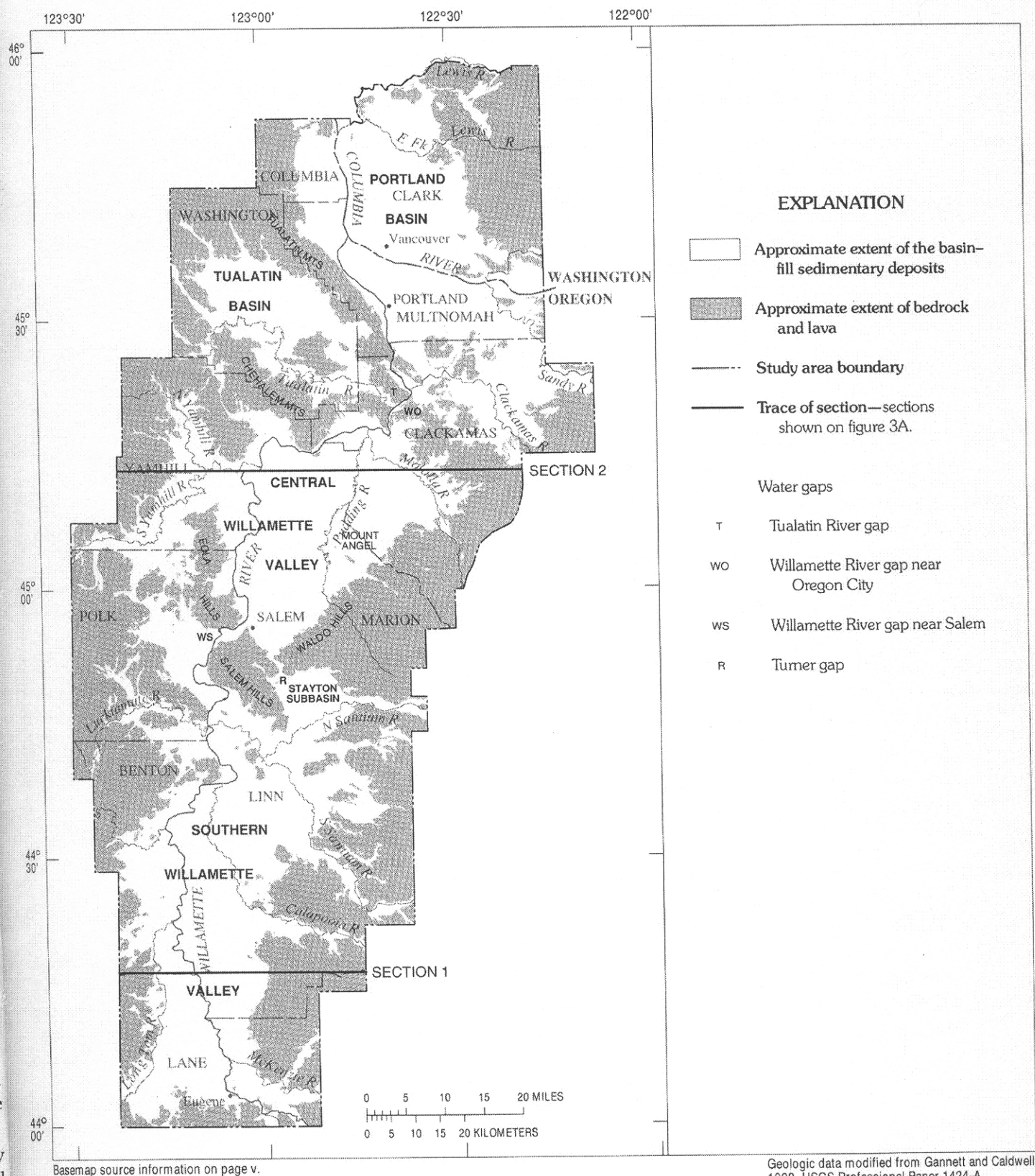


FIGURE 2.—Location of Willamette Lowland and structural basins.

TECTONICS OF THE WILLAMETTE VALLEY, OREGON

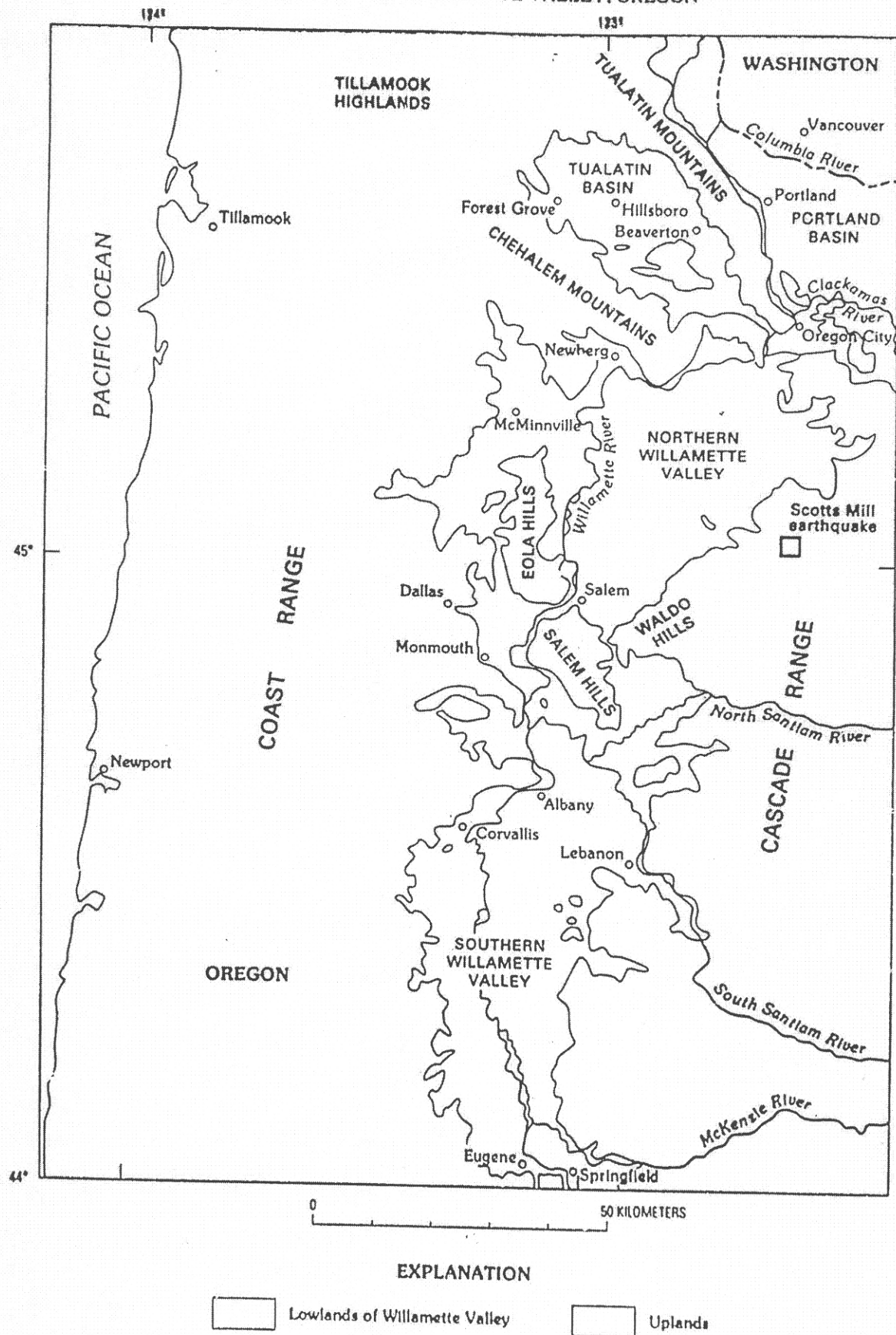


Figure 77. Geographic and physiographic features of the Willamette Valley and Portland and Tualatin basins, northwestern Oregon. The square indicates the epicenter of the March 25, 1993, Scotts Mills earthquake.

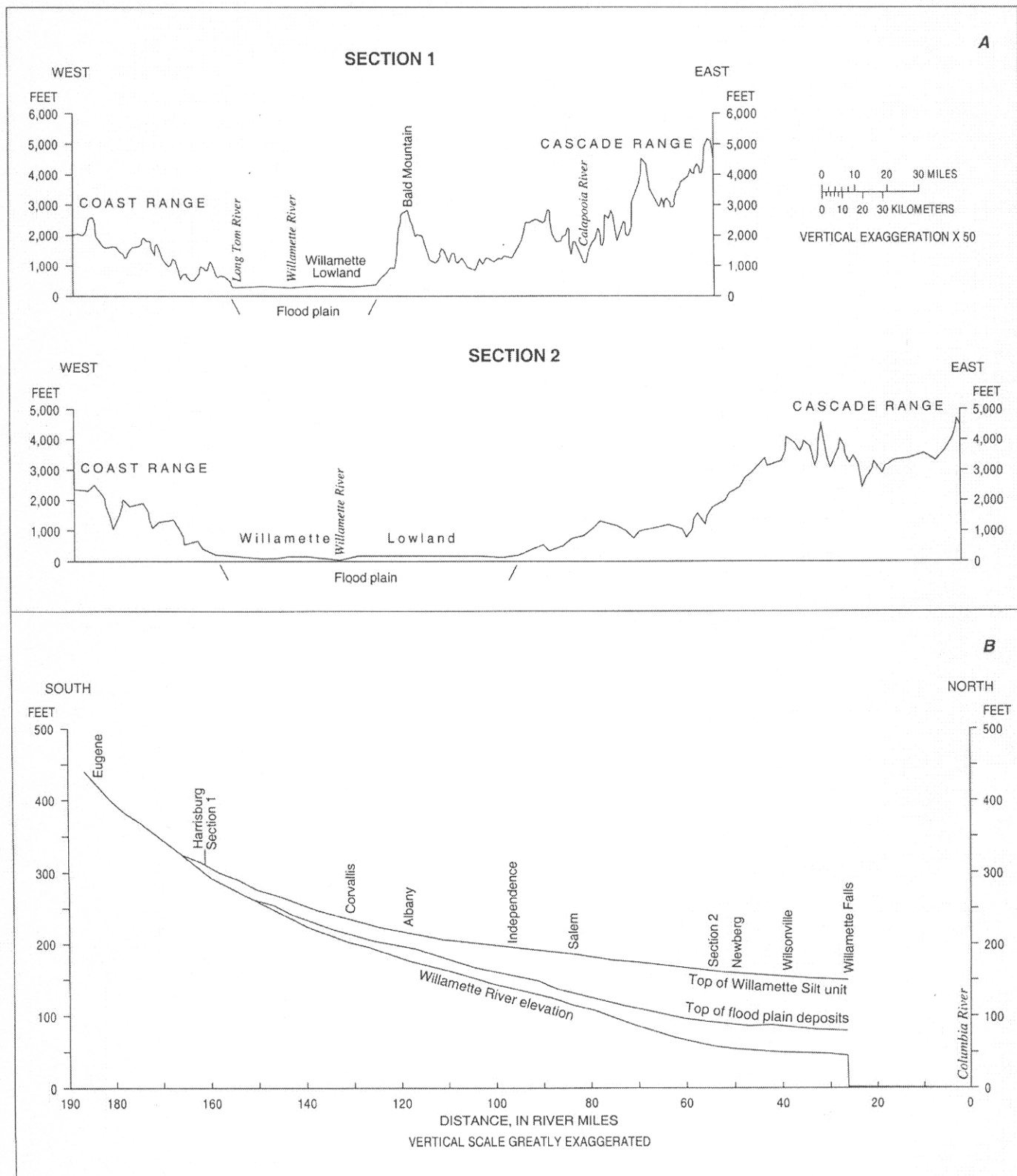


FIGURE 3. (A) Topographic sections west-east across study area and (B) Bank section along Willamette River.
(Trace of topographic sections shown on figure 2.)

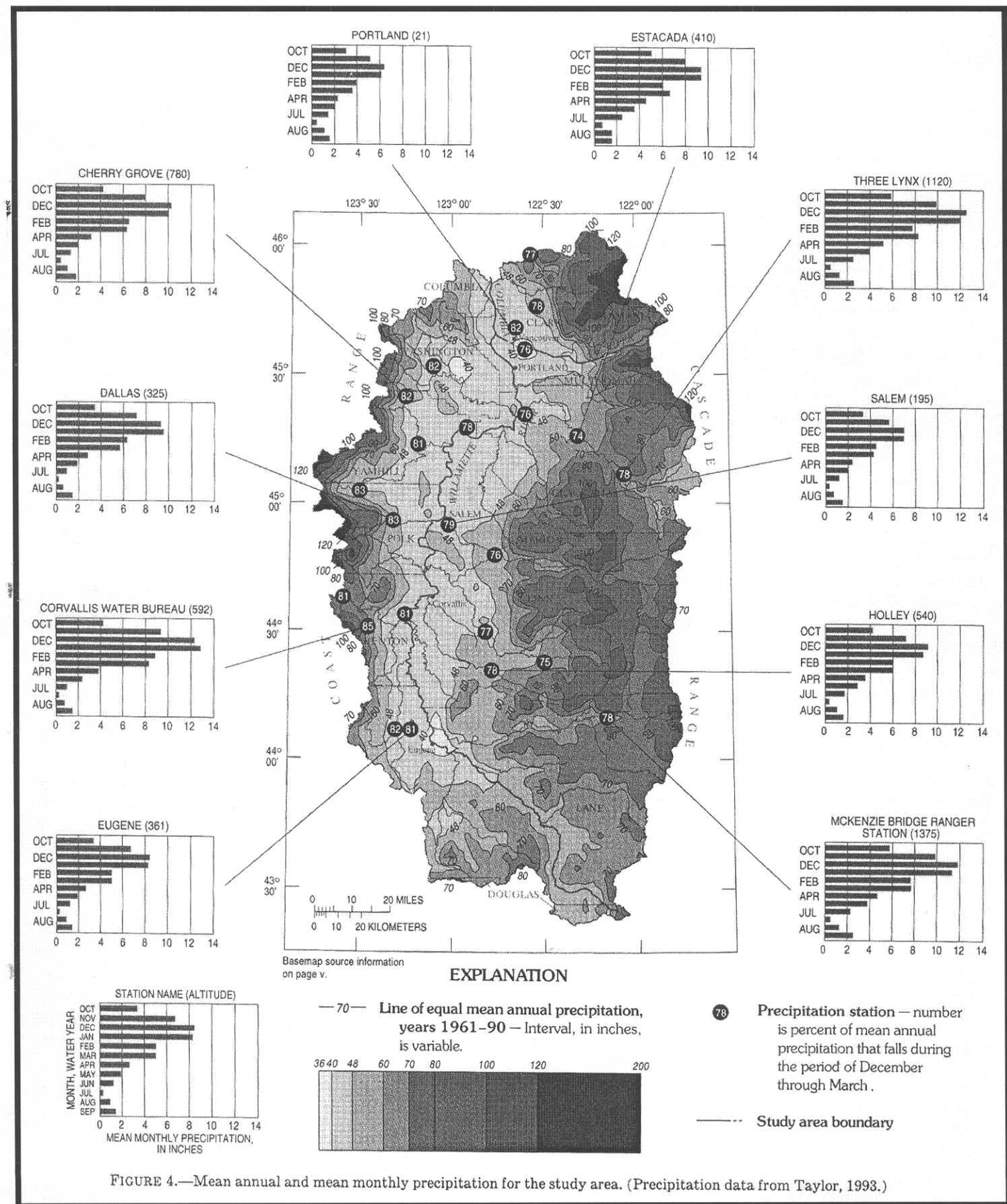


FIGURE 4.—Mean annual and mean monthly precipitation for the study area. (Precipitation data from Taylor, 1993.)

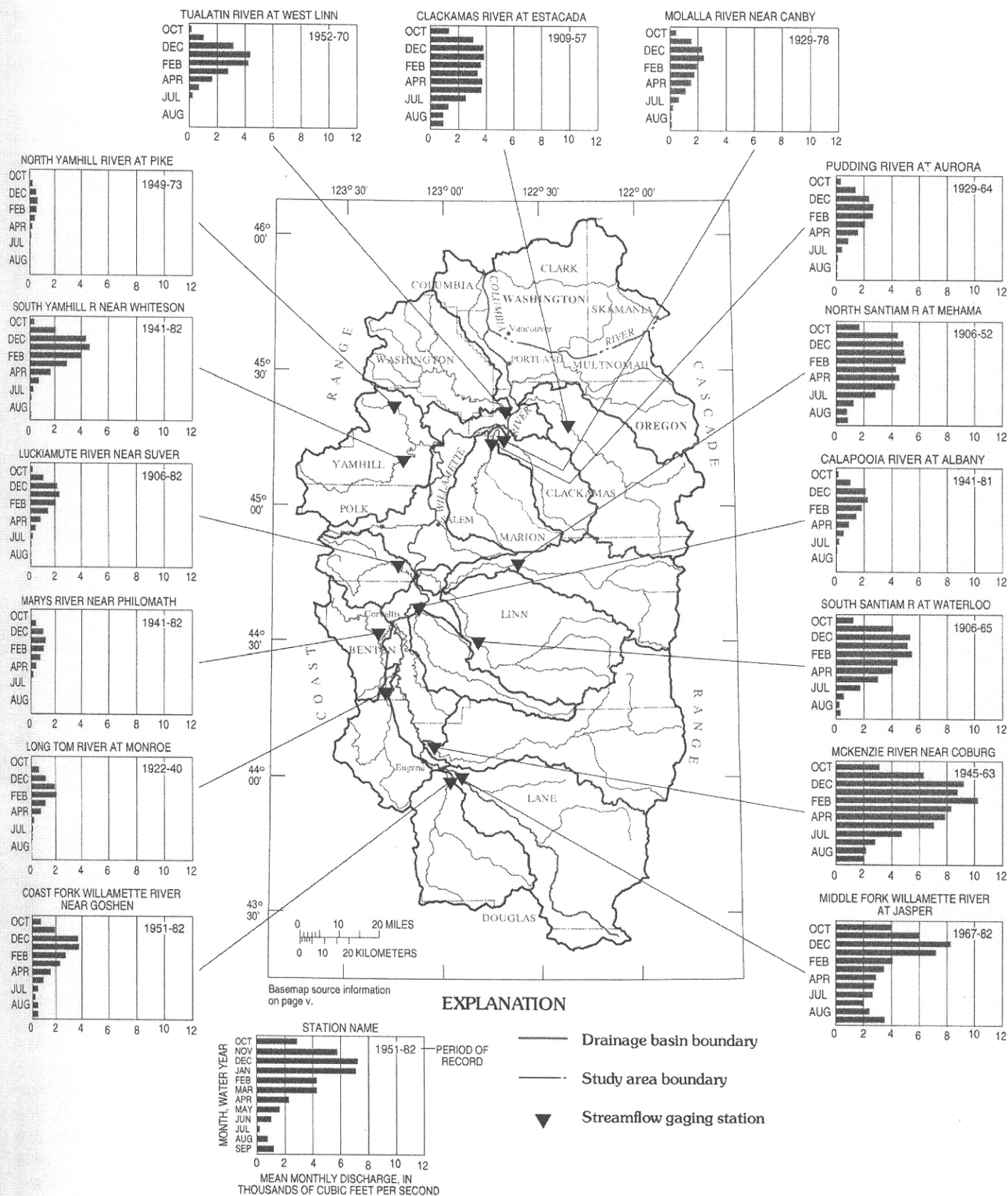
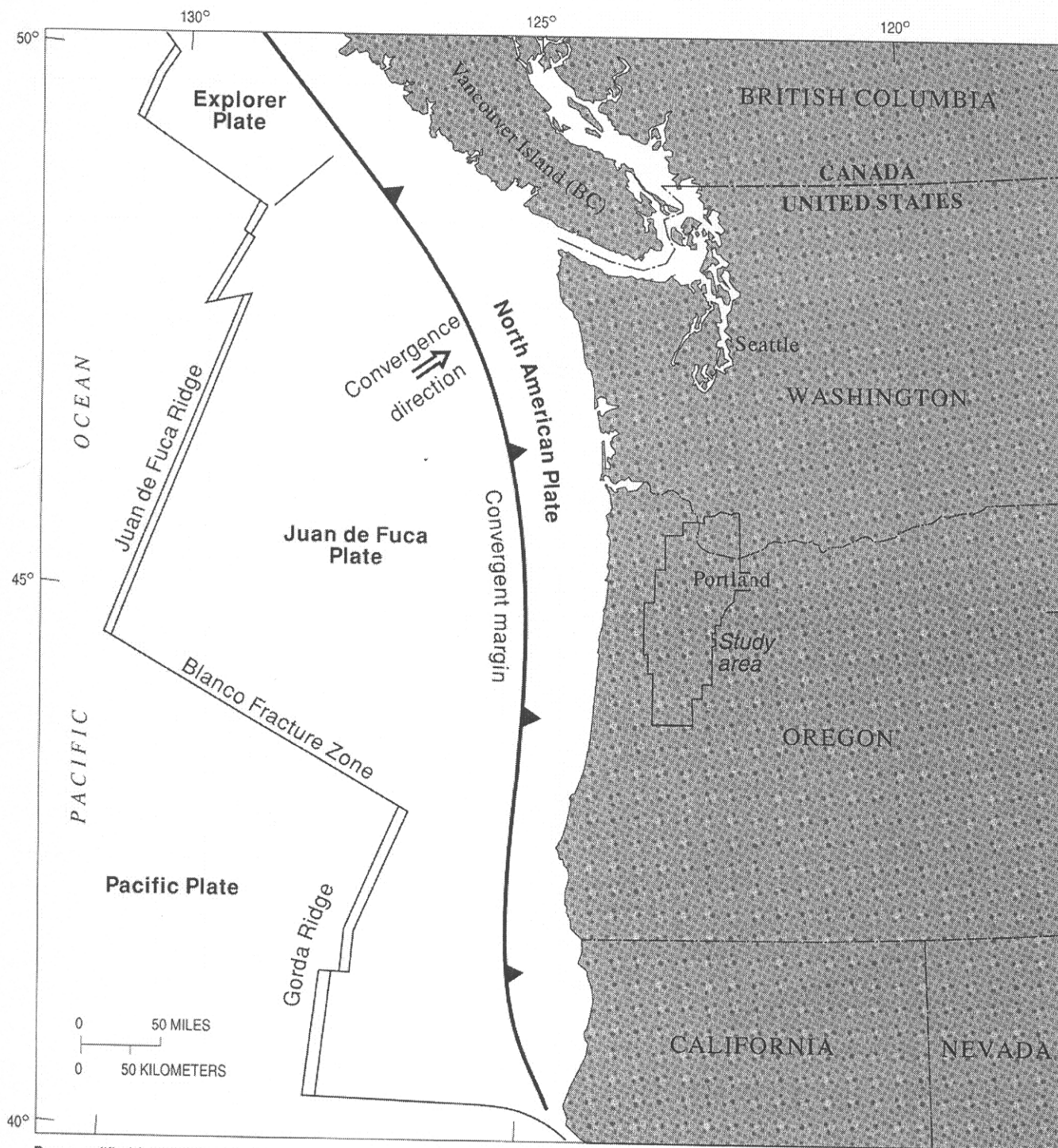


FIGURE 5.—Mean monthly discharge for selected major tributaries of the Willamette River.



Base modified from Digital Chart of the World, DMA, 1992.

Geology modified from Guffanti and Weaver, 1988.

FIGURE 5.—Tectonic setting of the Oregon and Washington continental margin.
(Modified from Guffanti and Weaver, 1988.)

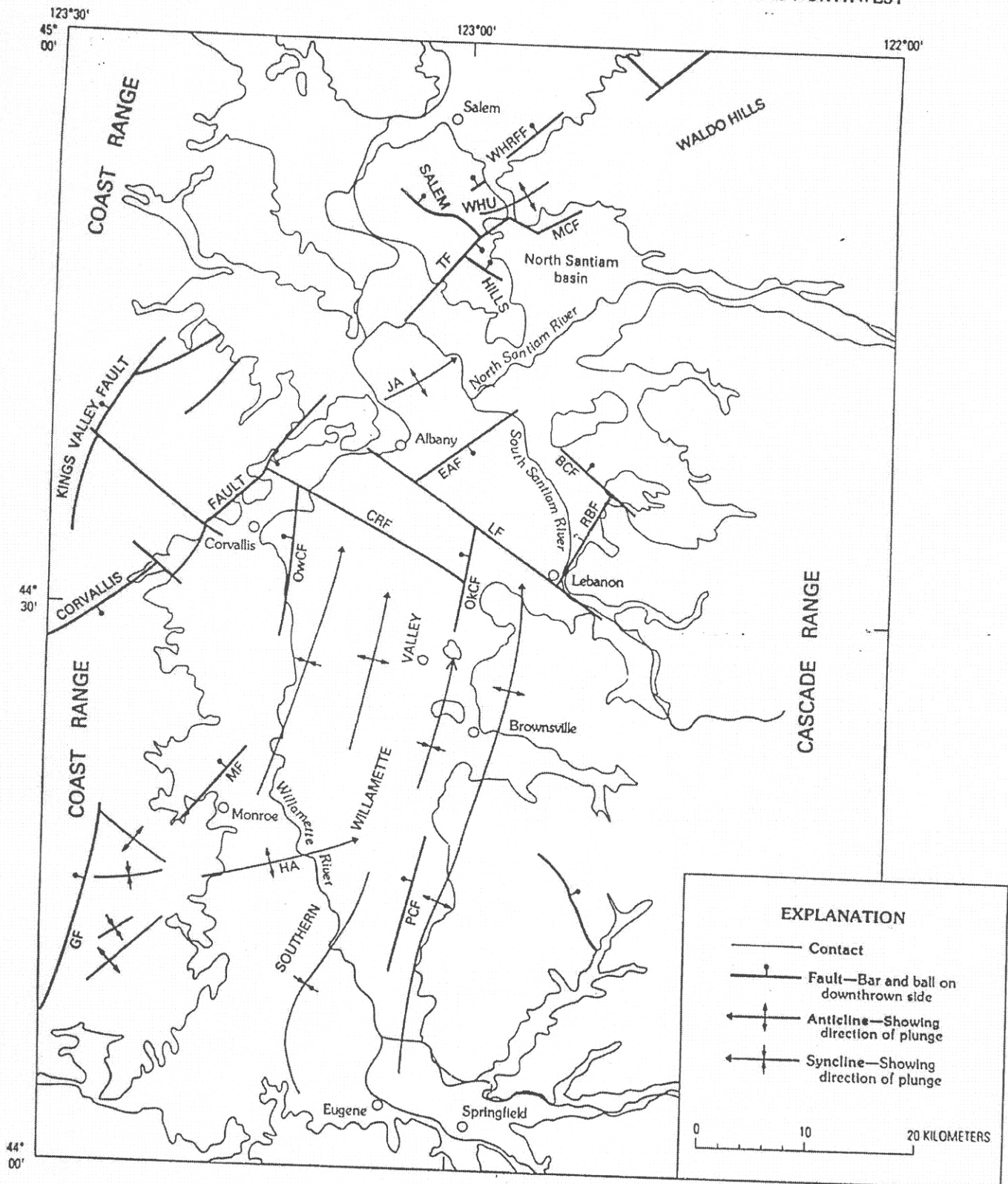
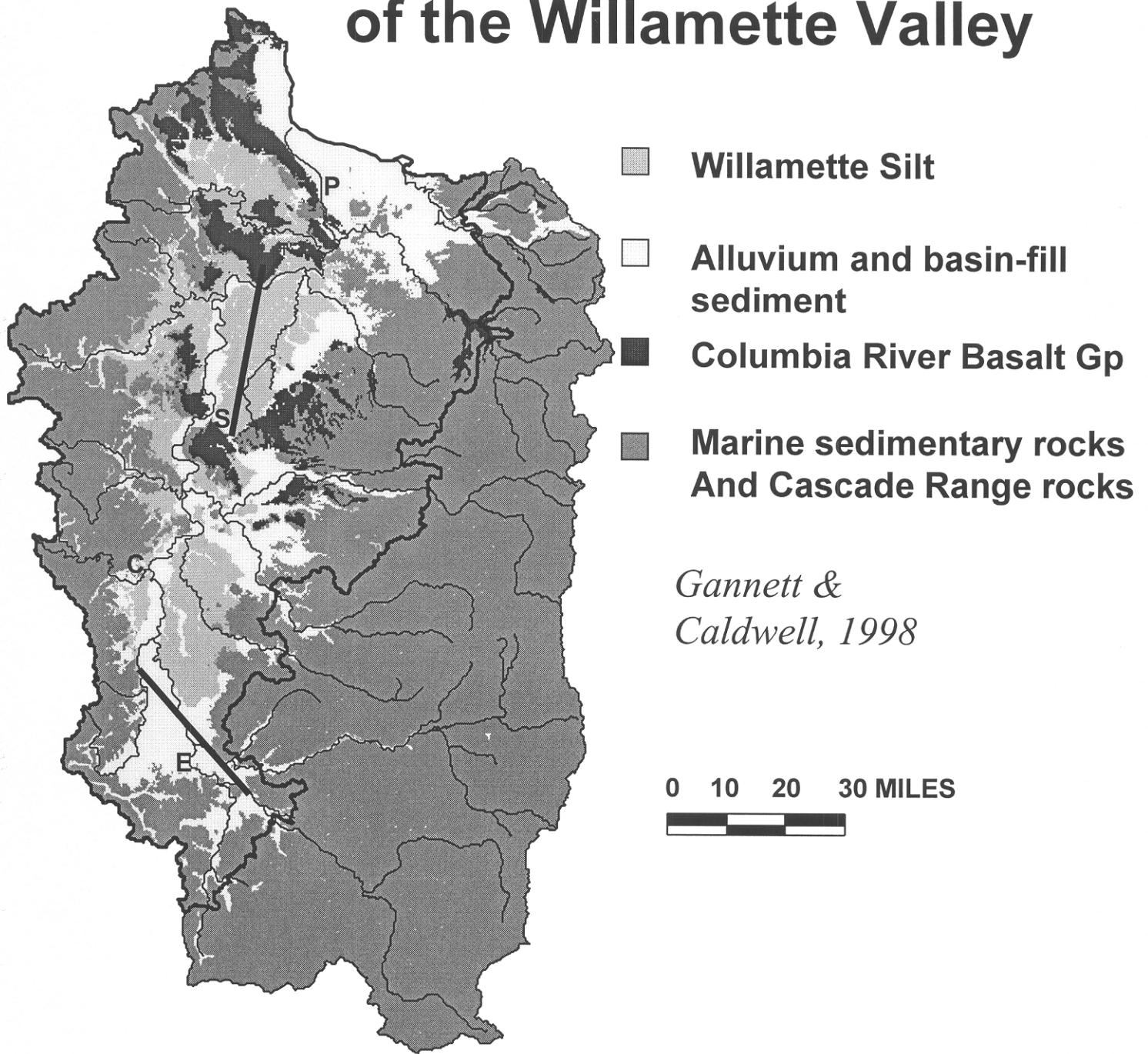


Figure 84. Tectonic map of the southern Willamette Valley, Oregon. Areas underlain by alluvial and fluvial deposits that postdate the Columbia River Basalt Group are unshaded; areas underlain directly by bedrock are shaded. BCF, Beaver Creek fault; CRF, Calapooia River fault; MF, Monroe fault; OwCF, Owl Creek fault; OkCF, Oak Creek fault; PCF, Pierce Creek fault; RBF, Ridgeview Butte fault; TF, Turner fault; WHRFF, Waldo Hills range-front fault; WHU, Waldo Hills uplift.

Generalized Geology of the Willamette Valley



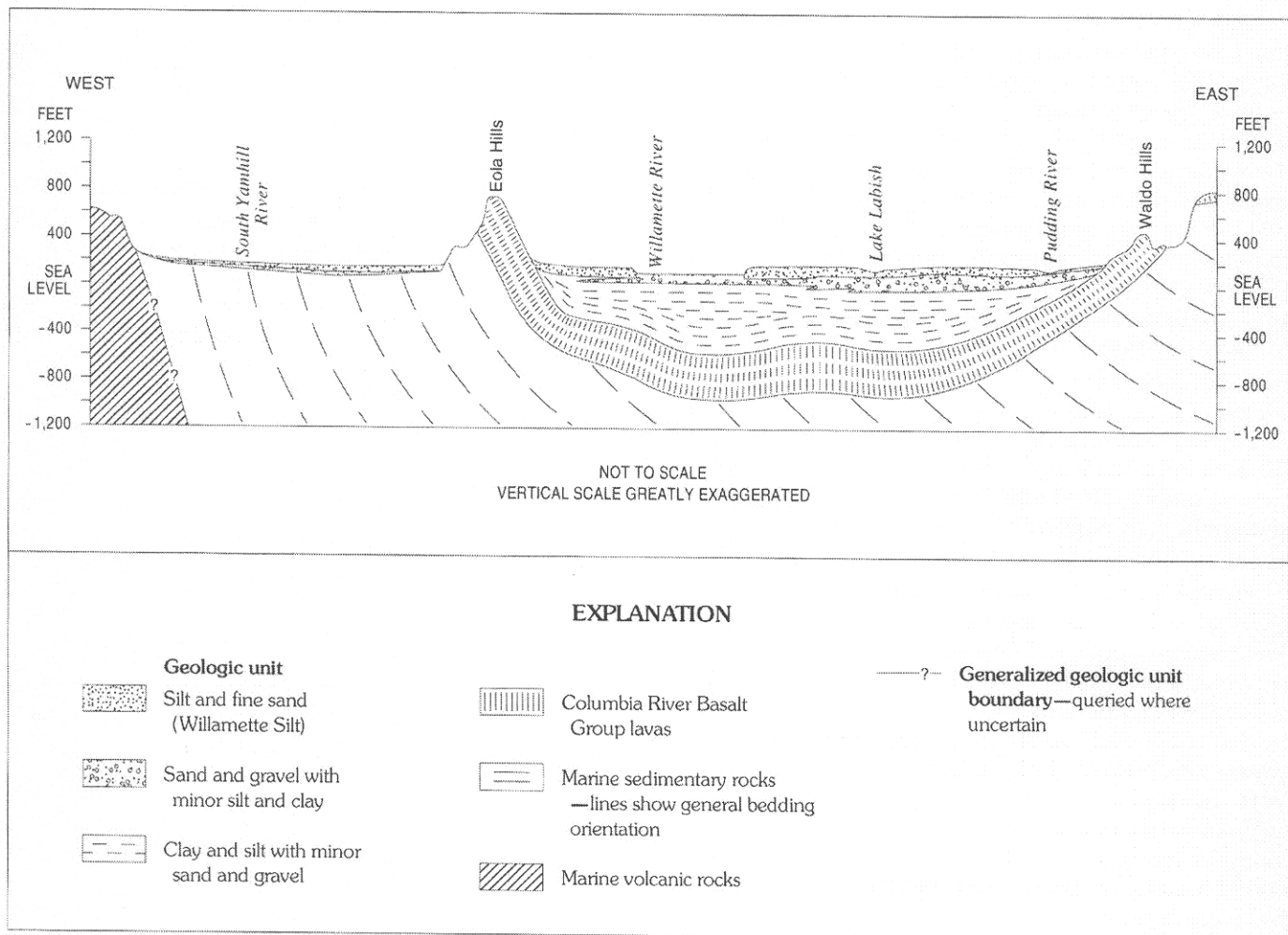


FIGURE 7.—A generalized geologic section west-east through the central Willamette Lowland.

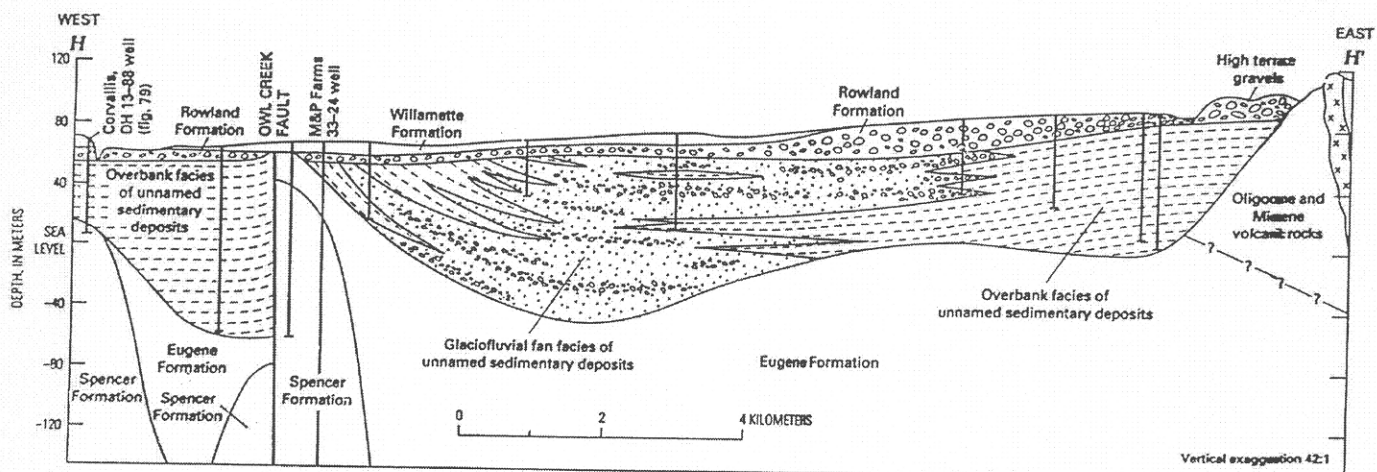
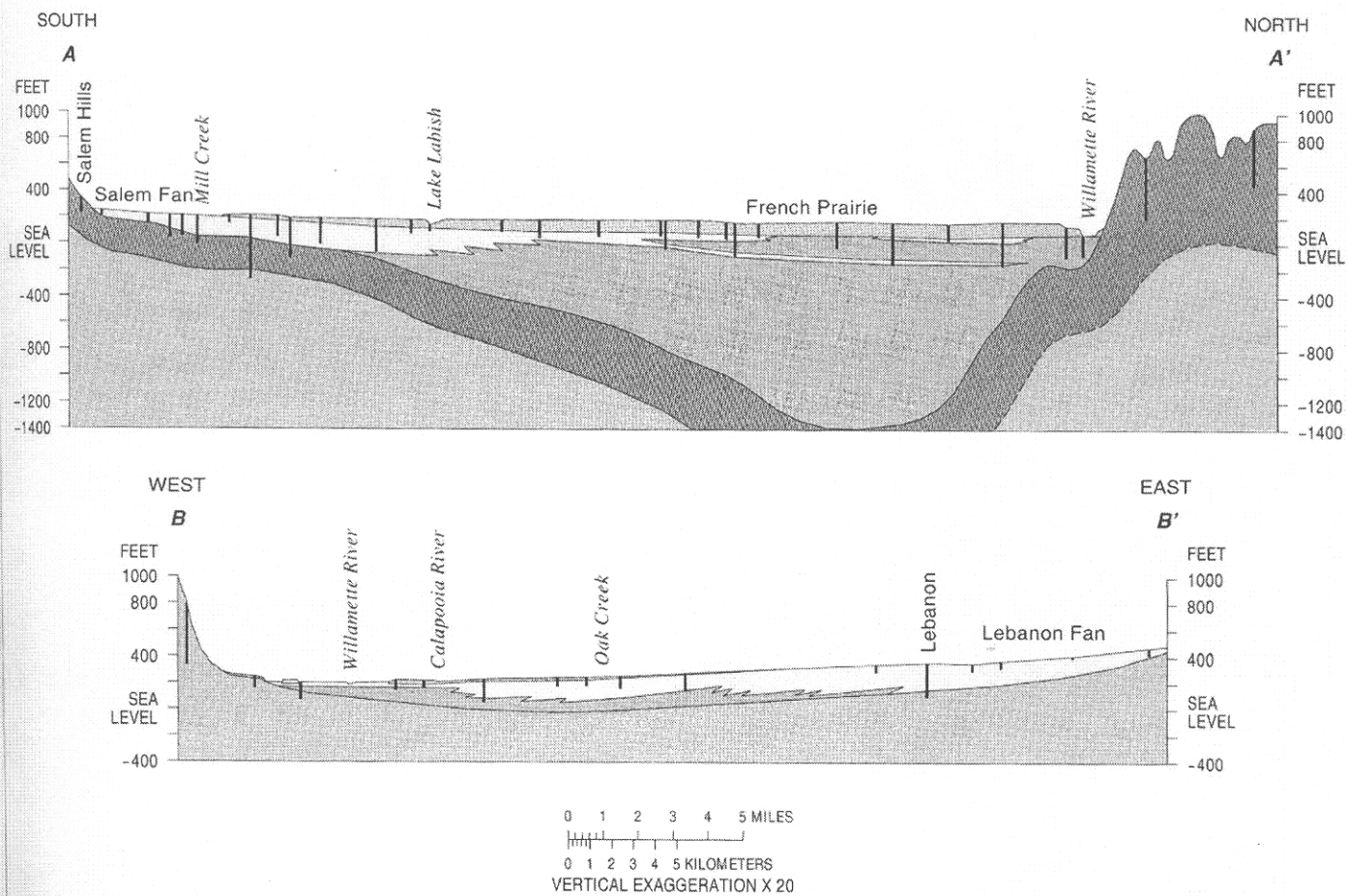


Figure 82. Structural cross section between Corvallis and Lebanon, Oreg., showing channel and overbank facies of unnamed fluvial sedimentary deposits, high terrace gravels, late Pleistocene outwash deposits of the Rowland Formation, and catastrophic flood deposits of the Willamette Formation. Data are from water wells, engineering bore holes, and petroleum-exploration wells.



EXPLANATION

Hydrogeologic unit



Willamette Silt unit



Willamette aquifer



Willamette confining unit



Columbia River basalt aquifer



Basement confining unit



Hydrogeologic unit boundary
dashed where inferred



Well

Geologic data modified from Gannett and Caldwell,
1998, USGS Professional Paper 1424A.

FIGURE 9.—Hydrogeologic sections. (A-A'—North-south section in central Willamette Valley. B-B'—East-west section in southern Willamette Valley. Trace of sections shown on figure 8.)

SYSTEM	SERIES	AREA						
		SOUTHERN WILLAMETTE VALLEY (Frank, 1973)	FRENCH PRAIRIE (Price, 1967a)	MOLALLA-SALEM SLOPE (Hampton, 1972)	TUALATIN VALLEY (Hart and Newcomb, 1975)	PORTLAND AREA (Trimble, 1963)	PORTLAND BASIN (Swanson and others, 1993)	WILLAMETTE LOWLAND (This study)
QUATERNARY	HOLOCENE	YOUNGER ALLUVIUM	ALLUVIUM	VALLEY ALLUVIUM	YOUNGER ALLUVIUM	ALLUVIUM	UNCONSOLIDATED SEDIMENTARY AQUIFER	HOLOCENE ALLUVIUM
	PLEISTOCENE	OLDER ALLUVIUM AND TERRACE DEPOSITS	WILLAMETTE SILT	WILLAMETTE SILT UNDIVIDED ALLUVIAL DEPOSITS SPRINGWATER FORMATION ? BORING LAVAS	OLDER ALLUVIUM UNDIFFERENTIATED TERTIARY AND QUATERNARY VALLEY FILL ? BORING LAVAS	SAND, SILT, AND LACUSTRINE DEPOSITS SANDS, GRAVELS, AND CONGLOMERATES OF CASCADE ORIGIN (Walters Hill, Springwater, Gresham, and Estacada Formations) ? BORING LAVAS		WILLAMETTE SILT COARSE-GRAINED FLOOD SEDIMENTS (Portland Basin)
TERTIARY	PLIOCENE	?	TROUTDALE FORMATION	TROUTDALE FORMATION	TROUTDALE FORMATION	TROUTDALE FORMATION	LOWER SEDIMENTARY SUBSYSTEM FINE-GRAINED SEDIMENTS CONFINING UNIT 2 TROUTDALE SS. AQUIFER CONFINING UNIT 1 SAND & GRAVEL AQUIFER	COARSE-GRAINED BASIN-FILL SEDIMENTS BORING LAVAS
			SANDY RIVER MUDSTONE	SARDINE FORMATION CRBG	TROUTDALE FORMATION SANDY RIVER MUDSTONE RHODO. FM. CRBG	TROUTDALE FORMATION SANDY RIVER MUDSTONE RHODO. FM. CRBG		FINE-GRAINED BASIN-FILL SEDIMENTS CRBG
	MIOCENE	?	COLUMBIA RIVER BASALT GROUP	CRBG	CRBG	CRBG	OLDER ROCKS (Including the Columbia River Basalt Group)	CRBG
	OLIGO-CENE EOCENE	MARINE SEDIMENTARY AND INTRUSIVE ROCKS, AND WESTERN CASCADE ROCKS	MARINE SEDIMENTARY ROCKS NOT EXPOSED	MARINE ROCKS WESTERN CASCADE ROCKS	MARINE SEDIMENTARY AND VOLCANIC ROCKS	MARINE ROCKS WESTERN CASCADE ROCKS		MARINE ROCKS WESTERN CASCADE ROCKS

NOTE: CRBG = COLUMBIA RIVER BASALT GROUP
RHODO. FM. = RHODODENDRON FORMATION

FM. = FORMATION
SS. = SANDSTONE

FIGURE 6.—Selected geologic units in parts of the Willamette Lowland as delineated by previous investigators, and as generalized in this study.

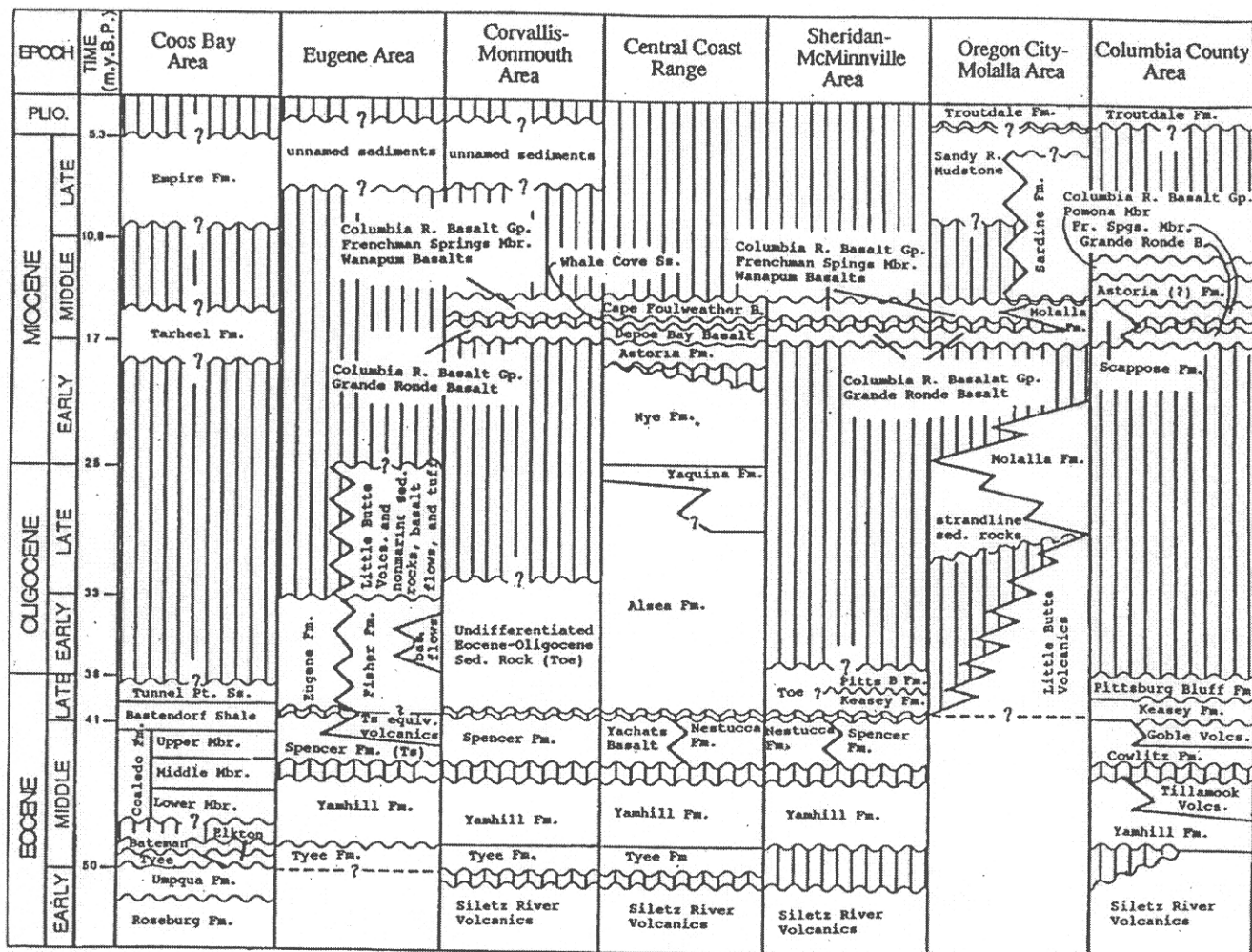
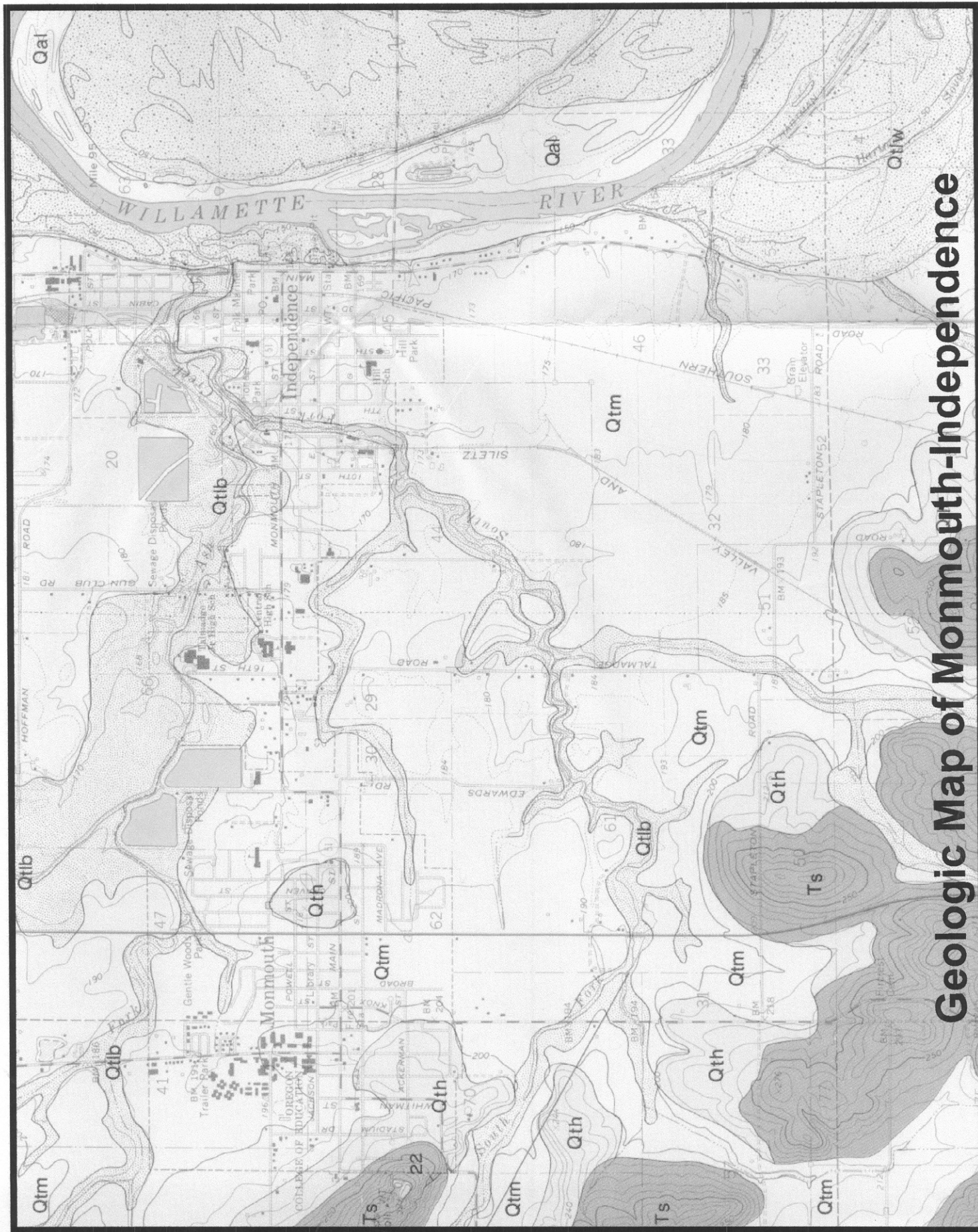


Figure 3. Stratigraphic correlation chart for Tertiary rocks of western Oregon (modified from Yeats and others, 1991).



Geologic Map of Monmouth-Independence

MONMOUTH GEOLOGIC MAP

BEDROCK GEOLOGIC UNITS

EXPLANATION

SURFICIAL GEOLOGIC UNITS

Qal

Recent river alluvium: Unconsolidated cobbles, coarse gravel, sand, and some silt and clay within active channels of Willamette River. Generally 15-45 ft thick, consisting of stratified sands and well-rounded pebbles, gravels, and cobbles of primarily basaltic and andesitic composition; often overlain by 3-15 ft of light-brown sand and silt overburden. Characterized by low relief, point-bar and channel-bar deposits; many areas unvegetated, others support dense stands of brush and phreatophytes, such as willows and cottonwoods. Subject to major flooding, critical stream-bank erosion, and lateral channel migration; includes many areas located between 1852 meander line and present channel that illustrate possible extent of future changes

Qtlw

Lower terrace deposits of the Willamette River (Quaternary): Unconsolidated to semiconsolidated cobbles, gravel, sand, silt, clay, muck, and organic matter of variable thickness (30-50 ft) on the flood plain and lowland terraces immediately above the Recent river alluvium (Qal); typically 5-20 ft of light-brown silt and clay or very fine sand overlying 10-45 ft of moderately well-sorted sand and locally cemented gravel. Surface topography characterized by a low, undulating, fluvial surface with abandoned channels, meander scrolls, oxbow lakes, and sloughs; subject to major and local flooding, some catastrophic channel migration of major scale, ponding, and high ground water. Flood-plain soils are predominantly well drained and somewhat excessively drained silty clay loams, silt loams, and sandy loams; good ground-water yields generally of 100-500 gallons per minute

Qtlf

Lower terrace deposits of tributary rivers and streams (Quaternary): Unconsolidated to semiconsolidated gravel, sand, silt, clay, and organic matter generally 15-30 ft thick on lowland terraces and flood plains immediately above major tributary rivers of the Willamette River. Gravel deposits are very thin to variable in thickness, according to tributary drainage source, generally limited to active stream beds or former meander channels, and located at or near bed rock beneath 20-30 ft of sand, silt, and clay. Somewhat tortuous meandering streams entrenched 15-45 ft, often flowing on Tertiary sedimentary bed rock or semiconsolidated older valley-fill alluvium. Surface topography characterized by a low, undulating fluvial surface of swell and swale relief, abandoned meander loops, and oxbow lakes; subject to high ground water and ponding and major and local flooding; flood-plain soils are predominantly well drained and somewhat excessively drained silty clay loams, silt loams, and sandy loams. Some soft, compressible organic soils of low shear strength may occur locally, particularly within abandoned channels and oxbows. Major stream-bank erosion commonly occurs at outer bends of meander loops by shallow earthflow and slump due to undercutting. Ground-water yields generally small

Qtlb

Lower terrace deposits of alluvial bottomlands (Quaternary): Flat, moderately to poorly drained areas with soft, organic compressible soils of low shear strength locally; characterized by low relief, ponding, and high ground water. Deposits typically consist of somewhat stratified very fine sands, silty sandy clays, silty clays, and silty clay loams, with slight to moderate plasticity (ML-CL); 4-12 ft thick along bottomlands of interior drainages of low, rolling sedimentary bedrock units. Deposits locally may represent somewhat thicker accumulations of silt and silty clay materials of fluvial and/or loessal origin derived in part from Willamette Silts. Similar deposits along creeks are associated with deposits of units Qtm and Qth and are often modified by ditching and field drainage for agriculture; typical examples are deep (more than 60 in.) clay (CH), silty clay (CH), and silty clay loam (CL or ML) black Bashaw clay soils of Baskett Slough (Rickreall quadrangle). Similar thicknesses of reddish-brown sandy silt material (ML-CH) in basaltic terrain (Ter)

Qtm

Middle terrace deposits (Quaternary): Semiconsolidated gravel, sand, silt, and clay forming very flat terraces of major extent along the Willamette River. Generally 10-30 ft of light-brown silty clay and interbedded very fine sand and silt (ML or CL-CH) surficial material, believed primarily related to Willamette Silts, including associated glacial erratics consisting of tiny fragments and pebbles up to boulders greater than 4 ft in diameter. Soils somewhat poorly drained and poorly drained silt loams and silty clay loams to moderately well-drained and well-drained silt loams subject to seasonal high ground water and ponding. Sand and gravel (GP, SM), where present, usually occur below 30 ft depth, locally more abundant near Monmouth-Independence and in the lower part of Ash Creek. Total thickness 0-85 ft, but often only 40-50 ft; within Rickreall 7½-minute quadrangle, 15-35 ft of brown clay or silt generally occurs above several to 30 ft of gravelly clay, block sands, and gravels. Generally small ground-water yields, except near Monmouth-Independence, where sand and gravel may yield up to 300 gallons per minute

Qlg

Linn gravel (Quaternary-upper Pleistocene): Stratified fine to coarse fluvial gravels deposited as an alluvial fan in the Stayton-Turner-Salem areas during an early stage of the Santiam River; of limited extent within the map area; uppermost few feet of gravels extensively oxidized and weathered, often chalky; thickness ranges from 30-40 ft to possibly as much as 300 ft. Regionally, the upper foot or so of gravel is cemented by an impermeable clay pan locally, which restricts drainage. Composition of gravels mostly basalt, but also andesite, dacite, rhyolite, quartz, and diorite essentially uniform. Within map area near Salem, soils are well drained and somewhat poorly drained gravelly silt loam and gravelly loam. Extensively utilized as source of sand and gravel. Good ground-water yields greater than 100 gallons per minute

Qth

Higher terrace deposits (Quaternary-middle Pleistocene): Generally semiconsolidated light and clay of variable thickness (3-15 ft) on higher terraces and remnants of old higher terrace sedimentary bedrock foothills; mantled by moderately well-drained and well-drained silt loam colluvium, slope wash, and alluvial fan deposits near sedimentary bedrock foothills; transitional with pediments. Material generally similar to unit Qtm, particularly in West glacial erratics related to Willamette Silt but also some gravelly alluvium. Some higher terrace of Salem Hills between Salem and Ilwaco Hill not shown due to scale. Also includes weath cobbles and gravels which extend beyond the study area west of Rickreall (8-10 ft thick) a margin of Sidney quadrangle (10-50 ft thick), where they are equivalent to the Leffler gravel. These deposits also mantled by 3-15 ft of light-brown silt loam and silty clay loam soils. Ge ground-water yield

Tcr

Columbia River Basalt Group (Miocene): Medium-gray to black, fine-grained, even-textured phryic basalt, unweathered flows generally dense, fairly crystalline, exhibiting massive columnar base to diced or hackly jointing in entablature. Unit consists of weathered and unweathered b with interflow zones characterized by vesicular flow-top breccia, ash, and baked soils. Ma generally ranges 400-600 ft, with thickness greatly modified by erosion and weathering individual flows range from 40 ft to more than 100 ft in thickness.

Formations recognized within the Yakima Basalt Subgroup (Beeson, 1980, personal communication) (1) Grande Ronde Basalt: two to four "low Mg" N₂ flows, including one to two "Winter Water" (typical exposure at Dairy Queen, West Salem); one to two thick "low Mg" flow(s), 100-150 ft, quarried throughout map area; one to two flow(s) of "high Mg" N₂ basalt, generally deeply weathered above the "Winter Water" flow(s); and (2) a thinner layer of younger Wanapum Basalt, representing flow(s) of the Frenchman Springs Member, observed only in South Salem within the study area occurs outside the map area in the vicinity of Turner.

Weathered flows consist of reddish-brown to grayish-brown, crumbly to medium-dense base variable and believed related to individual basalt flows; some exposures are altered to red clay (l of 30 ft, and occasionally as deep as 60-175 ft, while others are only slightly weathered at surface in Salem Hills (generally between 500-900 ft elevation within area bounded by Pringle Scho Jackson Hill) show extensive laterization which has resulted in deposits of bauxite (Corcoran and Soils are reddish-brown, well-drained silty clay loams and gravelly silty clay loams. Unit yield quantities of ground water from permeable rubbery zones between flows

Ti

Intrusive rocks (Oligocene): Dense basalt, andesite, and gabbro dikes and sills of very limited map area (Rohy Hill, Sidney quadrangle); Rohy Hill quarry geochemically not part of Columbia Group (Beeson, 1980, personal communication). Another limited exposure of porphyritic intrusive flow, with vertical columns 1-2 ft in diameter in contact with claystone along east bank of Li near Buena Vista Road (river mile 3.2). Presumed post-Eocene (Oligocene?) age (Helm and

Toe

Eocene-Oligocene sedimentary rock (middle and lower Oligocene and upper Eocene): Equivalent marine sedimentary rocks (Tts) of Baldwin and others (1955), Ilwaco tuffs (Tts) of Mundorff Formation (Tu) of Thayer (1939), Eocene-Oligocene marine sedimentary rocks (Tm) of Pr undifferentiated Tertiary rocks (Tui) of Gonthier (in press). Consists of two lithologic and fine Willamette River (Baldwin and others, 1955) but undifferentiated in this map due to poor exposure light-gray to tan sandy tuffaceous siltstone equivalent in age to early Oligocene Keesey Fm section near border of Amity-Rickreall 7½-minute quadrangle, where approximately 1,000 ft of Oligocene strata well exposed in Yamhill River near Yamhill locks, where steeply dipping and co Younger unit is fine- to coarse-grained tuffaceous sandstone equivalent in age to middle Olig Bluff Formation; basal stratum approximately 150 ft of dark-gray, coarse-grained, calcareous sandstone, chiefly composed of detrital igneous rock fragments. White, fine-grained, massively, pumiceous volcanic glass approximately 250 ft thick exposed for 3 mi along hillside south of Fin quadrangle; good exposures of pebbly tuff, tuffaceous conglomerate, and fine-grained platy tu Hill Road in Sidney 7½-minute quadrangle.

Tuffaceous marine sandstone and siltstone of Oligocene sedimentary rock correspond to Ol Formation described by Hickman (1969), which contains early to middle Oligocene molluscan foraminiferal analyses (McKeel, 1980) of oil and gas wells within the study area indicate unit 2,000 ft of upper Refugian and Refugian strata (Reichhold-Merrill #1, Sidney quadrangle) are basal siltstone, claystone, and shale of late Norizian (provincial West Coast late Eocene) age (Ri and Reichhold-Merrill #1)

Ts

Upper Eocene sandstone: Equivalent to Helmick beds (Thb) of Mundorff (1939) and Spencer (in press); very fine- to medium-grained, thinly laminated (fissile) to thin-bedded, as well as pr massive, light-gray to yellowish-brown moderately well-sorted micaceous, calcareous, lithic (tuffaceous) sandstones; frequently interbedded with fine-grained marine tuffaceous siltstone, th clay shale, and claystone; comprised of almost equal proportions of quartz, feldspar, and cemented with calcite (in concretions), minor constituents include approximately 2% glaucon (biotite, muscovite, and chlorite), and less than 1% authigenic pyrite; well compacted, carbons consisting of plant stems, leaves, and other organic fragments common; calcareous concretions, containing carbonaceous material, prominent along Willamette River south of Buena Vista (I range); pebbly lenses, abundant organic matter, and paleoecology indicate strandline environments from chiefly volcanic terrain. Weathered outcrops of massive, very fine- to medium-grained & friable, ranging in color from white to yellowish-brown, pale-brown, or yellowish-orange.

According to McKeel (1980), this unit is bracketed by upper Narizian strata in the Reichhold (Amity quadrangle), by upper Narizian and Narizian strata in the Reserve-Bruer #1 well (Amity and by upper Narizian strata in the Reichhold-Merrill #1 well (Salem West quadrangle). Age about 800 ft

Ty

Yamhill Formation (middle and upper Eocene): Medium- to dark-gray, massive to faintly bedded tuffaceous shale and siltstone. Occasional beds of medium-gray to greenish-gray, fossiliferous sandstone; minor limestone concretions.

According to McKeel (1980), this unit contains 2,000-3,000 ft of Narizian and lower Narizian Reichhold-Finn #1 and Reserve-Bruer #1 wells, located in the Amity quadrangle. Shown only in th

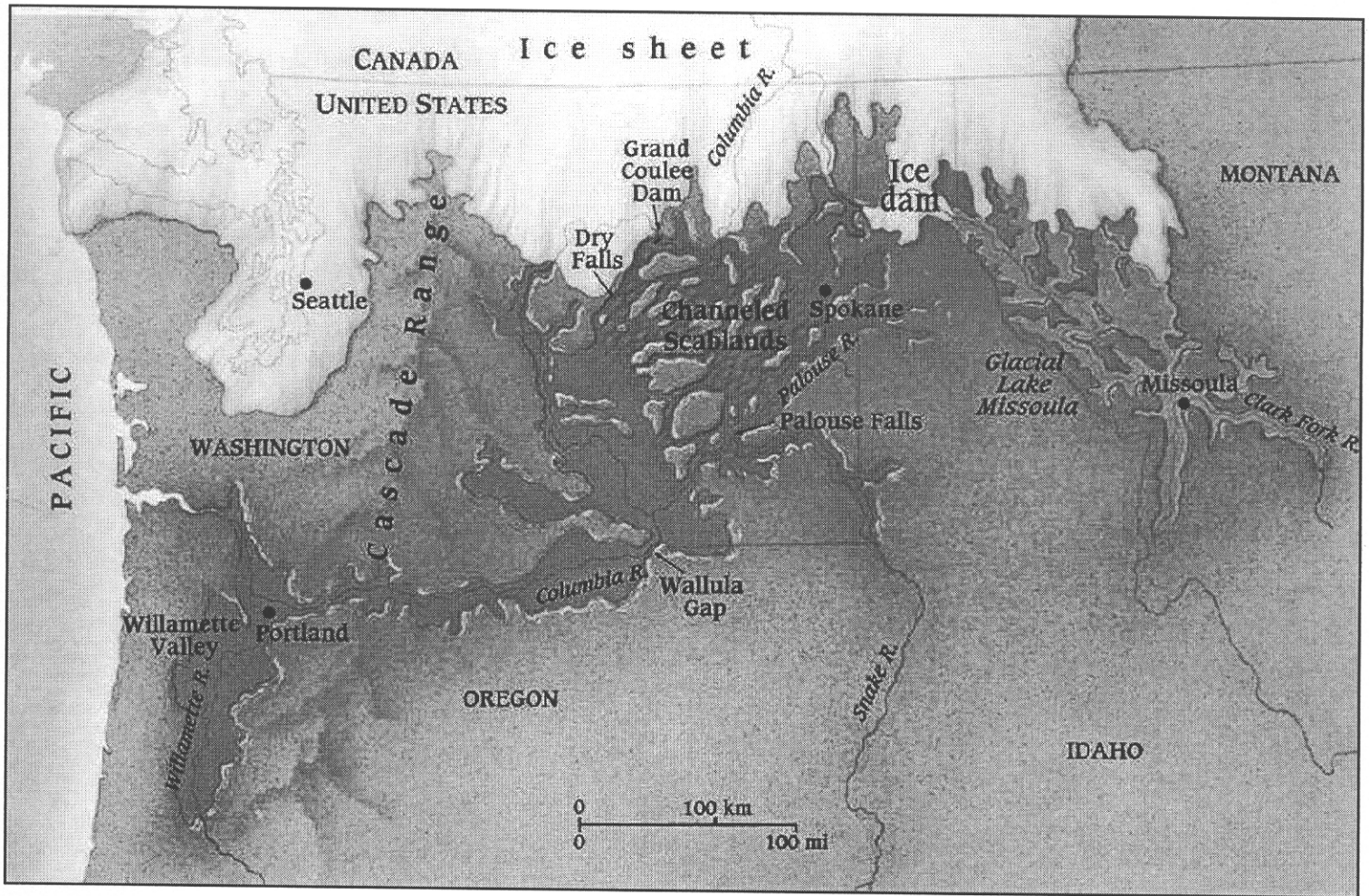
OTHER SYMBOLS

Lineament: Selected major lineaments identified from 1:76,000 false-color infrared aerial phot Army Corps of Engineers, 1978), orthophotographs, and topographic maps. Features include a major escarpments, concentric curvilinear drainages, aligned drainages across saddles, and part ed are short linear segments along drainages of less than 1 mi length; general trends NE and . lineament features observed in western Oregon

Landslide topography: Large areas of deep bedrock failure characterized by irregular topograp stratigraphy, overall anomalous moderate to shallow slope, prominent arcuate headscarps, b blocks, springs, sag ponds, and disrupted drainage patterns. Most prominent along west side of S south and west side of Eola Hills, where undercutting of soft marine sediments (Eocene to Oligocen rock, unit Toe) has resulted in massive landsliding of blocks of more resistant unit Ter. Subject debris avalanche along oversteepened escarpments and to slump in some areas (bowed and tip Deep bedrock slides within upper Eocene sedimentary rock (Ts) within Monmouth quadra smaller than those associated with units Ter/Toe; characterized by small knobby blocks of sea within general hummocky terrain

Landslide scarp: Characterized by steep cliff, often arcuate, and backward-tilted block below

Basaltic colluvium and/or landslide debris: Generally reddish-yellow or reddish-brown base and/or landslide debris, deeply weathered, overlying Oligocene sedimentary rock (Toe), ge landslide topography or beneath steep cliffs capped by Columbia River Basalt Group (Ter); includ and some earthflow and debris-flow topography. Probably generally 6-35 ft thick but may include basalt of greater thickness. Soils well-drained silty clay loams and gravelly silty clay loams over and clay



The Missoula Floods

- 15-12ka**
- perhaps 100 floods**
- 500 mi³ of water, 40 hrs.**
- 50 million cfs (3500 CR)**

Jim O'Connor, 2003

Missoula Flood Deposits



Jim O'Connor, 2003

Up to 30 m thick in the northern valley.

Deposited in as many as 40 beds up to 2 m thick.

Deposited between 15-12 ka.

Contains ice-rafterd erratics.

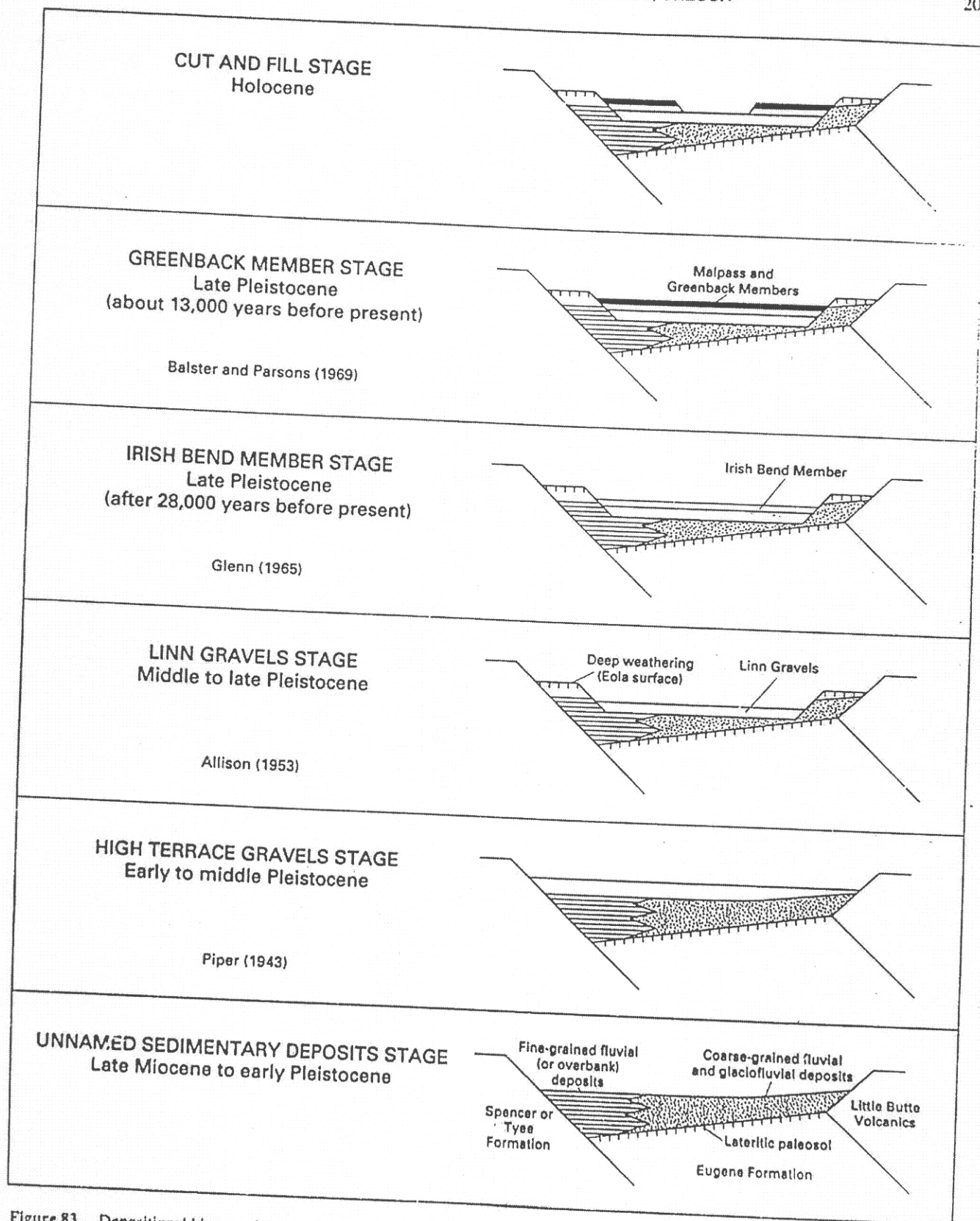
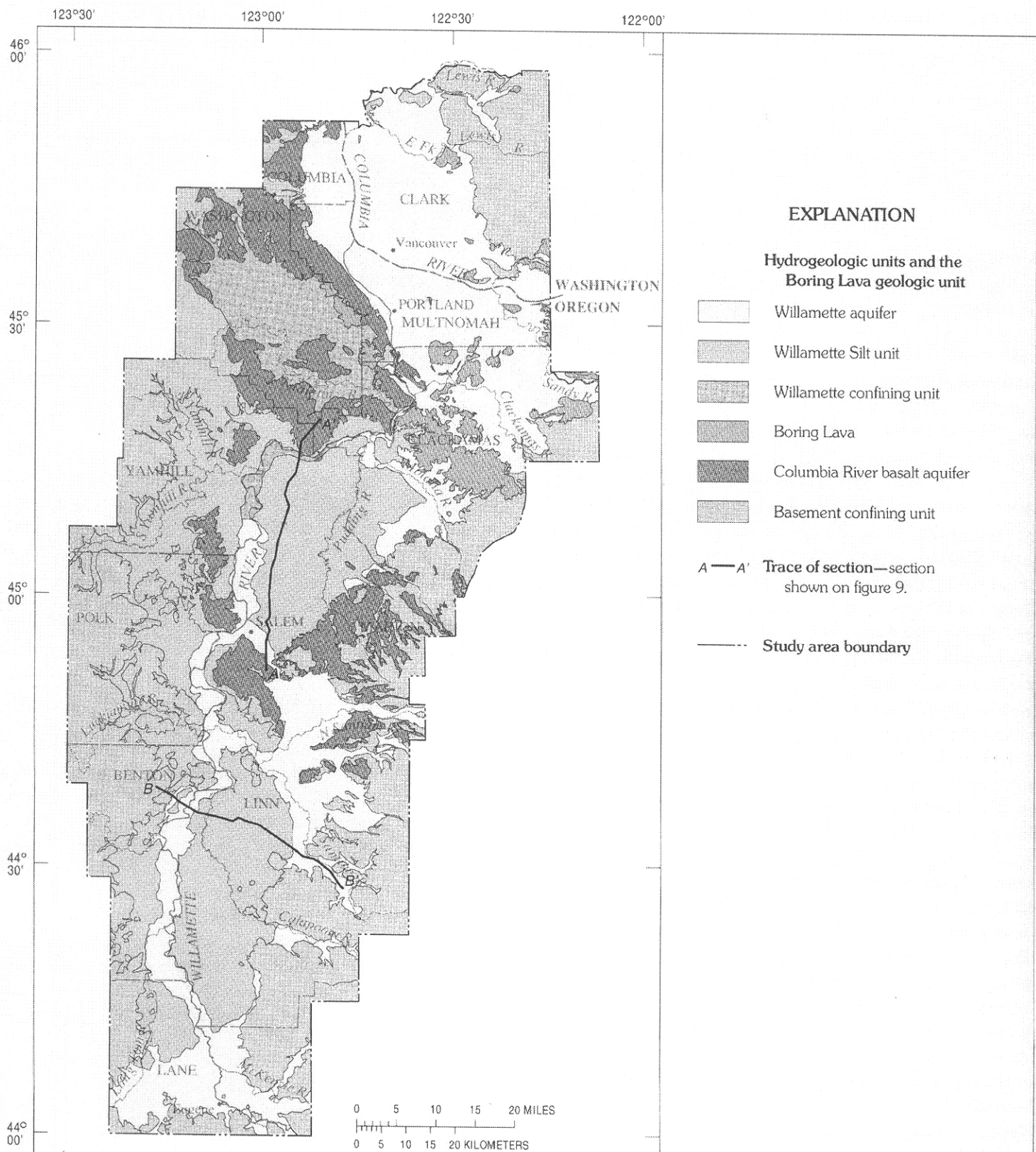


Figure 83. Depositional history of the southern Willamette Valley, Oregon, after Miocene time. Modified from Roberts (1984).



Basemap source information on page v.

Geologic data modified from Gannett and Caldwell, 1998, USGS Professional Paper 1424-A.

FIGURE 8.—Surficial extent of hydrogeologic units and the Boring Lava.

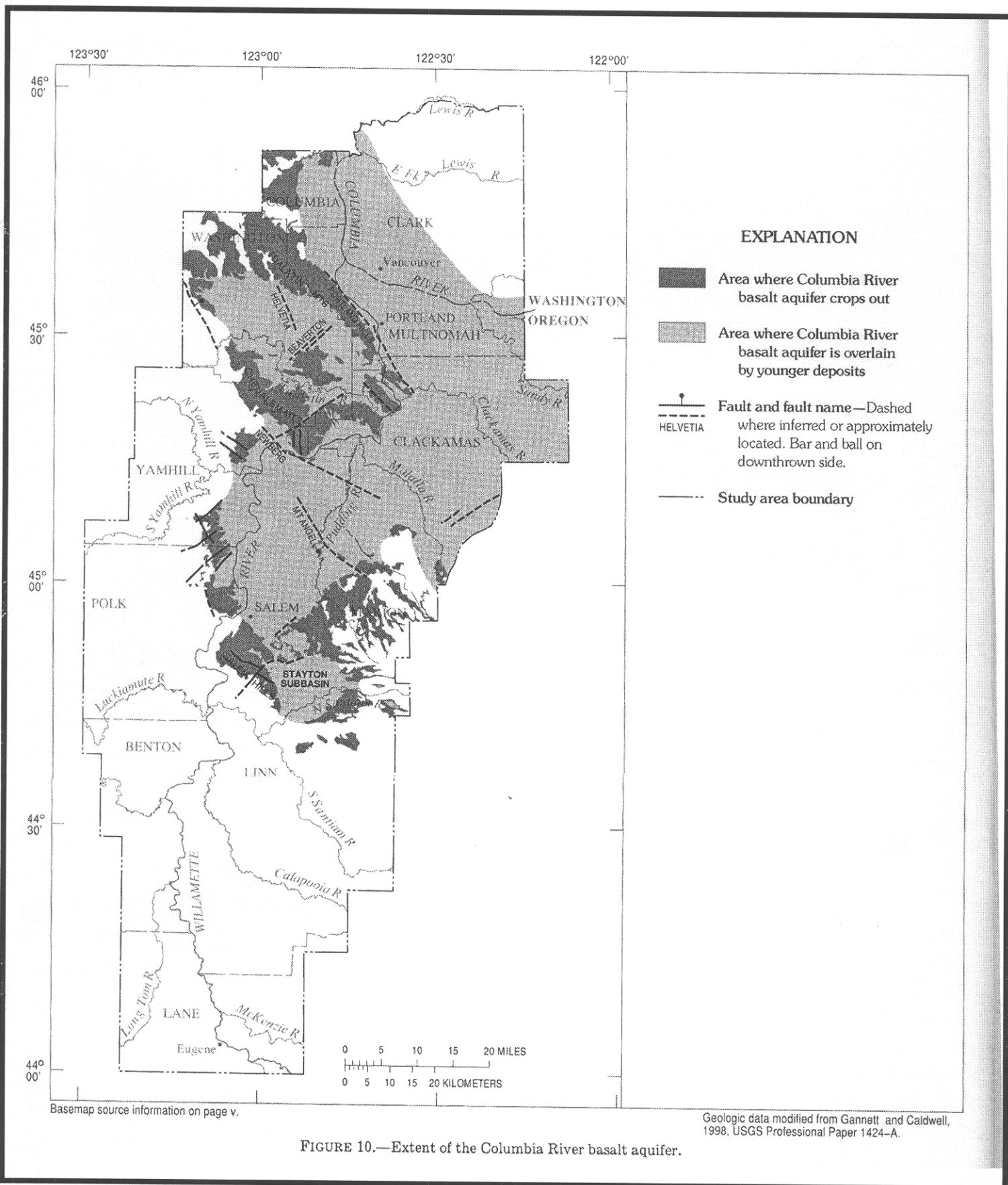
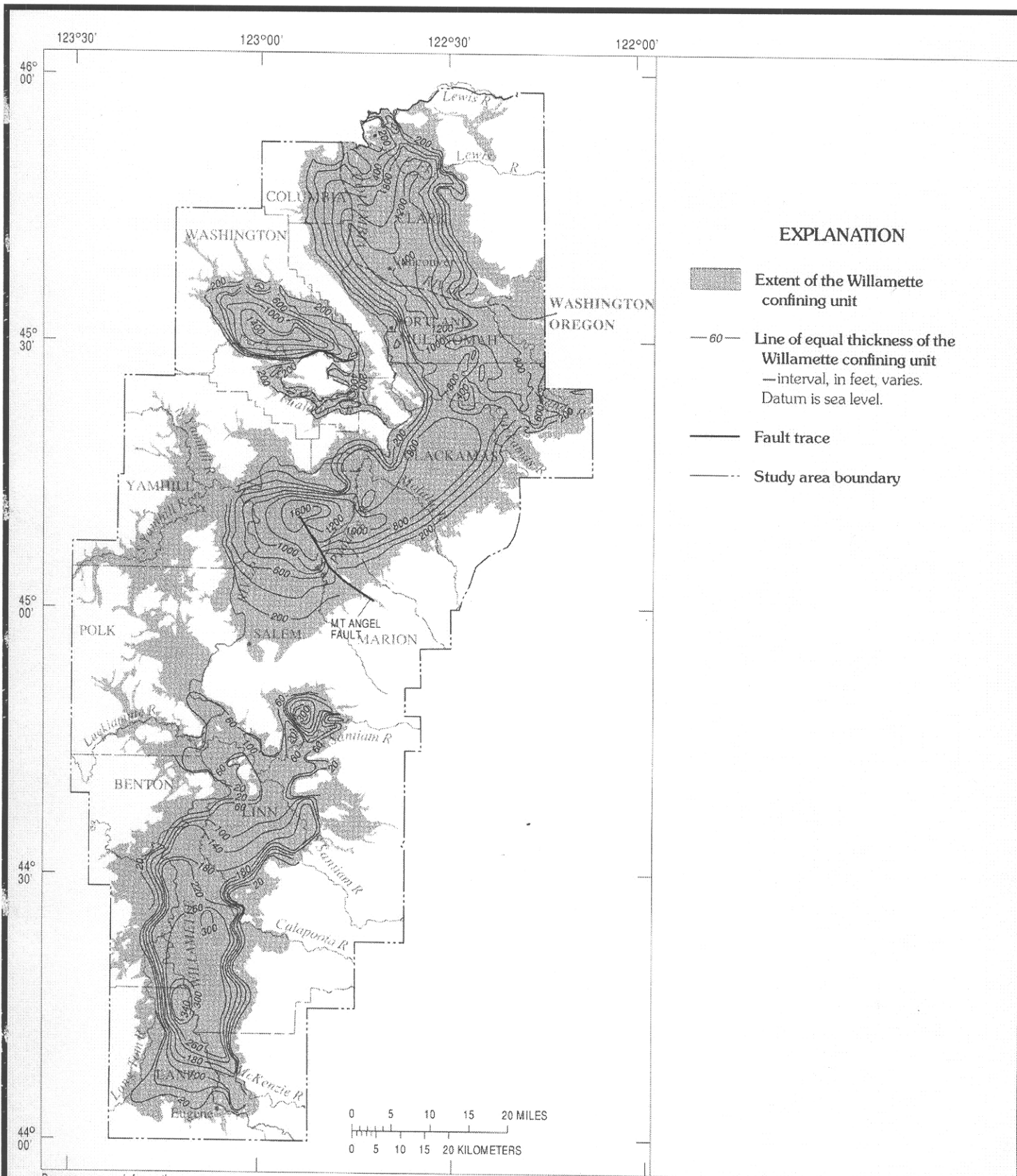


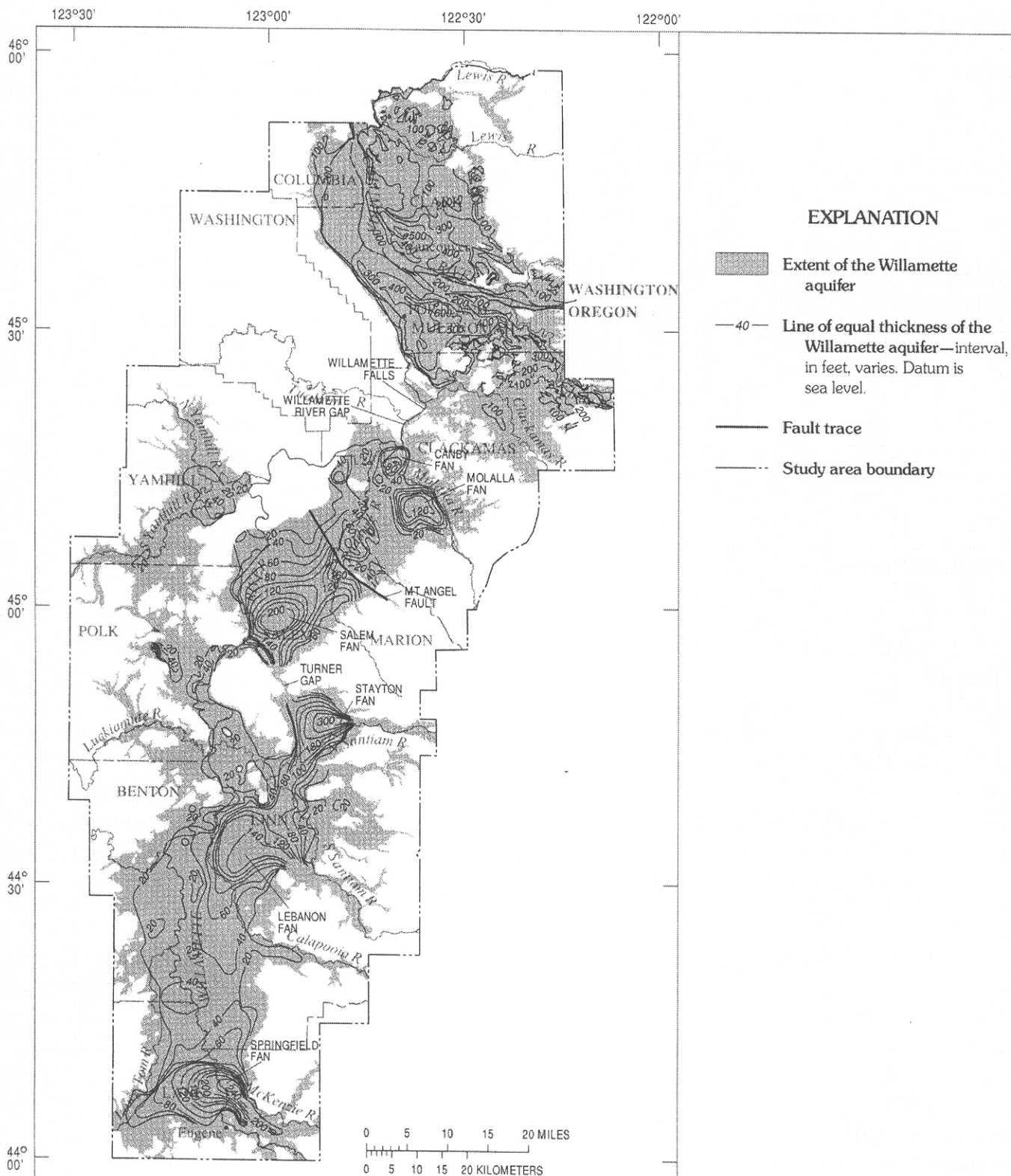
FIGURE 10.—Extent of the Columbia River basalt aquifer.



Basemap source information on page v.

Geologic data modified from Gannett and Caldwell, 1998, USGS Professional Paper 1424-A.

FIGURE 12.—Extent and thickness of the Willamette confining unit.



Basemap source information on page v.

Geologic data modified from Gannett and Caldwell, 1998, USGS Professional Paper 1424-A.

FIGURE 13.—Extent and thickness of the Willamette aquifer.

22

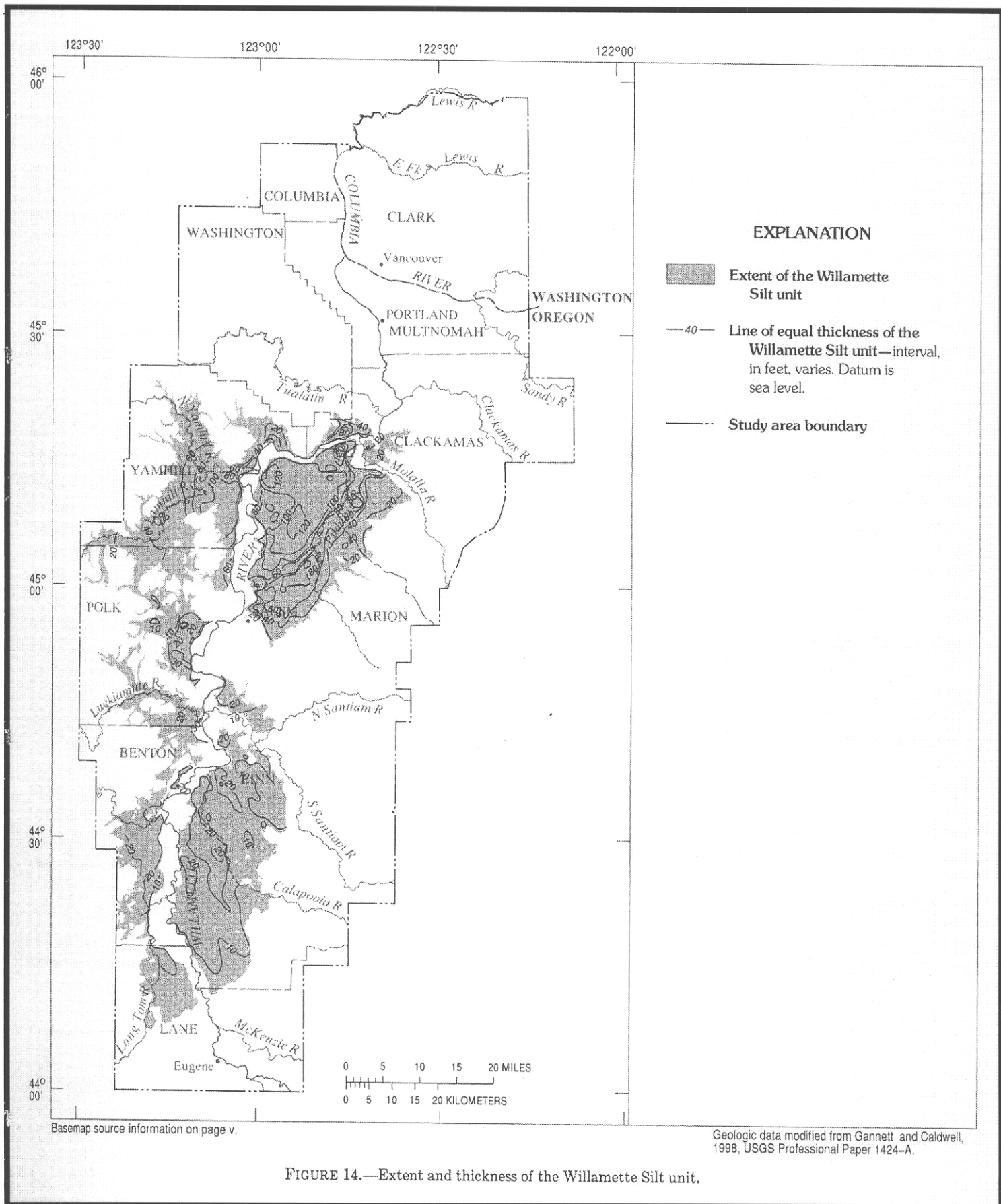
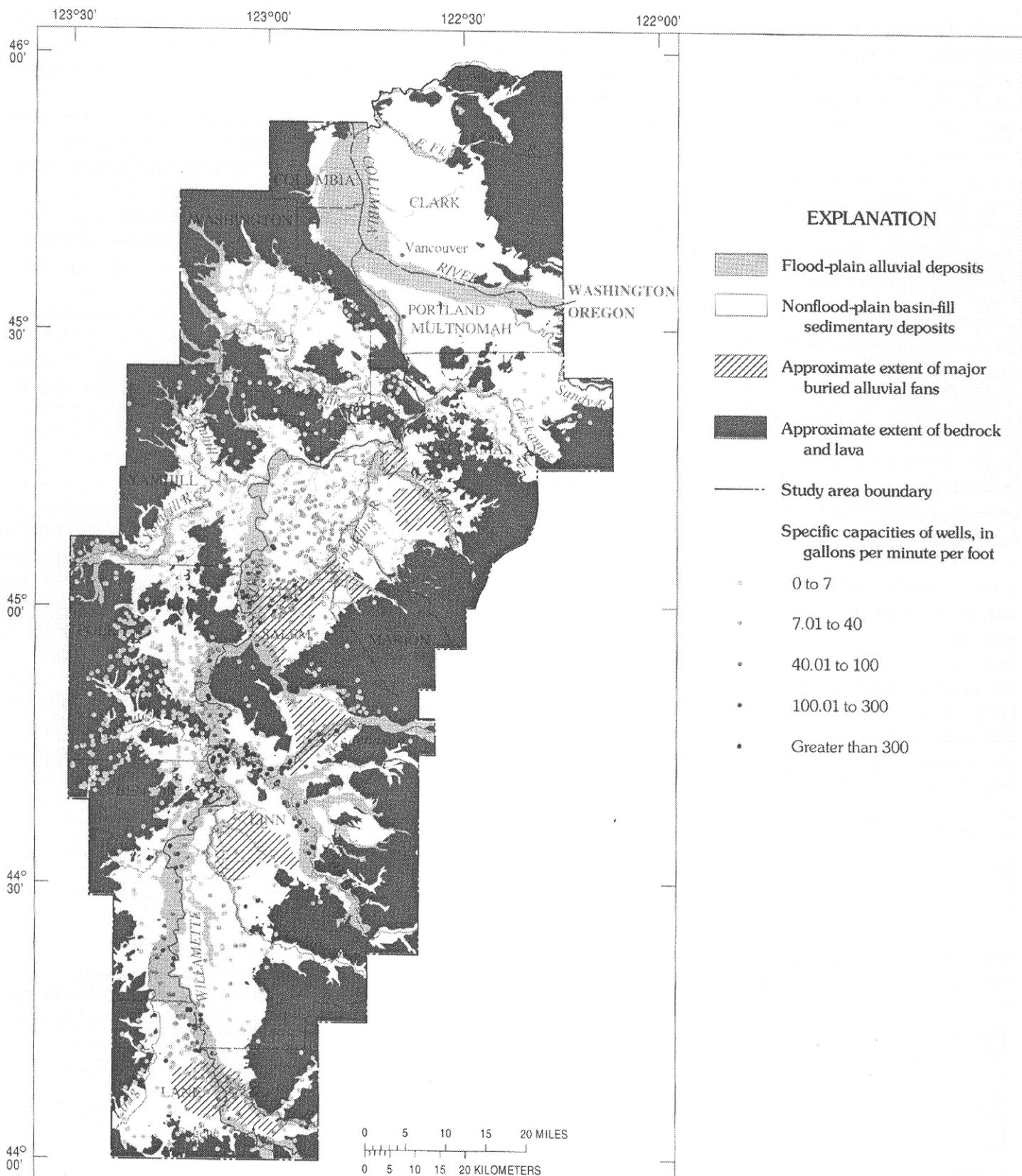


TABLE 3.—*Estimates of hydraulic conductivity for the regional hydrogeologic units, Willamette Lowland, Oregon and Washington*
[--, unknown]

Hydrogeologic unit	Number of values	Hydraulic conductivity, in feet per day	
		Median	Range
Willamette Silt unit	5	0.1	0.01–8
Willamette aquifer	¹ 90	240	0.03–7,000
	² 1,178	110	3–440
	³ 268	7	0.03–1,500
	⁴ 2,094	15	3–200
Willamette confining unit	⁵ 113	2	0.01–90
Columbia River basalt aquifer ⁶	--	1	0.001–750



Basemap source information on page v.

Geologic data modified from Gannett and 1998, USGS Professional Paper 1424-A.

FIGURE 15 — Distribution of specific-capacity values for wells in the Willamette Lowland.

25

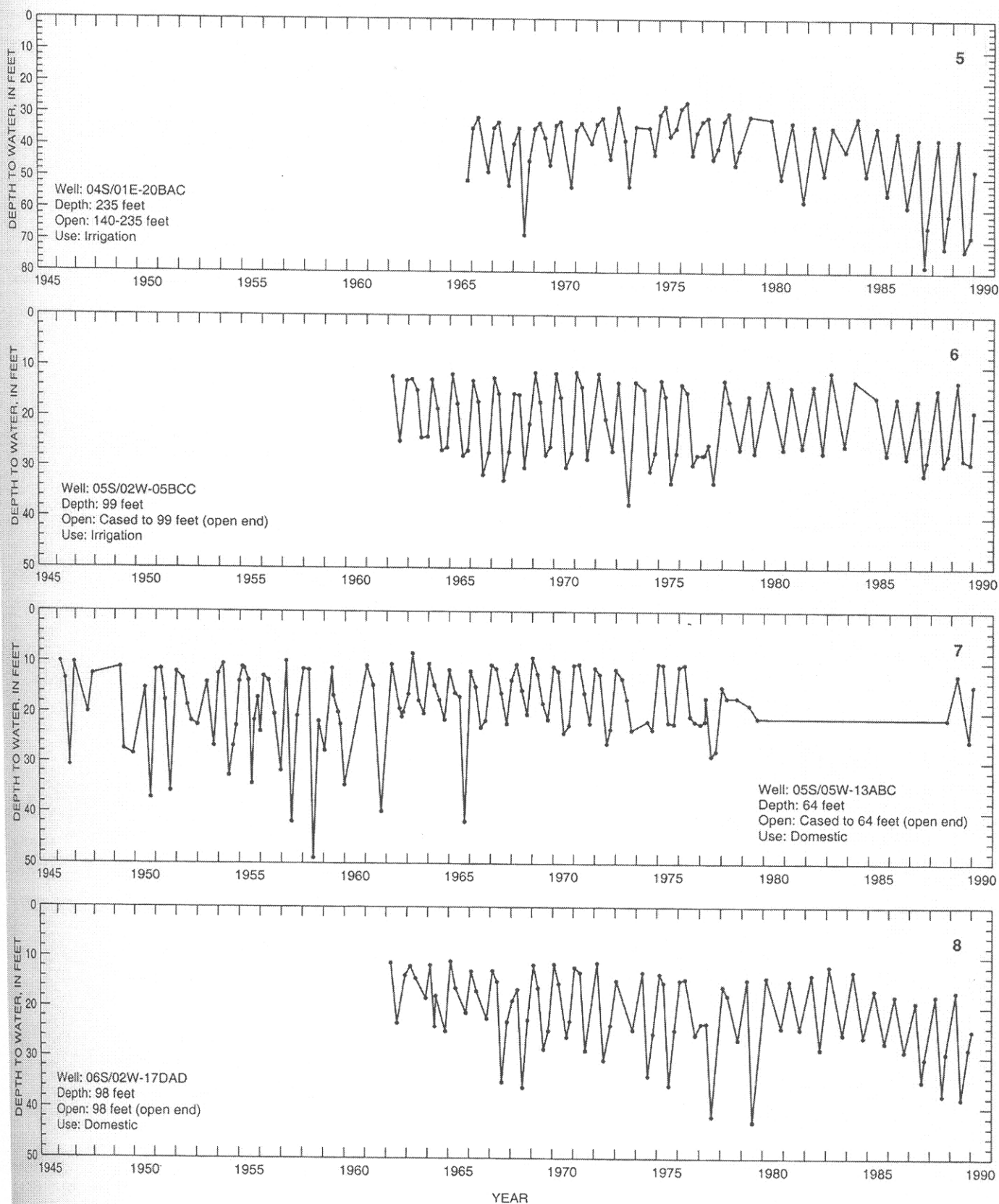


FIGURE 18b.—Water levels in wells completed in the Willamette aquifer, central Willamette Valley.
Graph number (1-16) is also well number on figure 17.

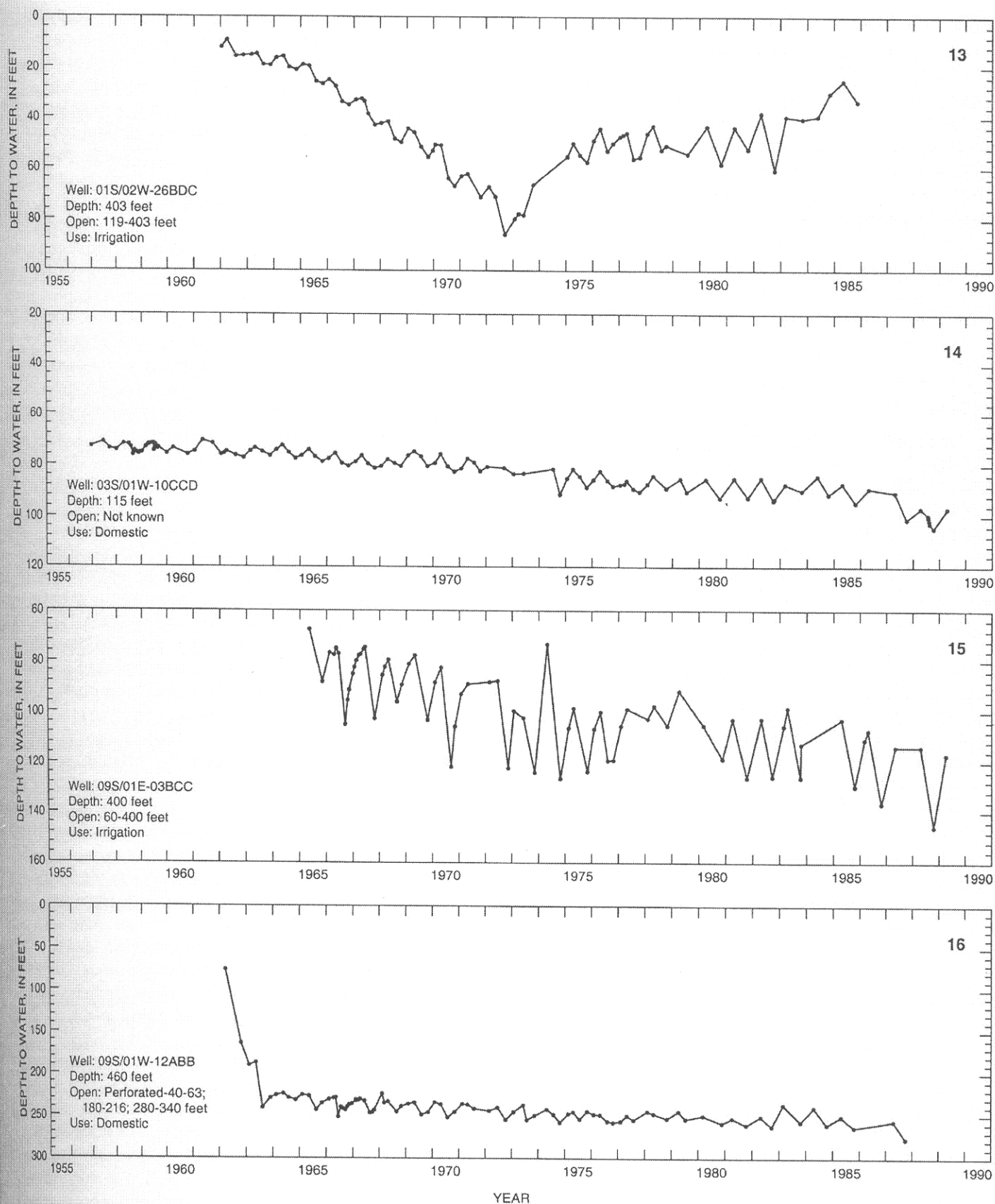


FIGURE 18d.—Water levels in wells completed in the Columbia River basalt aquifer.
 Graph number (1-16) is also well number on figure 17.

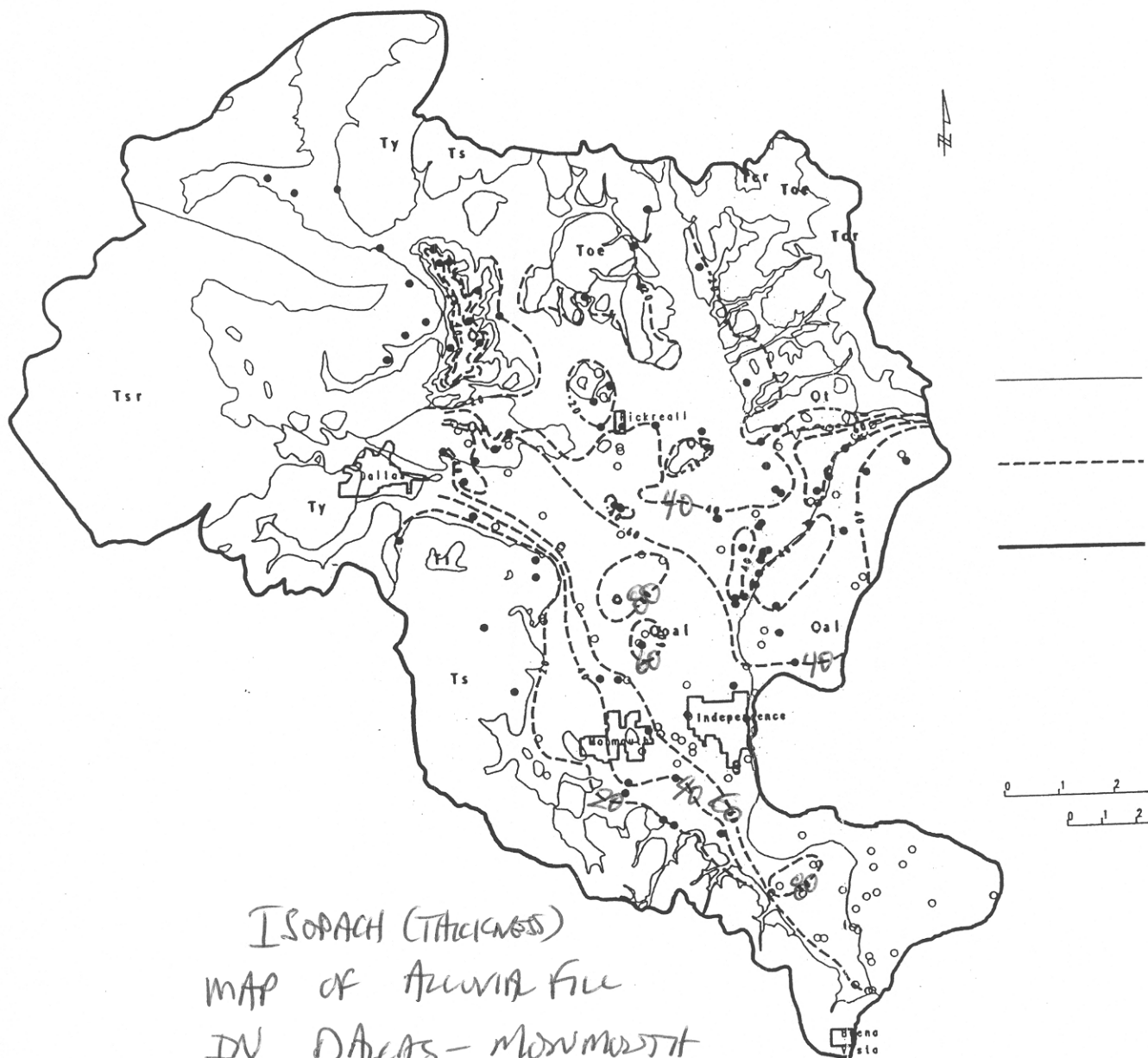
TABLE VII

HYDROGEOLOGIC CHARACTERISTICS OF THE GEOLOGIC/AQUIFER UNITS

AQUIFER	WELL DEPTH (ft) MEAN	STATIC WATER LEVEL (ft) MEAN	YIELD (gpm)		no. of wells	SPECIFIC CAPACITY (gpm/ft)				HYDR. CONDUCT. (ft/d) MED.	STORAGE COEFFICIENT	RECHARGE (ft)
			MEAN	MED.		LOW	HIGH	MEAN	MED.			
Qal	48	19.5	302	75	36	1.10	607.1	59.9	40.0	170.0	0.2	8-15
Qoal	68	21.1	79	30	80	0.02	175.0	7.3	2.0	19.0	.001-.0.2	2-5
Qt	95	12.8	13	8	13	0.04	2.4	0.5	0.3			
Toe	119	34.8	15	10	20	0.01	2.3	0.5	0.2			
Ts	134	37.9	11	8	41	0.01	30.0	1.6	0.1	0.3	.00001-.001	2-5
Ty	174	22.1	22	9	33	0.01	1.7	0.3	0.1			
Tsr	171	36.4	18	8	16	0.01	12.5	1.1	0.1	0.2	.00001-.001	2-5

*From Gonthier (1963)

The specific capacity of a well is defined as the pumping rate divided by the drawdown in the well (Freeze and



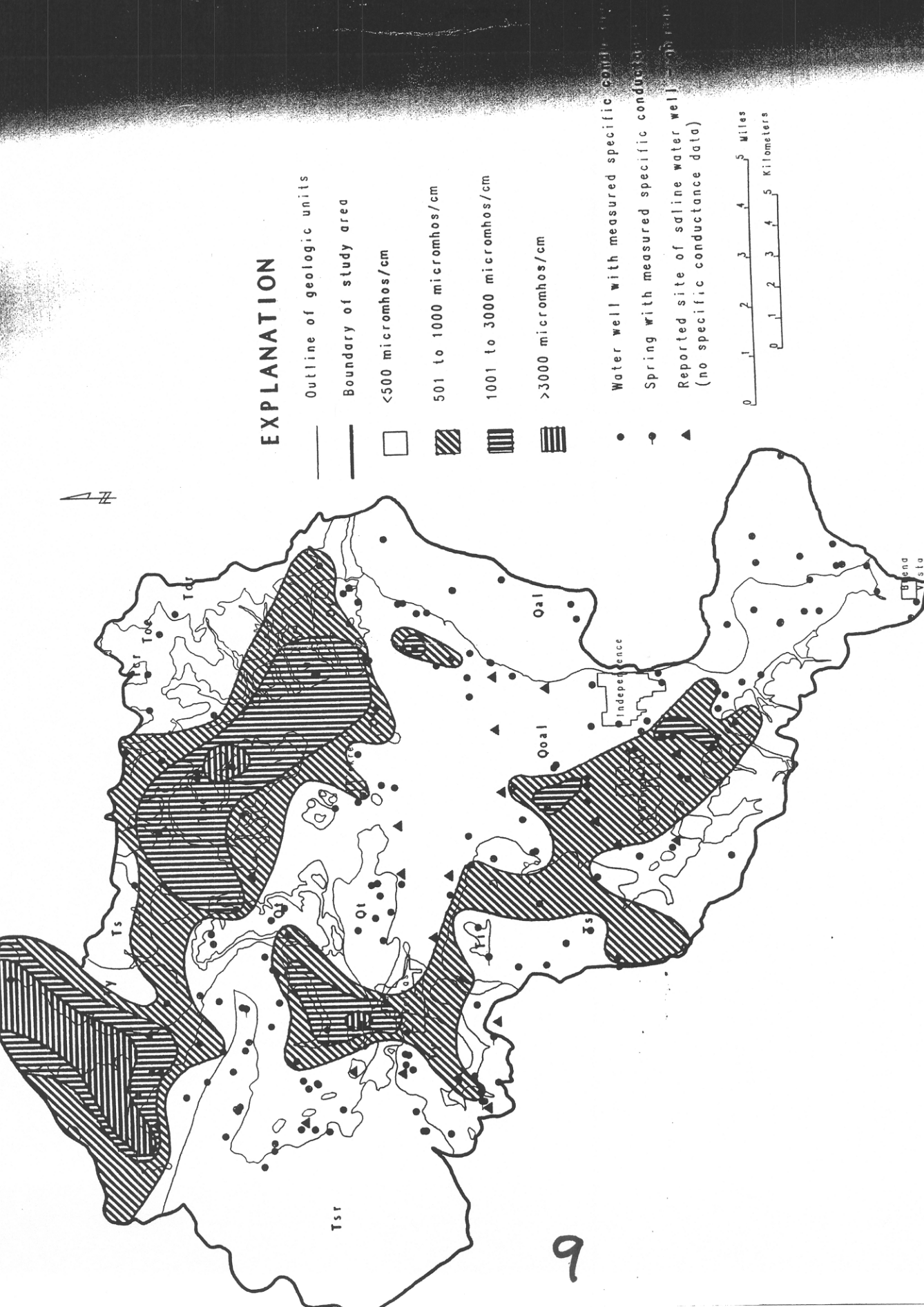


Figure 26. Groundwater salinity hazard map based on specific conductance measurements.

saline spring (6S/5W-21cad1), the oil and gas well (6S/4W-6bd), and ocean water plot below the best-fit line representing the more dilute waters.

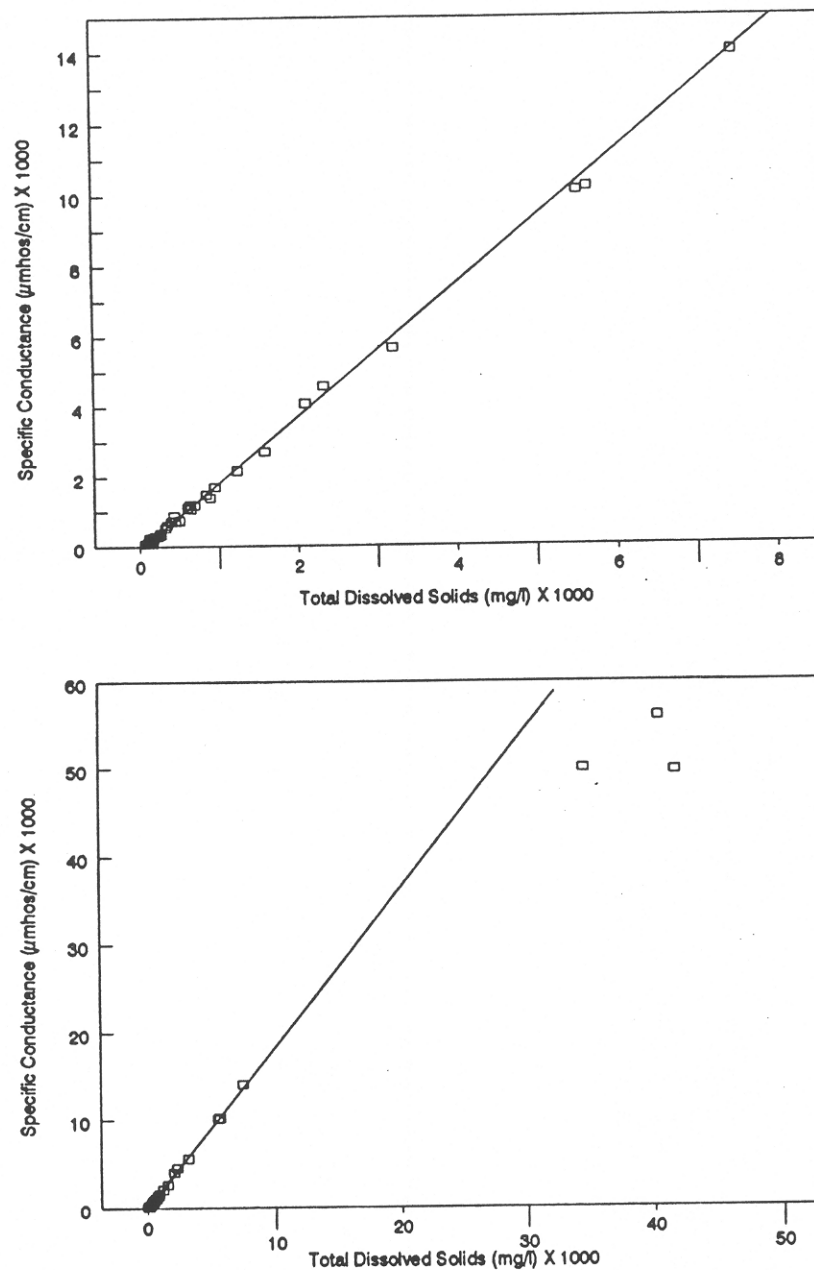


Figure 25. Plots of TDS versus specific conductance for Dallas-Monmouth area groundwater and seawater.

TABLE 1.—Discharge characteristics for selected rivers, Willamette Lowland, Oregon and Washington

[mi², square miles; ft³/s, cubic feet per second; --, not regulated]

Name of gaging station ¹	Drainage area (mi ²)	Year flow regulation began	Annual discharge (ft ³ /s) of			Period record
			Minimum	Mean	Maximum	
Middle Fork Willamette River at Jasper	1,340	1953	1,880	4,060	6,220	1967–91
Coast Fork Willamette River near Goshen	642	1942	510	1,600	2,700	1951–91
McKenzie River near Coburg	1,337	1963	4,580	6,020	8,280	1945–63
Long Tom River at Monroe	391	1941	310	700	1,230	1922–40
Marys River near Philomath	159	--	100	460	820	1941–82
Calapooia River at Albany	372	--	240	900	1,510	1941–81
South Santiam River at Waterloo	640	1966	1,700	2,910	4,550	1906–65
North Santiam River at Mehama	655	1953	2,060	3,250	4,330	1906–52
Santiam River at Jefferson	1,790	1953	4,250	7,600	11,630	1908–53
Luckiamute River near Suver	240	--	230	890	1,460	1905–91
South Yamhill River near Whiteson	502	--	460	1,720	3,120	1940–91
North Yamhill River at Pike	67	--	160	240	370	1949–73
Molalla River near Canby	323	--	520	1,160	1,820	1929–78
Pudding River at Aurora	479	--	700	1,220	1,980	1929–64
Tualatin River at West Linn	706	1975	1,050	1,530	2,540	1952–70
Clackamas River at Estacada	671	1958	1,660	2,690	3,920	1909–57
Clackamas River near Clackamas	930	1958	1,720	3,640	5,720	1963–82
Willamette River at Portland	11,100	1941	13,710	32,180	54,490	1973–91
East Fork Lewis River near Heisson	125	--	417	757	1,117	1930–79

¹ All rivers located in Oregon except the East Fork Lewis River.

The stream discharge is derived principally from rainfall runoff. Additionally, snowmelt from some of the eastern tributaries provides increased flows into the late spring, and ground-water discharge contributes to streamflow as well (particularly to most stream reaches in the lowland areas). The discharge pattern coincides with the precipitation pattern. Although the total amount of runoff is very different between wet and dry years (Oster, 1968), the seasonal pattern of runoff in both wet and dry years is similar. Generally, the initial rains of the early fall recharge the soil zone and contribute little runoff. After the soil has reached field capacity, runoff begins to increase. By November, runoff closely corresponds to the pattern of precipitation, and the largest monthly flows occur throughout the study area between November and April (fig. 5)—a direct result of heavy rains and some early snowmelt. The combination of warm winter temperatures and heavy rains falling on snow generally results in the largest rates and volumes of runoff, as exemplified by the disastrous floods of December 1964 and February 1996. Runoff also is large during the spring, when streams draining the Cascade Range carry large volumes of snowmelt. Throughout the study area, streams recede to minimum flows between July and October, when precipitation is lowest and the temperature is relatively high.

There are marked differences in the volume and seasonal distribution of tributary discharge (Friday et al., 1984). The differences are a function of which mountain range a stream drains. The major eastern tributaries (Clackamas, Molalla, Pudding, North Santiam, South Santiam, Calapooia, McKenzie, and Middle Fork Willamette Rivers) drain about 60 percent of the Willamette River Basin and account for about 75 percent of the mean annual discharge of the Willamette River Basin (table 1, using data from the Santiam River at Jefferson gage to represent the combined influence of the North Santiam and South Santiam Rivers). These eastern tributaries contribute more (and seasonally prolonged) discharge compared with the western tributaries because they have drainage basins that (1) are larger, (2) are at higher altitudes, (3) receive more rainfall, (4) receive more snow, (5) are capable of receiving and transmitting more ground water, and (6) contain permanent glaciers.

The major western tributaries (Tualatin, North Yamhill, South Yamhill, Luckiamute, Marys, and Long Tom Rivers) drain the Coast Range and its foothills and account for about 17 percent of the mean annual discharge of the Willamette River Basin (table 1). The Coast Range was not subject to glaciation and, as a result, does not contain large glacially derived alluvial valleys that store and transmit large quantities of ground water.

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TABLE 4.—*Estimates of transmissivity and storage coefficient derived from specific-capacity data and aquifer tests in the Willamette Lowland*[gal/min, gallons per minute; gal/min/ft, gallons per minute per foot; ft²/d, square feet per day; --, no data]

	Well number	Pumping rate (gal/min)	Specific capacity (gal/min/ft)	Transmissivity, specific capacity ¹ (ft ² /d)	Transmissivity, formula ² (ft ² /d)	Storage coefficient, specific yield (percent)
			<u>Willamette aquifer—flood plain deposits</u>			
	16S/4W-25ccd	1,200	--	--	78,000	--
	16S/4W-36bbc	1,230	--	--	79,000	--
	16S/4W-36bbd	1,210	--	--	76,000	--
	15S/4W-17aad	300	75	20,000	--	--
	15S/4W-28bad2	550	466	120,000	270,000	5.0
	14S/4W-06cdc	300	16.7	4,400	--	--
	13S/5W-35abc	400	40	11,000	--	--
	162 wells	--	--	³ 29,735	--	--
			<u>Willamette aquifer—buried alluvial deposits</u>			
	04S/2W-02acb2	64	2.3	--	12,000	.07
	15S/4W-32cab4	980	41	11,000	6,200	--
	16S/3W-30dba	300	41	11,000	36,000	--
	16S/3W-32dbd1	235	17	4,600	2,700	.02
	17S/2W-26ccal	875	86	23,000	67,000	6.0
	13S/3W-18bbc2	310	4.9	1,300	--	--
	13S/3W-28cab	165	2.4	600	--	--
	14S/3W-05baa	400	5.7	1,500	--	--
	14S/3W-07ddc	75	2.8	700	600	--
	14S/4W-01dab2	200	3.0	800	--	--
	14S/4W-21dac	650	16.1	4,300	4,900	--
	15S/4W-16adc	300	2.5	700	--	--
	34 wells ⁴	--	--	³ 4,540	--	--
	127 wells ⁵	--	--	³ 3,010	--	--
			<u>Columbia River basalt aquifer</u>			
	02S/2W-1J1	--	--	--	3,080	--
	1 well	--	--	10,460	--	--

¹Transmissivity calculated using specific-capacity data.²Transmissivity calculated using aquifer-test data.³Average transmissivity value.⁴Wells completed in buried alluvial fans.⁵Wells completed in buried alluvium not in fans or flood plains.

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TABLE 5.—Computed values for specific yield and storage volume from previous investigations, Willamette Lowland, Oregon

[Qal, alluvium, flood deposits; Qyal, alluvium, young; Qoal, alluvium, older; --, range or area not given; WT, water table]

Deposit	Depth zone (feet)	Average specific yield (percent)	Range of specific yield (percent)	Area (acres)	Storage volume (acre-feet)
<u>Eugene-Springfield</u> ¹					
Qal	10-100	15.2	13.1-19.2	--	1,400,000
Qal	100-150	12.9	--	--	700,000
<u>Harrisburg-Halsey</u> ²					
Qyal	10-30	19	17-20	30,000	110,000
Qoal	10-50	13	11-18	90,000	470,000
Qoal	50-80	12	11-14	30,000	110,000
Qoal	50-100	9	8-9	25,000	110,000
<u>Corvallis-Albany</u> ³					
Qyal	10-35	19	18-21	25,000	120,000
Qoal	10-50	14	11-16	60,000	320,000
Qoal	50-100	11	7-17	47,000	310,000
<u>French Prairie area</u> ⁴					
Qal	10-100	17.1	15.4-19.1	134,000	2,000,000
Qal	100-200	16.9	13.2-23.8	134,000	2,140,000
<u>Stayton Subbasin</u>					
Qal	WT-50	17	--	42,140	300,000
Qal	50-100	14	--	42,140	320,000
<u>Leon-Albany plain</u>					
Qal	WT-50	18	--	81,690	450,000
Qal	50-100	15	--	81,680	570,000
<u>Interbasin area</u>					
Qal	WT-50	17	--	19,000	120,000
Qal	50-100	10	--	19,000	90,000
<u>Ankeny Bottom area</u>					
Qal	WT-50	18	--	23,420	150,000
Qal	50-100	10	--	23,420	100,000
<u>Molalla-Salem Slope (valley plain and adjacent areas)</u> ⁵					
Qal	WT-100	14.6	11-18	118,800	1,245,000
Qal	100-200	13.6	7-19	118,800	1,618,000

¹ Frank, 1973.² Frank, 1976.³ Frank, 1974.⁴ Price, 1967a.⁵ Hampton, 1972.