AN ABSTRACT OF THE THESIS OF

WENDY ADAMS NIEM for the degree of MASTER OF SCIENCE

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Title: DRAINAGE BASIN MORPHOLOGY IN THE CENTRAL COAST RANGE OF OREGON

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The four major streams of the central Coast Range of Oregon are: the westward-flowing Siletz and Yaquina Rivers and the eastward-flowing Luckiamute and Marys Rivers. These fifth- and sixth-order streams conform to the laws of drainage composition of R. E. Horton.

The drainage densities and texture ratios calculated for these streams indicate coarse to medium texture comparable to basins in the Carboniferous sandstones of the Appalachian Plateau in Pennsylvania. Little variation in the values of these parameters occurs between basins on igneous rock and basins on sedimentary rock. The length of overland flow ranges from approximately $\frac{1}{4}$ mile to $\frac{1}{2}$ mile. Two thousand eight hundred twenty-five to 6,140 square feet are necessary to support one foot of channel in the central Coast Range.

Maximum elevation in the area is 4,097 feet at Marys Peak which is the highest point in the Oregon Coast Range. The average elevation of summits in the thesis area is approximately 1500 feet. The calculated relief ratios for the

Siletz, Yaquina, Marys, and Luckiamute Rivers are comparable to relief ratios of streams on the Gulf and Atlantic coastal plains and on the Appalachian Piedmont.

Coast Range streams respond quickly to increased rainfall, and runoff is rapid. The Siletz has the largest annual discharge and the highest sustained discharge during the dry summer months. The volume of discharge probably reflects the fracture permeability of the Siletz River Volcanics which may supply substantial base flow.

The drainage pattern of the central Coast Range streams is independent of the geology, suggesting that the streams are antecedent. The wind gaps, barbed drainages, valley sizes, and scale of the large meanders suggest that each pair of streams in the central Coast Range (one pair consists of one westward-flowing stream and one eastward-flowing stream) represents a single ancient stream system which was severed during uplift of the Coast Range. Geologic evidence further supports the hypothesis that streams which originated in the ancestral Cascades flowed westward over a newly emergent coastal plain during the Oligocene to an ancient Pacific shoreline. During early stages of uplift of the Coast Range, the stream meanders became entrenched, but as the rate of uplift increased, the streams were severed.

Pleistocene events modified the western and eastern margins of the range but had limited effect within the range because elevations of the summits apparently were insufficient to support valley glaciers although snowfields may have developed locally. Presently, the streams are entrenching their channels, and stream piracy and reverses in some drainages are imminent.

Drainage Basin Morphology in the Central Coast Range of Oregon

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INTRODUCTION

Location and Size of Area

The study area is located in the central part of the Coast Range of western Oregon. The Pacific Ocean is the western border and the west bank of the Willamette River (approximately 123° W long.), the eastern border. The north boundary is the Siletz and Luckiamute - Yamhill and Salmon divide, and the south boundary is the Yaquina and Marys - Alsea divide. The major streams are the Siletz River, Yaquina River, Marys River, and Luckiamute River.

The area is approximately 1320 square miles. Two of the major streams flow westward into the Pacific from the crest of the Coast Range, and two of the major stream networks flow eastward into the Willamette (Fig. 1).

Three major highways traverse the study area. U.S. Highway 101 extends north-south along the entire western margin of the area. U.S. Highway 99W provides north-south access through the eastern part of the area. U.S. Highway 20 especially along the pre-1970 route closely follows the course of the Marys River and Yaquina River valleys. The Corvallis-Toledo railroad line even more faithfully follows the course of the streams.

On the west side of the Coast Range crest, Oregon State

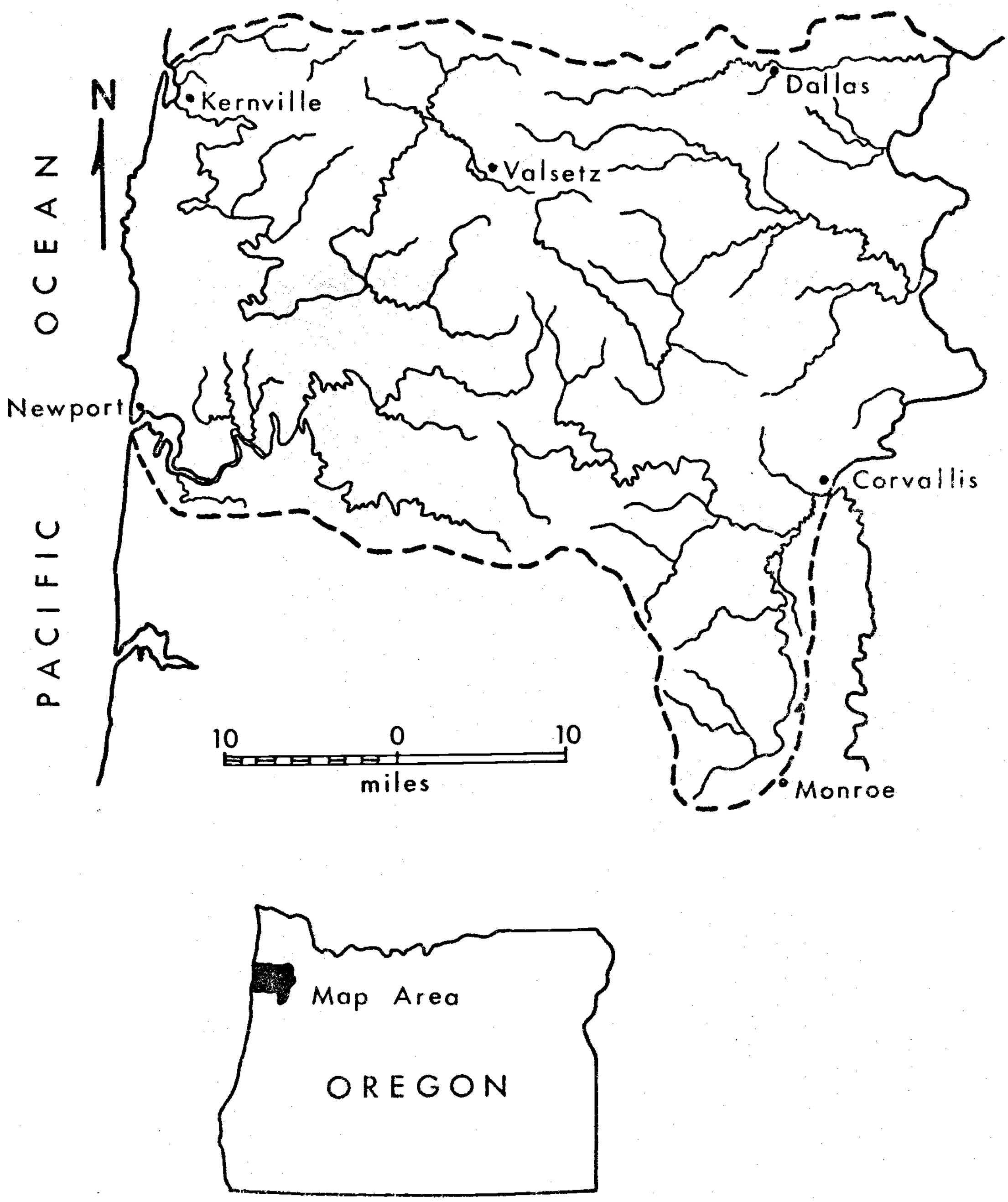


Figure 1. Location of area.

Highway 229 connects Toledo, Siletz, and Kernville. On the east side of the crest, Oregon State Highway 223 connects Wren, Kings Valley, Pedee, and Dallas. Numerous county roads and private logging company roads honeycomb the area. During the rainy winter months many of the unpaved roads are impassable or unsafe for 2-wheel drive vehicles.

Purposes of Investigation

The central Coast Range aroused the investigator's scientific curiosity in 1970 during her first trip through the range. A brief examination of maps and aerial photographs of the area strongly suggested that these streams have a history that is more complex than is immediately apparent. Entrenched meanders and similar trends of stream valleys across the crest suggest that the streams pre-date uplift of the Coast Range. Therefore, the purposes of this investigation began to take form, namely (1) to describe the morphology of the drainage basins in the central Coast Range and (2) to relate the morphology of the drainage basins to the history of these streams.

Previous Investigations

J. S. Diller (1896) published pioneering observations on the geomorphology of the Coast Range. His discourse primarily noted the highest peaks and lowest passes in the range. With the scant data available to him, he concluded that Euchre Peak near the head of the Siletz "is probably the highest peak of the range" (1896, p. 449). He also mentioned that Marys Peak is very high but did not believe that that peak exceeded Euchre Peak in elevation. Diller noted an asymmetry to the Coast Range such that western spurs are longer and slope more gently to the sea than the eastern spurs which are shorter and drop more rapidly to the Willamette Valley.

He observed "traces of peneplains at many points throughout the range" (p. 487) and noted numerous monadnocks particularly in the northern Coast Range.

Ira S. Allison, professor emeritus of Oregon State University, and Ewart M. Baldwin, professor of geology at the University of Oregon, have been prolific writers in geomorphic matters of western Oregon. However, their efforts have been primarily focused on Pleistocene erosional and depositional features of the Willamette River. Allison (1935; 1936; 1953) is responsible for naming most of the alluvial units. Baldwin has published on a broader range of geomorphic topics from the antecedent nature of the Columbia River (Lowry and Baldwin, 1952) to reconstructing the drainage of the Long Tom River (Baldwin and Howell, 1949) to descriptive geomorphology of lithologic control on stream valley cross sectional shape (Baldwin, 1964a).

A few scientific reports have included brief references to the geomorphology of the Coast Range. Bostwick (1959) pointed out terraces, benches, and entrenched meanders as evidence of rejuvenation. Schlicker and others (1973) briefly reviewed mass wasting and stream flooding hazards for Lincoln County.

C. A. Balster and R. B. Parsons have conducted some of the most recent and most detailed geomorphic work in the Coast Range. In 1968 they published a regional geomorphology of the Willamette Valley, focusing primarily on geomorphic surfaces. Their map (scale 1 inch equals 3.25 miles) which accompanies the report illustrates the distribution of geomorphic surfaces related to the Willamette River. The oldest of these surfaces, the Eola, is probably middle Pleistocene in age and therefore is geologically quite young.

In two more detailed sources, Balster and Parsons (1966; 1968b) detailed the geomorphology in 3,500 acres between Price Creek and Woods Creek in the Luckiamute drainage on the east side of Kings Valley. On their map (scale 1 inch equals approximately $\frac{1}{2}$ mile) they were able to distinguish terraces and floodplain, pediments, alluvial fans, and landslides. They concluded that Woods Creek channel has been at equilibrium for at least 9,570 $\pm$ 510 years. They found that landslides (debris avalanches and debris slides) and earthflows (debris flow) are the only mass movements of mappable size in the area. Surprisingly, slumps were almost negligible in their area. Rockfall is the predominant mass movement during the dry summer months.

In 1938 in a paper on the origin of the Willamette Valley, E. T. Hodge suggested that the streams of the Coast Range are antecedent and that their original westward drainages were deranged and reversed by a "great fracture" parallel to Oregon's ancient coastline. To this fracture, he attributed the straightness (sic) of the present Oregon coastline, the drowned valleys at the mouths of the Pacific slope streams, and the eastward tilt of the land surface of Oregon (sic). He did not present evidence for his statements, and the scientific merit of the paper has been open to question. For example, in his discussion of the origin of the Willamette River floodplain, he proposed that increased rainfall during the Pleistocene resulted in erosion of "a tremendous quantity of silts" from the Cascade Mountains. This sediment was delivered to the Willamette "by the torrential mountain streams". Then, of the Willamette River, he stated "Being a wise river as well as a member of the 'Amalgamated Union of North American Rivers' the river refused to carry it and spread it far and wide over the bottom of its valley in the form of a floodplain".

Other than these reports, the geomorphology of the central Coast Range of Oregon has been unstudied.

Methods of Investigation

The study area is covered by the following U.S. Geological Survey topographic quadrangle maps at a scale of 1: 62,500: Albany, Alsea, Cape Foulweather, Corvallis, Dallas, Euchre Mtn., Marys Peak, Monroe, Salem, Toledo, Valsetz, and Yaquina. The contour interval is 50 feet on all the maps except Albany and Salem which have a contour interval of 25 feet. All of the quadrangles were published between 1956 and 1957. However, some maps are based on planetable surveys whereas others are based on aerial photographs.

In order to have uncluttered working sheets of these topographic quadrangles, 18 by 24-inch vellum overlays of the streams were drafted. Streams on the overlays were not differentiated into perennial and intermittent streams. Major divides were added with a drawing pencil.

For purposes of identification, each stream segment in each of the four basins was labeled. First-order streams (see following section on stream order) were assigned consecutive numbers in red pencil preceded by a lower case "a". Similarly, second-, third-, fourth-, and fifth-order streams were identified with a blue "b", green "c", orange "d", and purple "e", respectively, and consecutively numbered. In addition, the numbering generally commences in the headwaters of each basin and proceeds toward the mouth.

Due to the large expense of air photo coverage for 1320 square miles, first-order streams in this study were chosen as those streams without tributaries on U.S. Geological Survey 15-minute topographic quadrangle maps. With the use of aerial photographs it would be possible to delineate further smaller channels in the drainage basins. It is believed that the results of this study are reproducible by other investigators whereas data for first-order streams chosen by inspection of aerial photographs may not have been reproducible by others due to the subjectivity of choosing first-order streams on photographs.

Stream lengths and basin perimeter lengths were measured with a Keuffel and Esser map measure graduated in half inches. Measurements were recorded to the nearest tenth of an inch in a standard laboratory computation notebook; these measurements were later converted to feet in an adjacent column. The amount of fall (change in elevation) and average slope of each stream segment were computed and recorded in separate columns.

The drainage areas were measured with a Keuffel and Esser planimeter. The most crenulated contours were visually chosen.

Physiography

The central Coast Range occurs in Fenneman's (1931) Pacific Border Province which is characterized by a chain of mountains on the west and a parallel chain of valleys on the east. In Washington the Province from west to east is composed of the Olympic and Coast mountains, the Puget trough, and the Cascade Mountains. In Oregon, the Coast Range, Willamette Valley, and Cascade Mountains are the major features. In California the central valley is flanked on the west by the Coast Ranges and on the east by the Sierra Nevadas.

The panorama of the Coast Range is very similar to the Appalachians and Ouachita Mountains in the eastern and central part of the United States, respectively. In general, the tree-covered summits present a smooth convex profile from a distance.

A narrow coastal plain fringes the western border of the central Coast Range. This strip of recent sand and Pleistocene marine terrace gravels is boldly interrupted by Yaquina Head and Cape Foulweather which are composed of erosion-resistant basalt. Post-Pleistocene sea level rise is responsible for the large estuaries at the mouths of the Yaquina River and Siletz River. Drowning of these stream valleys extends upstream 15 miles along the Yaquina and 8 miles along the Siletz. The processes at work along the sea-land interface will not be investigated in this study because these present numerous possibilities for dissertations themselves.

The eastern flank of the Coast Range slopes toward the Willamette River. Many parts of this eastern flank especially north of the study area are extremely flat owing to Pleistocene inundation of the Willamette Valley. Rich black soils have developed on the flat surfaces of the old Pleistocene lake floor. Extremely flat areas occur along Baskett Slough and Mud Slough (north of Rickreall) which are tributaries of Rickreall Creek and between Evergreen Creek and Marys River southwest of Corvallis.

Geologic Setting

The Oregon Coast Range is composed of Tertiary age rocks that have been gently deformed into a low anticlinorium. Sedimentary rocks are areally most extensive in the study area (Fig. 2) although igneous rocks, both extrusive and intrusive, are important as ridge- and highland-formers.

The oldest rocks exposed in the Coast Range are Eocene in age (approximately 55 million years old). According to Snavely and Wagner (1963), an oceanic trench occupied the present site of the Coast Range during Eocene time. The Eocene sea lapped against an ancestral Cascade Range about 100 miles east of the modern shoreline. The Klamath Mountains were highlands to the south. A thick series of basaltic lavas, breccias, and tuffs were extruded upon the ancient sea floor. Snavely and others (1973) have estimated from geophysical testing that there may be as much as 20,000 feet of these volcanic rocks, called the Siletz River Volcanics. Seven thousand to eight thousand feet of marine sands and muds were deposited unconformably over the volcanic basement in late Eocene time. These lithified sediments were called the Tyee Formation.

A series of marine mudstones, siltstones, and sandstones were deposited upon these oldest rocks which had been folded, faulted, and truncated by erosion during the late Eocene (Baldwin, 1964a).

During the Oligocene (approximately 37 to 26 million

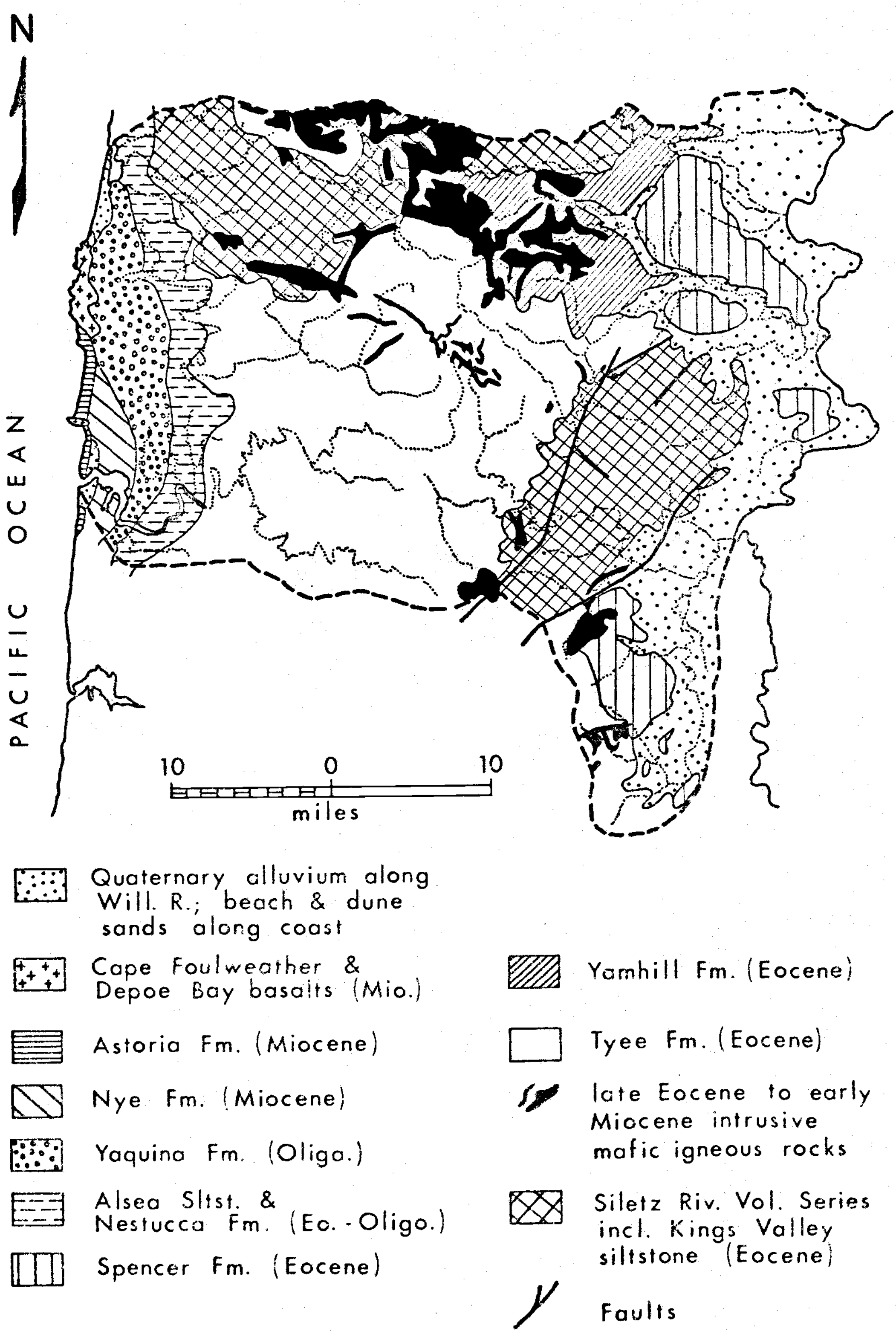


Figure 2. Geologic map (after Wells and Peck, 1961).

years ago) the rate of sedimentation exceeded the rate of subsidence of the trough, and the trough became infilled with sediment. Much of this sediment is volcaniclastic in origin, consisting ov volcanic glass shards, pumice pebbles and cobbles, and dacite and andesite fragments (Goodwin, 1973). Some of this material was deposited as cross-bedded strata and as channel fills. The textural maturity of the sediments, index of refraction of the glass shards, and the stratigraphy of the Oligocene Yaquina Formation are strongly suggestive that these sediments were deposited by streams and that the sediments were derived from the ancestral Cascade volcanic upland. Locally, coal beds were deposited, indicating swampy conditions. In the Miocene (approximately 26 to 12 million years ago), the Astoria sandstones and mudstones were deposited in the western part of the shoaling trough. The Astoria Formation also contains abundant volcaniclastic material (Cressy, 1974; Neel, 1976; Smith, 1975; Cooper, 1977) which was apparently deposited as a broad delta (Niem, 1976).

Miocene igneous intrusions possibly related at depth to the outpourings of Columbia River Basalt on the Columbia River Plateau occurred in scattered locations throughout the Coast Range. Locally, the intrusions reached the surface producing volcanoes along the coastline as at Cape Foulweather.

Younger sedimentary units are scarce in the Coast Range.

The only Pliocene unit is the Troutdale Formation which is exposed along the crest of Coxcomb Hill in the city of Astoria (Schlicker and others, 1972). Pleistocene gravels are well exposed in marine terraces along the present coastline, and Pleistocene events in the Willamette Valley appear to offer many challenging research possibilities.

Uplift of the Oregon Coast Range apparently began sometime during the late Miocene, lasted at least through the Pleistocene, and may still be quietly active at present.

A predominant trend of faulting in the Coast Range has not yet been determined because detailed geologic investigations are still in progress. Similarly, trends of joint systems which may also have affected stream courses have not been systematically studied.

Climate

The thesis area lies within the northern temperate zone of westerly atmospheric flow. The Coast Range is the first land obstacle to storms bred in the North Pacific and as such, the area bears the full force of wind and precipitation as marine air masses pass over the land. The physical barrier of the Coast Range forces the moist marine air to rise. In rising, the air is cooled and precipitation occurs. The wettest areas in the State of Oregon occur along the northern boundary of the thesis area. More than 120 inches of precipitation per year are recorded locally (Fig. 3).

The maximum annual precipitation (Fig. 3) occurs in the

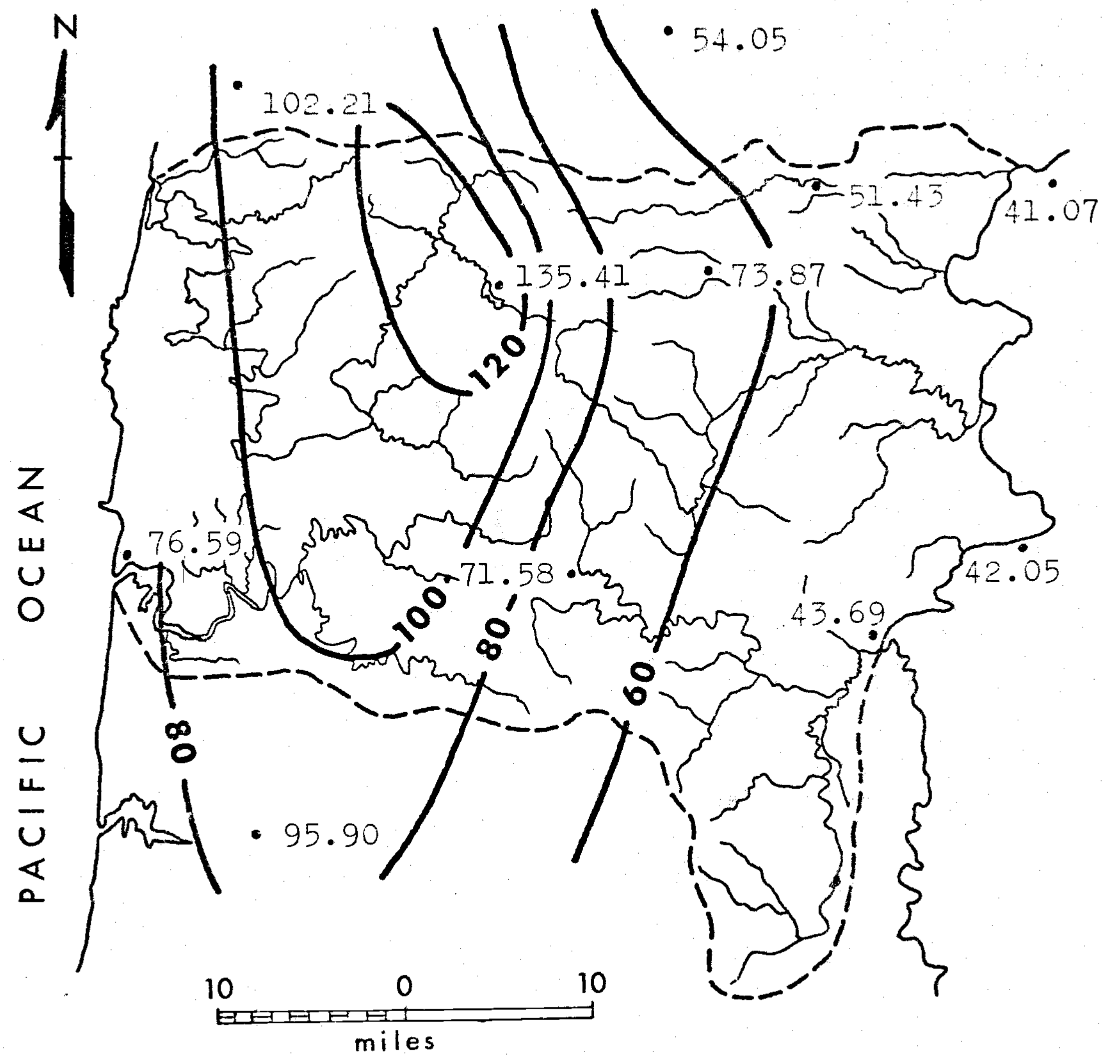


Figure 3. Isohyetal map of average annual precipitation in inches (1956-1975).

headwaters of the Salmon, Siletz, and South Yamhill Rivers. The least annual precipitation occurs along the Willamette River. Isohyetal lines roughly parallel the mountain range and are transverse to the predominant westerly winds. The maxima of precipitation are not closely related to elevation maxima. For example, Mary's Peak which is the highest point in the Oregon Coast Range (4,097 feet) is not associated with the area of 120+ inches of annual precipitation.

Most of the annual precipitation occurs in the winter months, November through March (Fig. 4) in the form of rain. A heavy snowfall is an unusual event along the coast while heavy snows may block traffic through the Coast Range passes several times each winter.

Winter temperatures are mild averaging 38° F to 43° F throughout the area in January. Along the coast annual variation of average monthly temperatures is 15° F or less (Fig. 4B). On the east flank of the mountains this annual variation is less than 30° F. Temperature extremes are rare due to the ameliorating effect of marine air from the Pacific. At Salem, the lowest temperature between 1931 and 1960 (Climates of the States, 1967) was -10° F which occurred in January, 1950. In July, 1941, a temperature of 108° was recorded.

Violent atmospheric disturbances such as tornadoes, thunderstorms, and hailstorms are rare although storms of hurricane force (winds of 74 miles per hour or more) strike

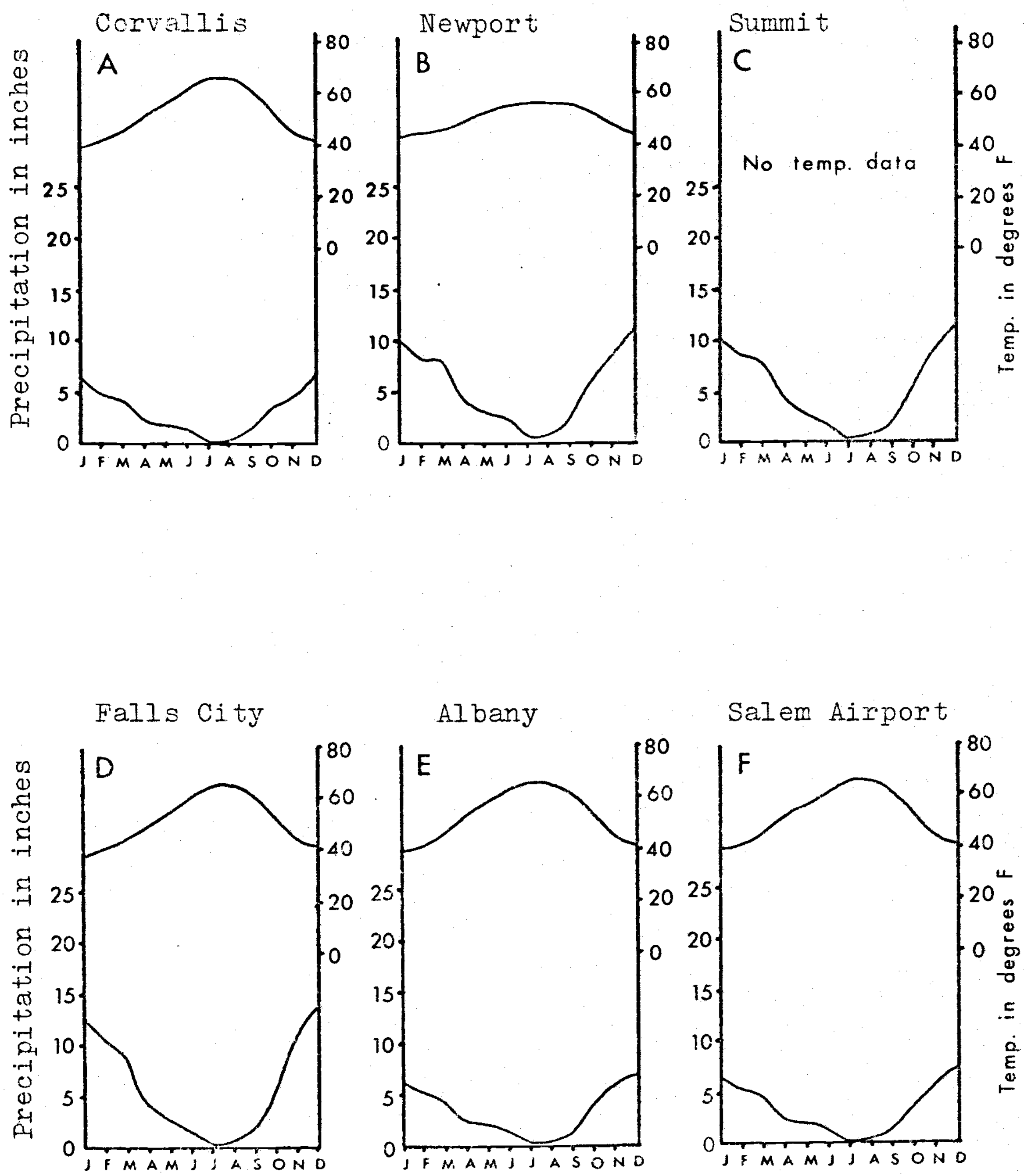


Figure 4. Climatic graphs for the 30-year period 1931-1960 (U. S. Dept. of Commerce climatological standard normals for stations in the central Coast Range).

the coast several times a year. Occasionally these storms push through the passes and inflict their effects on the western interior valleys.

The north coastal area is the least sunny spot in the state (Climate of the States, 1967). December is the cloudiest month, with only 20% sunshine. By April, sunshine occurs approximately 50% of the time. July, the sunniest month of the year, has only 55% sunshine. A coastal fringe of summer fog is very common due to the interaction of warm air and cold water upwelling offshore.

The persistent cloud cover during the rainy months decreases the amount of evaporation. Therefore, water remains at the earth's surface for an increased length of time where it may be active in a variety of denudational processes.

Vegetation

Northwestern Oregon and western Washington are the most densely forested region in the United States (Franklin and Dyrness, 1973). Conifers are vastly predominant in this forest; Kuchler (1946) reported the ratio of 1:1,000 hardwoods to conifers. The dominant conifers are large and long-lived (Table 1).

Apparently, the history of climatic events since the Miocene epoch (26 to 12 million years before present) has been of primary importance in establishing the dominance of conifers in the area (Franklin and Dyrness, 1973). The U.S.

TABLE 1. Ages and dimensions typically attained by forest trees on better sites in the Pacific Northwest (adapted from Franklin and Dyrness, 1973).

Species	Common Name	Age Years	Diameter Inches	Height Feet
Abies amabilis	Pacific silver fir	400+	35 - 45	150 - 180
Picea sitchensis	Sitka spruce	800+	70 - 90	230 - 245
Pseudotsuga menziesii	Douglas-fir	750+	60 - 85	230 - 265
Thuja plicata	Western redcedar	1,000+	60 - 120	200+
Tsuga heterophylla	Western hemlock	400+	35 - 50	165 - 215

International Biological Program's Coniferous Forest Biome project reports that the factors of the present climate listed below are particularly favorable to coniferous species: (1) high total precipitation that occurs mostly during winter and a relatively dry summer and (2) very mild winters.

Franklin and Dyrness (1973) recognize two vegetation zones in the northern Coast Range of Oregon: (1) coastal Sitka spruce (*Picea sitchensis*) zone and (2) western hemlock (*Tsuga heterophylla*) zone. The Sitka spruce zone has a uniformly wet and mild climate with frequent fog and low clouds and occurs at elevations less than 500 feet although on mountains adjacent to the ocean the zone extends up to 2,000 feet. The most common coniferous tree species are Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*). Douglas-fir (*Pseudotsuga menziesii*) is an important constituent tree. Throughout the central Coast Range red alder (*Alnus rubra*) is the dominant species in disturbed areas, and many old landslide sites are first noticed by groves of even-aged red alder. Lodgepole pine (*Pinus contorta*) is common along the ocean where prevailing onshore winds sculpt the growing trunks into contorted shapes. The understory in mature forests of the Sitka spruce zone is lush and dense and includes swordfern (*Polystichum munitum*), Oregon oxalis (*Oxalis oregana*), salal (*Gaultheria shallon*), devilsclub (*Oplopanax horridum*), huckleberries, and salmonberry (*Rubus* *spectabilis*). Locally, manzanita (*Arctostaphylos spp.*) is very dense on dry sandy substrates.

The western hemlock zone is the more extensive of the two vegetation zones. Also it is the more important zone in terms of lumber production. Although the name implies that western hemlock is the dominant species, Douglas-fir dominates large areas of the zone. The name is based on the potential climax species; Douglas-fir is the subclimax species. The major forest tree species in the zone are: Douglas-fir, western hemlock, and western redcedar although grand fir and Sitka spruce occur locally (Franklin and Dyrness, 1973). Hardwoods are uncommon except on recently disturbed sites such as landslides and logging damaged areas. The most widespread hardwoods are red alder, bigleaf maple (*Acer macrophyllum*), and golden Chinkapin (*Castanopsis chrysophylla*). Along major streams common hardwoods are: black cottonwood (*Populus trichocarpa*), Oregon ash (*Fraxinus latifolia*), bigleaf maple, and red alder.

The lush green vegetation mantle that covers the Coast Range is broken in places by clearcut logging and "grass balds". Aldrich (1973) studied the grass balds of the Oregon Coast Range as a Ph.D. research topic. He determined from U.S. Geological Survey 15-minute topographic maps and detailed field reconnaissance that five balds, acceptable for vegetation analysis, occur in the central Coast

Range from elevations of less than 2,000 feet to over 4,000 feet. Of these, he examined three randomly selected balds more closely. His research of literature on the topic found numerous explanations for the existence of balds in south-eastern United States, including fire, soil drought, grazing, limited seed dispersal, and succession. No one cause was chosen for the explanation of Oregon Coast Range balds. All of the balds in the central Coast Range occur on peaks that are underlain by intrusive igneous rocks. Merkle (1951) published a list of species occurring in the bald on Marys Peak. The balds are typically covered with low-growing grasses and herbs.

The vegetation mantle of the Coast Range has suffered from frequent fires. Heusser (1960) found six charred layers in a 6,000 year old bog in Devils Lake near Lincoln City, suggesting six fires in that area alone in that time period.

Streams

Streams perform many functions for humankind. In Oregon's history alone, it was the Snake and Columbia Rivers which provided the route for the Lewis and Clark Expedition to Oregon in the first decade of the nineteenth century. Streams provide navigation, water for domestic and industrial purposes, recreation, power generation, and, on the darker side, refuse disposal.

Viscissitudes in a stream's character also require special adjustments by those who live near streams. Rapids and falls which add scenic beauty limit navigation. Flooding which replenishes the sediment over the surface of the floodplain also may sweep away man's fragile structures.

Man's close association with rivers since the time of his earliest recorded history has led him to study streams and to seek answers to his many questions about them. In the last 100 years, these studies have provided many answers and have presented many new questions. The analysis presented here includes various approaches to the description of the streams in the central Coast Range of Oregon.

QUANTITATIVE DRAINAGE BASIN MORPHOLOGY

The quantitative description of drainage basins has been molded by engineers (such as R. E. Horton, 1932, 1945), geologists (M. E. Morisawa, 1962, 1968; L. B. Leopold, 1964; and S. A. Schumm, 1956), and geographers (A. N. Strahler, 1952, 1957 and T. Oberlander, 1965). The following section conforms with the sequence of quantitative description which has been established by these investigators.

A drainage basin is considered in this paper to be that area which supplies water (and products of weathering) to a given stream channel. The four major drainage basins in the study are roughly equal in size ranging from 258 sq mi to 334 sq mi (Fig. 5; Table 2). The Luckiamute is the largest basin, and the Yaquina is the smallest basin. A divide separates a given drainage basin from all other watersheds.

Drainage Divides

Many previous reports have stated that the divide of the northern Coast Range parallels the coast line. In a broad sense and especially since the range trends north-south, that statement is true. However, closer examination of the divide reveals that its position is highly variable. In the north, the headwaters of the westward-flowing Nehalem lie within 10 miles of the city of St. Helens on the Columbia River. The divide between the westward-flowing Wilson and Trask system and the eastward-flowing Tualatin occupies a mid-range position. The eastward-flowing Yamhill

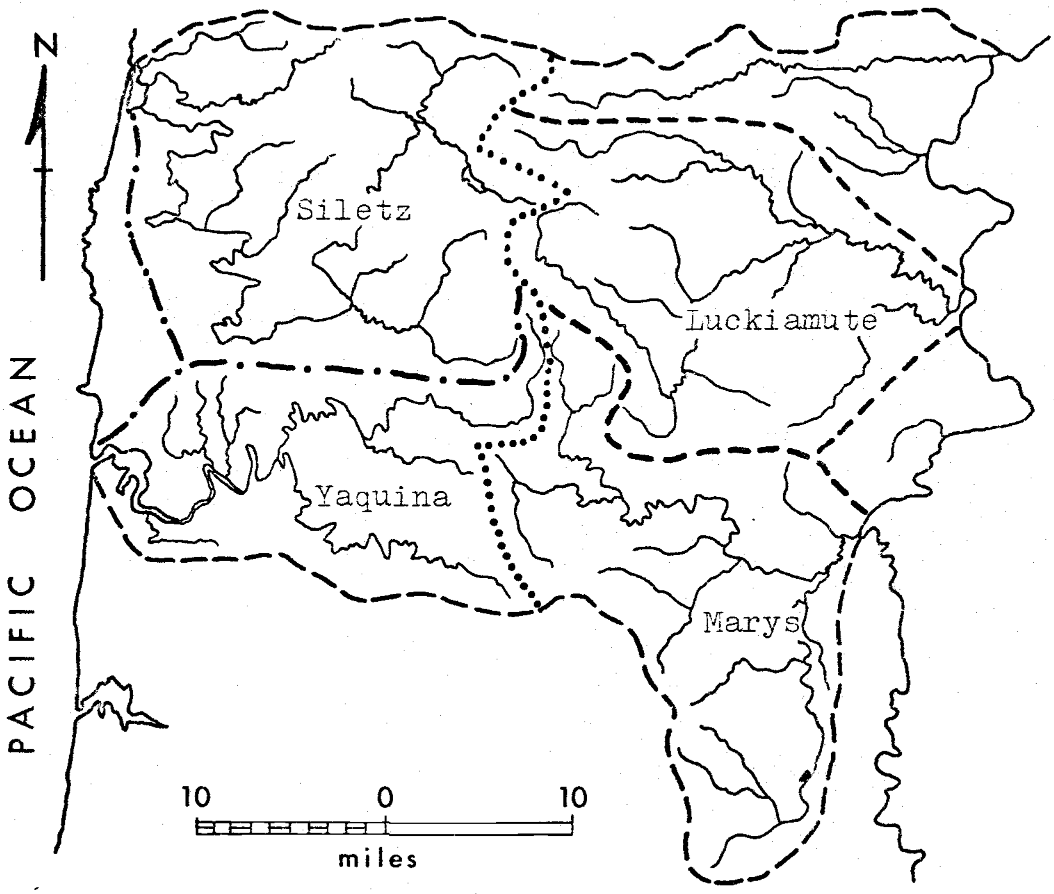


Figure 5. Drainage divides in the central Coast Range.

has its headwaters less than 10 miles from the coast whereas the Alsea River originates approximately 10 miles west of the Willamette River near Monroe. Within the thesis area the divide between westward-flowing and eastward-flowing streams is located roughly at mid-range.

A few generalizations can be made about the divides within the thesis area (Fig. 5). Major east-west trending divides are ridges with relief of 400 to 1500 feet whereas north-south trending divides are low saddles with 150 to 200 feet of relief between stream heads as depicted on U.S. Geological Survey 15-minute topographic maps. Many intrabasin divides throughout the area are very narrow. In places, the divides are barely wide enough to support a single-lane gravel road for fire access.

Stream Order

The natural hierarchy of streams is familiar to every schoolchild who has taken a day-long hike in search of a good fishing pool or swimming hole. The range is broad, from a mere trickle to the mighty Mississippi. For purposes of comparison, a system of ranking streams in the hierarchy has been created. This system is called stream ordering, and there are several methods of stream ordering in use. European scientists assign the main trunk of a stream order one, the largest tributary is order 2, the largest tributary of a tributary is order 3 and so on upstream until the smallest channel has been numbered and has the highest number (Fig. 6A). Horton (1932) preferred the system of ordering streams starting with the smallest tributary in the headwaters and working toward the mouth of the main stream. The length of a second or higher order stream in both Horton's and the European schemes includes the length of the largest tributary (Figs. 6A and 6B). Some workers have considered the largest tributary to be the largest one; others have chosen the largest tributary as that which has the largest drainage area.

According to Morisawa (1968), Strahler's (1957) modified version of the Horton system (Fig. 6C) is more objective and straightforward. In Strahler's system, the fingertip tributaries in the headwaters are designated first-order. In other words, first-order streams have no tributaries. Two streams of a given order converge to produce a stream of the next higher order. Thus, two first-order streams join to form a second-order stream; two second-order streams flow together to form a third-order stream and so on. However, a lower order stream flowing into a higher order stream does not change the order. For example, a first-order stream junction with a third-order stream does not produce a fourth-order stream. Only the junction of two or more like-order streams can produce a stream of the next higher order.

The length of a stream of given order is measured from the upstream confluence of two streams of the next lower order to the confluence of the given stream with a stream of like or higher order. Thus, the length of the second-order

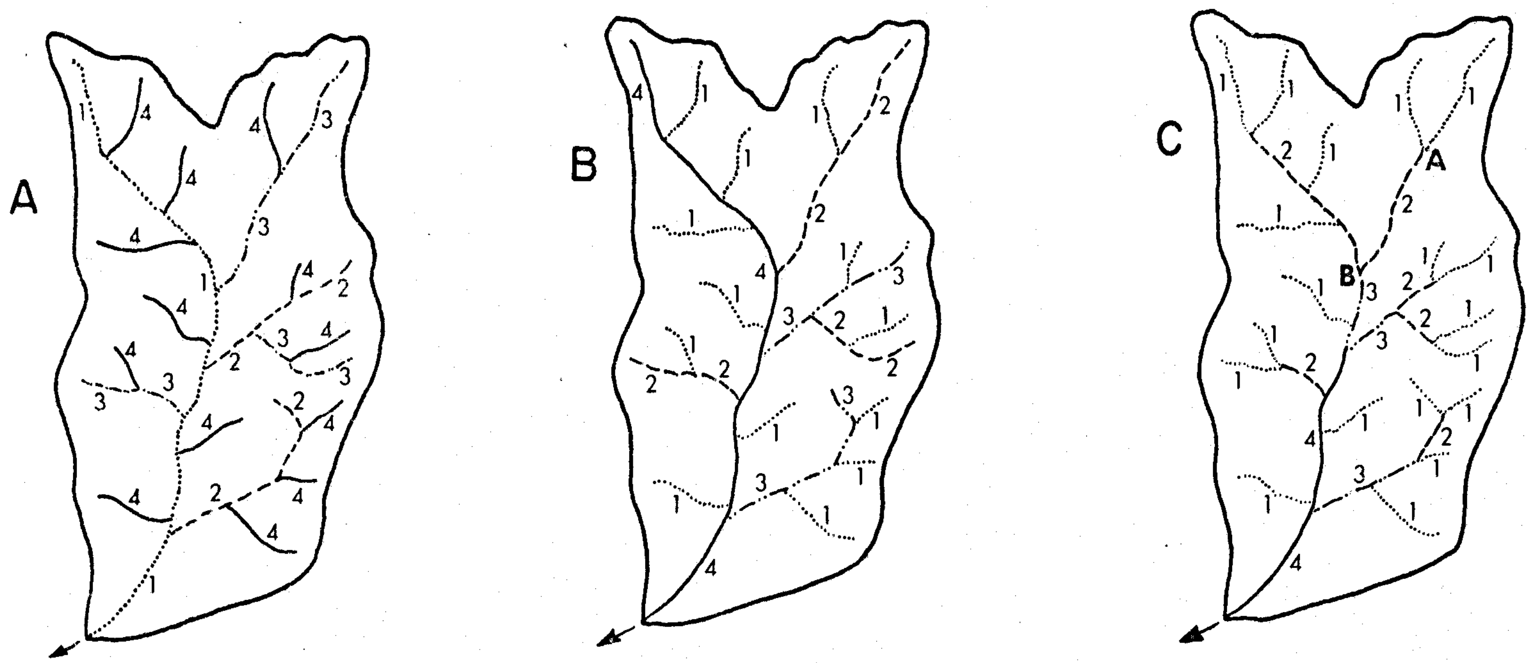


Figure 6. Stream ordering methods of Europeans (A), Horton (B), and Strahler (C). Points A and B in diagram C are referred to in the text. Drainage basin shape modified from Morisawa (1968).

stream in the northeast quadrant of the basin in figure 6C is the distance from A to B along the stream channel.

The Strahler (1957) method was used in this investigation. Thus, the order of the streams in the thesis area are: Siletz - fifth-order; Luckiamute - sixth-order; Yaquina - fifth-order; and Marys - fifth-order. The Luckiamute was divided into its two fifth-order streams (Luckiamute-principal and Luckiamute-secondary) in order that all comparisons would be made for streams of the same order.

Stream Numbers and Bifurcation Ratios

Horton (1945) noted that within a drainage basin, the number of streams decreases in an orderly way with increase in stream order. Numerous investigations published in the 1950's found similar trends. Figure 7 illustrates that for streams in the thesis area the logarithm of the number of streams plotted against order forms a straight line. Lines were fitted to the data points in figure 7 by regression analysis following the least squares method described by Haring and Lounsbury (1975, p. 118-119). The straight line plot indicates that the streams in the thesis area conform with Horton's law of stream numbers.

In addition, the relationship of number of streams in each order is stated by the bifurcation ratio. The bifurcation ratio is the ratio of the number of streams of a given order to the number of streams of the next higher order. The bifurcation ratios in the thesis area range from:

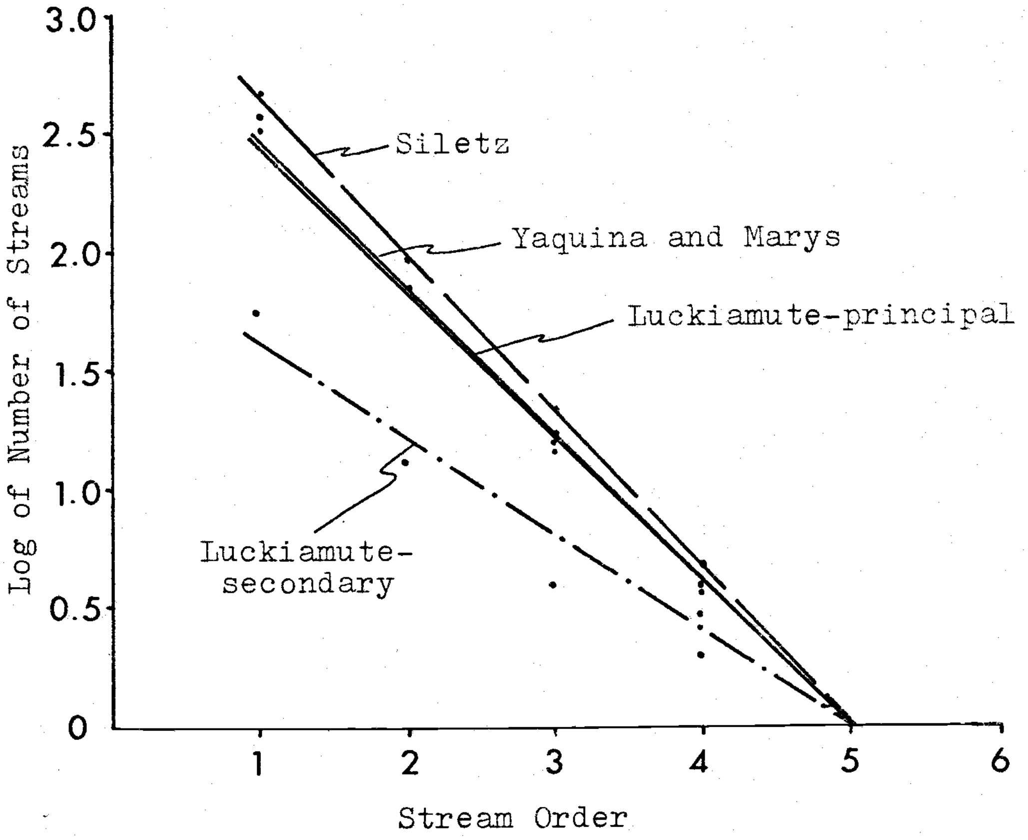


Figure 7. Relation of log number of streams to stream order for basins in the central Coast Range of Oregon.

Siletz basin 3.67 to 6.0, av. 4.76; Luckiamute-principal basin 3.0 to 4.86, av. 3.47; Luckiamute-secondary 2.0 to 4.3, av. 2.3; Yaquina basin 4.0 to 4.77, av. 4.37; and Marys basin 3.0 to 5.0, av. 4.33 (complete figures appear in Appendix B).

The bifurcation ratio of a large number of basins in the United States is approximately 3.5 (Leopold and others, 1964, p. 138), but there is variation, especially where geologic phenomena strongly influence the drainage. Published examples of bifurcation ratios range from 2.00 to 5.67. Because bifurcation ratios apparently vary little with climate and geology across the United States (3.2 in Maryland with annual precipitation of 40 inches; 3.5 in New Mexico with annual precipitation of 13 inches; 3.5 in the badlands of South Dakota with annual precipitation of less than 20 inches), there appears to be little that can be interpreted from the number obtained. However, the figures are presented as part of the quantitative description of the basins.

Stream Lengths

Similarly, average stream length increases with increasing stream order. Average stream lengths of first-order in the thesis area range from 0.65 mile to 0.83 mile (Appendix C) which are less than the average length of 1 mile for first-order streams published by Leopold and others (1964, p. 142). Average lengths for all stream orders in the thesis area are less than the average lengths projected by Leopold and others (1964) for streams of the same orders in the contiguous United States. Figures published by Leopold and others for average lengths of streams in arid New Mexico are as little as one-hundredth of the average projected for the United States in general. It is concluded that average length computed for an area as large as the United States in which there is such diversity of climate and rock type may not be as useful for comparisons of drainage basins as average lengths computed for basins in areas of similar climate, geology, and geomorphic history. Figures for average stream lengths in climatic and geologic conditions similar to the central Coast Range were not available.

Drainage Density, Texture Ratio, and Stream Frequency

The data on stream numbers and lengths in the preceding paragraphs can be further useful in describing the amount of dissection of an area by relating the length of stream channels to basin area and the number of streams in a basin. The results provide length of stream channel per unit area, called drainage density, and the number of streams per unit area, called stream frequency. In addition, Smith (1950) developed a measure called texture ratio to describe the closeness or proximity of one channel to another. Texture ratio relates the number of crenulations of the most crenulated contour in the basin to the length of the perimeter of the basin. The most crenulated contour is chosen by visual inspection. It is assumed that crenulations on the chosen contour represent small channels that are not sufficiently large to be depicted on a U.S. Geological Survey 15-minute topographic quadrangle map and that the number of crenulations or channel crossings of the contour is a measure of channel spacing.

Texture ratio also provides a more precise description of dissection than the highly subjective verbal categories of well dissected and poorly dissected.

Drainage densities and stream frequencies were determined for each of the four major basins in the thesis area and the results are presented in Table 2. In addition, four third-order basins in the Siletz drainage and two third-order basins in the Marys drainage were selected for their variability of drainage density at the visual level. Drainage density figures for these third-order basins range from 1.35 mi/sq mi to 3.1 mi/sq mi compared to 0.86 mi/sq mi calculated for the fifth-order basins. Stream frequency of the six selected third-order basins range from 1.1 streams/sq mi to 6.19 streams/sq mi; stream frequencies for the fifth-order basins range from 1.36 to 1.97 streams/ sq mi (Appendix A).

Because the fifth-order basins cover such a large area, a single contour does not yield a representative number of crenulations, and therefore, a texture ratio for such a large basin probably does not accurately represent the state of dissection. For example, in the Siletz basin headwaters,

Table 2. Drainage densities and stream frequencies in central Coast Range of Oregon

Stream	No. of Streams	Total Channel Lengths (mi)	Basin Area (sq mi)	Drainage Density (mi/sq mi)	Stream Frequency (streams/sq mi)	Texture Ratio (5th order)
Siletz	612	581	310	1.87	1.97	17.4
Luckiamute principal	413	397	278	0.86	1.48	11.5
Luckiamute secondary	75	78	56	0.92	1.33	4.2
Yaquina	455	434	258	1.68	1.76	25.3
Marys	419	489	307	1.59	1.36	18.0

elevations range from 1,000 feet to more than 3,300 feet, and a most crenulated contour is fairly high, such as the 2,250-ft contour. However, working downstream into the next quadrangle, the maximum elevation drops, and the 2,250-ft contour is only rarely present. In this quadrangle in which elevation ranges from 50 feet above mean sea level to 2,000 feet, the most crenulated contour might be chosen at 1,250 feet. Therefore, it is difficult to choose a most crenulated contour that will be representative of the entire basin. In an attempt to force the issue, a contour was chosen, and the method was worked through to a conclusion. All but one of the texture ratios thus obtained for the fifth-order basins in the thesis area indicate a fine texture (Smith's, 1950, limits of texture ratio are less than 4.0 is coarsely textured, 4 - 10 is medium-textured, 10 - 50 is finely textured, and greater than 50 is ultra-fine texture). However, the texture ratios of the six third-order basins indicate a coarse to medium texture which agrees with a visual estimation of the texture (Table 2, Fig. 8).

Figure 8 was adapted from Strahler (1957, p. 916). The solid circle data points are second- and third-order basins in various climatic and geologic conditions in the United States. The points from the central Coast Range of Oregon (represented by +'s) are most similar to basins in the gently dipping Carboniferous sandstones of the Appalachian Plateau in a humid climate and are similar in texture ratios to basins in igneous and metamorphic rocks of the Southern

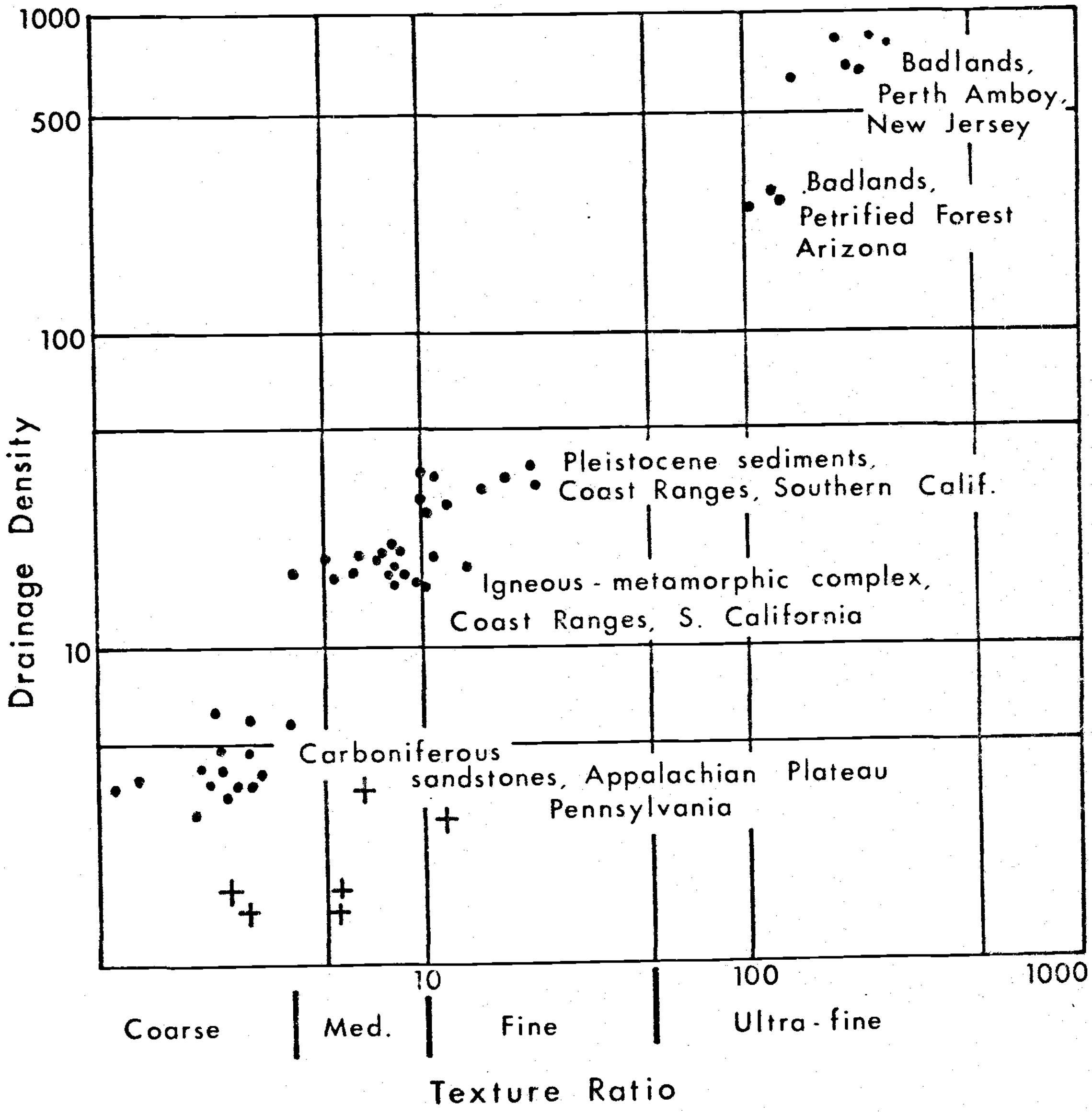


Figure 8. Comparison of drainage densities and texture ratios of six third-order streams in the central Coast Range (+) to second- and third-order streams in other parts of the United States (●). Diagram modified from Strahler (1957, p. 916).

California Coast Ranges. As might be expected, the one Oregon Coast Range basin with fine texture occurs on the south-facing slope at Valsetz where the greatest annual precipitation in the area occurs.

Length of Overland Flow

The distance between channels is defined by the reciprocal of the drainage density (area divided by total channel length). One-half that distance is the length from the drainage divide to the channel, or the length of overland flow. Overland flow is an important erosional agent which moves rock particles dislodged by rain-drop impact or entrained by the flowing sheet of water to the nearest downslope channel. It occurs wherever rainfall intensity exceeds the rate of infiltration and is most noticeable where vegetative cover is sparse.

Sheet erosion, the result of overland flow, would be expected on clear-cut slopes, on overgrazed pastures, in areas that have recently suffered forest fire, and on the grass balds in the thesis area. It is an important process involved in valley widening (Thornbury, 1969, p. 102). Two climatic factors probably limit the amount of sheet erosion on the grass balds in the Oregon Coast Range. Most of the annual precipitation in western Oregon occurs during winter, and during this season, because of their elevation, most of the balds receive snow more often than rain. Runoff from snow cover is less than runoff from rain because part of the snow cover sublimates rather than melts. Runoff of meltwater may not involve any erosion, especially if the rate of melting is slow, until the snow cover has been reduced to a few inches or less to the point when rock particles are exposed to entrainment by flowing water.

The length of overland flow in the thesis area ranges from 0.27 mi in the Siletz basin to 0.58 mi in the Luckiamute-principal basin (Table 3). These distances compare favorably with lengths of overland flow computed by Horton (1932, p. 361) for streams in New York State where there is approximately 40 inches of annual precipitation and a similar density of vegetation cover.

Constant of Channel Maintenance

Once the length of overland flow is known, a natural question arises, "How much surface area is required to maintain one foot of channel?". Schumm (1956) defined the constant of channel maintenance as a measure of the drainage area necessary to maintain one foot of channel. The constant of channel maintenance is the reciprocal of the drainage density times 5280 (Schumm, 1956, p. 607). For the fifth-order basins in the thesis area, the constant of channel maintenance ranges from 2,825 sq ft in the Siletz basin to 6,140 sq ft in the Luckiamute basin (Table 3).

Table 3. Length of Overland Flow and Constant of Channel Maintenance for Fifth-order Basins in the Central Coast Range of Oregon.

Stream	Overland Flow (mi)	Constant of Channel Maintenance (sq ft)
Siletz	0.27	2,825
Luckiamute principal	0.58	6,140
Luckiamute secondary	0.54	5,739
Yaquina	0.30	3,142
Marys	0.32	3,321

Basin Shape

Several methods of measuring basin shape have been proposed. Horton (1932) applied form F (basin area/(basin length)^2) and shape S (basin length/basin width) where basin length is measured from a point on the basin divide opposite the mouth of the main stream and basin width is normal to basin length. Miller (1953) used a circularity ratio C (basin area/area of a circle with circumference equal to length of basin perimeter).

Schumm (1956) defined an elongation ratio E (diameter of a circle of area equal to basin area/maximum length of basin measured parallel to the principal drainage line). As the elongation ratio approaches one, the shape of the basin approaches a circle. Visual inspection of figure 5 shows that the fifth-order basins are not circular. Table 4 lists the values of basin shape parameters for the five fifth-

Table 4. Values of Some Basin Shape Measures for Drainage Basins in the Central Coast Range of Oregon.

Form F (Horton, 1932)

$$\frac{\text{Basin Area}}{(\text{Basin Length})^2}$$

Siletz	0.49
Luckiamute principal	0.44
Luckiamute secondary	0.44
Yaquina	0.40
Marys	0.71

Shape S (Horton, 1932)

$$\frac{\text{Basin Length}}{\text{Basin Width}}$$

Siletz	1.09
Luckiamute principal	1.31
Luckiamute secondary	1.58
Yaquina	1.79
Marys	1.05

Circularity ratio C (Miller, 1953)

$$\frac{\text{Basin Area}}{\text{Area of a circle with same basin perimeter}}$$

Siletz	1.50
Luckiamute principal	1.57
Luckiamute secondary	2.05
Yaquina	1.22
Marys	1.51

Elongation ratio E (Schumm, 1956)

$$\frac{\text{Diameter of circle with area = basin area}}{\text{Max. length of basin measured parallel to princ. drainage}}$$

Siletz	0.26
Luckiamute principal	0.38
Luckiamute secondary	0.56
Yaquina	0.32
Marys	0.43

order basins in the thesis area.

The shape of the basin influences the character of the discharge of the main stream and this, in turn, affects the energy and erosive power of the stream. In a long narrow basin such as in a trellis drainage pattern, flow reaches the main channel at different times, and therefore peak discharge is distributed over a long span of time. However, in a wide, square, or fan-shaped basin, peak flows from the tributaries may arrive nearly simultaneously, causing the discharge of the main stream to be rapidly higher and shorter-lived (Morisawa, 1968).

Basin Relief

Local relief in the thesis area is highly variable. The highest points at elevations of 2,700 feet or more are underlain by igneous rocks, either the Eocene Siletz River Volcanics or the Oligocene to Miocene intrusives. Relief is greatest where the antecedent streams have deeply incised their courses and consequent streams have cut steep V-shaped canyons into the igneous rocks. Steep stream gradients and high slopes are common. Mass-wasting is frequent throughout the range especially during the wet winter.

Generally, the relief is not as great on the Tyee Formation which underlies much of the area (Fig. 2). The Tyee Formation consists of less resistant sandstones and mudstones which are gently arched over the axis of the Coast Range. These gently dipping sedimentary strata are impermeable and support many short intermittent streams which quickly dry up during the dry summer when surface runoff is curtailed and base flow is negligible. Furthermore, the sedimentary strata are less resistant to erosion than the igneous rocks. The combination of gentle dips and little resistance to erosion produces low-lying hills. The summits average approximately 1,500 feet. Figures 9A and 9B are topographic cross sections across the area constructed from the 1:250,000 Salem topographic sheet. These sections and the sections in Appendix D dramatically portray the effect of lithology on summit elevations and provide no suggestion of an ancient peneplain.

For purposes of comparing basins, Schumm (1956, p. 612) developed a parameter, called relief ratio, to express the relief in a basin as a dimensionless number. The relief ratio together with sufficient climatic and discharge data may have further use in estimating sediment yield of a basin (Strahler, 1957). The amount of sediment removed from a basin through stream channels is of interest to engineers, geologists, and oceanographers as well as geomorphologists. Relief ratio was defined by Schumm (1956) as the ratio of total basin relief to basin length, measured parallel to the principal drainage line in the basin. The relief ratios for fifth-order streams in the thesis area are:

Siletz	0.007
Yaquina	0.007
Marys	0.007

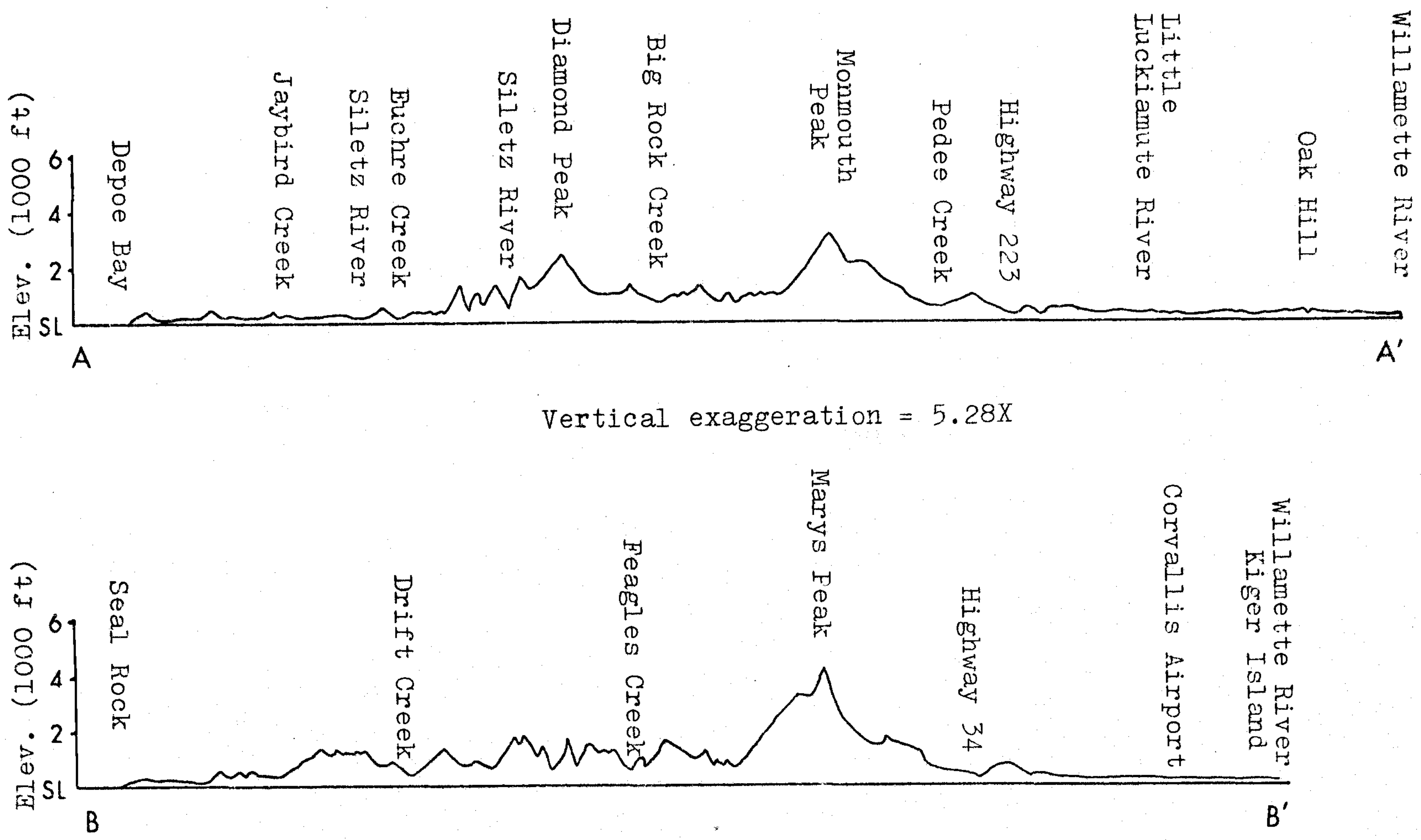


Figure 9. Physiographic cross sections along west-east lines A. from Depoe Bay to 10 miles south of Salem, approximately 44° 47' 45" N latitude and B. from Seal Rock to Corvallis airport, approximately 44° 30' N latitude.

Luckiamute principal	0.010
Luckiamute secondary	0.022

The relief ratios for the Siletz, Yaquina, and Marys compare favorably with relief ratios for fourth- and fifth-order streams on the Gulf Coastal Plain and Atlantic Coastal Plain published by Schumm (1956). The values for the relief ratio of the two Luckiamute fifth-order streams are larger than the published ratios for coastal plain streams but less than published ratios for fourth- and fifth-order streams on the Piedmont.

Longitudinal Profiles

For most humid climate streams, the longitudinal profile is concave-upward (Leopold and others, 1964; Morisawa, 1968; Thornbury, 1969; Small, 1972). The concave-upward form has aroused speculation for a long time although many geomorphologists now accept the explanation that increased discharge downstream accounts for the steeper gradient in the headwaters and lower gradient toward the mouth. All of the fifth-order streams in the thesis area have concave-up longitudinal profiles (Appendix E) although some first-order streams in the upper reaches of the Siletz River are convex-upward as they plunge off the highlands down the walls of the Siletz River gorge in the Siletz River Volcanics.

The longitudinal profiles exhibit several knickpoints, and these are especially pronounced along the Siletz River.

These knickpoints are attributed to more resistant flows, dikes, or sills rather than to fault scarps or changes of sea level because at each knickpoint a change in lithology can be observed. Longitudinal profiles of the four major streams are included in Appendix E.

Discharge

The relationship between the action of flowing water and sculpture of the land was recognized by Aristotle, Avicenna, and other early natural scientists. In the 16th century, Agricola, a German mining expert, clearly described the processes involved (Morisawa, 1968, p. 4-5):

> The little brooks first wash away the surface soil and then cut into the solid rock and carrying it away grain by grain finally cut even a mountain range in two. . . . In a few years they thus dig a deep depression or river bed across a level or gently sloping plain. . . . In the course of years these stream beds reach an astonishing depth, while their banks rise up majestically on either side. . . . When the mountain cliffs on either side have become progressively lowered in height, wide valleys are formed and in them fertile fields appear bordering the stream. At this stage, the mountain lies back from the stream on either margin of the valley. . . . This is because the stream wears away its banks, sometimes only one of them which is made of softer materials and at other times both banks. The material which it removes from its banks it deposits either in its bed or carries it off downstream to lay it down somewhere else. . . . It will eat into the softer portions of the bank and be deflected away from the harder. And so we see that the stream will assume a sinuous course, and now swinging from side to side will incise a new bed for itself, and abandon its former one. This process results in making the valley wider still. In this way whole mountains are destroyed by the action of water and their debris scattered far and wide.

The volume of water (measured in cubic feet) which passes a given point on the channel bank in one second is called discharge. The value of discharge for a given stream varies upstream or downstream from the given point because drainage basin area decreases or increases. The value of discharge at the given point also varies with rainfall; discharge increases directly as rainfall increases although the relationship is complicated by infiltration and evaporation.

As discharge increases, erosion, bed load, and suspended-sediment load increase although the amount of suspended-sediment increases more rapidly than the discharge during a flood (Fig. 10).

Surface water records for the streams of the central Coast Range vary in length of time of record (Table 5). The flow of the Siletz River has been monitored for the longest period, 56 years. Stream gaging of the Yaquina began in October 1972 with discharge recorded 1.1 mile west of Chitwood. Earlier records for the Yaquina are from a stream gage on Mill Creek, a third-order stream 3.5 miles southeast of Toledo with a drainage basin area of only 4.18 square miles. It is assumed that records for Mill Creek are not a valid representation for the much larger Yaquina.

Average discharge for the period of record for the four major streams varies from 445 cubic feet per second (Yaquina) to 1,592 cubic feet per second (Siletz; Table 5). Hydrographs in Appendix F illustrate the stream flow for the

Table 5. Discharge data for streams of the central Coast Range of Oregon

Stream	Period of Record to 1975 (years)	Av. Discharge for Period of Record (cfs)	Extremes during period of record				Hgt. of Max. Flood	Date of occurrence
			Max. (cfs)	Date of Occurrence	Min. (cfs)	Date of occurrence		
Siletz	56	1,592	34,600	11/22/09	48	multiple	31.6	11/20/21
Yaquina	3	445 (1974 only)	6,150	11/16/73	2.8	9/27/74	---	---
Luckiamute	41	940	32,900	12/22/64	0.65	8/13/66	34.5	12/22/64
Marys	35	477	13,600	12/22/64	0.60	8/23/67	20.9	1/15/74
Rickreall Creek	18	152	7,160	12/22/64	dry	multiple	8.8	12/22/64

water year 1973-74 (October 1973 to September 1974; most recent data available). The hydrographs for November, 1973 (Fig. 11 and Appendix G) are strongly peaked which indicates that the Coast Range streams respond quickly to increased rainfall and that runoff is rapid.

The volume of discharge of the Siletz clearly reflects both the maximum rainfall in the thesis area which occurs in the headwaters near Valsetz and the permeable character of the Siletz River Volcanics which most probably supplies greater base flow to the Siletz than the impermeable Tyee and younger sedimentary strata supply to the other streams. In addition, the slope of the flow-duration curve (Fig. 12) of the Siletz is less steep than the flow-duration curves of the other streams in the thesis area. Steep flow-duration curves indicate a large amount of direct runoff, whereas, less steep flow-duration curves result from storage at the surface or as ground water which tends to equalize discharge. Therefore, the discharge of the Siletz is greater and more equally distributed over the year than in the other streams of the central Coast Range.

Except for a brief two-year record (1972-74) on the Yaquina, the amount of sediment carried by the central Coast Range streams has not been measured. Therefore, it is not possible to relate here the amount of discharge to the amount of suspended sediment in central Coast Range streams.

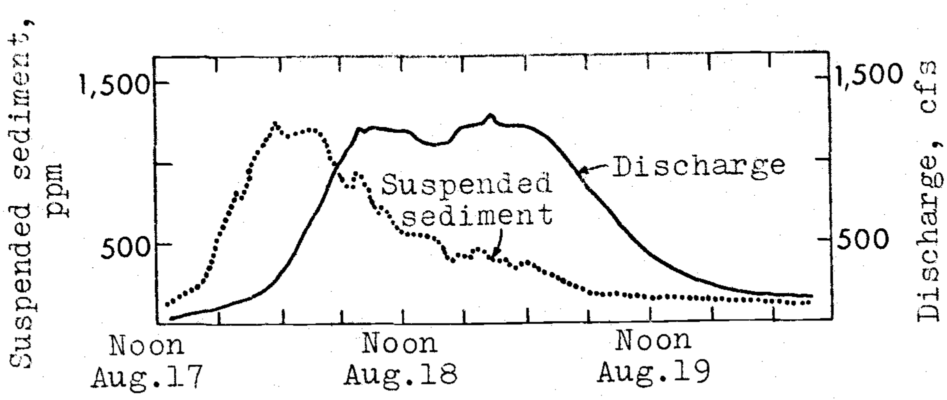


Figure 10. Suspended-sediment load and flood discharge of Enoree River, South Carolina, August 17-19, 1939 (from Morisawa, 1968, p. 63).

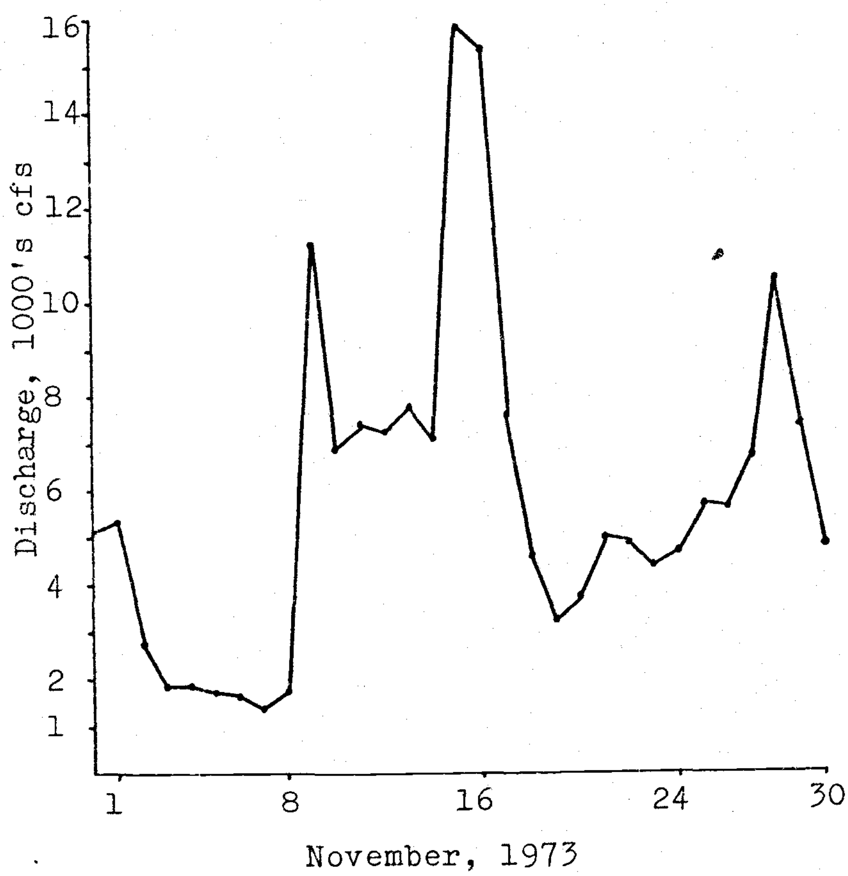


Figure 11. Hydrograph of Siletz River, central Coast Range of Oregon, during November, 1973.

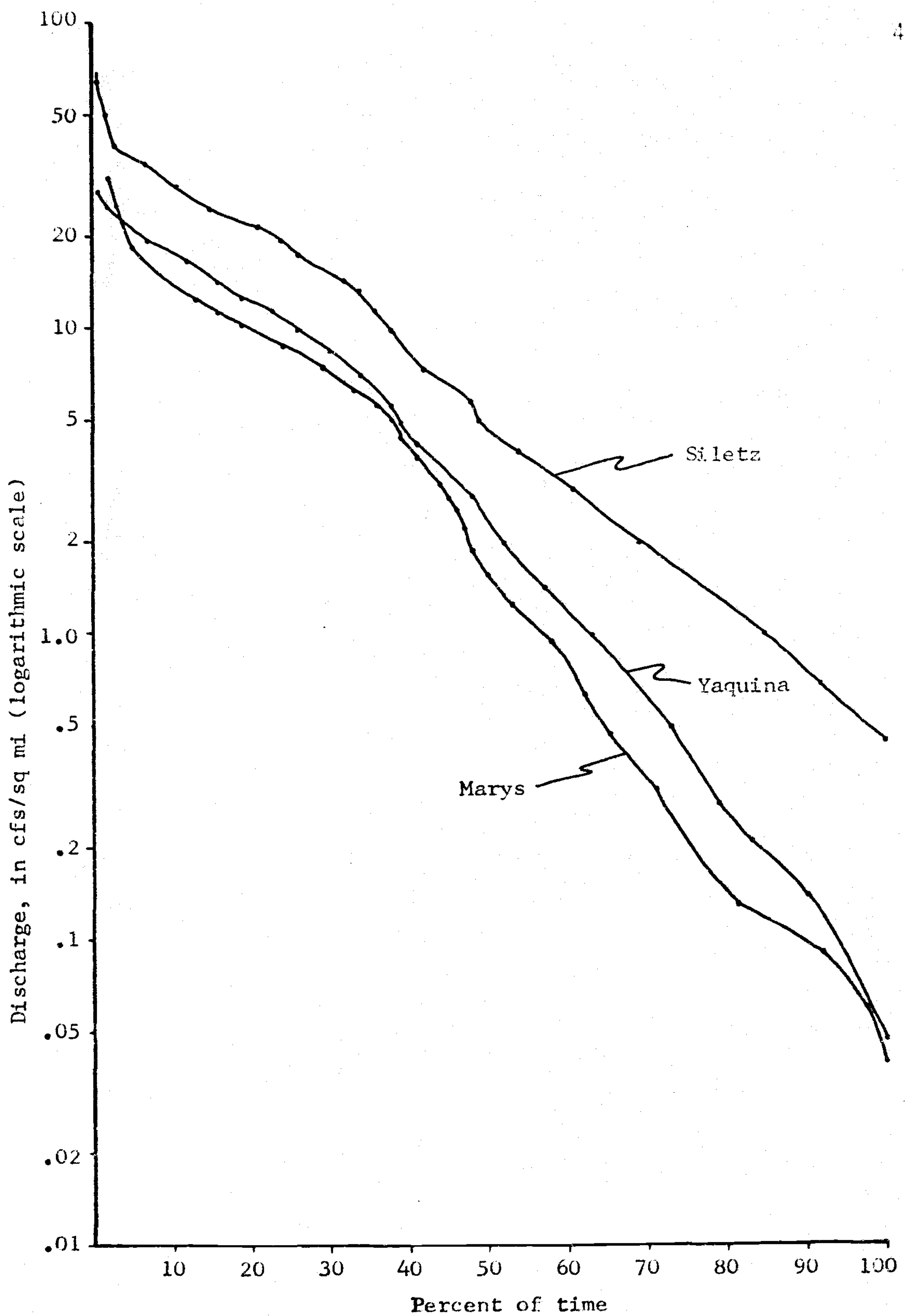


Figure 12. Flow-duration curves for streams of the central Coast Range of Oregon for the water year 1973-1974.

DESCRIPTIVE GEOMORPHOLOGY

Siletz River

The Siletz River originates on Fanno Ridge northeast of Valsetz, Oregon and in the highlands in the vicinity of Laurel Mountain (Valsetz quadrangle) where elevations exceed 3500 feet amsl. The poorly drained uplands northwest of Laurel Mountain and on Fanno Ridge which have less relief than surrounding summits may be some of the "peneplain remnants" mentioned by Diller (1896) although the gentle slopes are probably due to the gently dipping upper surface of the concordant Fanno Ridge sill. From these uplands, the streams rapidly cascade down into the deep gorges for which the Siletz River is famous.

Channel Pattern

Meanders in the Siletz River occur in both the hard, resistant Siletz River Volcanics and the soft, less permeable Tyee, Nestucca, and Yaquina Formations, suggesting that this pattern was superimposed upon the rocks now at the surface. The meanders are deeply entrenched in the Siletz River Volcanics especially along the South Fork below Valsetz dam, in the lower reaches of Gravel Creek (Fig. 13), and along the main channel to the confluence with Wildcat Creek.

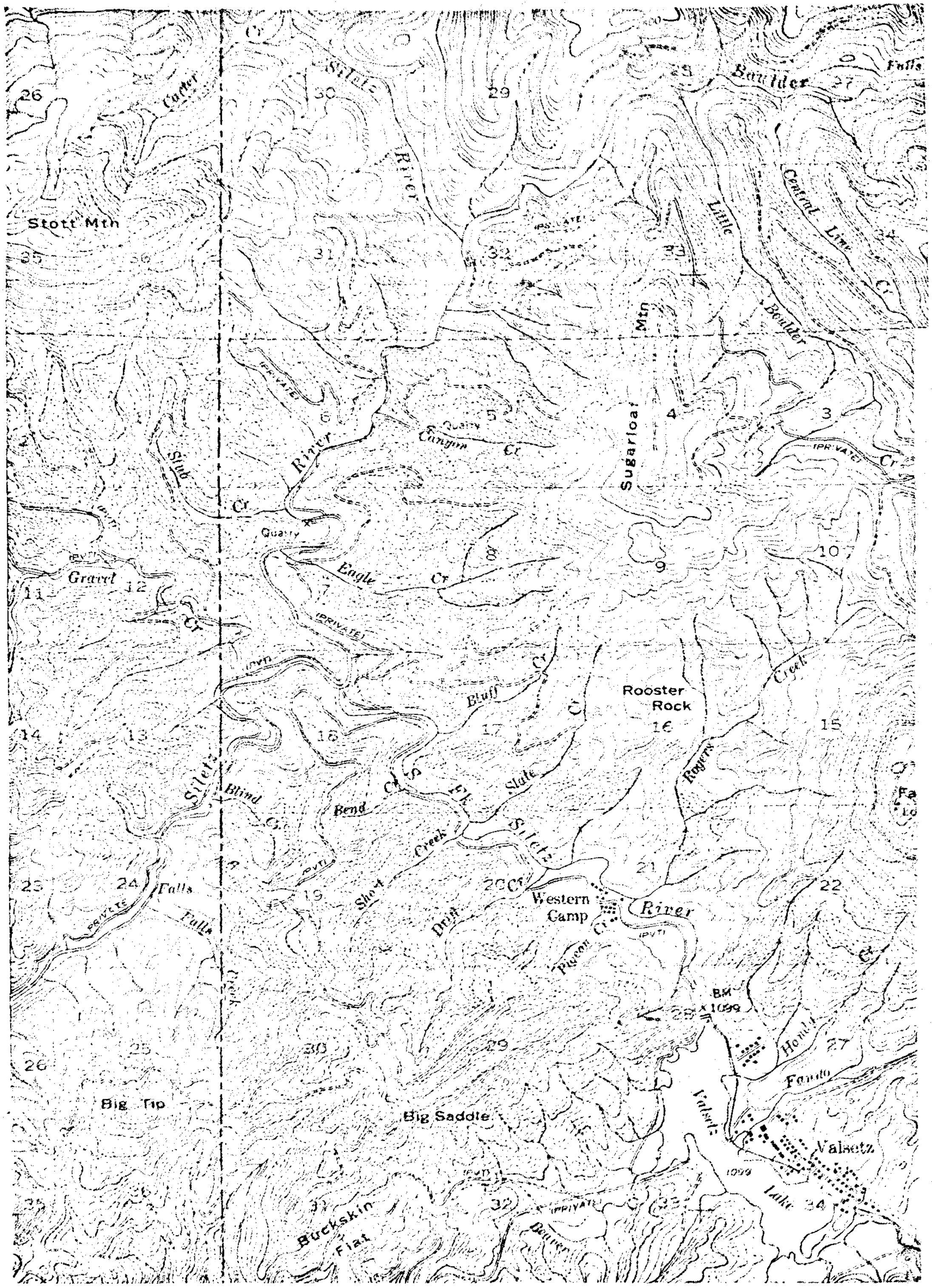


Figure 13. Topographic map of part of Siletz River drainage northwest of Valsetz (U. S. Geol. Survey Valsetz quadrangle, scale 1:62,500).

Drainage Pattern

The drainage pattern is generally dendritic with a radial pattern of consequent streams off Sugarloaf Mountain (Fig. 13) and Euchre Mountain and Little Euchre Mountain (Fig. 14).

Stream Piracy

Stream piracy occurs when headward erosion of one stream intersects another stream and diverts the water from the latter stream to the former (Press and Siever, 1974, p. 916). A clear example of stream piracy in the Siletz drainage involves Big Rock Creek and Sunshine Creek. South-flowing Big Rock Creek, through headward erosion, has apparently captured the headwaters of west-flowing Sunshine Creek immediately below Young Creek (Fig. 15). The wind gap near the center of section 17, T. 9 S., R. 8 W. and the width of the valley above Young Creek suggest that this reach of the stream formerly flowed through the wind gap to Camp Russell and to the main stream of the Siletz. The valley of Big Rock Creek below Young Creek, in contrast, is very narrow suggestive of the youth of the valley. Baldwin (1964a) estimated that Big Rock Creek has lowered the valley of the captured stream by more than 100 feet since capture.

Geologic Controls

Lithology appears to have only a small effect on the drainage pattern of the fifth-order antecedent Siletz River.

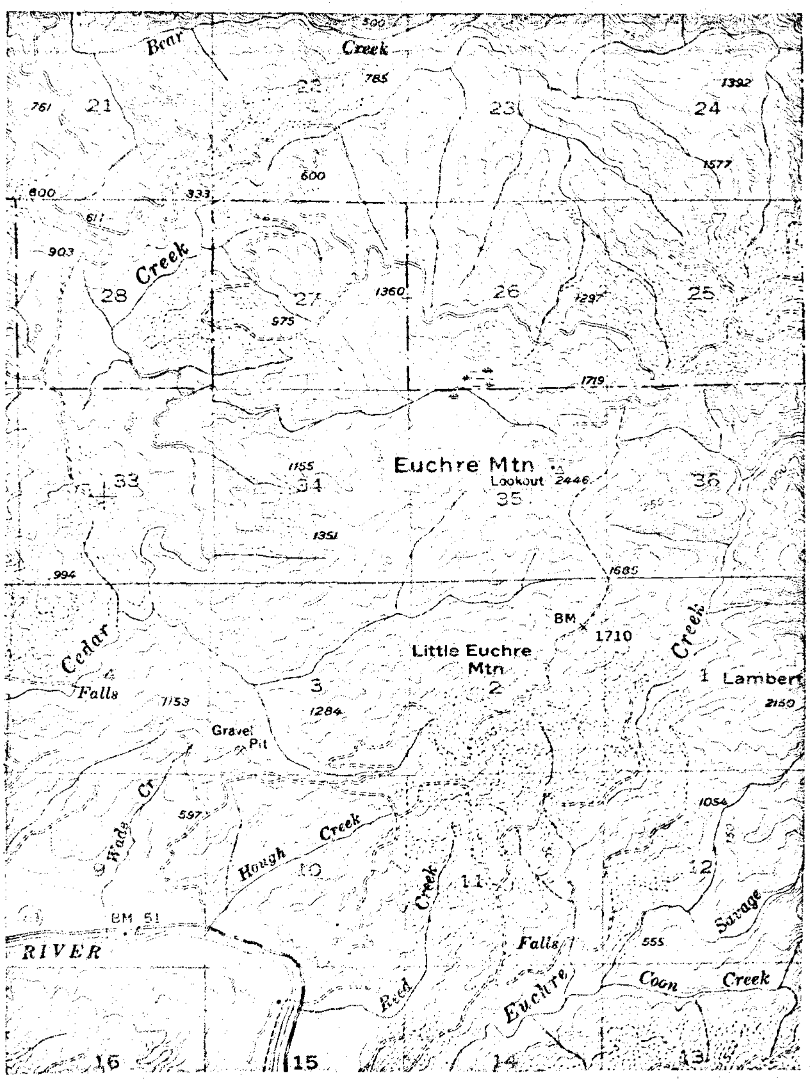


Figure 14. Topographic map of part of Siletz River drainage west of Valsetz (U. S. Geol. Survey Euchre Mountain quadrangle, scale 1:62,500).

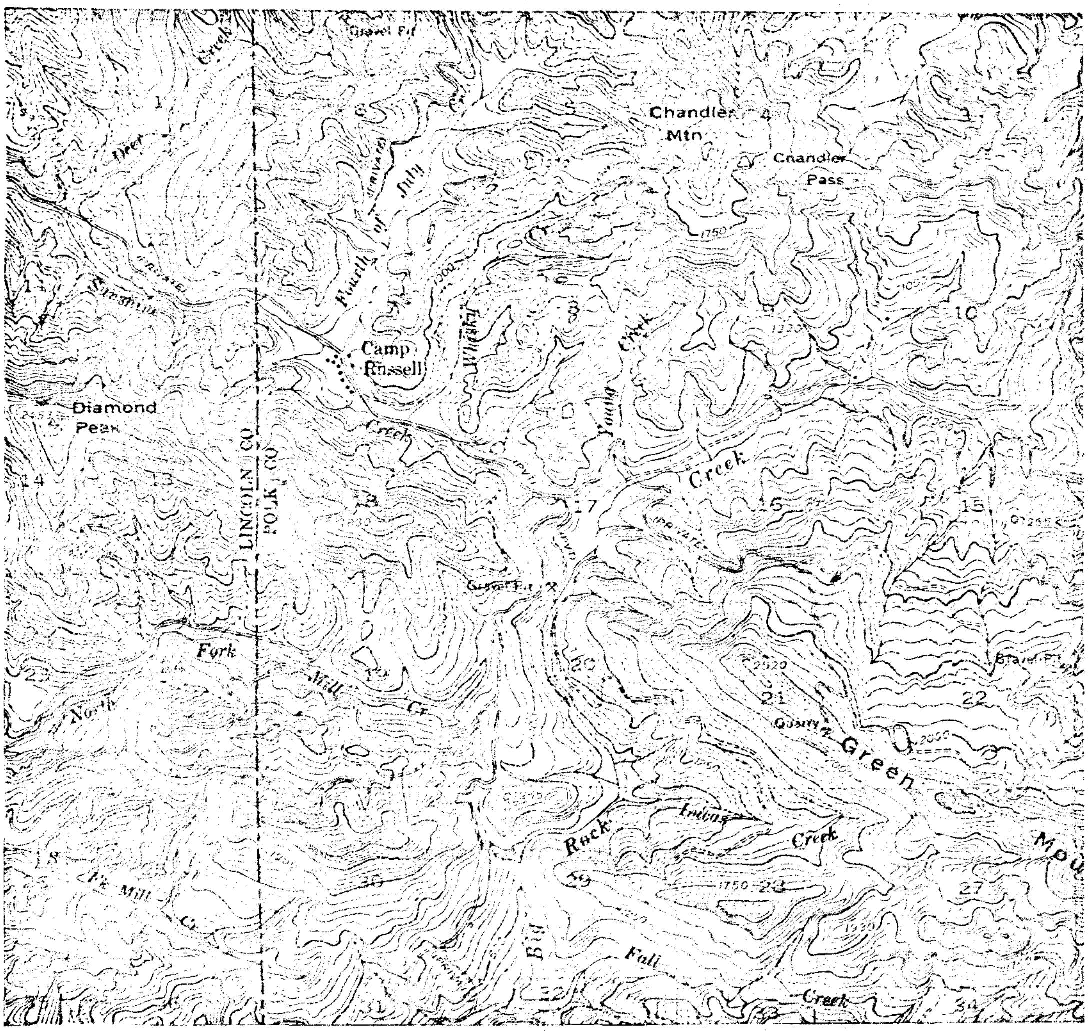


Figure 15. South-flowing Big Rock Creek apparently pirated the headwaters of west-flowing Sunshine Creek, Siletz River drainage southwest of Valsetz (U. S. Geol. Survey Valsetz quadrangle, scale 1:62,500).

Locally, however, a rapids or falls is produced in the channel where the stream drops over the edge of a sill (Baldwin, 1964a). The Fanno Ridge sill northeast of Valsetz has a well-developed joint system (Baldwin, 1964a). The effect of joints on streams appears to be quite pronounced in first-order tributaries of the North Fork of the Siletz River and of Gravel Creek, Elk Creek, and Sunshine Creek for example. Sharp bends of nearly 90° are produced by intersection of the stream course with a joint. A particularly strong joint or small fault trending northwest-southeast in the upper reaches of Warnick Creek produces an occurrence which is rare in nature; two first-order tributaries flow into Warnick Creek at the same location from opposite directions (Fig. 16). The joint control of the patterns of the first-order streams suggests that these streams are consequent.

Valley dimensions also appear to be related to lithology. In the volcanics and intrusives, local relief is much greater, the valleys are narrow, and the entrenched meanders are deeply incised. Over sedimentary rocks, the relief is not as high, the valleys are broader, and the incision of meanders is not as deep, probably because the maximum elevations also are less. Locally, upturned edges of sills and dikes produce constrictions of the channel as at Valsetz dam (Figs. 13 and 17; Baldwin, 1964a).

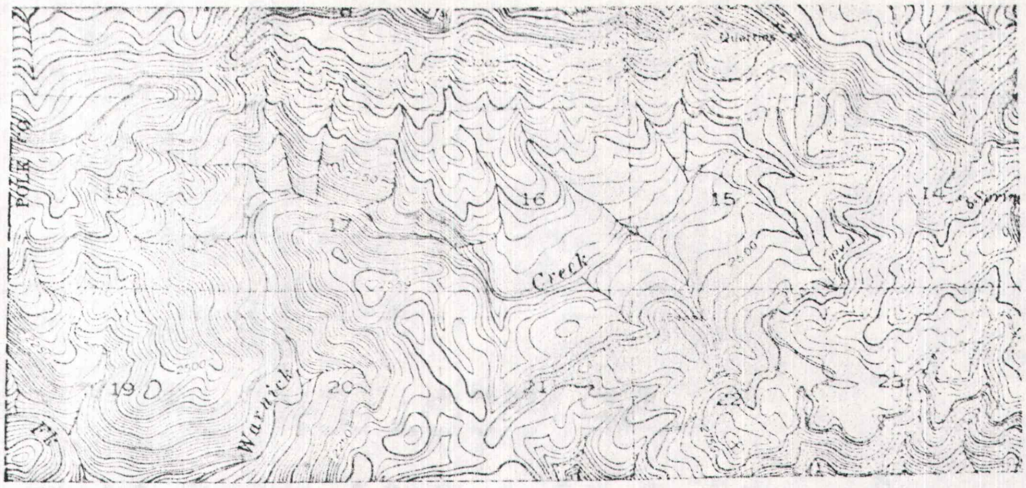


Figure 16. Warnick Creek in headwaters of Siletz River. Note straightness of first-order streams trending northwest-southeast in sections 15 and 16 (U. S. Geol. Survey Valsetz quadrangle. scale 1:62,500).

Figure 17. Constriction of channel of the South Fork of the Siletz River at Valsetz dam produced by the upturned edge of a basalt sill. River flows from left to right. Note entrenched meanders of the South Fork of the Siletz downstream from the constriction.

Luckiamute River

The Luckiamute drainage consists of the Little Luckiamute River and Luckiamute River (called Luckiamute-principal in the quantitative section above) and Soap Creek (called Luckiamute-secondary in the quantitative section above). The headwaters of the Little Luckiamute River flow off the dip slope of the Fanno Ridge sill and tumble over several smaller sills west of Black Rock, Oregon. The wide valley at Black Rock is carved into sedimentary strata between sills (Baldwin, 1964a) (Fig. 18). Between Black Rock and Falls City the valley, once again, is deeply incised through a gently eastward dipping sill. Several named tributaries of the Little Luckiamute west of Falls City including Dutch Creek, Berry Creek, and Teal Creek similarly flow through narrow canyons cut into sills.

The headwaters of the Luckiamute River flow off Monmouth Peak (Bald Mountain) and the slopes south of the Valsetz valley. These streams have recently completed piracy and further piracy is imminent.

Drainage Pattern and Stream Piracy

The radial drainage pattern around Monmouth Peak (Bald Mountain) is one result of piracy in the headwaters. The divide between the South Fork of the Siletz River and the Luckiamute River (Point D on Fig. 19) is very low and has an interesting history. According to Baldwin (1964a) the wind gap at the head of the Siletz River at the east end of

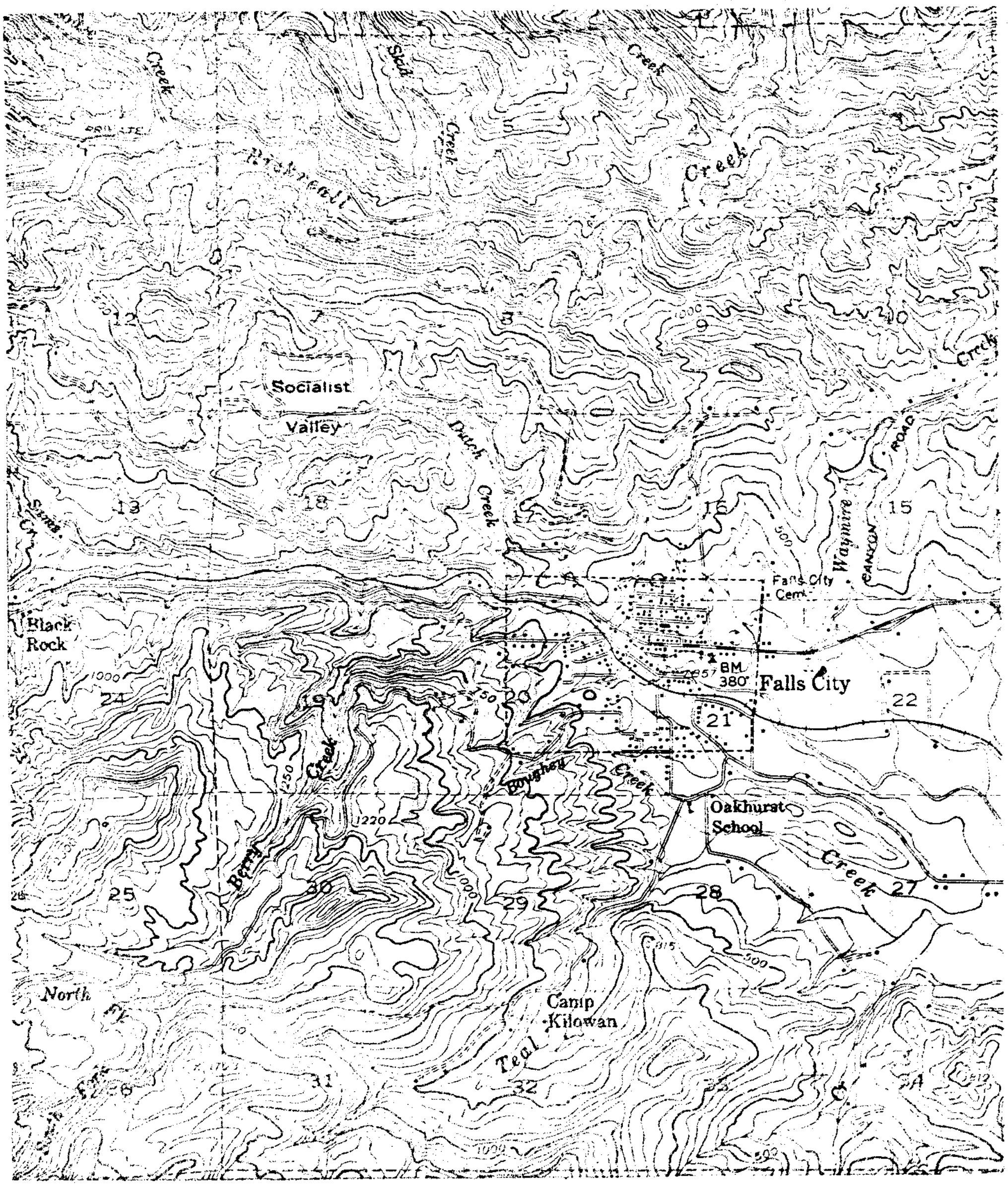


Figure 18. Topography west of Falls City. Note narrow valleys and right-angle bends of first-order streams (U. S. Geol. Survey Dallas quadrangle, scale 1:62,500).

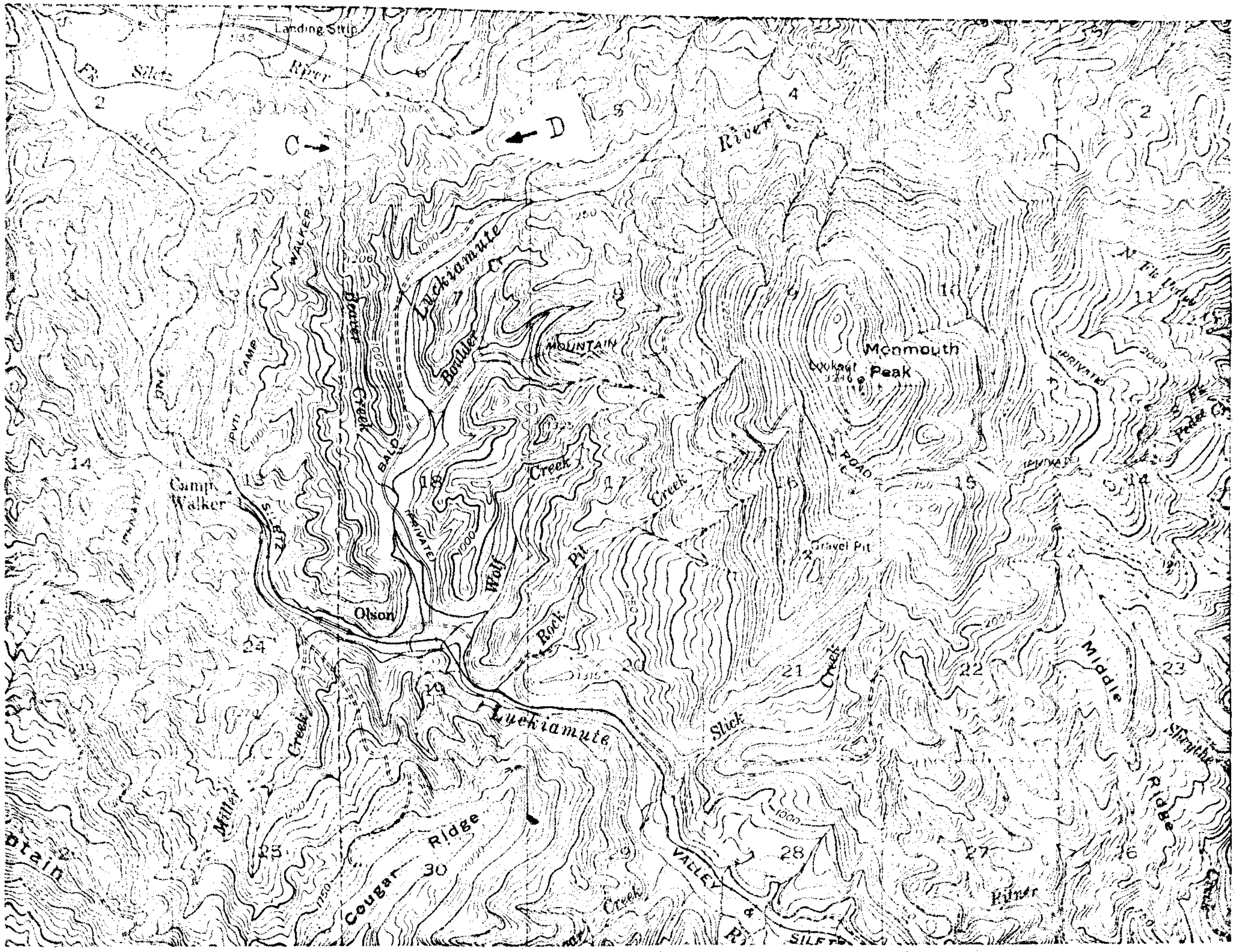


Figure 19. Radial drainage off Monmouth Peak (Bald Mountain), joint control of first-order streams, and low divides (U. S. Geol. Survey, Valsetz quadrangle, scale 1:62,500). Points C and D are referred to in the text.

Valsetz valley (Point D on Fig. 19) was formerly occupied by the present headwaters of the Luckiamute River which were pirated from the Siletz sometime in the geologic past. This paper proposes that formerly the Luckiamute and Siletz were a single stream which drained westward and that the wind gap at the east end of Valsetz valley was produced by tectonic uplift which occurred more rapidly than the ancient stream could cut down, thereby severing the Luckiamute-Siletz system to produce the present paired streams. This idea is discussed further in the following section on geomorphic history. The present upper reach of the Luckiamute may have been a tributary of the ancient Luckiamute-Siletz system.

Geomorphic evidence for an ancient single river system includes the barbed stream junctions of Wolf Creek, Rock Pit Creek, Slick Creek, Cougar Creek, and several unnamed tributaries (Fig. 19) of the Luckiamute River. The barbed pattern is indicative that the direction of flow of the main stream was previously opposite the present direction. The width of the valley of the headwaters of the Luckiamute and the width of the valley of headwaters of the South Fork of the Siletz suggest that the two streams may previously have been one.

Channel Pattern

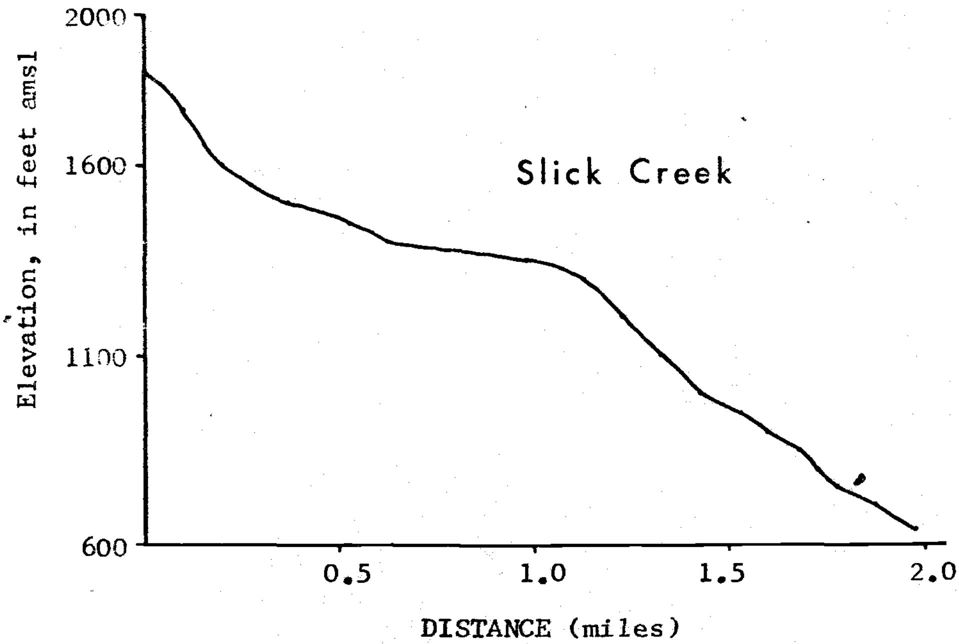
A striking feature which is not at first apparent is the two orders of meandering. The most quickly recognized order of meandering is the smaller of the two which apparently represents adjustment of the stream to present discharge. The larger order of meandering which is best preserved in the large meanders of the Yaquina River at Toledo and more subtly manifested in the valley form of the Luckiamute northwest of Kings Valley represents a much larger discharge, possibly produced by the ancient single-river system prior to severing.

Stream piracy seems imminent due to headward erosion of tributaries of the Luckiamute north of Camp Walker. The very low divide of less than one contour interval at point C in Figure 19 appears certain to be breeched in the near future (geologically).

Geologic Controls

Geologic controls is apparent in both consequent and antecedent streams in the Luckiamute basin. Lithology is closely related to valley width. Where streams flow over basalt sills, the valleys are narrow and steep-sided; where sedimentary strata underlie the bed, the valleys are broader. According to Baldwin (1964a), a dike causes the constriction of the Luckiamute valley southwest of Monmouth Peak (Bald Mountain) (Fig. 19). The gradient of Slick Creek on the south side of Monmouth Peak changes rapidly as it flows alternately over basalt sills and sedimentary strata. The longitudinal profile of the stream (Fig. 20) illustrates the strong lithologic control.

Jointing in the sills is most evident in the consequent



Vertical exaggeration = 10.56X

Figure 20. Longitudinal profile of Slick Creek, Luckiamute drainage.

streams. The courses of the effected streams suggest that there is a set of strong northwest-southeast trending joints and a set of weaker or not as well developed joints trending northeast-southwest. Some examples of streams whose courses apparently reflect joint control are: upper reaches of Black Rock Creek, north and south forks of Teal Creek, and many unnamed tributaries, some of which are illustrated in figures 18 and 21.

As the Luckiamute and Little Luckiamute flow eastward out of the terrain underlain by basalt, the valleys widen significantly and the hills that form the valley sides are lower and more rounded in profile. Water gaps in the foothills area are cut through Oligocene intrusives and have provided natural routes for highways and rail lines. Some examples of the wind gaps occur on the north edge of the community of Kings Valley, through Grant Hill southwest of Pedee, and through a ridge between Pedee and McTimmonds Valley. The narrow valley at Hoskins (Fig. 22) is carved into one of these Oligocene intrusives in the Kings Valley Siltstones.

Price Creek, Woods Creek, and Plunkett Creek appear to be consequent streams flowing off the dip slope of the Siletz River Volcanics which form the 2,000-ft high ridge between the foothills west of Corvallis and Kings Valley.

Pleistocene events, especially in the Willamette Valley, have obscured earlier geomorphic features. Pleistocene geomorphology in the Willamette Valley presents a field of in-

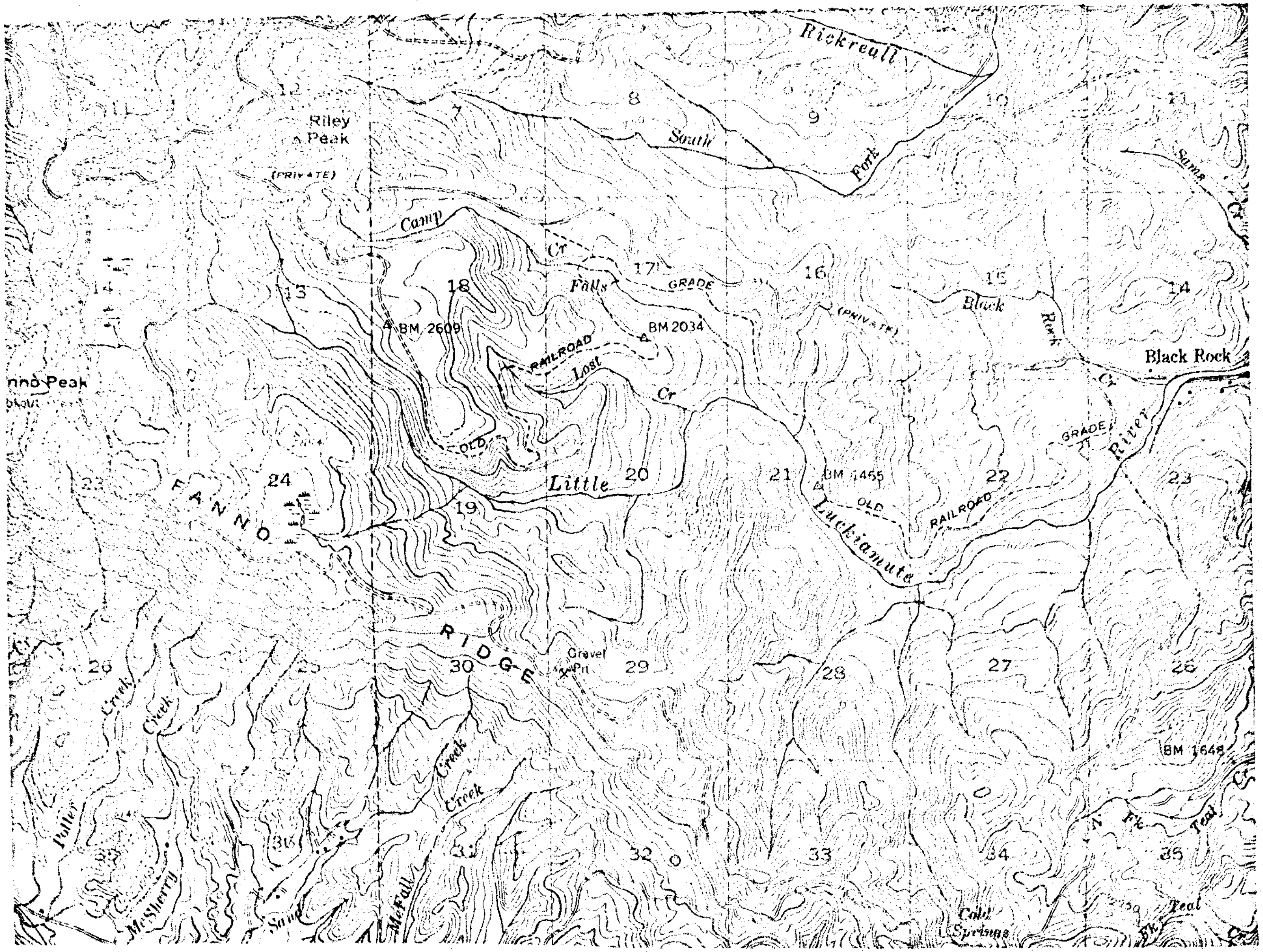


Figure 21. Streams flowing down dip slope of Fanno Ridge sill in Luckiamute drainage exhibit sharp bends due to jointing and falls due to changes in lithology (U. S. Geol. Survey, Valsetz quadrangle, scale 1:62,500).

Figure 22. Water gap at Hoskins, Oregon.

vestigation for several dissertations and will not be discussed in detail here.

It is generally accepted that the Willamette Valley was inundated during the Pleistocene (Allison, 1936; Baldwin, 1964b), and the lower reaches of the eastward-flowing streams in this paper meander over the flat surfaces produced by erosion and deposition during that inundation. Vokes and others (1954) interpreted the deeply weathered gravels in the saddles between Coffin Butte and the neighboring peaks as remnants of sediment that filled the Willamette Valley to a depth of several hundred feet.

The Pleistocene temporary base level apparently also accounts for the wide valleys and meandering of the streams on the west slopes of the Willamette Valley.

Yaquina River

The Yaquina River basin is roughly rectangular in shape with the long dimension oriented east-west.

The headwaters of the Yaquina and Marys Rivers flow parallel to each other southward away from Little Grass Mountain with a low narrow ridge (maximum 1250 feet above sea level) between them (Fig. 23). At Summit, Oregon, the Yaquina turns to the west, and the Marys turns to the east. The divide between the two streams is much lower than the high Fanno Ridge which separates the Siletz from the Luckiamute. Marys Peak with an elevation of 4,097 feet is the highest peak in the basins of the Yaquina and Marys Rivers

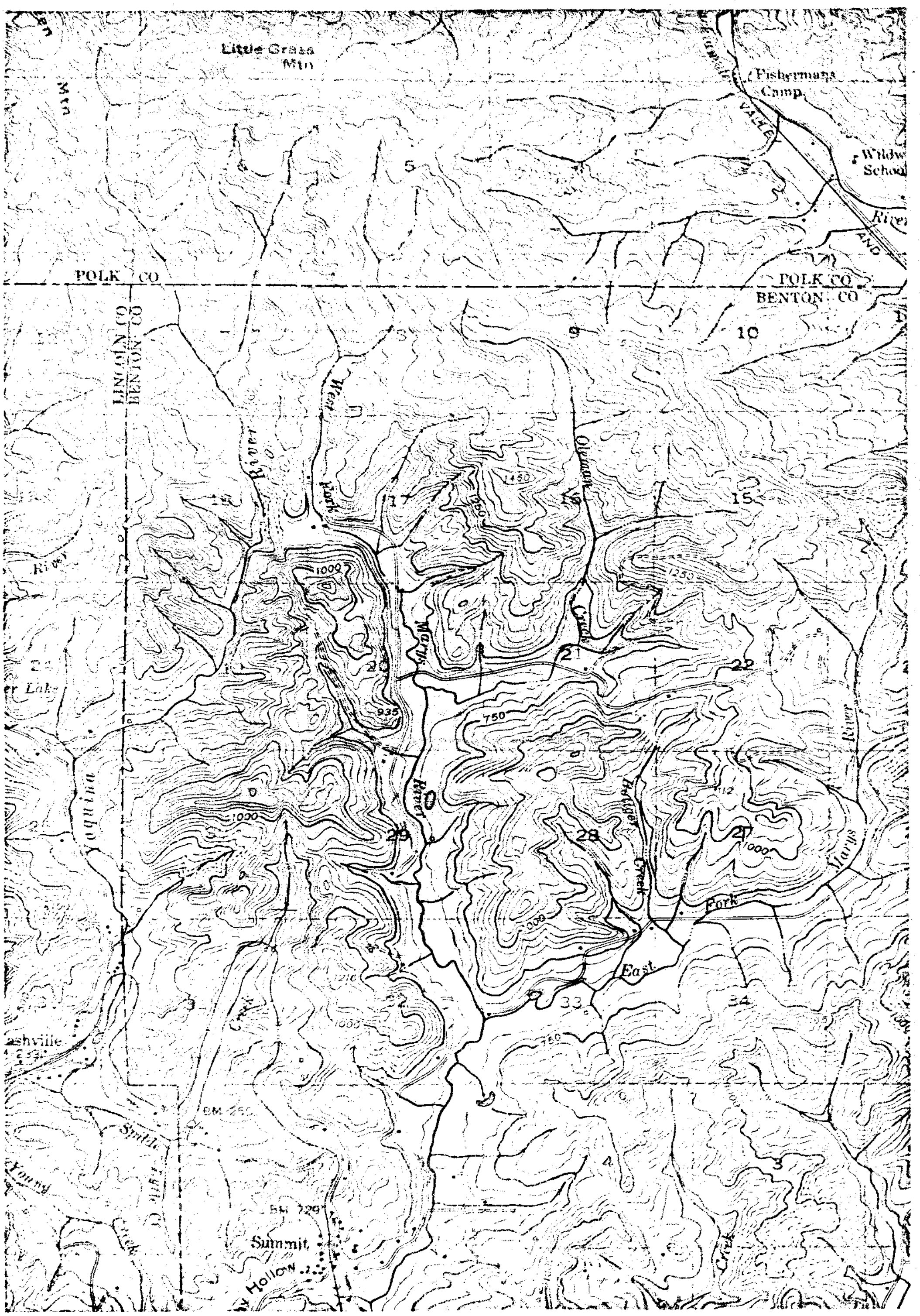


Figure 23. Headwaters of Yaquina and Marys Rivers. Note parallel courses of streams south of Little Grass Mountain, the wind gap at Summit, and the sharp bends in first-order streams due to jointing (U. S. Geol. Survey Marys Peak quadrangle, scale 1:62,500).

as well as in the Oregon Coast Range. In general, summit elevations in the Yaquina basin are considerably lower, averaging 1500 feet.

Drainage Pattern

The general pattern of the Yaquina system is dendritic. Consequent streams flowing off an unnamed peak approximately 2 miles northwest of Nashville (Fig. 24) form a radial drainage pattern.

Geologic Controls

Most of the Yaquina River flows over sedimentary rocks. East of Toledo, the Tyee Formation is the most widespread formation. The Tyee is much less resistant to erosion than the Siletz River Volcanics which are predominant in the Siletz River basin with the result that summits are lower and the narrow valleys have less relief. Similarly weak rocks (Oligocene to Miocene sedimentary strata) occur west of Toledo.

Although Baldwin (1955) did not discuss jointing in the Tyee, he noted the general east-west trend of Oligocene and Miocene dikes in the Marys Peak quadrangle which might reflect an east-west system of joints in the Tyee. Several unnamed first-order tributaries of the Yaquina River in the Marys Peak quadrangle appear to be influenced by joints (Figs. 23 and 25).

Figure 24. Radial drainage off an unnamed peak northwest of Nashville, Oregon, Yaquina drainage (U. S. Geol. Survey Marys Peak quadrangle, scale 1:62,500).

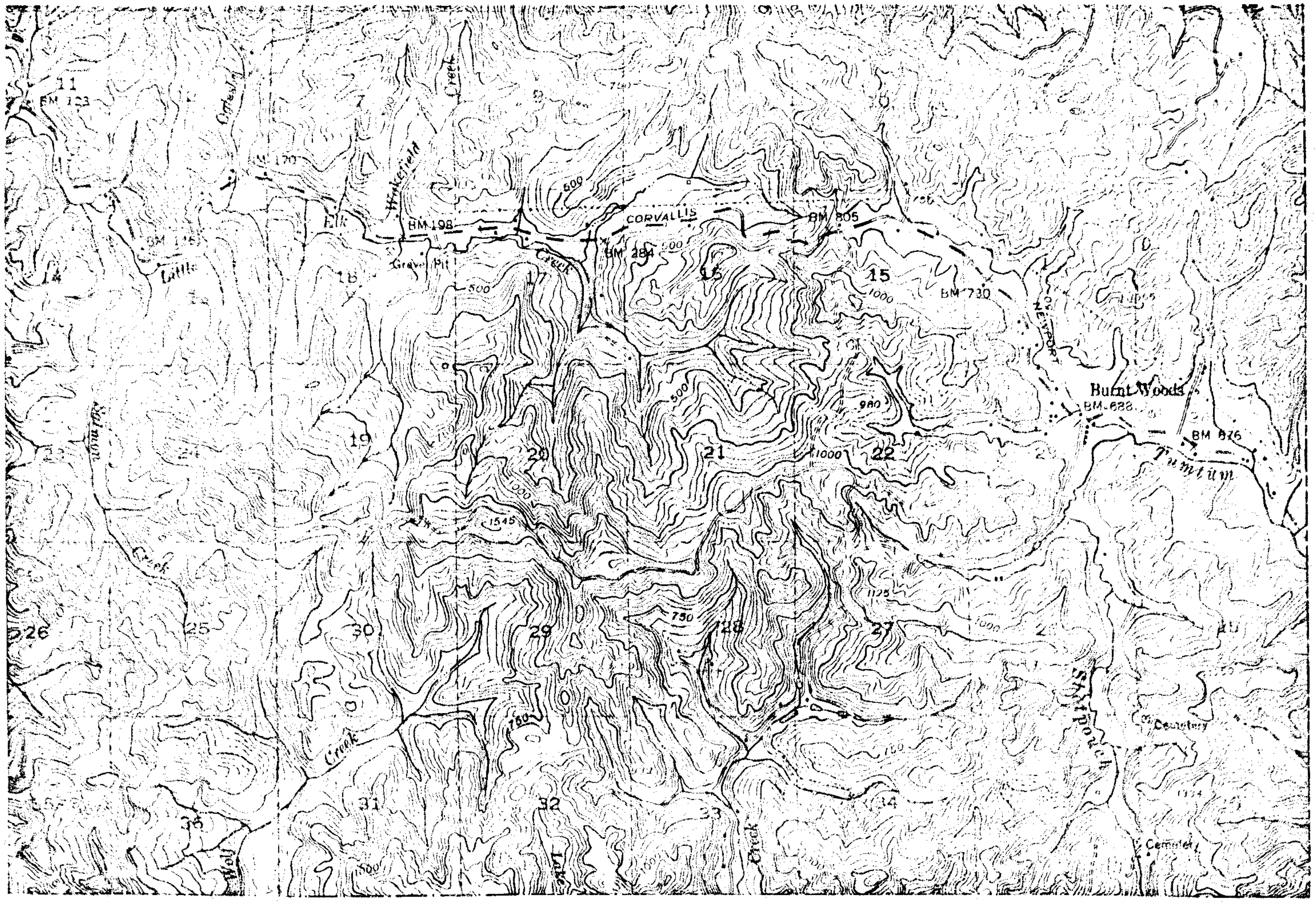


Figure 25. Sharp bends in many first-order streams in the Yaquina system suggest joint control. Note imminent stream piracy in NW¼ sec. 15. (U. S. Geol. Survey Marys Peak quadrangle, scale 1:62,500).

Channel Pattern

The most striking feature of the Yaquina River is its meanders. As mentioned above in the section on the Luckiamute River, at least two orders of meandering are present. A large-scale meandering which is locally deeply incised in the Tyee Formation apparently reflects an older, larger discharge (Fig. 26). A smaller meandering is particularly well-developed where tributaries cross the broad valleys of major streams and where inundation during higher stands of sea level in the Pleistocene has imprinted a very low gradient (Fig. 27).

Entrenched meanders are well-developed along many reaches of the Yaquina especially downstream from Nortons (NW NW sec. 32, T. 10 S., R. 8 W.) and along Elk Creek downstream from Harlan (SW$\frac{1}{4}$ sec. 8, T. 12 S., R. 8 W.). The meanders are related neither to faults nor to bedding and appear to be independent of the bedrock (Fig. 28).

The amplitude of the large-scale meanders increases generally toward the mouth although meanders of smaller amplitude are not uncommon. Amplitudes of three-fourths of a mile near Eddyville increase to 2$\frac{1}{4}$ miles at Toledo whereas radii of curvature increase from 0.2 mile to 0.3 mile.

The large-scale meanders are deeply incised, and cut-offs are highly unlikely under present conditions. Sometime since entrenchment of the meanders, however, a successful cut-off created the abandoned meander which encircles Boone Island, southwest of Toledo (Fig. 29).

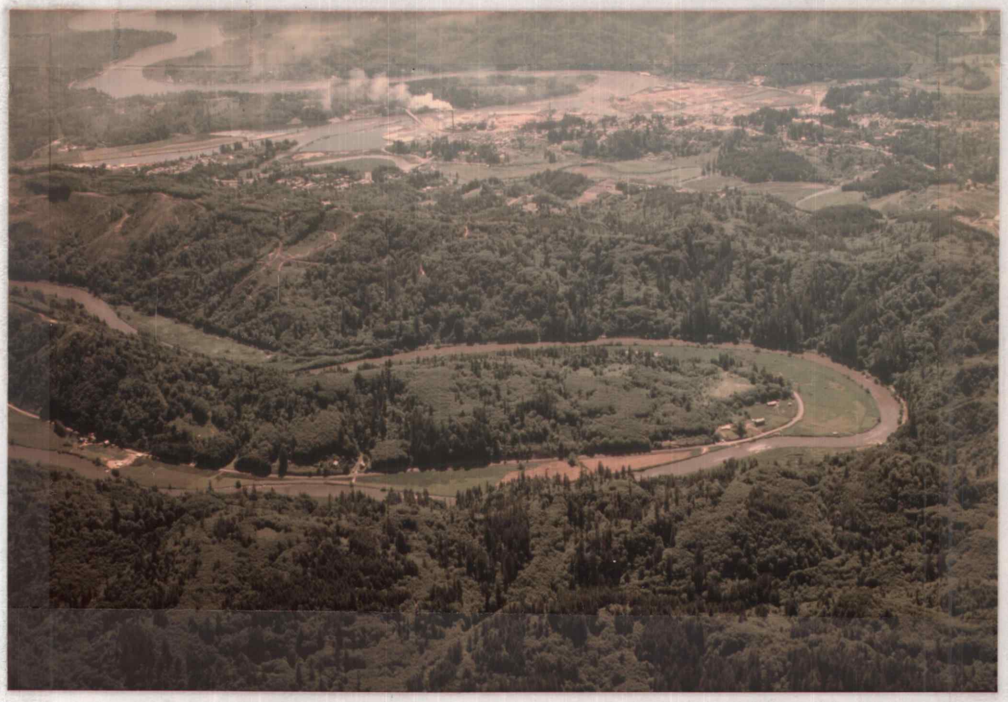


Figure 26. Oblique aerial photograph of large-scale meanders of the Yaquina River near Toledo, Oregon, looking west-southwest. Width of area in foreground of photo is approximately $2\frac{1}{4}$ miles.

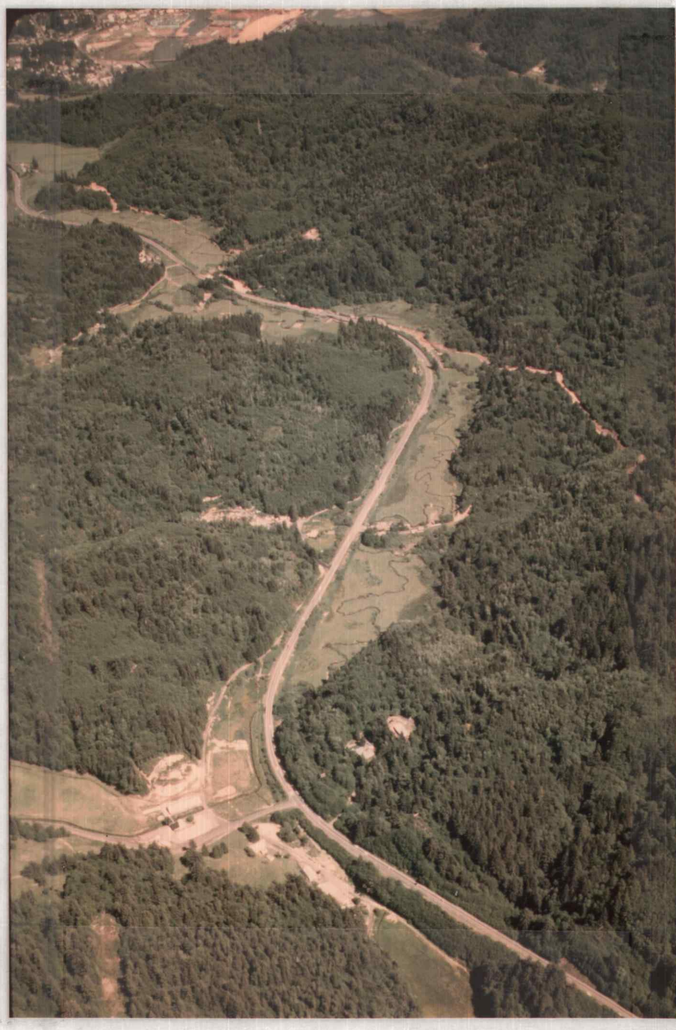


Figure 27. Oblique aerial photograph of smaller meanders in Beaver Creek northwest of Toledo, Oregon, adjusted to present discharge. Stream flows from bottom toward top of photo. Highway in photo is U.S. 20. City of Toledo in upper left corner.

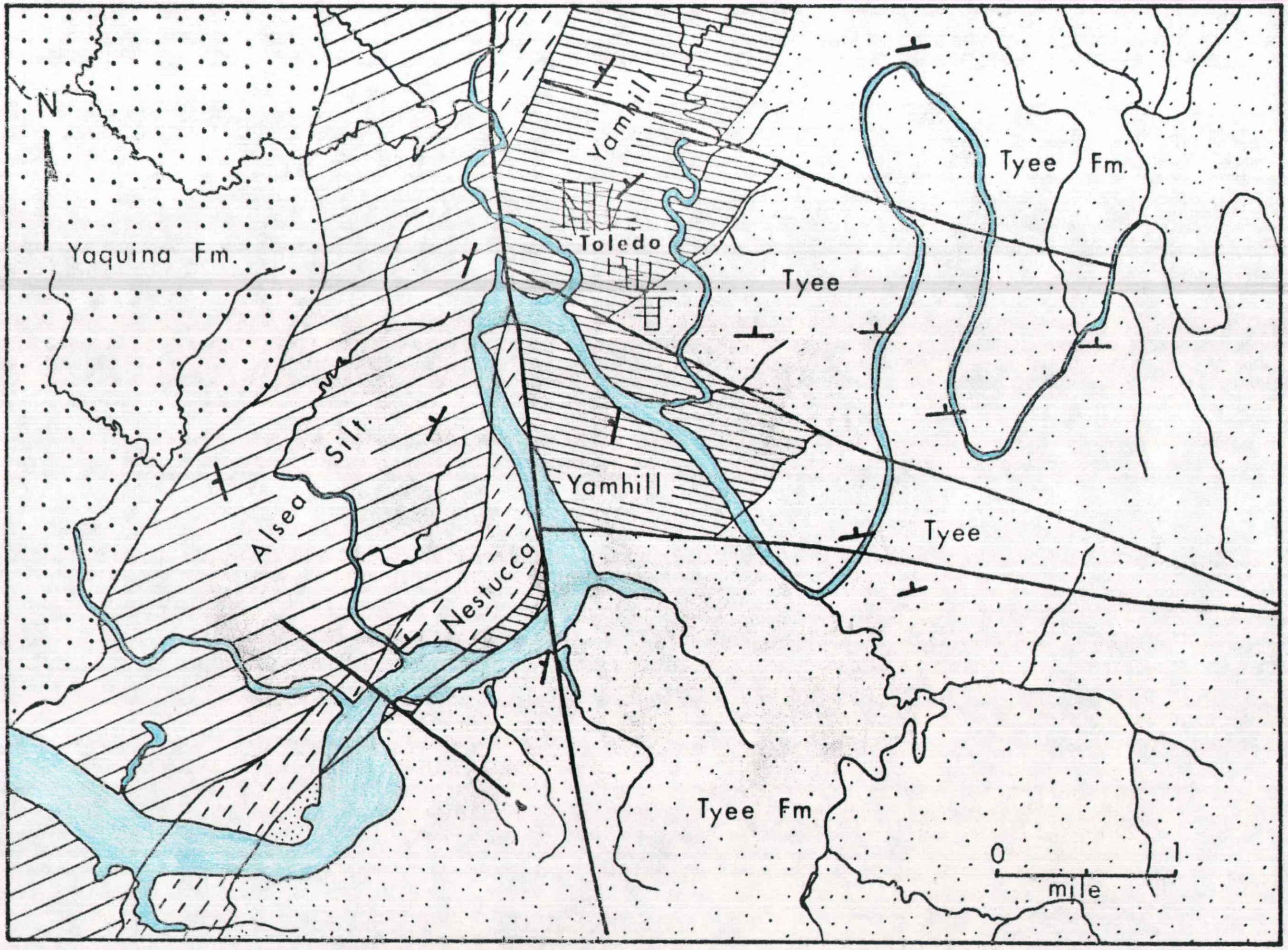


Figure 28. Generalized geologic map of Toledo, Oregon, area illustrating the lack of geologic control on the large-scale meanders of the Yaquina River (from Snavely and others, 1972).

Figure 29. Boone Island, west of Toledo, Oregon, was created by meander cut-off after the meanders were entrenched.

Stream Piracy

Stream piracy through headward erosion of Little Elk Creek seems imminent. The gradient of Little Elk Creek in its headwaters is much steeper (800 ft per mile) than the gradient of Tumtum River (less than 200 ft per mile) which is separated from Little Elk Creek by a low divide of 30 feet or less (Fig. 25). It appears that the divide will be breeched in the near future (geologically) and the headwaters of Tumtum River will be pirated from the Marys drainage. After initial piracy, the steep gradient of Little Elk Creek could be extended easily through the erodable alluvium that floors the Tumtum valley, and more of the Tumtum drainage could be diverted westward. The elevation of the valley of Little Elk Creek one mile west of the divide is less than 300 feet whereas the elevation of Blodgett near the mouth of Tumtum River is nearly 600 feet. With an elevation difference of this magnitude, a large part of the Tumtum River conceivably could be pirated to the west.

Marys River

Headwater streams of Marys River drain the south slope of Little Grass Mountain and the northwest slope of Marys Peak. They cascade precipitously from elevations of 2,000 to 3,000 feet down to 750 feet where stream gradients decrease and meandering begins.

Channel Pattern

The character of meandering of Marys Peak upstream from Philomath is different from the character of meandering downstream from Philomath. In the reach from Philomath to Blodgett the meanders are bold, large, and entrenched. In contrast, the radius of curvature of the meanders downstream from Philomath is much smaller. Small meanders also appear to be a fairly recent readjustment of the stream west of Blodgett where the sinuous shape of the valley suggests that earlier meanders had a radius of curvature of about one-half mile. Small meanders are also well-developed in Tumtum River.

Greasy Creek which is a major tributary that drains the east side of Marys Peak has carved a fairly deep valley in Tyee Formation between Siletz River Volcanics on the west and an Oligocene-Miocene intrusive on the east. Within this deep valley, the channel meanders in small loops with radius of curvature of 10 to 100 feet.

The divide at Summit (Fig. 30) between the Yaquina River and the Marys River is very low, less than one contour interval. This paper suggests that the Yaquina and Marys Rivers were once a single system which flowed west to the Oligocene sea and that subsequent uplift of the Coast Range outpaced the downcutting of the stream, thus severing the Yaquina-Marys system into a westward-flowing stream and an eastward-flowing stream.

Figure 30. Wind gap at Summit, Oregon, looking east through the gap toward Summit.

The basin shape of the Marys River is greatly modified by Muddy Creek. Muddy Creek and its tributaries are consequent on the east flank of the Coast Range. The divide between Muddy Creek and the Long Tom River, a yazoo of the Willamette, is very poorly defined. The Monroe topographic quadrangle depicts an intermittent channel connecting Muddy Creek and Long Tom River from three miles to five miles north of Monroe (Fig. 31). Although these streams may have been established before the Pleistocene, Pleistocene events, especially inundation of the Willamette Valley, apparently created a widespread local base level which deranged previously established drainages. Remnants of the inundation are manifested in the sizeable swamps such as the William L. Finley National Wildlife Refuge between Corvallis and Monroe and the extremely flat slope and the rich black soils along Bellfountain Road between Marys River and Evergreen Creek.

The course of Muddy Creek may have been initiated by rills produced in the old lake floor as the valley drained northward at the end of the Pleistocene.

Several wind gaps also may have been created by the drainage derangement produced during the Pleistocene. Examples of these wind gaps are: near a quarry on Gray Creek in sec. 32, T. 13 S., R. 5 W., south of Bailey Junction in sec. 29, T. 14 S., R. 5 W., and possibly one mile north of Monroe in NW NW sec. 28, T. 14 S., R. 5 W. and one mile northwest of Bellfountain in NE$\frac{1}{4}$ sec. 7, T. 14 S., R.

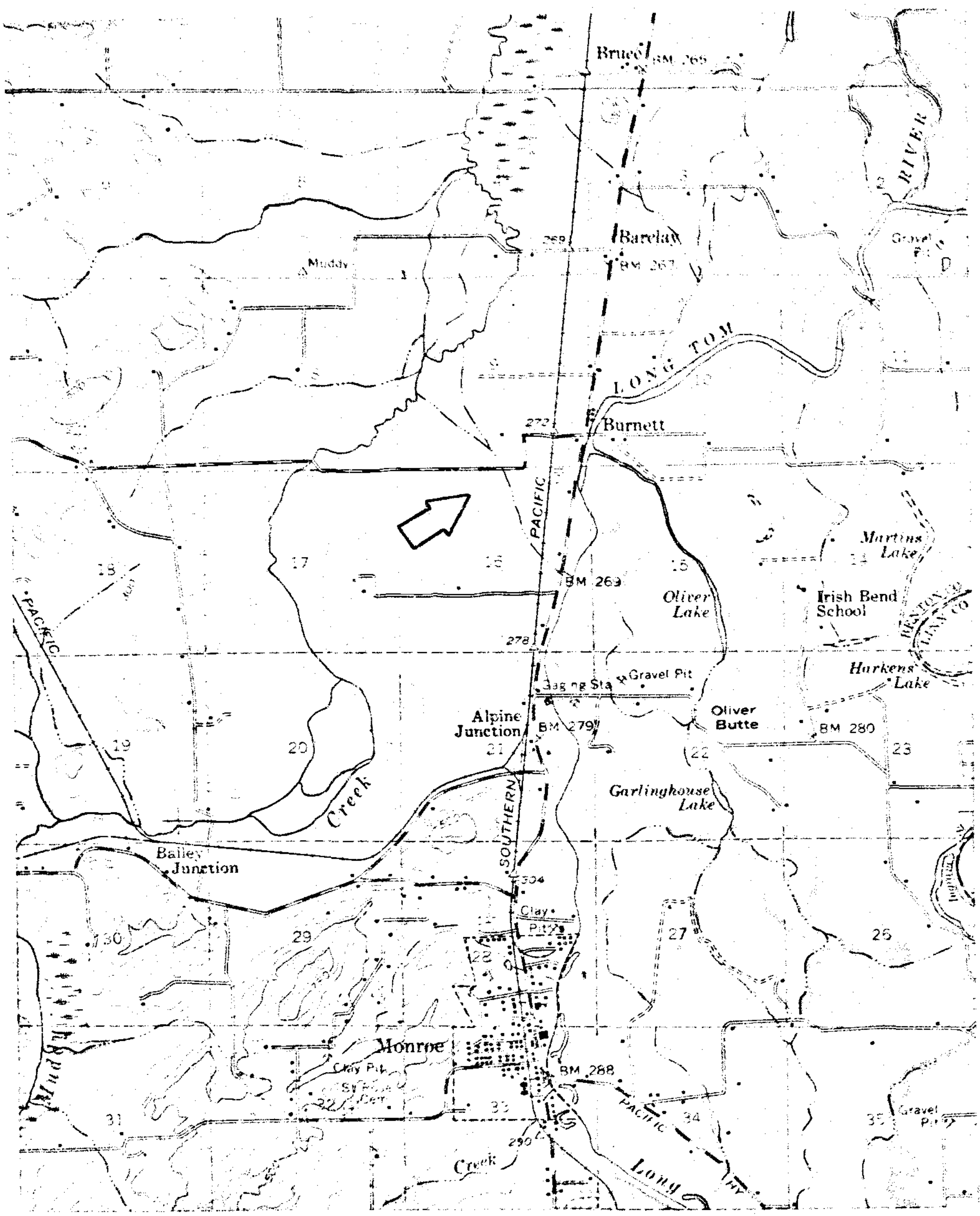


Figure 31. An intermittent channel connects Muddy Creek, a tributary of the Marys River, and Long Tom River, a yazoo of the Willamette, due to Pleistocene drainage derangement (U. S. Geol. Survey Monroe quadrangle, scale 1:62,500).

5 W. A gap which still contains an intermittent stream occurs approximately 5 miles south (air distance) of Philomath on Beaver Creek Road in sec. 2, T. 13 S., R. 6 W.

GEOMORPHIC HISTORY

Several lines of evidence suggest that paired streams, consisting of one east-flowing stream and one west-flowing stream, in the Oregon Coast Range are severed antecedent streams. Geomorphic evidence presented in the preceding sections favors the hypothesis that the streams are antecedent to the Coast Range uplift and that uplift of the range at first resulted in entrenchment of the ancient streams. Later, uplift exceeded downcutting, resulting in severance of the streams.

Geologic evidence, particularly stratigraphic and petrographic evidence, strongly supports the hypothesis that the paired streams in the Coast Range previously were through-going streams. Tertiary sedimentary strata along the western flank of the Coast Range contain volcaniclastic detritus which appears to have been derived from the ancestral Cascade Mountains and which was deposited by streams (Goodwin, 1973). Much of this detritus could not have withstood transport as bedload along the circuitous present route down the western flank of the Cascades, down the length of the Willamette, along the Columbia to the Pacific Ocean and then the long process of longshore drift from the mouth of the Columbia to the Newport-Lincoln City area of the central Oregon coast. A more simple explanation presented here assumes that sometime in the Oligocene the Coast Range began to rise, first appearing as a coastal plain. It is also assumed that the Willamette River did not exist prior to uplift of the Coast Range and that streams that originated in the ancient Cascades flowed westward across a newly emergent coastal plain to the ancient shoreline of the Pacific Ocean (Fig. 32). The Siletz-Luckiamute and Yaquina-Marys would have been two of these streams.

The streams meandered across the erodable surface newly raised from the sea in an effort to transport the voluminous sediment supplied to them in their headwaters.

Intrusions in mid-Oligocene to Miocene time heralded initiation of uplift in the Coast Range. The rate of uplift in the early stages apparently was slow, and the streams kept pace with the rise, incising their meanders. The Oligocene Yaquina Formation and Miocene Astoria Formation along the central coast of Oregon contain an appreciable percentage of volcaniclastic material which was deposited by streams, indicating that during this time the streams still flowed westward. However, in Pliocene to Pleistocene time the rate of uplift exceeded the rate at which the streams could downcut, and the streams were severed. Because very little post-Miocene sedimentary material is exposed onshore, the data are not yet available by which to date, geologically, the severance of the streams. The irregular divide along the length of the Coast Range and interesting stream patterns reflect the complicated history of uplift and erosion. Plate I is a reconstruction of the generalized

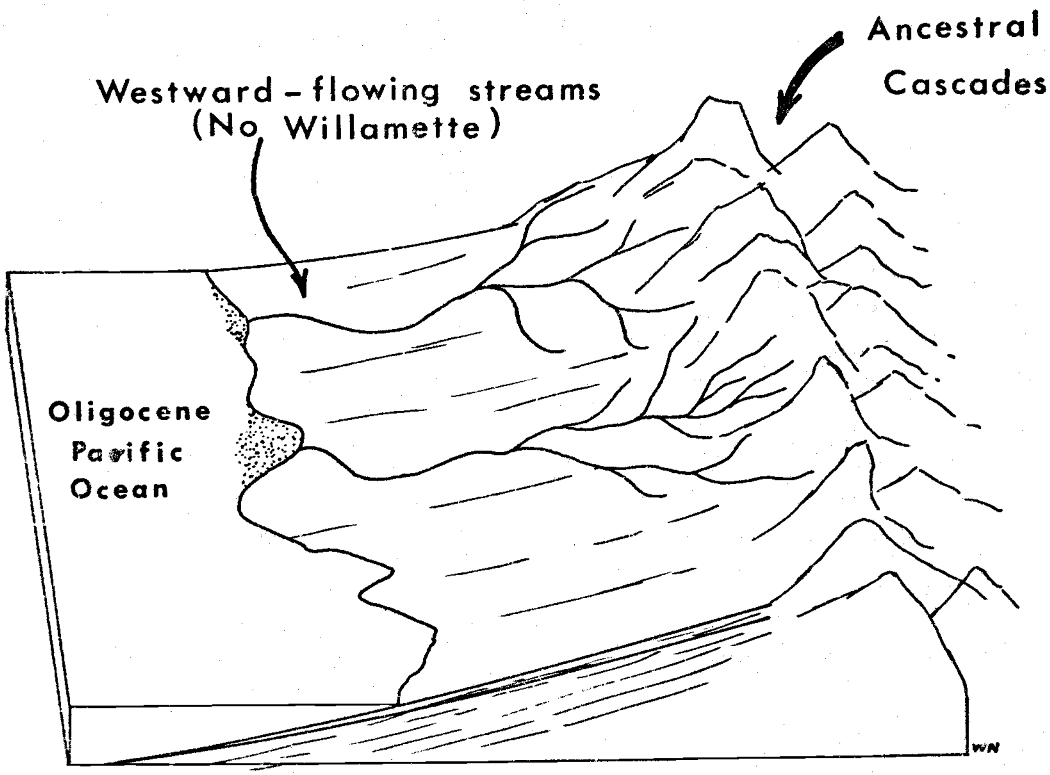


Figure 32. Paleogeographic reconstruction of western Oregon sometime during the Oligocene.

courses of the antecedent streams prior to severance.

Headward erosion near the crest of the Coast Range has resulted in stream piracy and makes further piracy imminent. In the Siletz-Luckiamute paired system, piracy will result in increased eastward drainage of water. In the Yaquina-Marys paired system, piracy will produce increased westward drainage.

REFERENCES CITED

Aldrich, F. T., 1973, A chorological analysis of the grass balds in the Oregon Coast Range: unpub. Ph.D. thesis, Oregon State University, Corvallis, 156 p.

Allison, I. S., 1935, Glacial erratics in Willamette Valley: Geol. Soc. America Bull., v. 46, p. 615-632.

__________, 1936, Pleistocene alluvial stages in northwestern Oregon: Science, v. 83, no. 2158, p. 441-443.

__________, 1953, Geology of the Albany quadrangle, Oregon: Oregon Dept. of Geol. and Mineral Industries Bull. 37, 18 p., map scale 1:62,500.

Baldwin, E. M., 1955, Geology of the Marys Peak and Alsea quadrangles, Oregon: U. S. Geol. Survey Oil and Gas Invest. Map OM 162.

__________, 1964a, Geology of the Dallas and Valsetz quadrangles, Oregon: Oregon Dept. of Geol. and Mineral Industries Bull. 35, 61 p., map scale 1:62,500.

__________, 1964b, Geology of Oregon. 2nd ed., Edwards Bros., Ann Arbor, Michigan, 165 p.

__________ and Howell, P. W., 1949, The Long Tom, a former tributary of the Siuslaw River: Northwest Sci., v. 23, p. 112-124.

Balster, C. A. and Parsons, R. B., 1966, A soil-geomorphic study in the Oregon Coast Range: Oregon Agric. Exp. Sta. Tech. Bull. No. 89, p. 3-30.

__________, 1968a, Sediment transportation on steep terrain, Oregon Coast Range: Northwest Sci., v. 42, p. 62-70.

__________, 1968b, Geomorphology and soils, Willamette Valley, Oregon: Oregon State Univ. Agric. Exp. Sta. Special Report 265, 31 p.

Bostwick, D. A., 1959, Field trip no. 1, Corvallis to Depoe Bay via Newport in Wilkinson, W. D., Field guidebook, College Teachers Conference in Geology: Oregon Dept. of Geol. and Mineral Industries Bull. 50, p. 17-32.

Cooper, D. M., 1977, Sedimentation, stratigraphy, and facies variation within the middle Miocene Astoria Formation in Oregon: unpub. Ph.D. thesis, Oregon State Univ., Corvallis, 399 p.

Cressy, F. B., Jr., 1974, Stratigraphy and sedimentation of the Neahkahnie Mountain-Angora Peak area, Tillamook and Clatsop Counties, Oregon: unpub. M.S. thesis, Oregon State Univ., Corvallis, 148 p.

Diller, J. S., 1896, Geological reconnaissance in northwestern Oregon: U. S. Geol. Survey 17th Ann. Report, p. 1-80.

Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill Book Co., New York, 534 p.

Franklin, J. F. and Dyrness, C. T., 1973, Natural vegetation of Oregon and Washington: Pacific Northwest Forest and Range Exp. Sta., U.S.D.A. Forest Service, General Tech. Report PNW-8, 417 p.

Goodwin, C. J., 1973, Stratigraphy and sedimentation of the Yaquina Formation, Lincoln County, Oregon: unpub. M.S. thesis, Oregon State Univ., Corvallis, 121 p.

Haring, L. L. and Lounsbury, J. F., 1975, Introduction to scientific geographic research. 2nd ed., Wm. C. Brown Co., Dubuque, Iowa, 128 p.

Heusser, C. J., 1960, Late Pleistocene environments of North Pacific North America: Am. Geog. Soc. Spec. Pub. no. 35, 308 p.

Hodge, E. T., 1938, Origin of the Willamette Valley: Geol. Soc. Oregon County News Letter, v. 4, no. 19, p. 215-19.

Horton, R. E., 1932, Drainage-basin characteristics: Trans. Am. Geophys. Union, v. 13, p. 350-361.

__________, 1945, Erosional development of streams and their drainage basins: hydrophysical approach to quantitative morphology: Geol. Soc. America Bull., v. 56, p. 275-370.

Küchler, A. W., 1946, The broad leaf deciduous forests of the Pacific Northwest: Ann. Assoc. Am. Geogr., v. 36, p. 122-147.

Leopold, L. B., Wolman, M. G., and Miller, J. P., 1964, Fluvial processes in geomorphology. W. H. Freeman and Co., San Francisco, 522 p.

Lowry, W. D. and Baldwin, E. M., 1952, Late Cenozoic geology of the lower Columbia River valley, Oregon and Washington: Geol. Soc. America Bull., v. 63, p. 1-24.

Merkle, John, 1951, An analysis of the plant communities of Marys Peak, western Oregon: Ecology, v. 32, p. 618-640.

Miller, V. C., 1953, A quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee: Tech. Rept. 3, Office Naval Res. Proj. NR 389-042, Columbia University.

Morisawa, M. E., 1962, Quantitative geomorphology of some watersheds in the Appalachian Plateau: Geol. Soc. America Bull., v. 73, p. 1025-1046.

__________, 1968, Streams - their dynamics and morphology: McGraw-Hill Book Co., New York, 175 p.

Neel, R. H., 1976, Geology of the Tillamook Head - Necanicum Junction area, Clatsop County, Northwest Oregon: unpub. M.S. thesis, Oregon State Univ., Corvallis, 204 p.

Niem, A. R., 1976, Tertiary volcaniclastic deltas in an arc-trench gap, Oregon Coast Range: Geol. Soc. America Abstracts with Programs, v. 8, no. 3, p. 400.

Oberlander, Theodore, 1965, The Zagros streams: Syracuse Geog. Series No. 1, 168 p.

Press, Frank and Siever, Raymond, 1974, Earth. W. H. Freeman and Co., San Francisco, 945 p.

Schlicker, H. G., Deacon, R. J., Beaulieu, J. D., and Olcott, G. W., 1972, Environmental geology of the coastal region of Tillamook and Clatsop Counties, Oregon: Oregon Dept. of Geol. and Mineral Industries Bull. 74, 164 p.

Schlicker, H. G., Deacon, R. J., Olcott, G. W., and Beaulieu, J. D., 1973, Environmental geology of Lincoln County, Oregon: Oregon Dept. of Geol. and Mineral Industries Bull. 81, 171 p.

Schumm, S. A., 1956, Evolution of drainage systems and slopes in badlands at Perth Amboy, N. J.: Geol. Soc. America Bull., v. 67, p. 597-646.

Small, R. J., 1972, The study of landforms. Cambridge University Press, London, 486 p.

Smith, K. G., 1950, Standards for grading texture of erosional topography: Am. Jour. Sci., v. 248, p. 655-668.

Smith, T. N., 1975, Stratigraphy and sedimentation of the Onion Peak area, Clatsop County, Oregon: unpub. M.S. thesis, Oregon State Univ., Corvallis, 190 p.

Snavely, P. D., Jr. and Wagner, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Div. Mines and Geol., Rept. Inv. No. 22, 25 p.

Snavely, P. D., Jr., MacLeod, N. S., and Wagner, H. C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: Am. Jour. Sci., v. 266, p. 454-481.

__________, 1972, Preliminary bedrock geologic map of the Yaquina and Toledo quadrangles, Oregon: U. S. Geol. Survey Open File Map, scale 1:48,000.

Strahler, A. N., 1952, Dynamic basis of geomorphology: Geol. Soc. America Bull., v. 63, p. 923-938.

__________, 1957, Quantitative analysis of watershed geomorphology: Trans. Am. Geophys. Union, v. 38, p. 913-920.

Thornbury, W. D., 1969, Principles of geomorphology. 2nd ed., John Wiley and Sons, Inc., New York, 594 p.

U. S. Dept. of Commerce, 1967, Climates of the states, Oregon: Climatography of the United States No. 60-35.

__________, 1970, Oregon, annual summary: Climatological data, v. 76, no. 13.

Vokes, H. E., Myers, D. A., and Hoover, Linn, 1954, Geology of the west-central border area of the Willamette Valley, Oregon: U. S. Geol. Survey Oil and Gas Invest. Map OM 150, scale 1:62,500.

Wells, F. G. and Peck, D. L., 1961, Geologic map of Oregon west of the 121st meridian: U. S. Geol. Survey Misc. Geol. Inv. Map I-325, scale 1:500,000.

APPENDICES

APPENDIX A

Third-order streams used in comparisons of drainage densities

Stream	Basin Area (sq. mi.)	No. of Streams	Stream Freq. (#/sq. mi.)	Stream Lengths (mi.)	Drainage Density (#/mi.)	Number of Crenulations (N)	Length of Perimeter (P)	Texture Ratio (N/P)	Lithology
Siletz drainage:									
Boulder Creek (c_1)	17.9	41	2.85	27.2	1.35	59	20.1	2.94	basalt
Warnick Creek (c_2)	7.7	13	6.19	13.2	1.72	35	13.2	2.65	basalt
S. Fk. Siletz River (c_4)	14.4	31	1.73	36.0	2.50	189	17.2	10.98	sandst.
Beaver Creek (c_5)	2.1	19	2.47	6.5	3.10	40	6.1	6.56	sandst.
Marys drainage:									
Hammer Creek (c_5)	22.6	27	1.19	33.8	1.50	66	12.2	5.41	sandst.
Oliver Creek (c_6)	17.1	19	1.11	23.3	1.36	40	7.4	5.41	sandst.

APPENDIX B

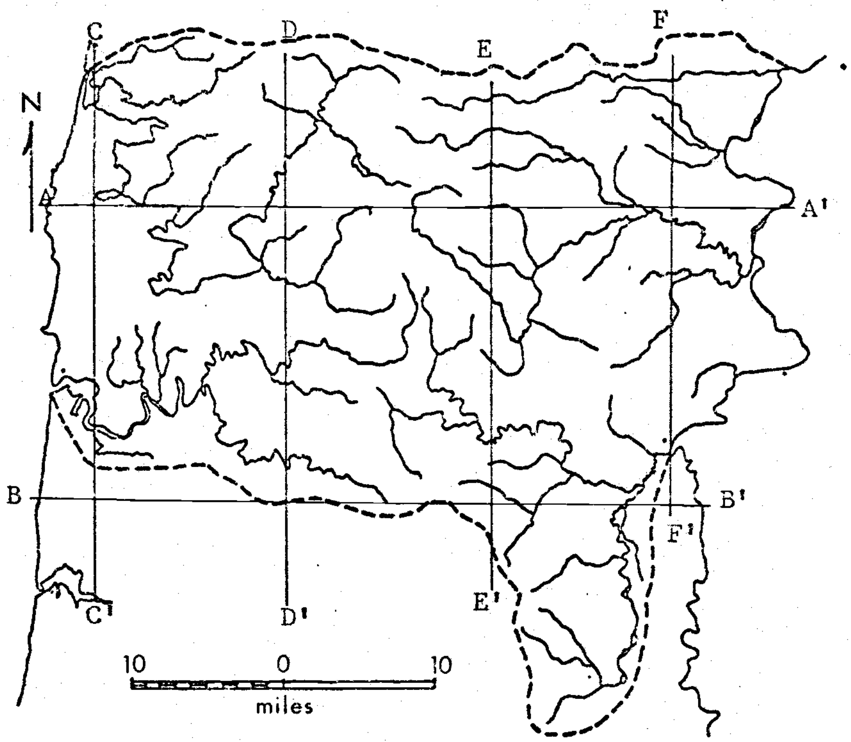
Table of Bifurcation Ratios for Basins in the Central Coast Range of Oregon

Stream	Order No.	Number of Streams	Bifurcation Ratio
Siletz	1	483	
			4.88
	2	99	
			4.50
	3	22	
			3.67
	4	6	
			6.00
	5	1	
			Av. 4.76
Luckiamute principal	1	327	
			4.81
	2	68	
			4.86
	3	14	
			4.67
	4	3	
			3.00
	5	1	
			Av. 3.47
Luckiamute secondary	1	55	
			4.23
	2	13	
			3.25
	3	4	
			2.00
	4	2	
			2.00
	5	1	
			Av. 2.30
Yaquina	1	358	
			4.77
	2	75	
			4.69
	3	16	
			4.00
	4	4	
			4.00
	5	1	
			Av. 4.37
Marys	1	325	
			4.64
	2	70	
			4.67
	3	15	
			3.00
	4	5	
			5.00
	5	1	
			Av. 4.33

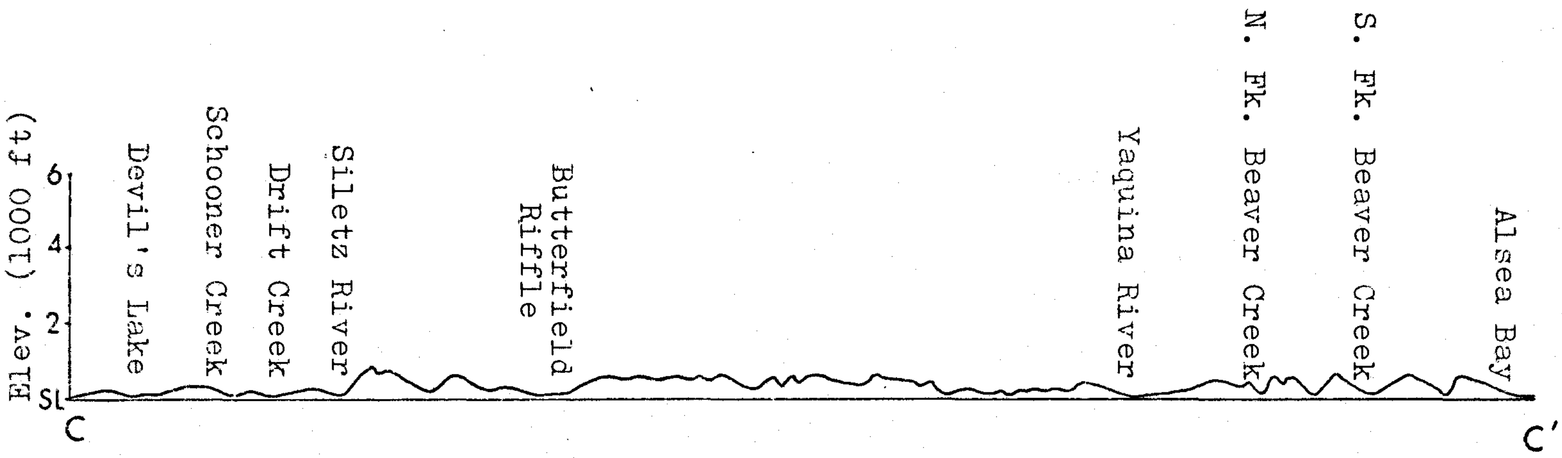
APPENDIX C

Table of Lengths of Streams in the Central Coast Range of Oregon

Stream	Order No.	Σ Channel Length (miles)	Average Length (miles)
Siletz	1	322.4	0.67
	2	113.0	1.14
	3	57.9	2.76
	4	23.1	3.85
Luckiamute principal	1	239.7	0.73
	2	89.7	1.32
	3	42.8	3.06
	4	24.3	8.09
Luckiamute secondary	1	50.8	0.92
	2	13.2	1.01
	3	3.4	0.84
	4	10.6	5.28
Yaquina	1	233.7	0.65
	2	82.5	1.09
	3	40.1	2.50
	4	42.0	10.51
Marys	1	268.1	0.83
	2	89.2	1.24
	3	52.1	3.26
	4	48.1	9.63

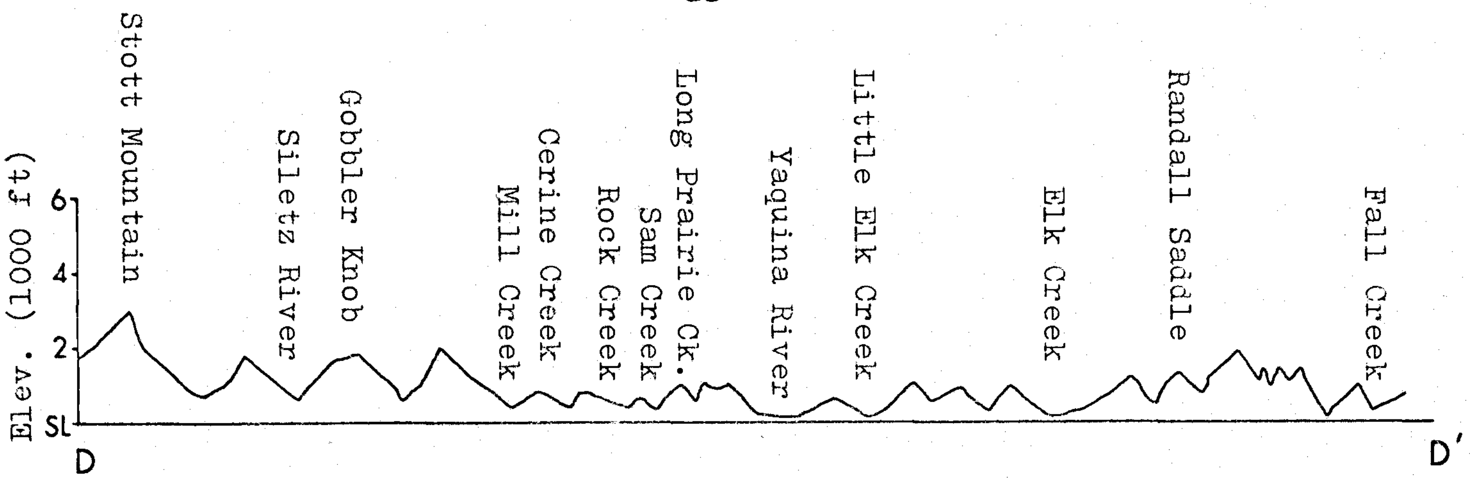


Index map of topographic profiles in figure 9 and Appendix D.

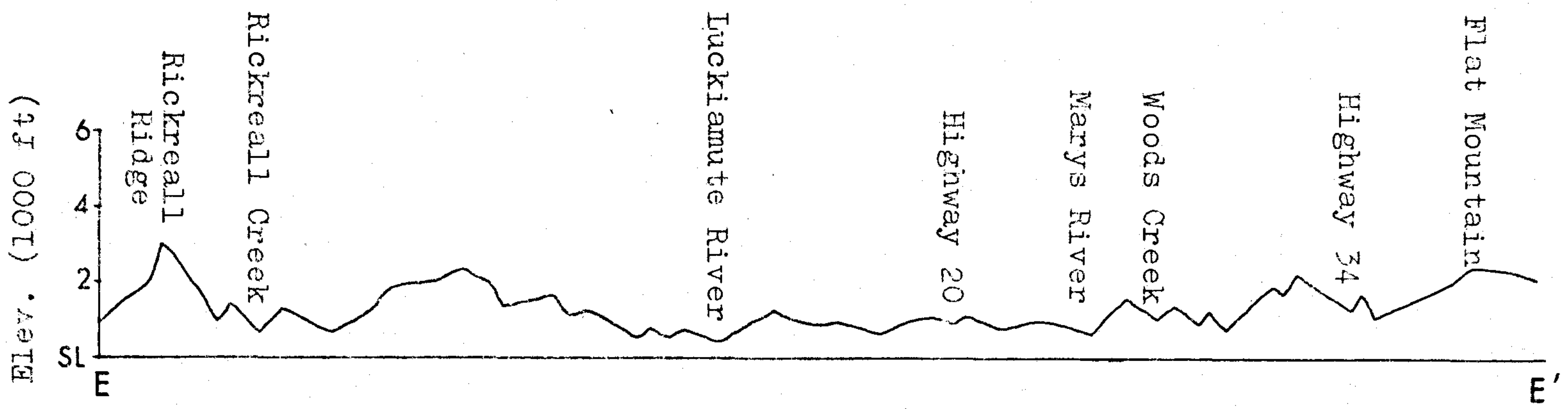


North to south physiographic cross section along longitude 124° W from Siletz Bay to Alsea Bay.

Vertical exaggeration = 5.21X

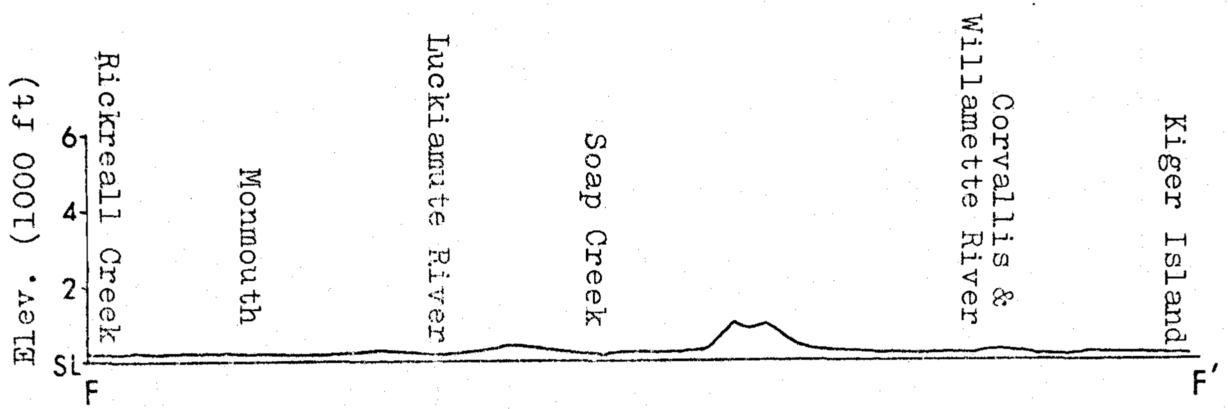


North to south physiographic cross section along longitude 123° 45' W (Stott Mountain to Fall Creek).



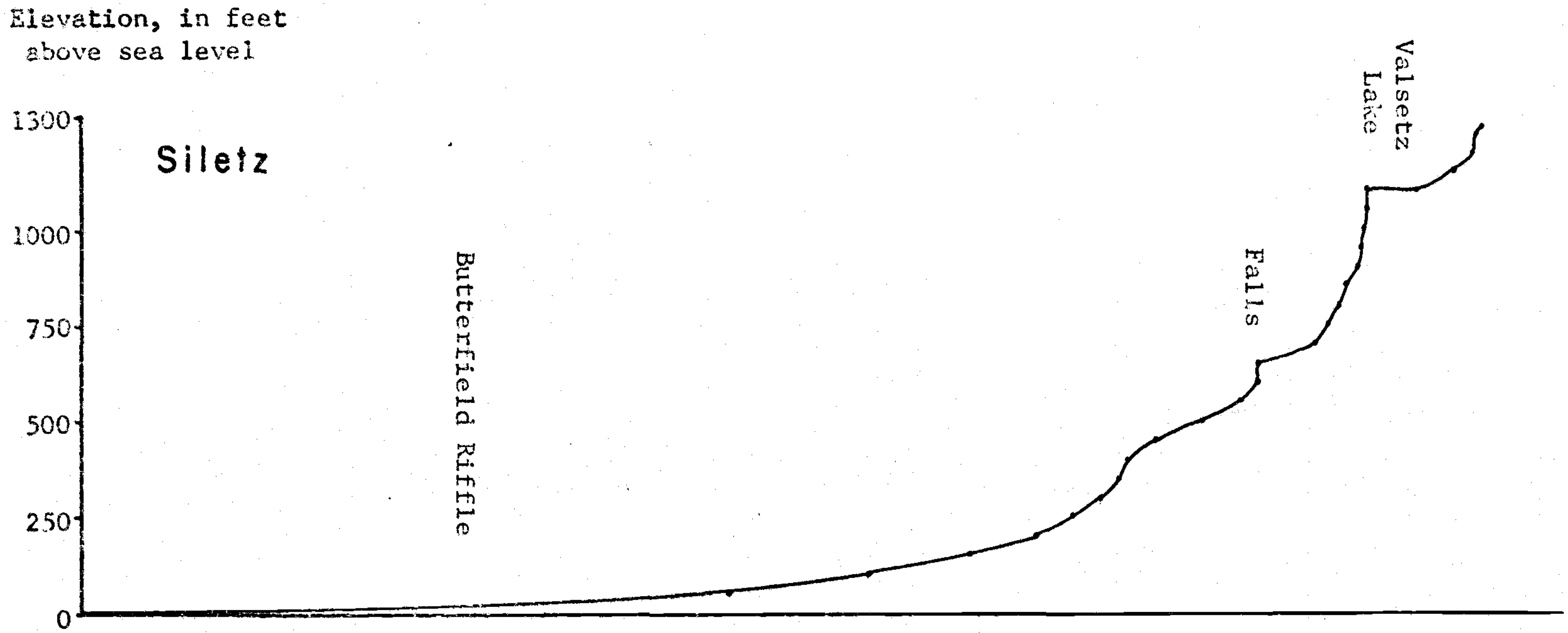
North to south physiographic cross section along longitude 123° 30' W. (Rickreall Ridge to Flat Mountain).

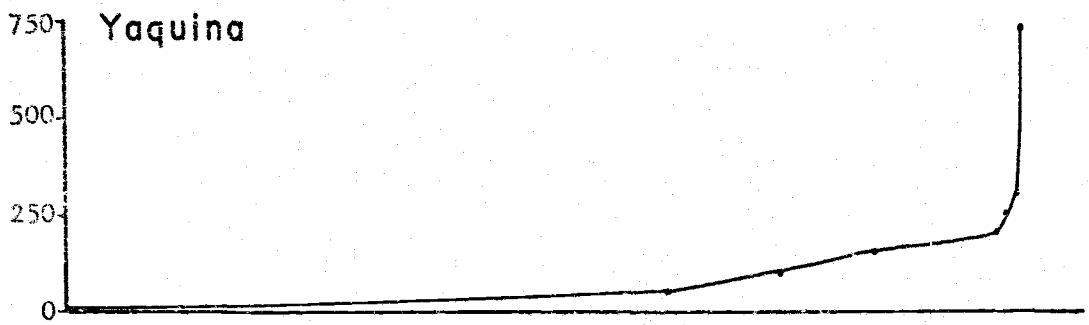
Vertical exaggeration = 5.21X



North to south physiographic cross section along longitude 123° 15' W (Rickreall to Kiger Island).

Appendix E. Longitudinal profiles of streams



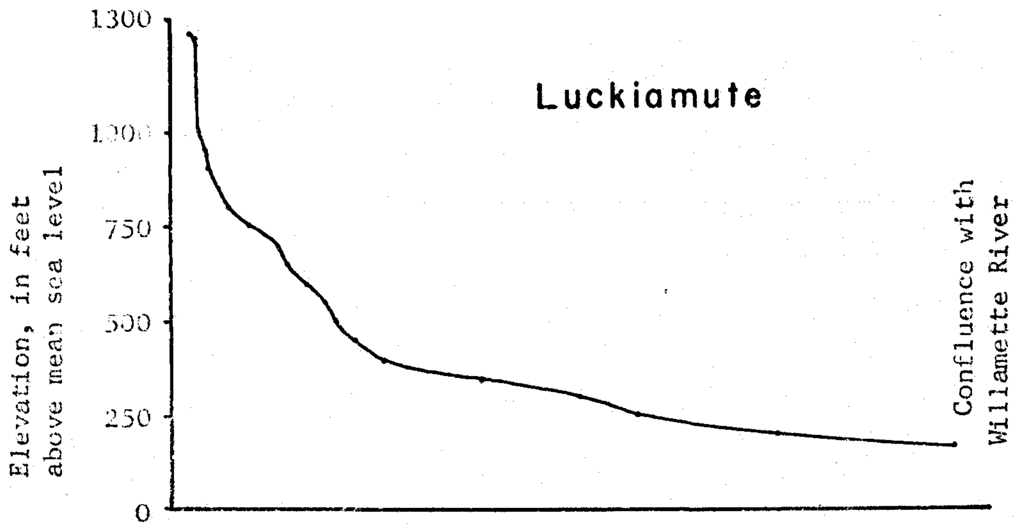


Horizontal Scale

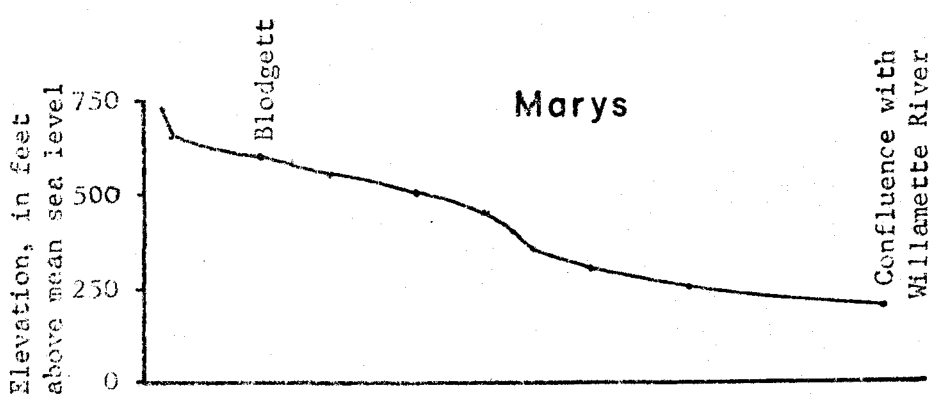
10 miles

Vertical Exagerration = 105.6X

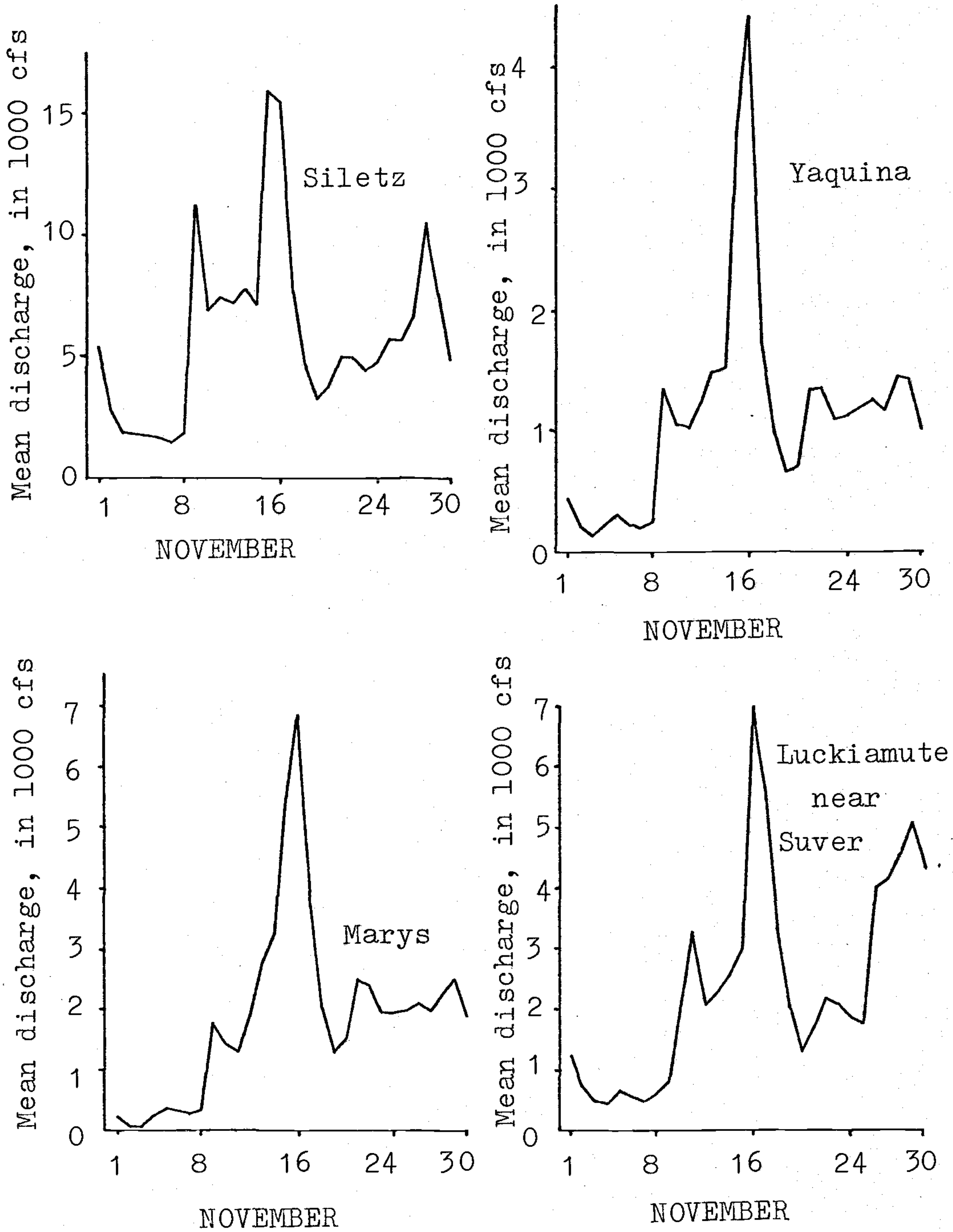
Appendix E. Longitudinal profiles of streams



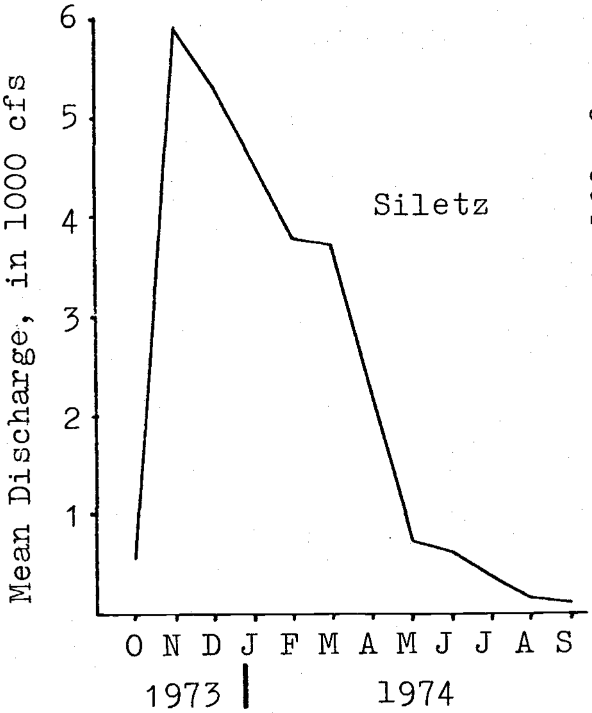
Vertical exaggeration = 105.6X

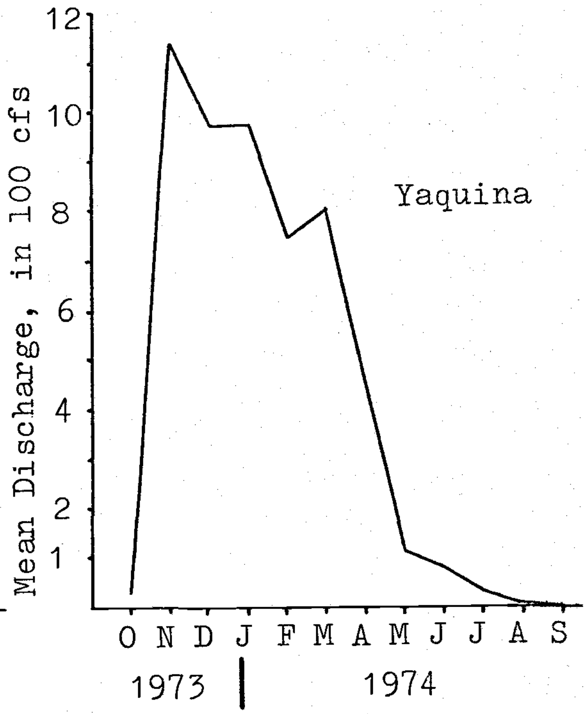


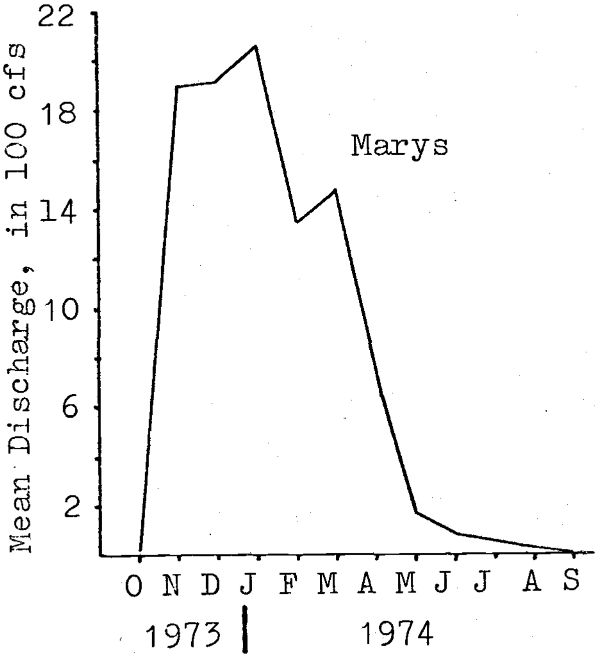
Appendix F. Mean discharge of central Coast Range streams during November, 1973.

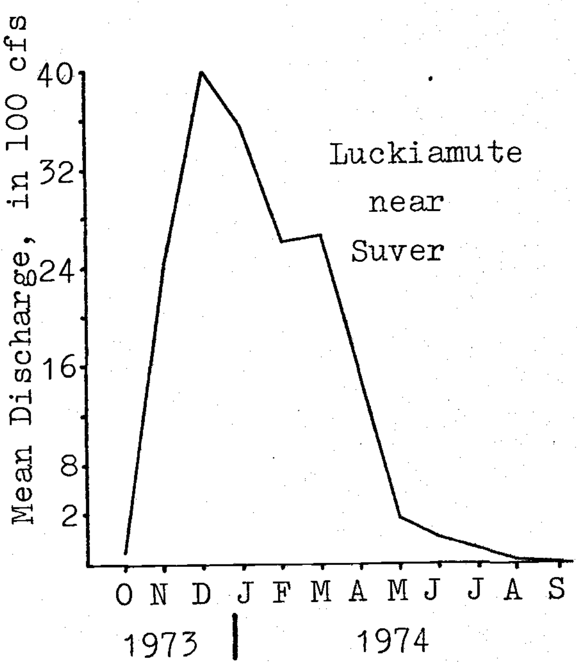


Appendix G. Mean monthly discharge during the water year, October 1973 to September 1974.









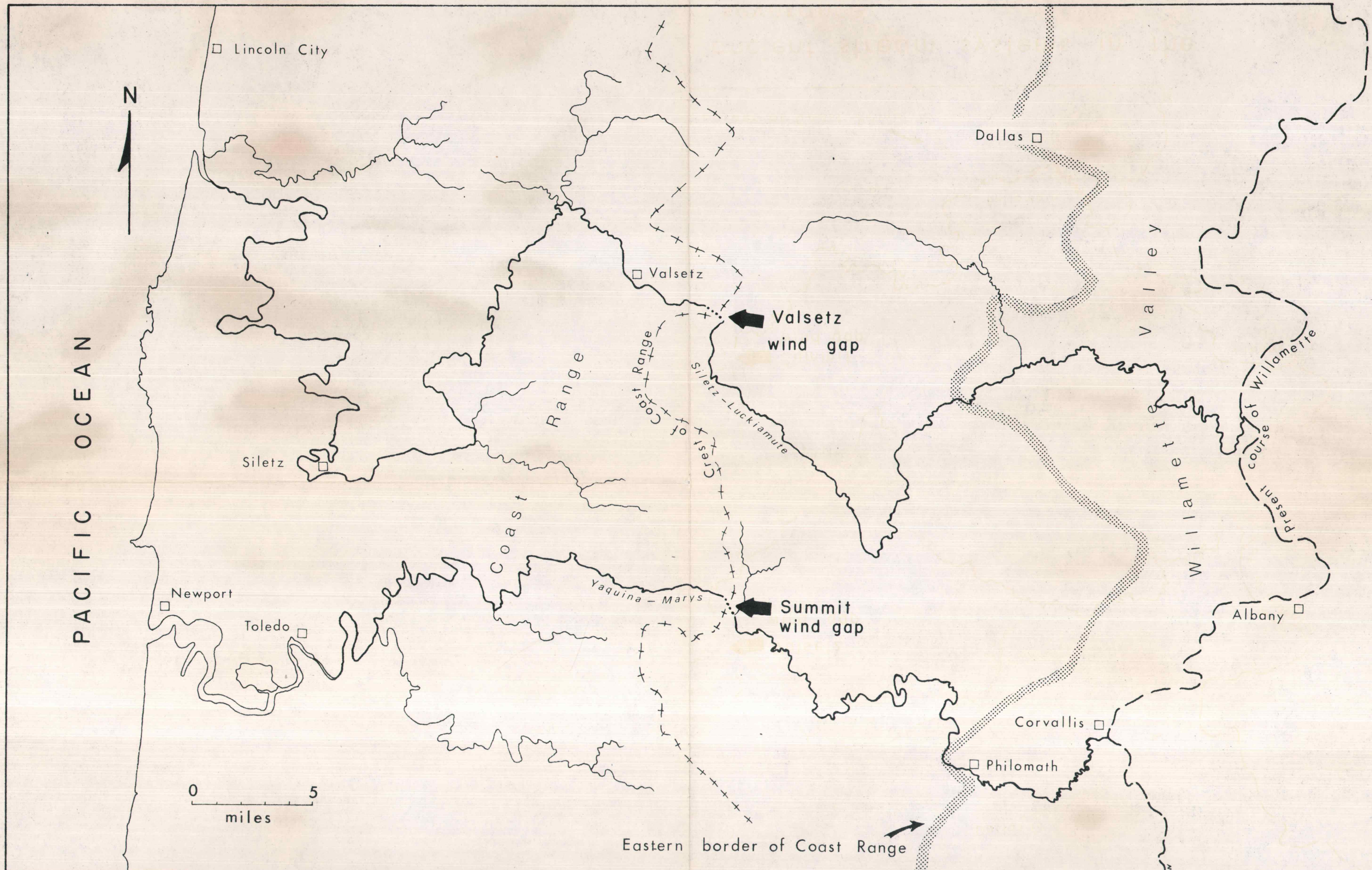


PLATE I. Reconstructed courses of the ancient stream systems in the central Coast Range prior to severance.