

**HYDROLOGY AND ENGINEERING GEOLOGY
OF THE COLUMBIA BASIN**

By

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and

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Field Trip
Hydrogeology and Engineering Geology
of the Columbia Basin

FOREWORD

This field guide has been prepared as a cooperative effort of several agencies. The portion of the guide which describes a tour of hydrogeological and engineering features of the Columbia Basin project was prepared by Mr. George E. Neff of the U.S. Bureau of Reclamation. That portion of the tour describing features of the Hanford Reservation and environs was prepared and assembled by Mr. Donald J. Brown of the Atlantic-Richfield-Hanford Company. Pen and ink drawings and materials descriptive of the Columbia Basin area were prepared by Mr. Gary T. Lobdell, a graduate student at Washington State University. The splendid cooperation of each of these persons is gratefully acknowledged.

James W. Crosby III
Professor of Geology and
Civil Engineering

ACKNOWLEDGMENTS

The information in this Field Guide has come from the following sources:

Bennison, A., H. Renfro, and D. Feray, 1973, Geological highway map of the Pacific Northwest region: The American Association of Petroleum Geologists.

Bretz, J. H., 1959, Washington's channeled scabland: Washington Division of Mines and Geology, Bulletin no. 45.

Geological Society of America, Cordilleran Section, March 1964, Field Trip to Columbia River dams: Washington Chapter of Association of Engineering Geologists.

Grolier, M. and J. Bingham, 1971, Geologic map and sections of parts of Grant, Adams and Franklin Counties, Washington: U.S. Geological Survey, Map I-589.

Huntting, M., V. Bennet, J. Livingston, and W. Moen, 1961, Geologic map of Washington: Washington Division of Mines and Geology.

United States Department of the Interior, Bureau of Reclamation, Pacific Northwest Region, 1975, Map of Columbia Basin project.

In addition to the information used above, some geological interpretations were made by the writers.

HYDROGEOLOGY AND ENGINEERING GEOLOGY
OF THE COLUMBIA BASIN

Field Trip Itinerary

First Day

<u>Mileage</u>	<u>Time</u>	
	0700	Leave Spokane. Proceed west on Highway 2 to Wilbur, then northwest on Highway 174 to Grand Coulee Dam. Arrival time approximately 0900. Introductory lecture by project personnel concerning geology and engineering.
0	0930	Headquarters Building at Coulee Dam. Pump discharge outlet structure.
1		Cut and cover section of feeder canal. Landslide area in the Latah Formation.
2		North Dam and Banks Lake. Turn right onto Highway 155. Ancient slides can be seen below the north wall of the coulee.
3		Electric City.
5		Horizontal basalt flows can be seen overlying granitic erosional surfaces. Varved silts of the Nespelem Formation can be seen in the road cut.
8		Steamboat Rock is visible to the right.
10		The granite surface dips under the basalt.
12		Glacial erratics (called "haystack rocks") lie above the west wall. Hanging valleys can also be seen in the basalt of the coulee. Cooling and flow structures are present in the basalt.
16		A small basalt dike can be seen in the east wall 100 yards north of the guard rail.
20		Flow structures are evident in the deep road cut. Erratics embedded on the west wall remind us of the power of glacial ice.

- 25 1020 The coulee monocline crosses the Grand Coulee.
Turn right onto Highway 2 to Dry Falls.
- 29 Dry Falls Dam. Main canal headworks. Turn left
onto Highway 17.
- 34 Dry Falls.
- 36 Dry Falls State Park Entrance. Turn around.
- 37 Five-minute photo stop to view Coulee Monocline and
Lower Grand Coulee.
- 38 1035 Twenty-minute stop at Dry Falls viewpoint and museum.
Leave at 1055 hrs. and back-track to Coulee City.
- 42 Coulee City. Take Pinto Ridge Road. An expansion
bar and springs can be seen.
- 43 Bacon Siphon and Tunnel.
- 46 An interflow zone and some pillow palagonite are
present in the road cut.
- 47 Bacon Syncline can be seen as well as Trail Lake
Coulee and Sink.
- 48 Main canal. Old basin fill sediments lie under the
expansion bar on the right.
- 51 Dry Coulee lies ahead and the Bretz Coulee is to
your right.
- 52 Turn left onto Summer Falls Road. The Pinto Thrust
can be viewed here. Lateral scour around the up-
stream side of the Pinto Anticline shows evidence of
high-water flow.
- 53 1110 Summer Falls and Billy Clapp Lake.
- 55 The scabland tracts can be seen to the north. A
scabland bar is nearby. A scarp in loessal sediments
can also be seen.
- 56 On top of the Pinto Anticline, Dry Coulee and Lower
Grand Coulee can be viewed to the west.
- 59 Main Canal and Crab Creek Coulee.
- 60 Turn left onto Route 28.
- 61 Rythmic sediments are present. Turn left onto Pinto
Dam Road.

64	1140	Pinto Dam. Return to Route 28 and turn right.
71		Bifurcation works and Crab Creek Siphons.
72		Dry Coulee can be seen.
76		Turn right onto High Hill Road, then left on West Canal bank.
77		Pumping discharge from Soap Lake Protective Works and High Hill Check.
78		Soap Lake Siphon inlet.
79		Turn left onto Route 17.
82	1210	Three wells of Soap Lake Protective Works.
86		Boulder outwash from Grand Coulee is present.
90	1235	Turn right onto Route 282 to Ephrata, then left on Route 28 to Oasis Park for lunch stop (or restaurant in Ephrata). Leave at 1330 hrs.
98		Turn right on Martin road. West Canal.
104		Turn left on J-NW.
105		Quincy pumping plant. Turn right on Route 28.
106, 110		Drainage relief wells.
111		Turn left onto West Canal bank.
112		W645WN drain. Turn left onto Route 281 (Q-NW). New drainage relief well site.
117		Turn left onto White Trail Road.
121		Turn right onto M-NW. W238 drain.
125		Turn left onto South Frontage Road of Interstate Highway 90.
127		W645 drain.
130		Turn right onto I-NW.
133.5		George Test Well. This well is used for irrigation.
137		W645 drain.
138	1430	Turn left onto 7-SW.

- 139 Turn right onto road to Frenchman Hills Tunnel.
The head of Frenchman Wasteway can be seen. Proceed east on 7-SW.
- 142 Frenchman Hills pumping plant.
- 144 Turn right onto Dodson Road. The Frenchman Hills Anticline, Royal Slope, and Saddle Mountains can be seen.
- 146 Turn left on 12-SW. Perched water tables in the Ringold Sand and Silt Formation are present here.
- 159 Turn left onto H-SE.
- 160 West Canal.
- 161 Potholes Reservoir overview. The Drumheller Channels and Frenchman Hills Anticline are viewed to the south.
- 165 1510 Potholes State Park rest stop.
- 169 O'Sullivan Dam on southern end of the Potholes Reservoir.
- 171 Potholes Canal Headworks.
- 177 Turn right onto Route 17.
- 190 Turn right onto Route 26.
- 192 Turn right onto Route 24.
- 194 Potholes Canal.
- 198 PE16.4 wasteway. Turn left onto Sagehill Road.
- 200 1550 Top of Saddle Mountains.
- 202 Wahluke Branch Canal.
- 208 Turn right toward Ringold.
- 210 This is a landslide area where perched water tables in the Ringold Formation can be seen.
- 215 PE16.4 wasteway. Turn right toward Columbia River.
- 216 Turn right onto River Road. Ringold Springs are found in this area.
- 217 Turn around.

218	1610	Turn right toward Pasco.
223		Potholes Canal. Drain System pumping plant.
225		Turn right onto Glade North Road.
235		Esquatzel Diversion Canal.
236		Esquatzel Coulee pumping plant.
238		Center of half-circle, pivoting sprinkler system.
239		Rogers Walla Walla Effluent Disposal.
243	1640	Pasco. Proceed to the Red Lion Motor Inn. End of first day.

Introduction

The map on the following page shows the location of the Columbia Basin project within the state. The development of this project has resulted in hydroelectric power, irrigation, and flood control.

The dotted line on the map indicates the approximate route that this Guide Book describes. Geologic maps incorporated in the document illustrate the basic rock types of the area. These maps also show the scheduled highway route. In addition to these maps, three-dimensional aerial views showing topographic features have been included within the text for selected locations.

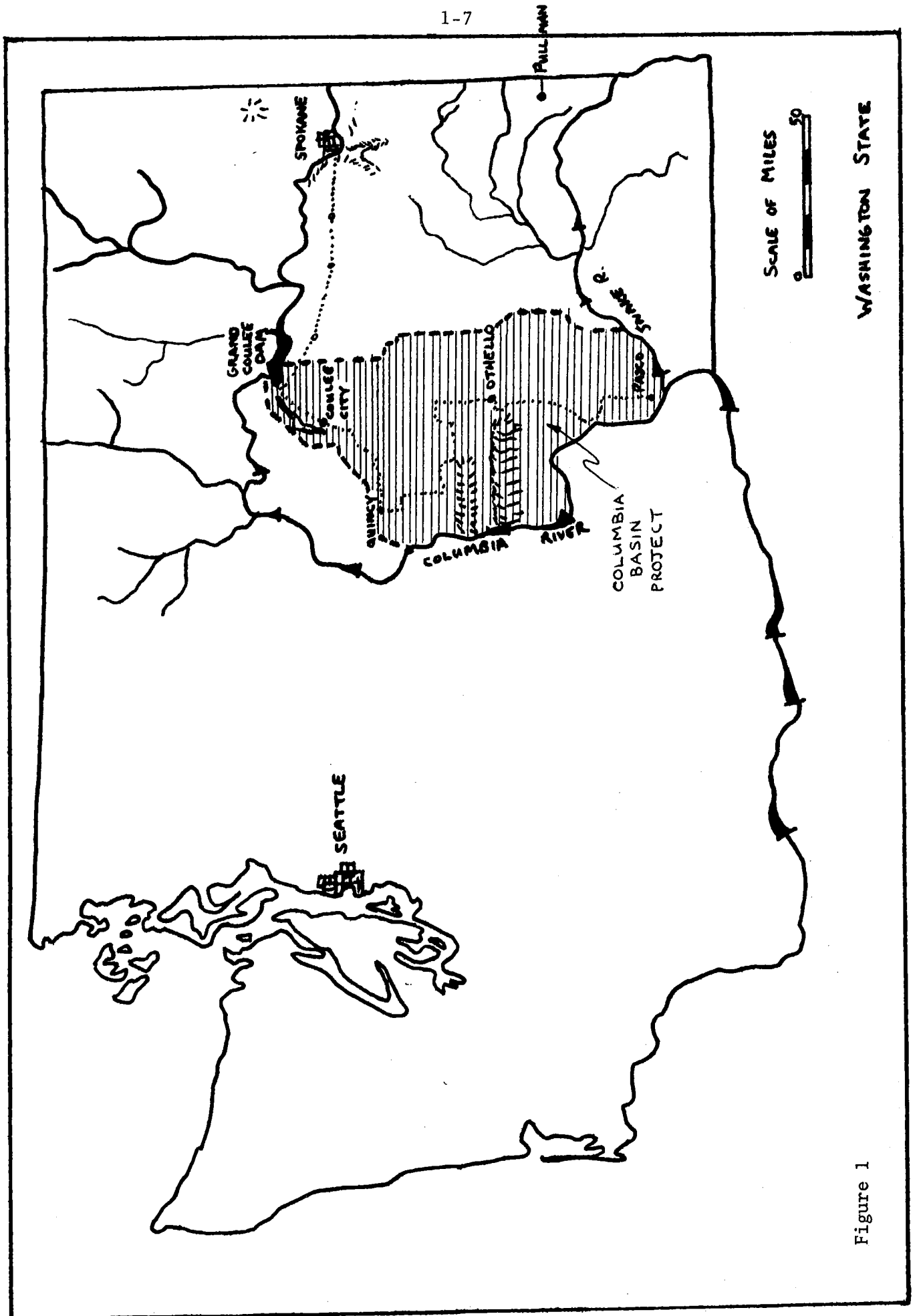
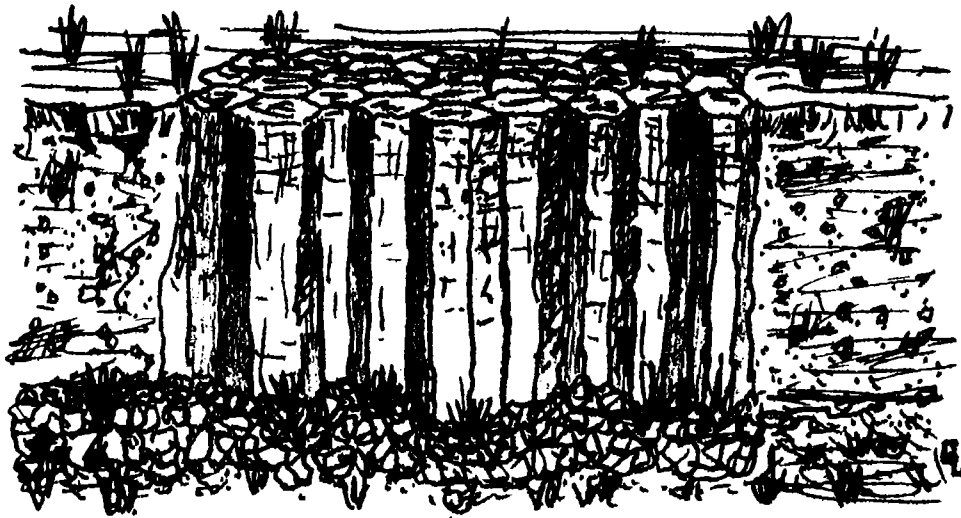


Figure 1

Heading west out of Spokane, Interstate Highway 90 rises above the city, giving a view of the Spokane Valley to the east. Both the city and the valley are situated on deposits of advance and recessional outwash composed primarily of silt, sand, and gravel with some clay. These deposits fill a Precambrian trough cut in quartzite, argillite, and quartz-feldspar gneiss by the last Continental Ice Sheet.

At the top of the "Sunset Hill," U.S. Highway 2 takes off to the right. Miocene volcanic rocks can be seen in the road cuts. These black aphanitic basalt flows display some of the best examples of columnar jointing in all of Washington, often with nearly perfect hexagonal cross-sections. Maximum thickness of the flows approaches two miles in south-central Washington; however, in this area they are not nearly so thick.



COLUMNAR JOINTING NEAR
SPOKANE, WA.

Nine miles out of Spokane, Highway 2 cuts through older glacial drift of Pre-Wisconsin age, comprised of sorted and unsorted gravel, sand, silt, and clay. Miocene volcanics, marking the border of the Continental Ice Sheet which moved southwest from Canada during the Wisconsin period, are encountered again as one moves out of these deposits.

Near Reardan, light-brown periglacial eolian deposits, which include massive, homogeneous, unconsolidated loessial silt and some water-deposited material, are encountered. From Reardan to Grand Coulee Dam, Miocene volcanics and periglacial eolian deposits alternate along the highway. Near Grand Coulee Dam, the basalt flows crop out under the glacial deposits and border Banks Lake to the west and Franklin D. Roosevelt Lake to the east.

Mesozoic granitic rocks are encountered at Grand Coulee Dam and extend over vast areas to the north and northeast. The dam itself is situated on these plutonics which include granite, quartz monzonite, quartz diorite, and granodiorite. At the dam site, the canyon of the Columbia River is about 2500 feet wide at the river level and almost 3000 feet deep. The river has cut through the basalts which once covered the area, exposing the granite below. Glaciolacustrine deposits of well-stratified gravel, sand, silt, and some clay are found along Banks and F. D. Roosevelt Lakes.

As one leaves Grand Coulee Dam and heads southwest, ancient slides can be seen below the north wall of the Upper Grand Coulee. After deglaciation, clay and silt zones slumped following downcutting by the Columbia River. Slumping has occurred along many miles of the Columbia.

Steamboat Rock, an erosional remnant from the period following deglaciation, can be seen on the right as one moves southward along Banks

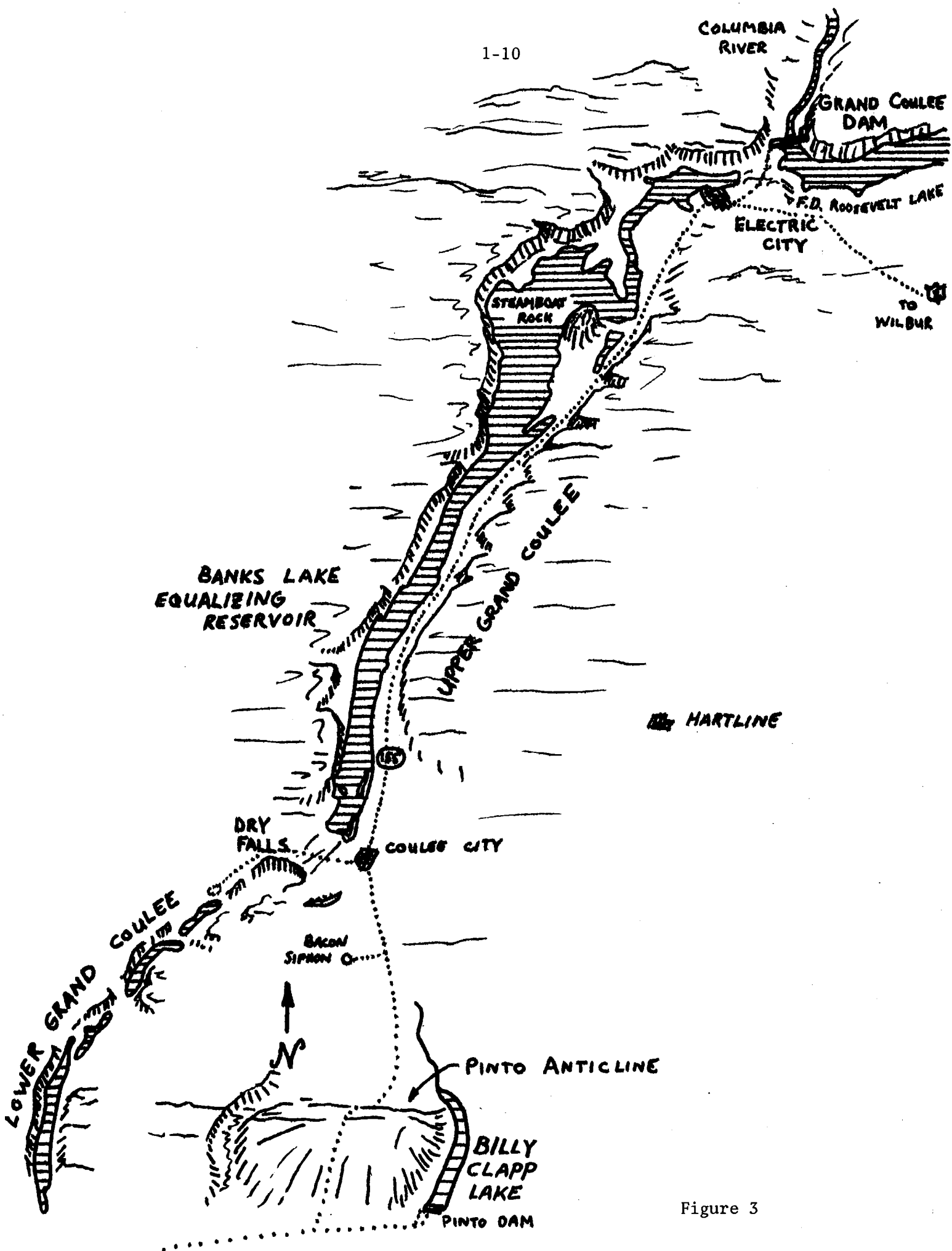


Figure 3

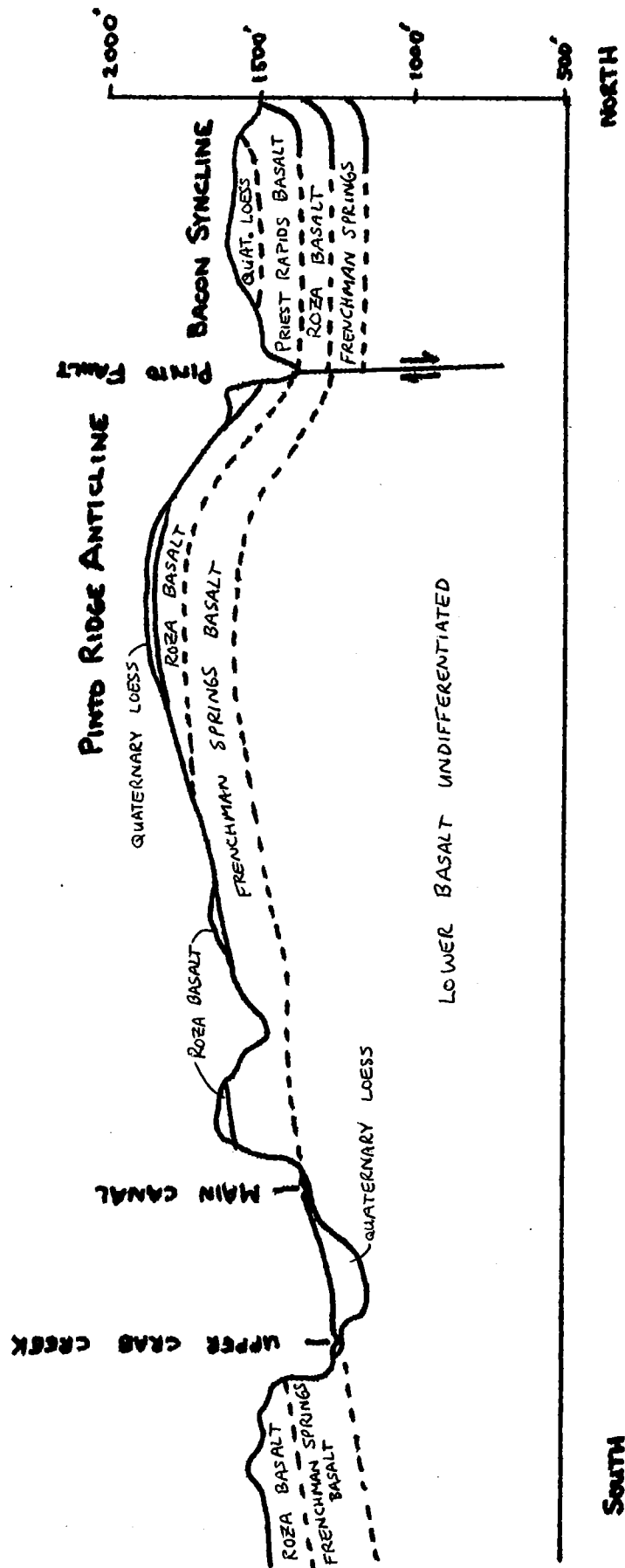
Lake. Continuing on, State Highway 155 heads down one of nature's greatest wonders, the Grand Coulee of the Columbia. The Grand Coulee is made up of the 25-mile long Upper Coulee and the 17-mile long Lower Coulee. The two coulees are separated by the Hartline Monoclinial Basin. Mesozoic basalts cap metamorphics to form the south rim of the Columbia River Canyon. Rising 900 feet above the highway, the Upper Coulee is cut by numerous floodwater tributaries entering from both sides.

At the southern end of the Upper Coulee, the Coulee Monocline carries the basalt beneath the Hartline Basin. When flood waters cascaded down the steep southeast-facing slope of the monocline, this fold was eroded upstream across the zone of broken rocks and into the higher, flat-lying basalt, forming the Upper Grand Coulee recessional gorge. Erosion and cataract retreat continued until the basalt flows at the head of the coulee were completely removed, exposing the granitic rocks that form the coulee floor and the foundations for Grand Coulee Dam today. The granite is tough, but, more importantly, it is not jointed like the basalt and therefore could not be plucked and removed by the flood. But erosion did lower the divide between the Columbia and the coulee to a point where the falls essentially destroyed itself. This is where the city of Grand Coulee sits today.

The cliffs of the Upper Grand Coulee disappear at its southern end as the monocline dips beneath the Quincy Basin. Here the gradient was close to zero, and the flood waters produced the classic scabland features as they spread out on the broader surface.

The scabland features leave the basin at Dry Falls. The ancient falls stand 400 feet high and nearly $3\frac{1}{2}$ miles wide and mark the start of the

CRAB CREEK COULEE



SCALE OF MILES



VERTICAL EXAGGERATION X 10

Figure 4

Lower Coulee which, unlike the Upper Coulee, has pre-glacial hanging tributary valleys along its entire west side but practically none on its east side. Gravel outwash deposits plug the southern end of the Lower Coulee. Still further to the south and southwest, immense quantities of sand and gravel fill the Quincy Basin. Considering the huge volume of rock which was scoured out to form the Grand Coulee, the area required for deposition of the resulting sediments would have to be very large.

From the Lower Coulee the road heads toward the Pinto Ridge Anticline. This flexure is a typical upright fold in which four members of the Yakima Basalt Formation are exposed: the Priest Rapids, the Roza, the Frenchman Springs, and the Lower Undifferentiated Basalts. To the north of Pinto Ridge is the Bacon Syncline. This counter-flexure is separated from the Pinto Anticline by the Pinto Fault. Quaternary age loess covers parts of both the anticline and the syncline.

As one continues south on State Highway 155, Crab Creek Coulee becomes visible. This coulee was formed by outwash from the receding glacier. The Main Canal also flows down this coulee from the Billy Clapp Lake Reservoir (formerly Long Lake Reservoir). Flow in the canal is controlled by Pinto Dam on the southern end of Billy Clapp Lake.

Returning to Highway 28, the road approaches Soap Lake. Approximately two miles before Soap Lake, the highway passes through a small, isolated patch of the Frenchman Springs Basalt. This outcrop is one of the small areas of this member not covered by outwash materials. The Priest Rapids and Roza Members of the Yakima Basalt Formation have been eroded away in most of this area and, in some places, even the Frenchman Springs Member is gone.

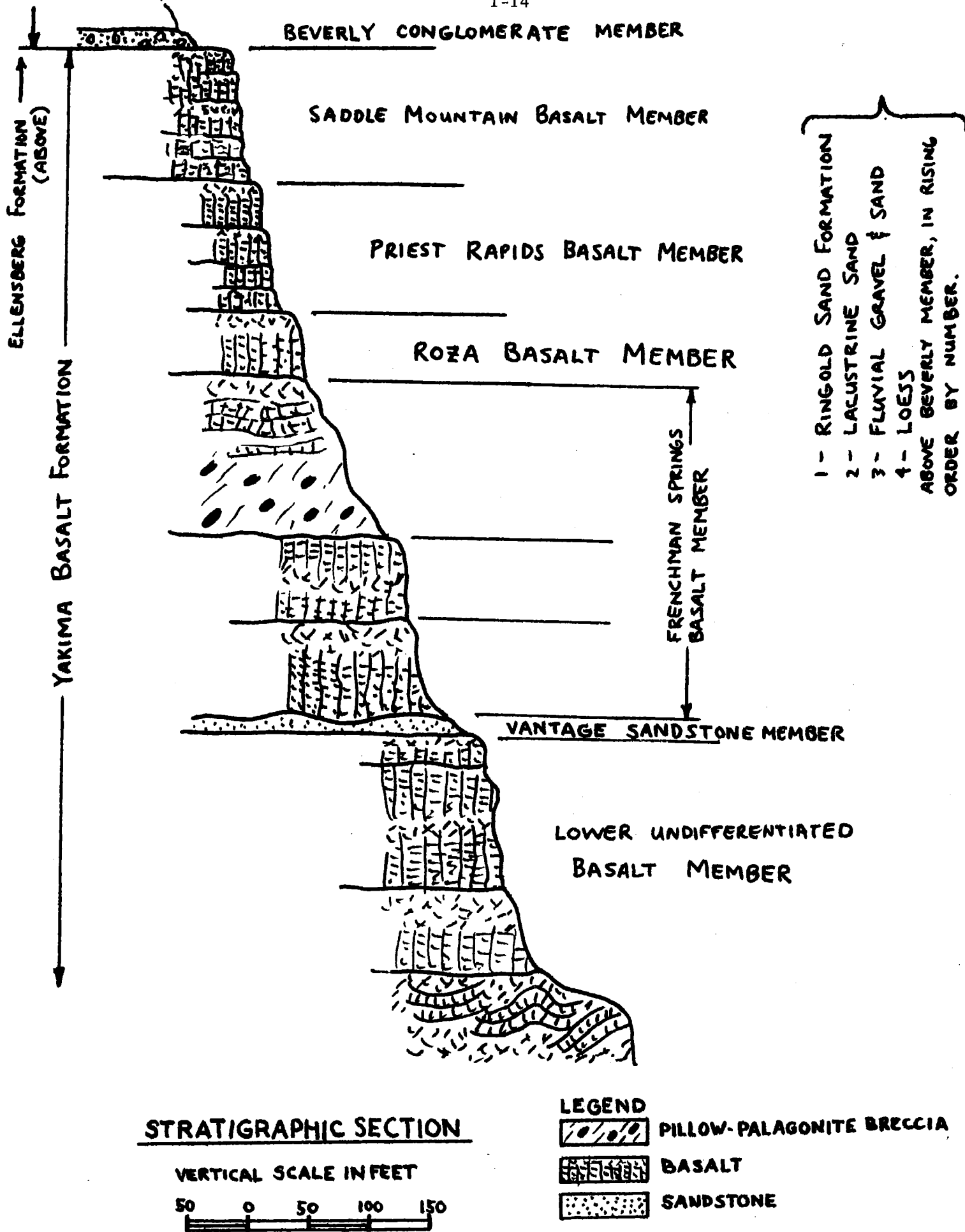


Figure 5

South from the town of Quincy lies the Quincy Basin. This low-lying area is covered with fluvial and lacustrine sands and gravels. Most of these materials are of basaltic origin, but some are composed of igneous and metamorphic debris carried down from the northern area of Washington by the glacial ice. Ice-rafted erratics ranging in size from boulders to granules occur frequently.

To the south lies the Frenchman Hills Anticline. This fold involves the lower five members of the Yakima Basalt Formation: the Priest Rapids Basalt, the Roza Member, the Frenchman Springs Basalt, the Vantage Sandstone, and the Lower Undifferentiated Basalt. The Saddle Mountain Basalt and the Beverly Conglomerate Members have been eroded away on the anticline itself but appear in the lower limbs to the south. Ringold sands and silts (Ellensburg Formation) cover the basalts in this area except in the exposed areas of the anticline. Quaternary loess caps the top of the fold and is thicker on the north or leeward side of the hills than on the southern windward side. The West Canal flows eastward along the northern margin of the anticline. When reaching the limb of the fold, the canal is diverted south through the Frenchman Hills Tunnel. This 1.9-mile tunnel passes through the Priest Rapids, Roza, and Frenchman Springs Basalt Members before emerging on the south side of the Frenchman Hills. Here, the canal bifurcates into a branch canal which heads southward toward the Saddle Mountain Anticline, with the continuation of the West Canal leading eastward.

To the south of the Frenchman Hills Anticline is the Saddle Mountain Anticline. The two folds are separated by a distance of about 11 miles. Lying in the low area between them is the Royal Slope which grades toward

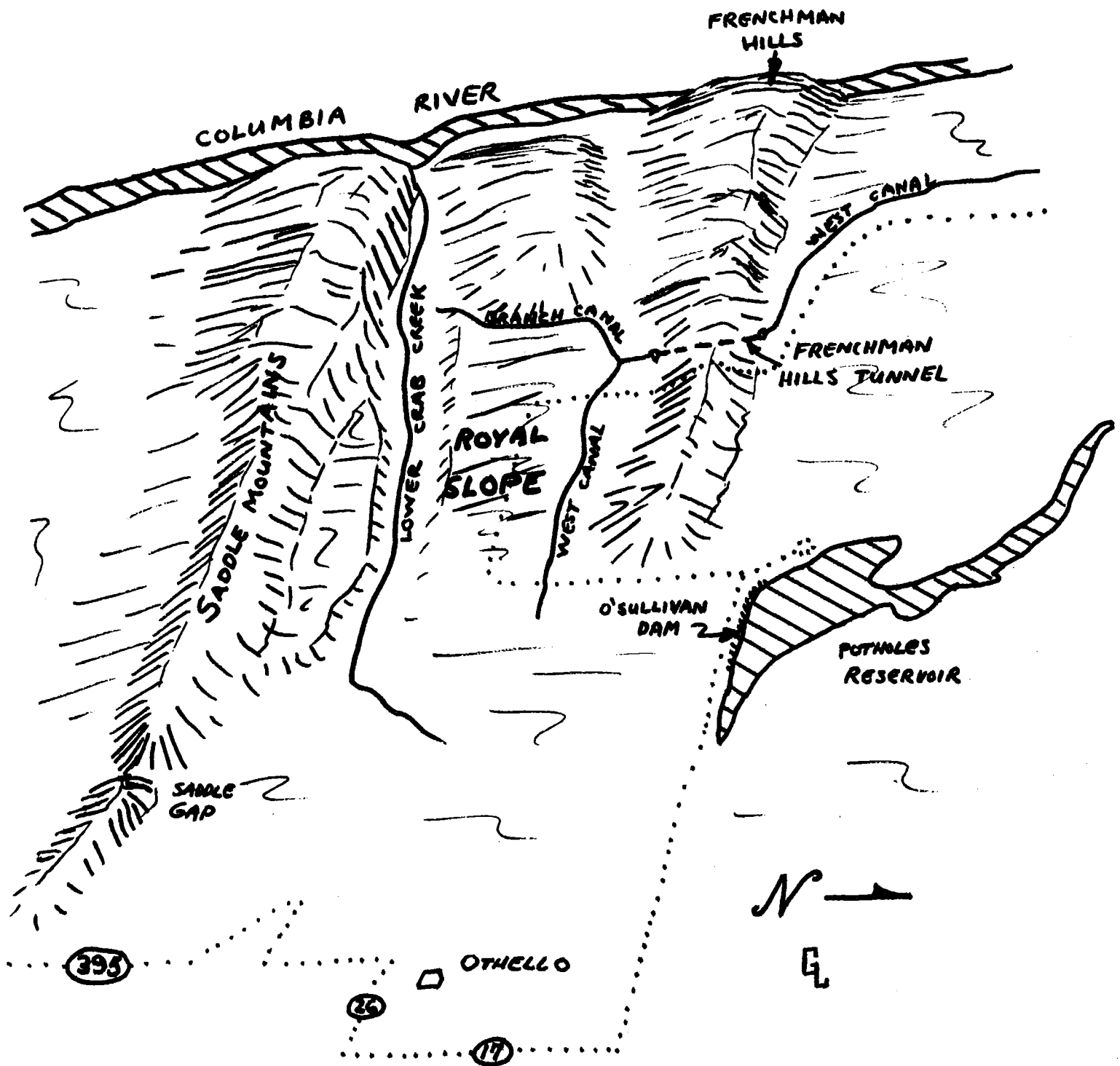


Figure 6

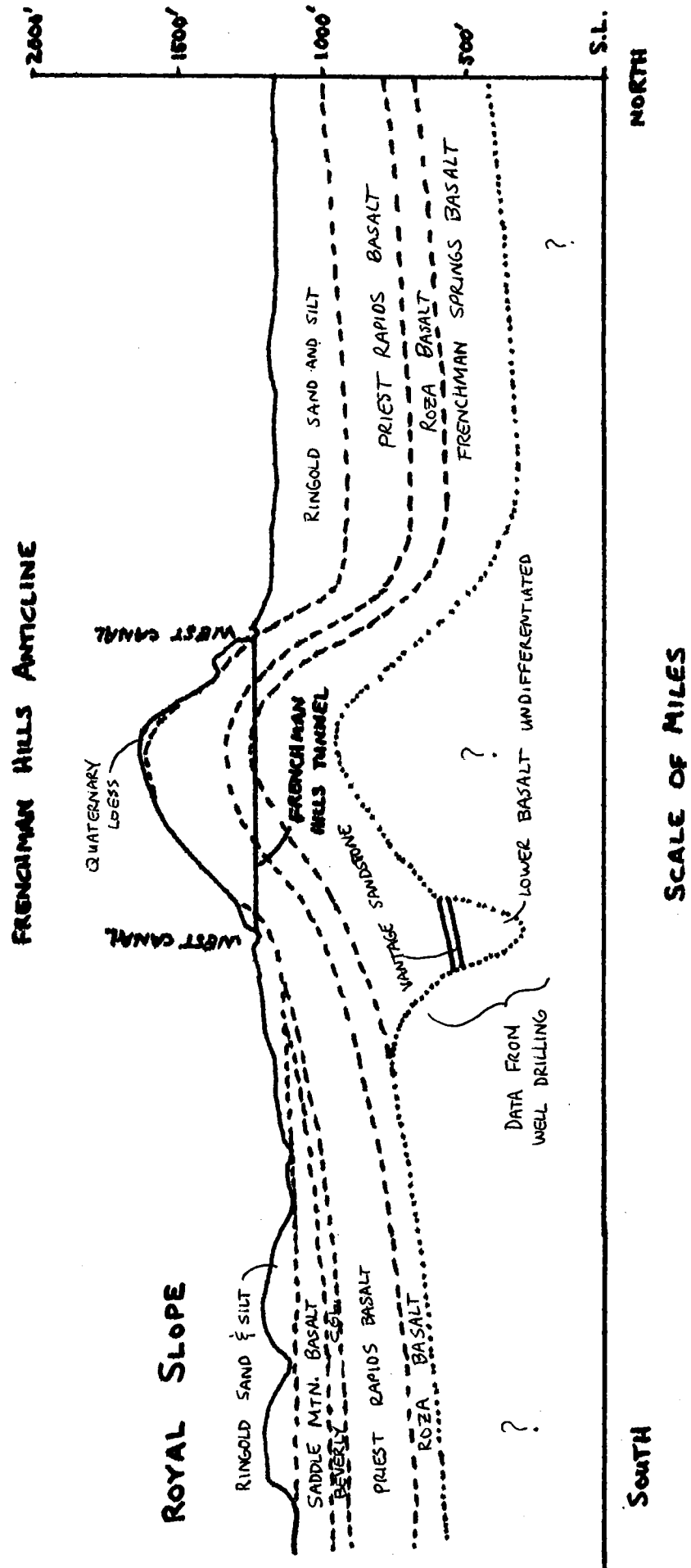
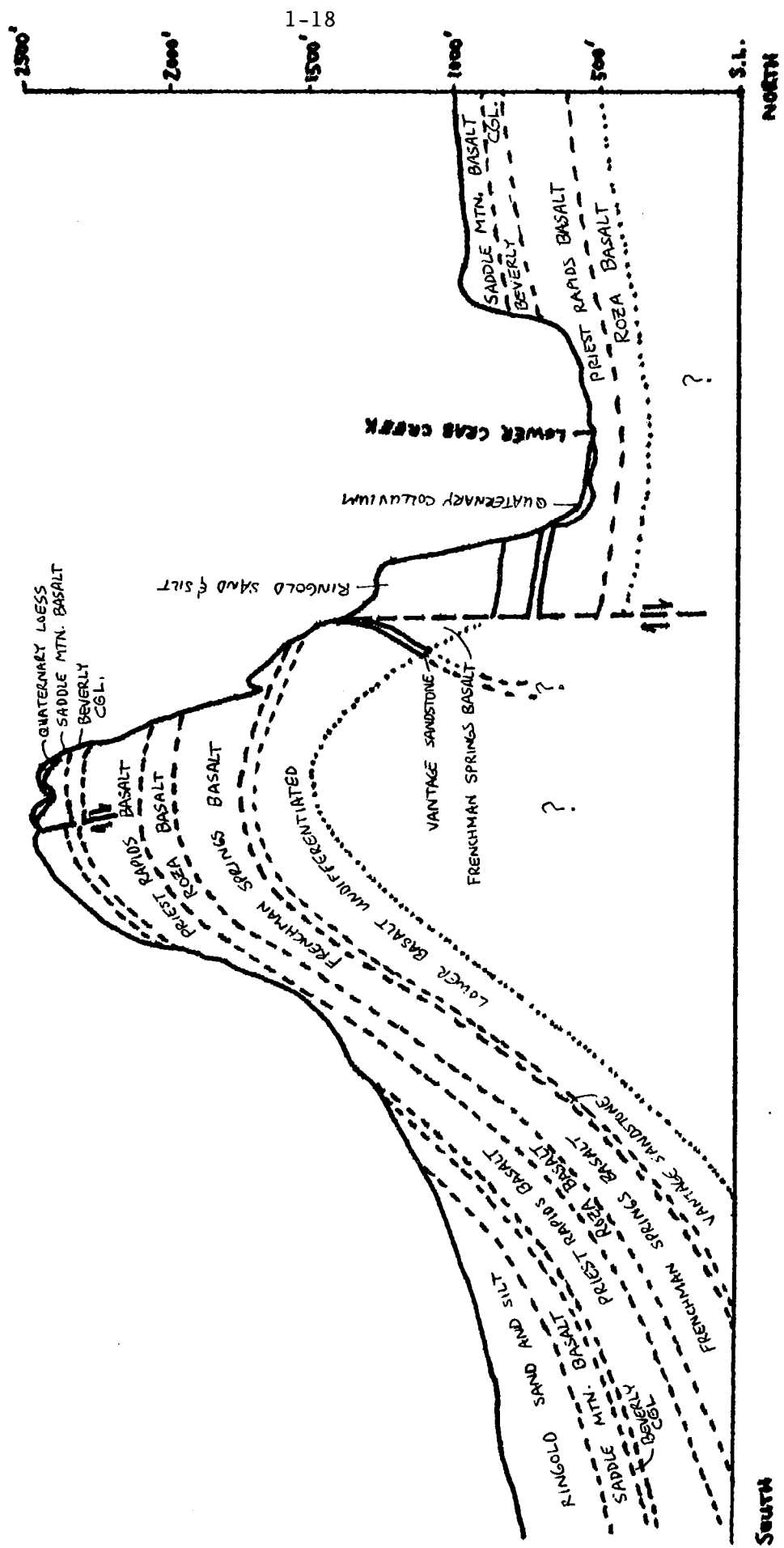


Figure 7

SADDLE MOUNTAIN ANTICLINE



Scale of Miles



Figure 8

Frenchman Hills. The Saddle Mountain fold involves all members shown on the stratigraphic section. Evidence from well logs indicates that the Saddle Mountain Anticline is an overturned fold. The section drawn through the fold shows the Vantage Sandstone Member overturned on the north limb. Dip angles of the beds also indicate an overturned condition. Midway down the northern limb, a dip-slip fault follows the hinge of the anticline. It has been speculated that this fault trends eastward from the Columbia River for a distance of 25 miles. Ringold sands and silts cover the low-lying areas but, like the Frenchman Hills, have been lost to erosion on the slopes.

Continuing toward the Potholes Reservoir, the road passes over Quaternary lacustrine clays, silts, and fine sands. Some loess is encountered as the road approaches Potholes State Park; however, the park itself lies on lacustrine deposits. O'Sullivan Dam on the southern end of the Potholes Reservoir is built on the Priest Rapids and Roza Basalts.

To the south of here lie the Drumheller Channels. At the east end of Frenchman Hills, the catastrophic flood crossed a 50-square mile area covered by a layer of weak sedimentary rocks called the Ringold Formation which was deposited during early Pleistocene time (2-3 million years ago). This part of the scablands is perhaps the most spectacularly eroded area of its size in the region. The erosional features can best be seen from the road that runs along the crest of O'Sullivan Dam. South of the dam is a wild jumble of cliffs, depressions, ponds, and remnants of lava flows. Local relief is from 150 to 200 feet.

All of the scabland rivers lead into the Pasco Basin. The southwestern edge of this basin is marked by the Horse Heaven Hills, which was

an effective barrier to the escape of water except for a single outlet: the Wallula Gap. Because all flood waters had to pass through this narrow opening, a huge lake formed in the Pasco Basin and extended more than 100 miles upstream into the valley of the Snake River. At the location where Lewiston, Idaho, sits today, this lake was nearly 600 feet deep.

The Saddle Mountain Anticline is encountered again while heading toward Ringold. The road to Ringold leads down through the Ringold Coulee. This coulee was formed in the same manner as other coulees in Washington -- by glacial meltwaters. The sediments from this area to Pasco include the Ringold and lacustrine sands and silts. A few glacial gravel deposits are also found.

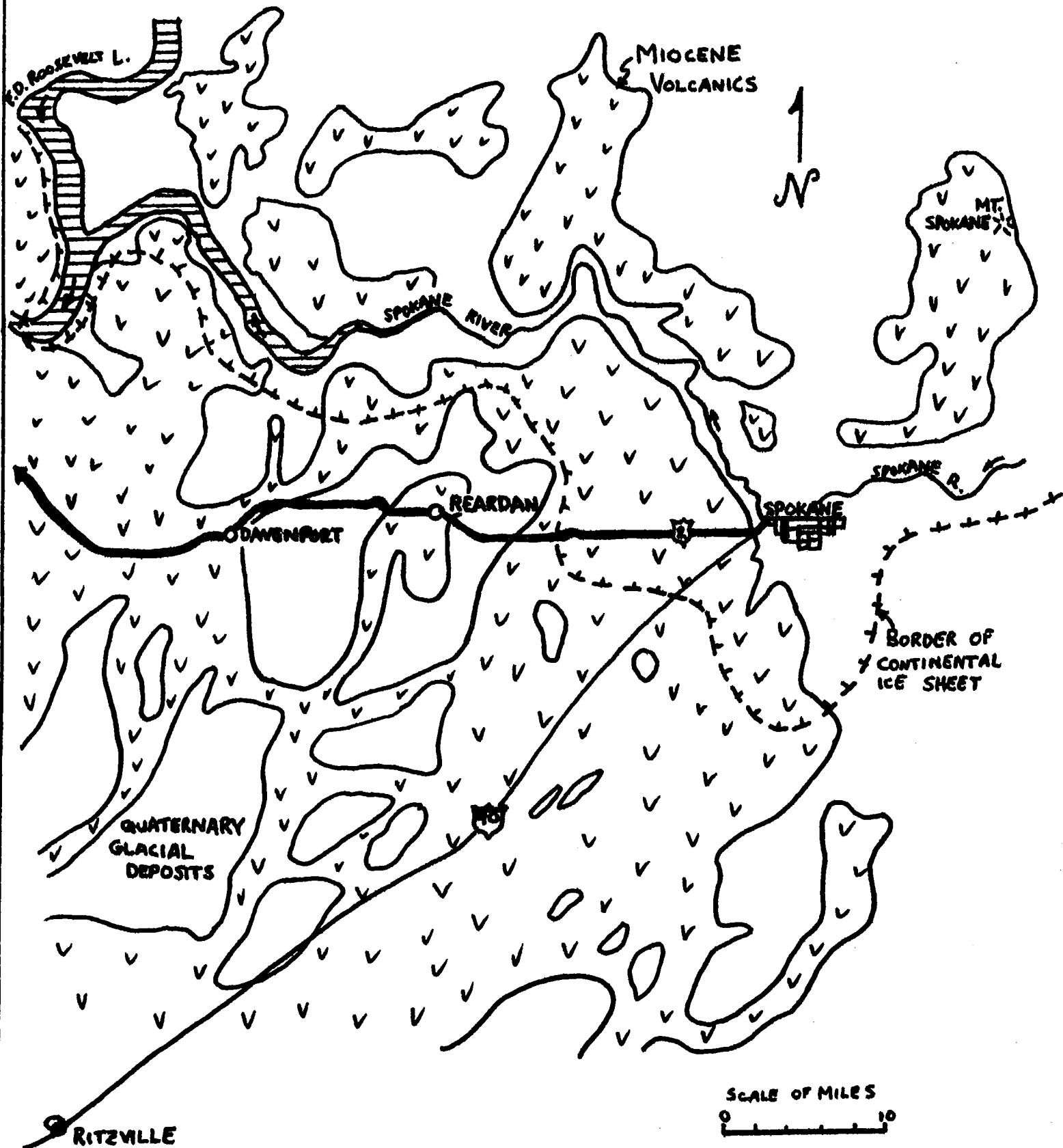


Figure 9

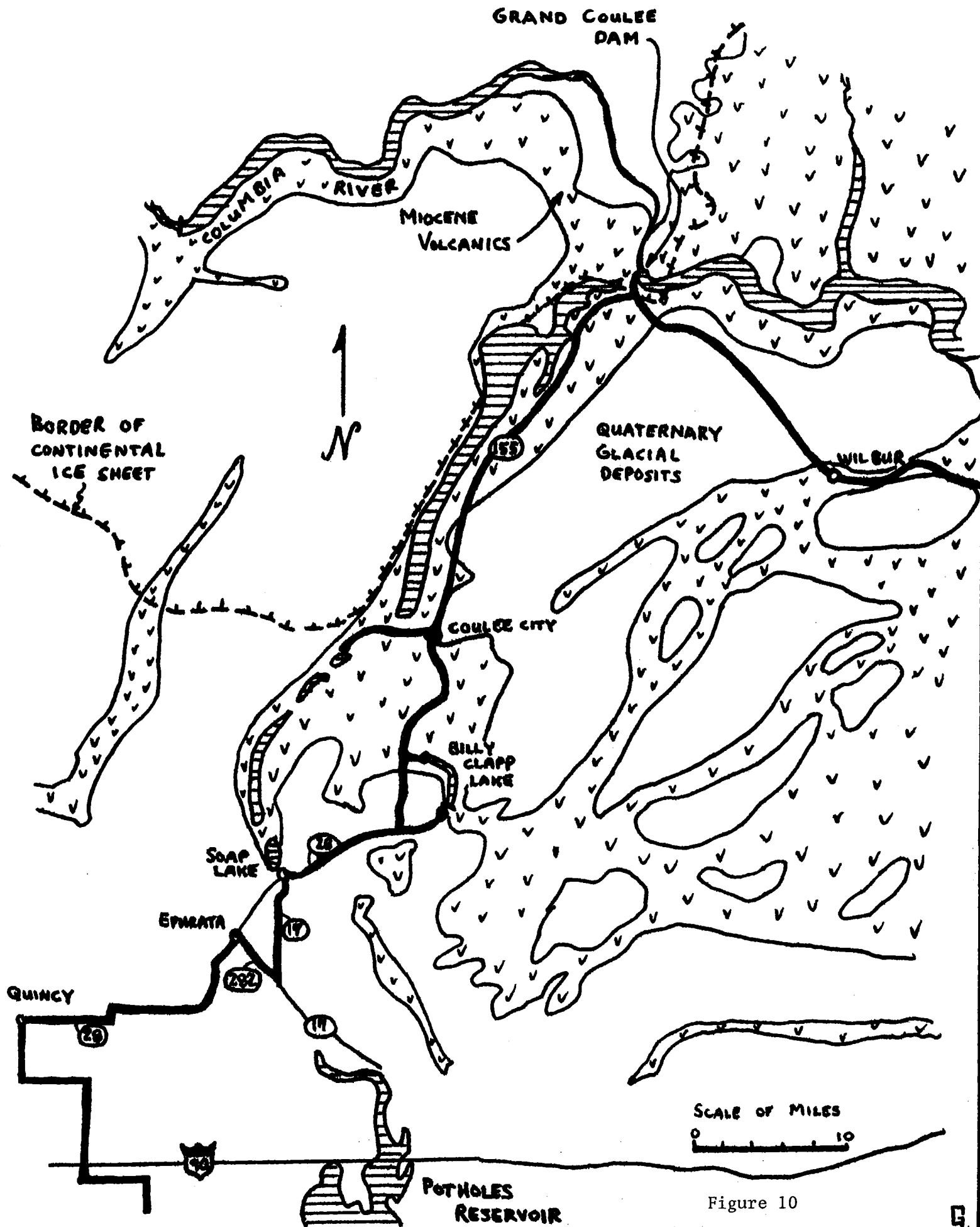


Figure 10

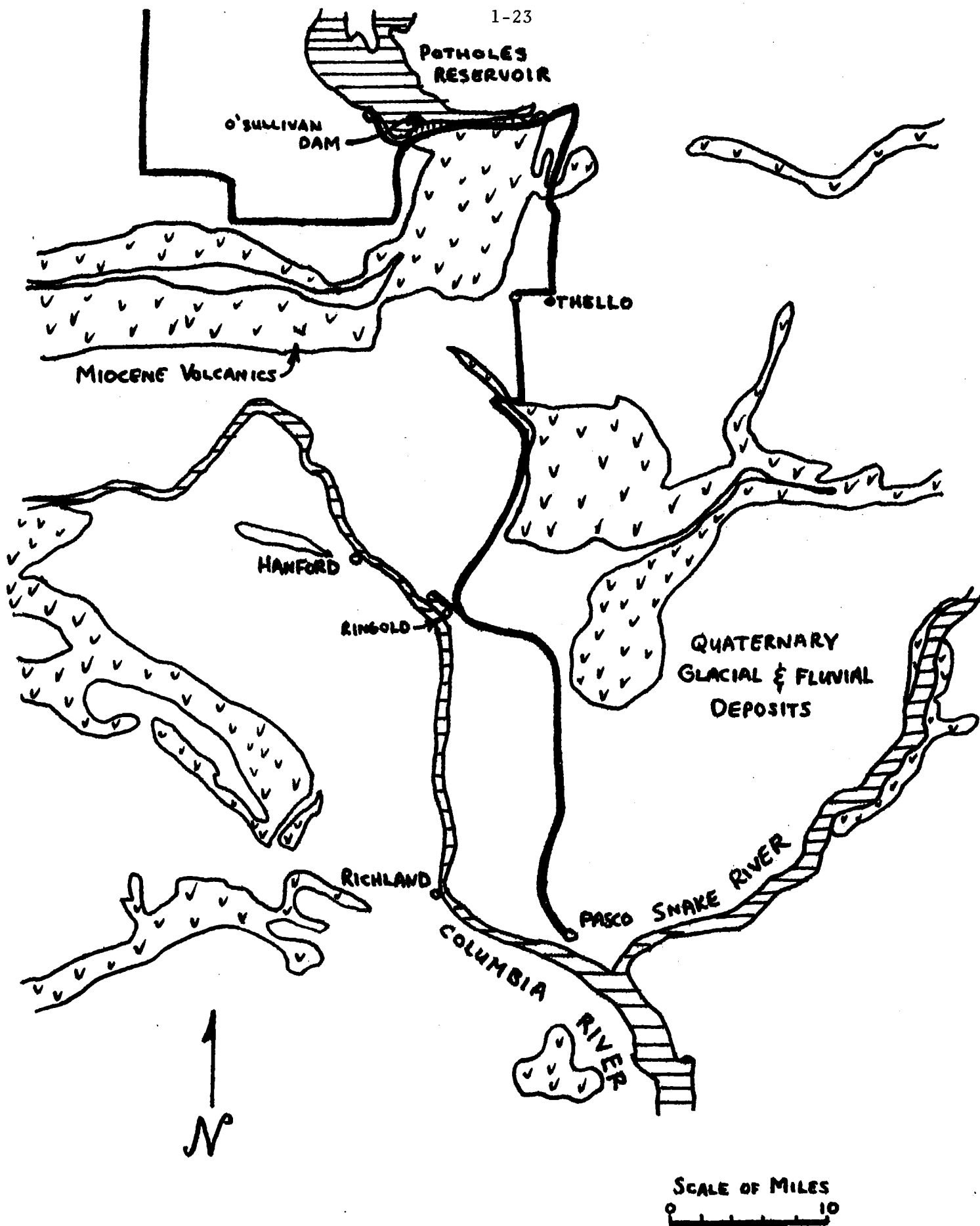


Figure 11

Second Day

(See Figure 1 for scheduled stops)

Mileage

- 0.0 Begin mileage at the Red Lion Motor Lodge in Pasco, Washington. Head southwest on US 12.
- 1.5 Cross bridge over Columbia River, stay on US 12 heading west to Richland, Washington.
- 8.5 Take State Highway 240 into Richland and proceed north on George Washington Way.
- 16.5 Turn left at Battelle's Pacific Northwest Laboratories, park vehicles in northwest parking lot.
- STOP 2-1. Dennis B. Cearlock, Manager, Water and Land Resources Department will host a tour of Battelle's Research Laboratory for modeling regional hydrological systems. A section of this laboratory is shown in Figure 2.
- 18.0 Return to vehicles and head north on Stevens Drive to 300 Area entrance to Hanford Reservation. Meet security patrol car and proceed north to Washington Public Power Supply System reactor construction sites.
- 25.0 Park vehicles as directed by security officer.
- STOP 2-2. David D. Tillson, Geological Engineer, for Washington Public Power Supply System will host a tour of the three nuclear power plants under construction at this site. Figure 3.
- Return to vehicles. Proceed north under security escort to the 100-N Area.
- 51.5 Enter 100-N Area and park as directed by security escort.
- STOP 2-3. Mr. Lynn A. Watson, Public Relations Manager, United Nuclear Industries, Inc., will host a tour of the reactor area. The discussion will be oriented toward the reactor operating systems and their relation to geological and hydrological engineering. Figure 4.
- 62.7 Return to vehicles and proceed under security escort to the Redox Separations Plant in the 200-West Area.
- Park vehicles as directed by security officer.

200-WEST
STOP 4

N REACTOR
STOP 3

AQUACULTURE
STOP 5



WNP 1
STOP 2

RINGOLD
STOP 6



BNW
STOP 1

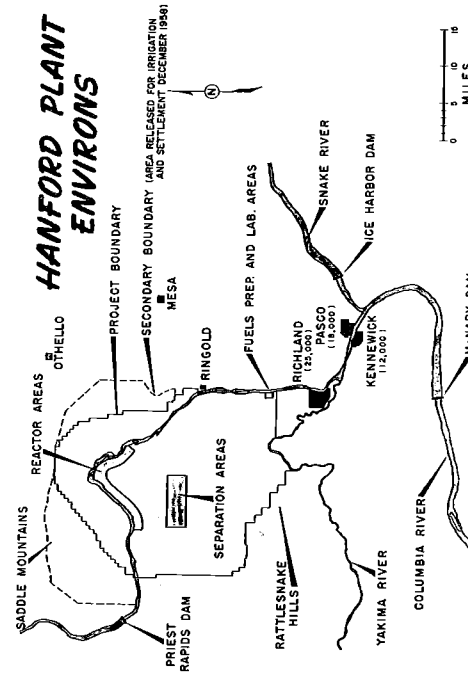


Figure 1

Location Of Stops In The Energy Research & Development Administration's Hanford Plant Environs

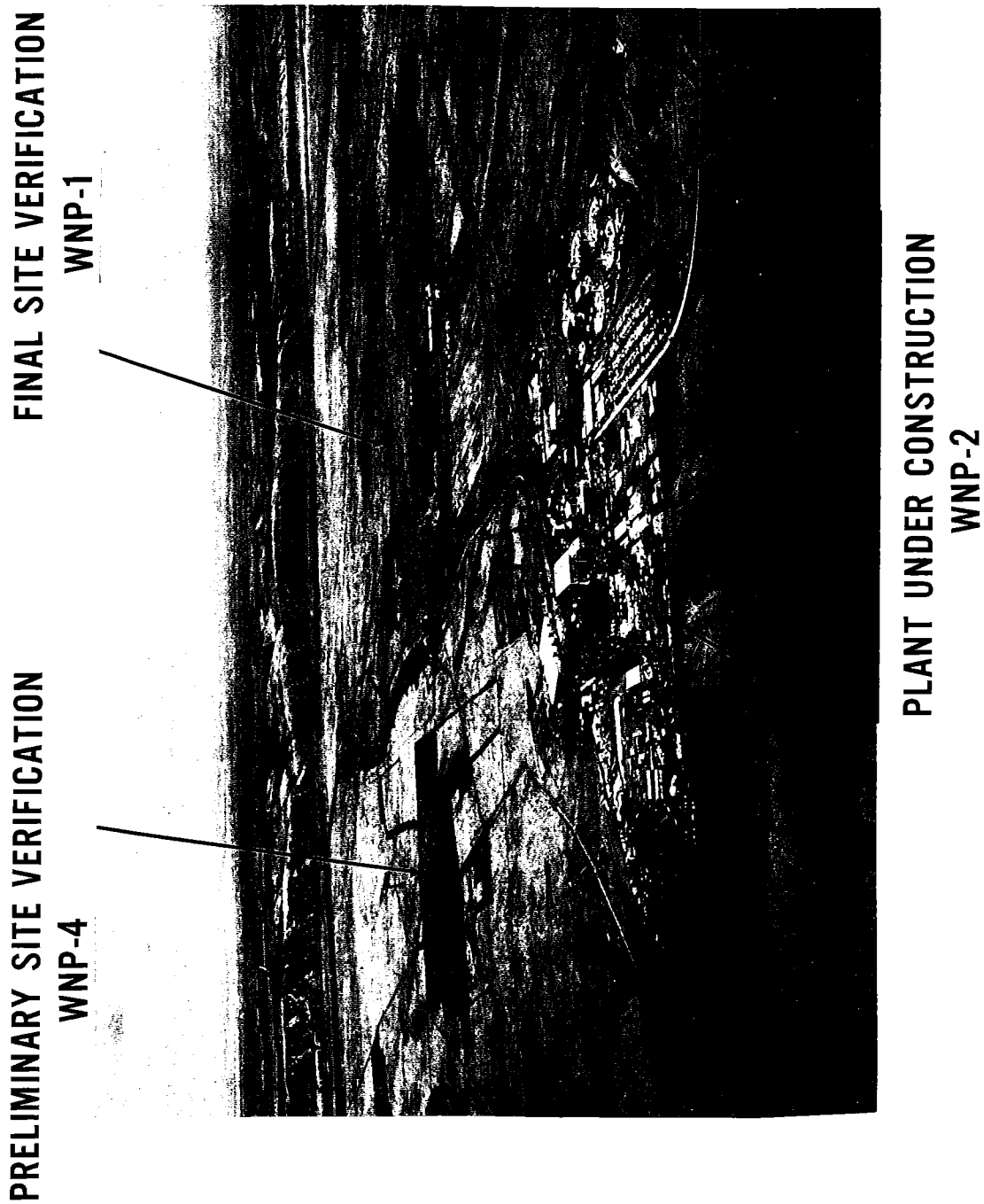


Figure 3
Washington Public Power Supply System Nuclear Power Plant Construction Sites



Figure 5
Aquaculture Business Which Utilizes Thermally Warm Artesian Water To Raise Tropical Fish

GEOLOGIC SETTING

The Pasco Basin is underlain by three principal rock types: dense, hard basalt (Columbia River Basalt) which forms the bedrock beneath the area; semi-consolidated lake and stream sediments (Ringold Formation) directly overlying the bedrock; and unconsolidated sands, silts and gravels (Glaciofluvial) carried into the area by glacial flood waters during the close of the Ice Age.

Figure 7 contains a diagrammatic cross section constructed through a portion of the Hanford Reservation and identifies the general stratigraphic position of these three main rocks. Also shown in Figure 7 are photographs of typical exposures of these sedimentary deposits commonly observed in the Pasco Basin.

Deep exploratory drilling by the Standard Oil Company of California has shown the basalt flows in the Pasco Basin have accumulated to a thickness of over 10,655 feet. In 1968 the Atlantic Richfield Hanford Company, in behalf of the U. S. Energy Research and Development Administration, cored several holes in the basalt near the center of the basin. A cross section is shown in Figure 8 summarizing the correlations made between core holes and the data from the nearby canyon sections. The marker flows (highlighted in a darker shade of grey) were identified on the basis of their unique chemical properties.

Intercalated between many of the basalt flows are extensive deposits of volcanic ash, tuffs, sands, silts and clays.

Most of the ridges and hills in the Pasco Basin are asymmetrical in shape. The anticlines have gently sloping south limbs and steeply dipping north limbs. Figure 8 shows a picture of the Yakima Basalt on the south flank of Saddle Mountain. These beds dip about 30 degrees to the south. The north limb of Saddle Mountain dips 75 to 85 degrees to the north.

The sedimentary rocks of the Ringold Formation are conformable with the surface of the underlying bedrock. These sediments can be differentiated into three distinct units; the lower blue clay zone, the middle silt and gravel zone and the upper silt zone. Along the 50 mile stretch of the Columbia River upstream from the 300 Area, the upper silt zone of the Ringold Formation is exposed. Because of the light buff colored characteristic of these silts the term "White Bluffs" has come into common usage, see Figure 7.

Directly overlying the Ringold Formation are the unconsolidated glacial-outwash sands, silts and gravels, see Figure 7. The coarser sediments are locally referred to as the Pasco Gravels and the finer-grained sediments are called Touchet Sediments.

GEOLOGIC HISTORY

Between 20 and 40 million years ago the site of the Pasco Basin was situated in or near the center of a regional topographic low area; analogous

Following the last flood, about 8,000 years ago, the ground surface in the Pasco Basin was further modified by the prevailing strong southwesterly winds. These winds have been tied to the jet stream (200 mile an hour winds above 50,000 feet) which cross the State of Washington between Richland and Spokane. It is not uncommon to record 50 mile per hour winds on the Hanford Reservation today. Figure 12 shows two types of dunes found on the Hanford Reservation and which are common to the Pasco Basin.

Figure 13, shows some of the methods used to drill wells in the Pasco Basin. Rotary drilling techniques were not used extensively in the past because of the difficulty encountered in drilling through the unconsolidated sands and gravels. Many of the wells drilled in the past were for domestic water supplies and large volumes of water could be obtained from the Pasco Gravels without need to drill into the basalts. In time, many farmers began building homes higher on the ridges and upland areas to raise winter wheat. Drilling wells several thousand feet into basalt for water was expensive and time consuming. With the advent of tungsten-carbide insert bits and air rotary technology, drilling basalt rock to great depth for water became more economical. Today, there are more than 80 wells over 1000 feet deep in the Pasco Basin.

The block diagrams in Figure 14 were constructed to depict the possible sequence of events that occurred in the Pasco Basin 18,000 years ago when the catastrophic flood occurred.

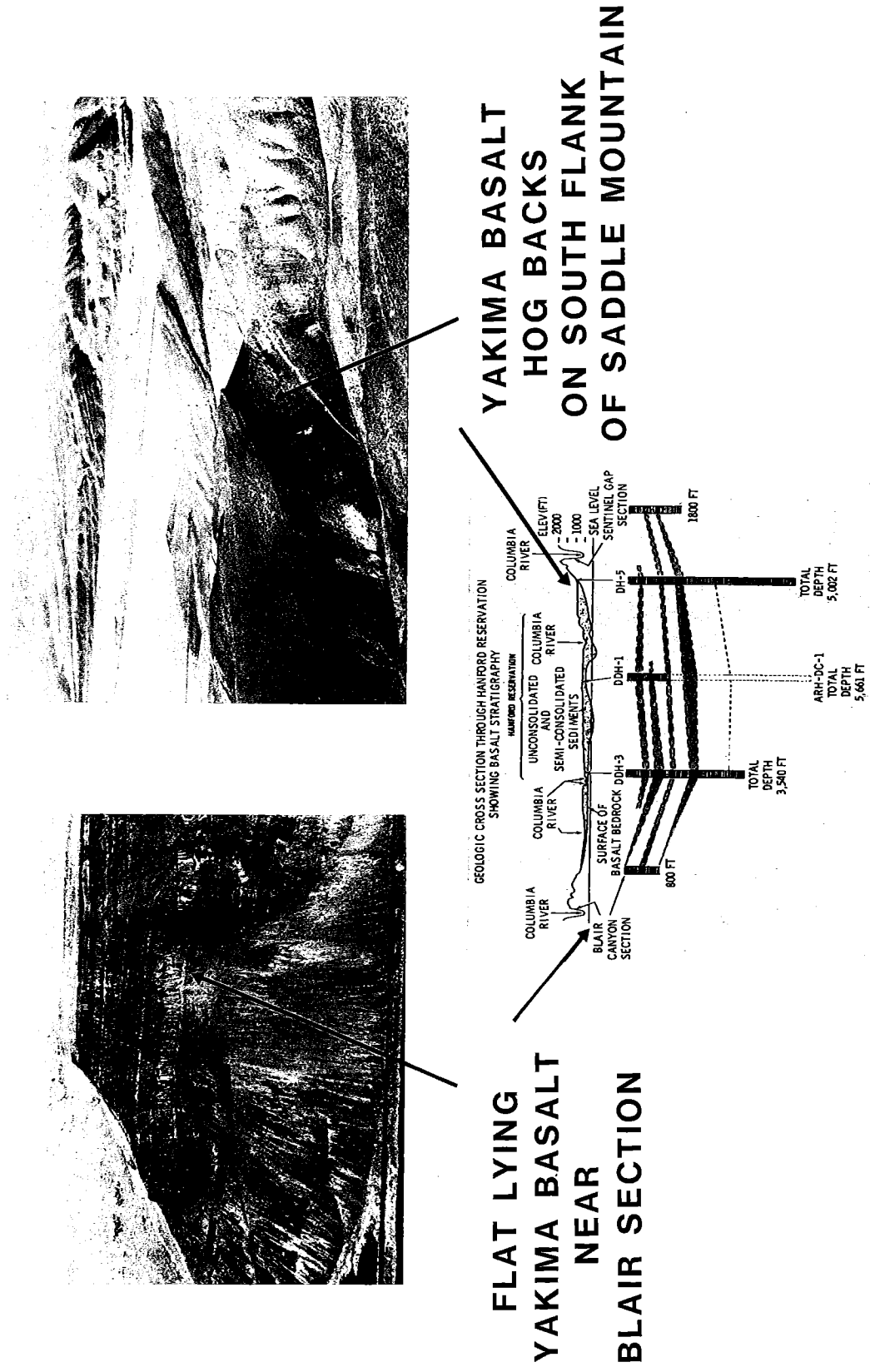
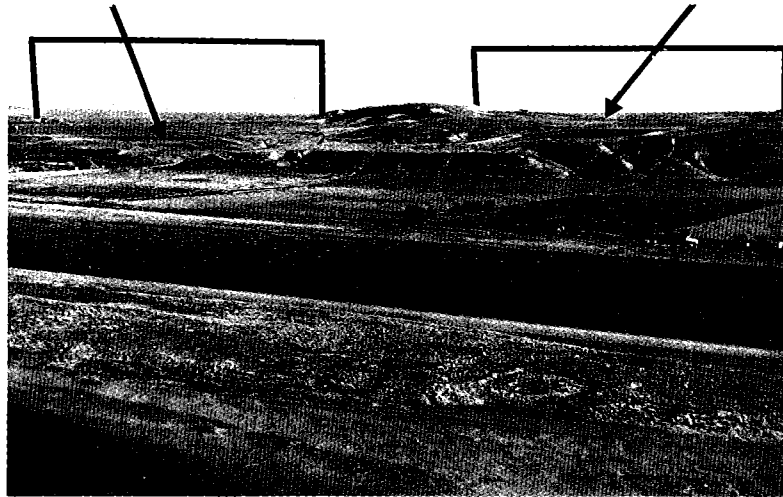


Figure 8
General Structure Of The Yakima Basalts In The Pasco Basin

RINGOLD COULEE

KOONTZ COULEE



WAVE CUT BENCH

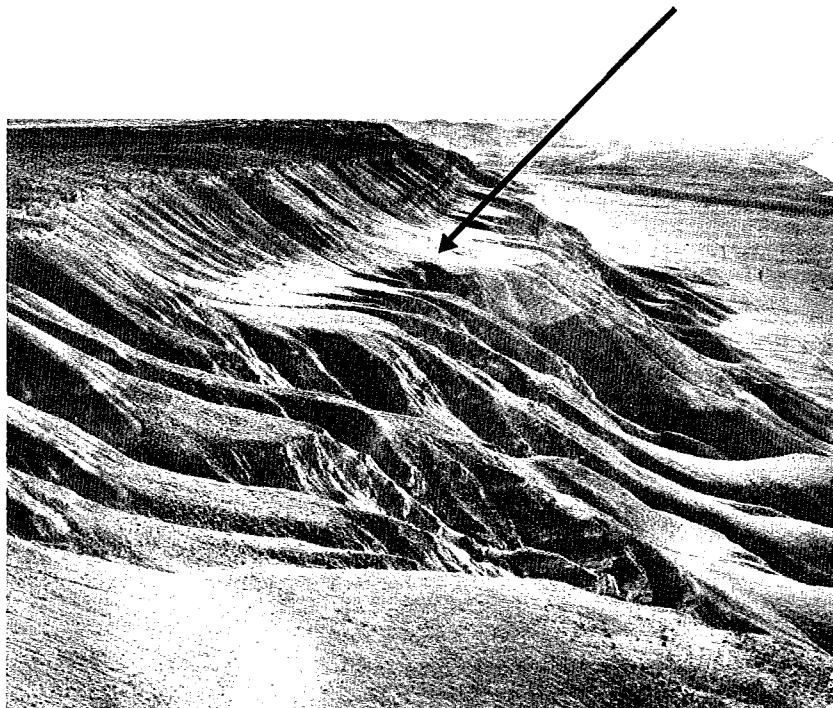


Figure 10

Flood Water Erosional Features Produced In The Ringold Formation



STABILIZED DUNES



ACTIVE DUNES

Figure 12

Depositional Features Related To Past And Present Wind Erosion

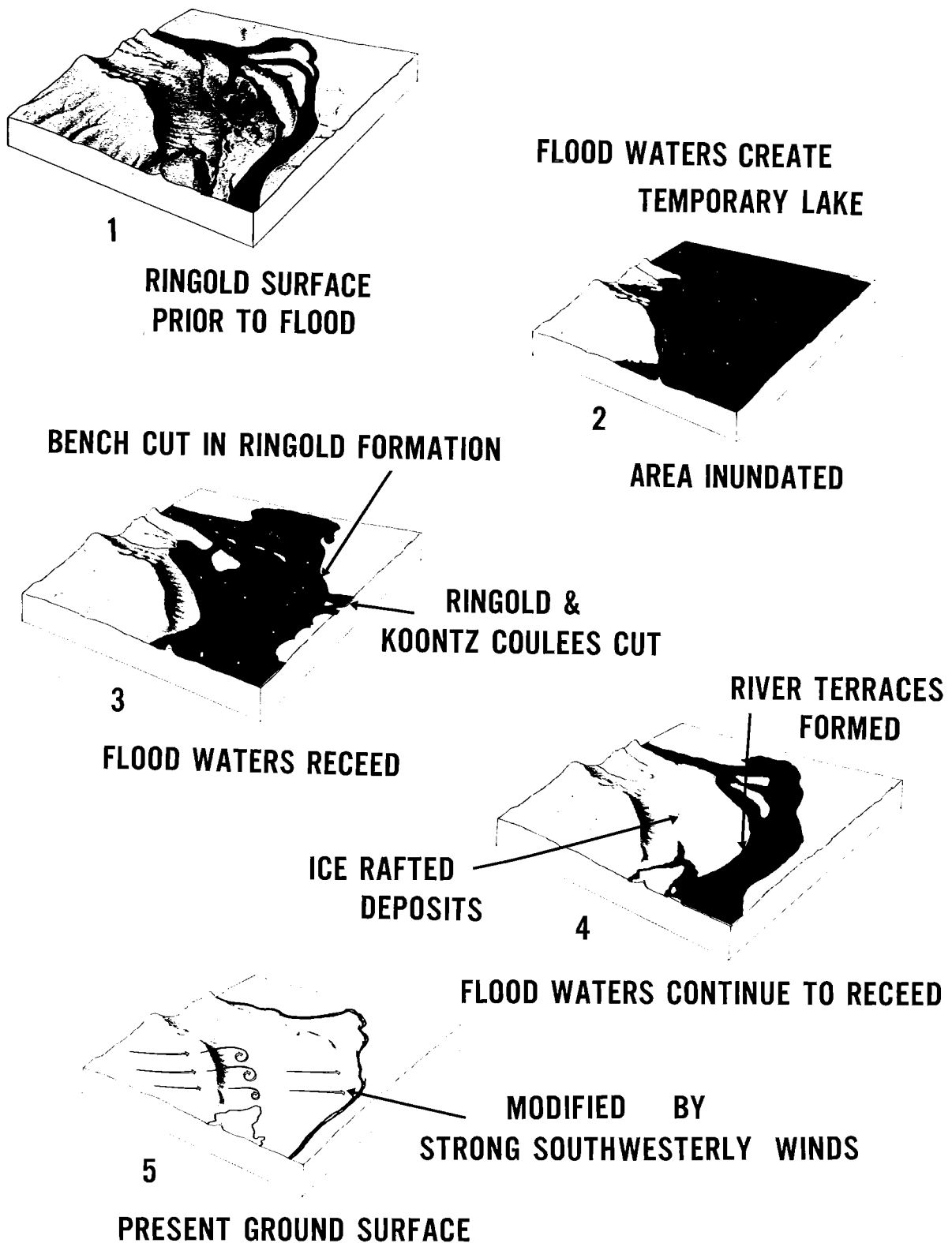


Figure 14

Block Diagrams Depicting Possible Sequence Of Events In Pasco Basin
Near Close Of Ice Age

- 114.5 Return to Ringold. Proceed toward Pasco.
- 122.5 Turn left onto Eltopia West Road toward Eltopia.
- 126.5 Eltopia. Turn left onto Highway 395.
- 140.5 Turn right onto Highway 260 (two or three miles south
of Connell) toward Kahlotus.
- 156.5 Kahlotus. Continue east toward Washtucna.
- 168.5 Washtucna. Turn right at far end of town onto
Highway 26 toward Colfax.
- 220.5 Colfax. Proceed south through Colfax. Turn left
at south end of town (prior to the hill) toward
Pullman on Highway 195.
- 238.5 Arrive at Pullman. End of second day.