DFoley

GEOLOGIC INTERPRETATION OF THE GEOTHERMAL POTENTIAL OF THE NORTH BONNEVILLE AREA

by

D. L. Nielson

M. R. Moran

EARTH SCIENCE LABORATORY

University of Utah Research Institute

Salt Lake City, Utah

Prepared for

U.S. Department of Energy

Division of Geothermal Energy

UNIVERSITY OF UTAH RESEARCH INSTITUTE
UURI
EARTH SCIENCE LABORATORY
420 CHIPETA WAY, SUITE 120
SALT LAKE CITY, UTAH 84108
TELEPHONE 801-581-5283

February 15, 1980

Mr. Pollard Dickson
Planning Director
City of North Bonneville
North Bonneville, WA 98639

Dear Mr. Dickson:

This letter will serve as a final report for the geothermal evaluation of the North Bonneville area which was funded by the Department of Energy's User Assistance Program. Included is the report and geologic map completed by our consultant Michael R. Moran. He has done a very good job of defining the geology of the area.

As part of this study we have used Mike Moran's report and recommendations in light of available water analyses and temperature gradients from the North Bonneville area. From this information we have developed a conceptual model of the geothermal system, and will propose an exploration program based on this model. We view this proposed program as the most efficient procedure for evaluating the geothermal potential of the N. Bonneville area. It is common to use electrical geophysical surveys for this type of exploration; however, we have not recommended these surveys because the hydroelectric plant and powerlines in the North Bonneville area will negate their usefulness.

Examination of Moffetts Hot Spring permits the evaluation of the geologic controls on the geothermal system. Moffetts is located along a strong northeast-trending linear feature. Poor exposures prevent actual examination of this feature, but geologic cross sections (Plate II) which I have drawn on the basis of Moran's mapping (Plate I) require displacements of up to 2000 feet along a reverse fault or zone of faults which I interpret as lying along the north side of the Columbia River Gorge. Several northwest-trending linear features intersect the northeast linear at Moffetts and it is thought that this intersection increases permeability along the structural zones so that thermal waters are able to migrate to the surface.

Evaluation of available chemical analyses of water from Moffetts Hot Springs indicates that about 85-90 percent of the water is cold groundwater with the remaining 10-15 percent being thermal waters. Thus it is thought that thermal waters are rising to the surface along fault zones and being diluted by fresh waters which are probably being supplied from subsurface flow through the Eagle Creek Formation as well as alluvial deposits and landslide debris. This process is sketched in Figure 1. Note in Figure 1 that some of the thermal fluids may also be lost through leakage into groundwater reservoirs as well as through mixing.

Subsequent geothermal exploration in the North Bonneville area should attempt to locate thermal fluids in structures beneath zones where these fluids are diluted by fresh waters or are lost to permeable aquifers. This can be most effectively accomplished by a program of intermediate-depth temperature gradient drilling. During the drilling program cuttings must be logged to refine the structural models presented here. The proposed hole locations are shown in Figure 2 and described below. The holes are located in geologically favorable areas which take into consideration proximity to

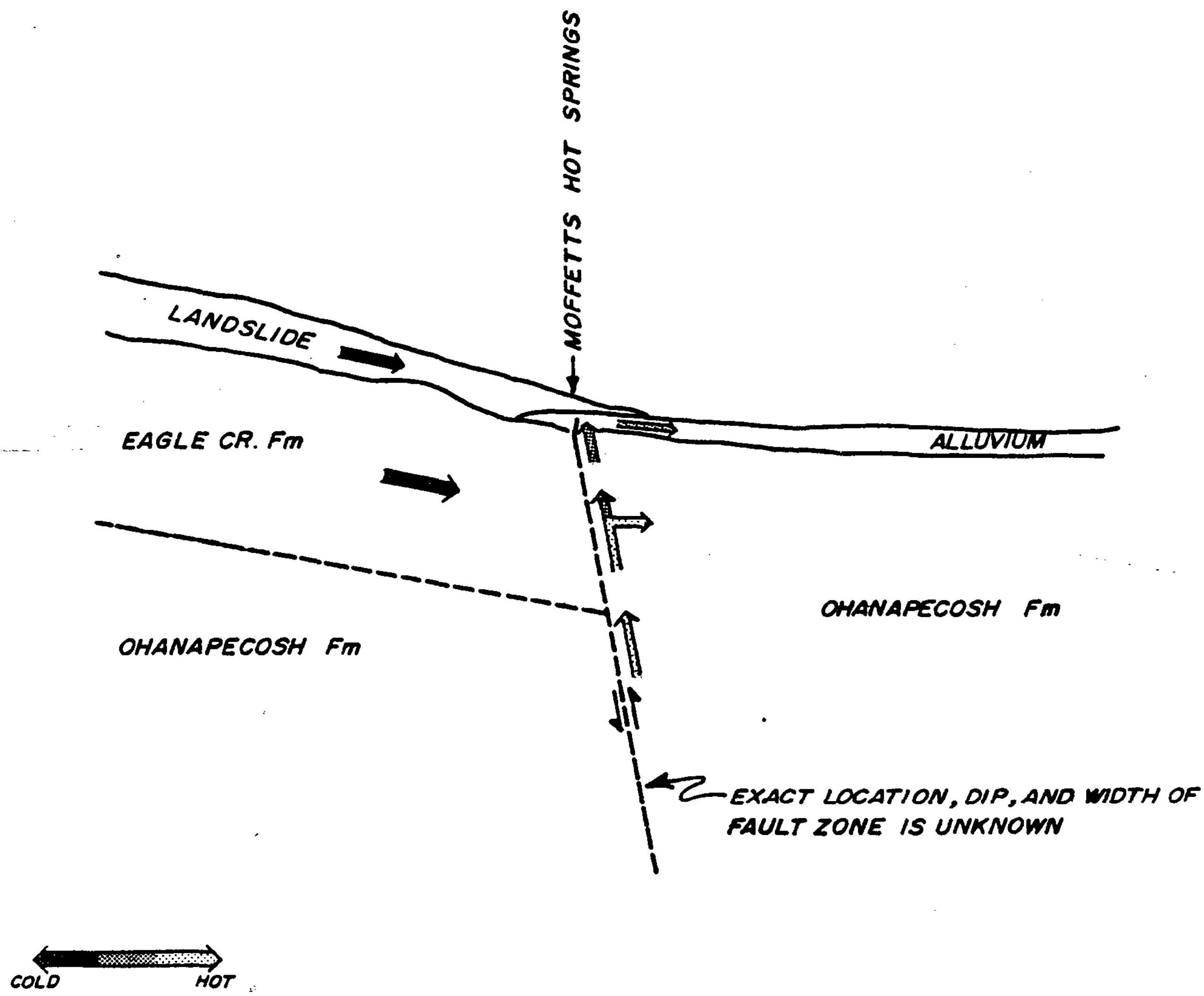


Figure 1 - Conceptual model of the geothermal system at Moffetts Hot Spring. Thermal waters rise along reverse fault and mix with cold groundwaters in Eagle Creek Formation and landslide debris. Diluted thermal waters leak to surface at Moffetts and are lost to groundwater flow in the alluvium and the Ohanapecosh Fm. Cross faults which are parallel or nearly parallel to the cross section may exist but are not shown.

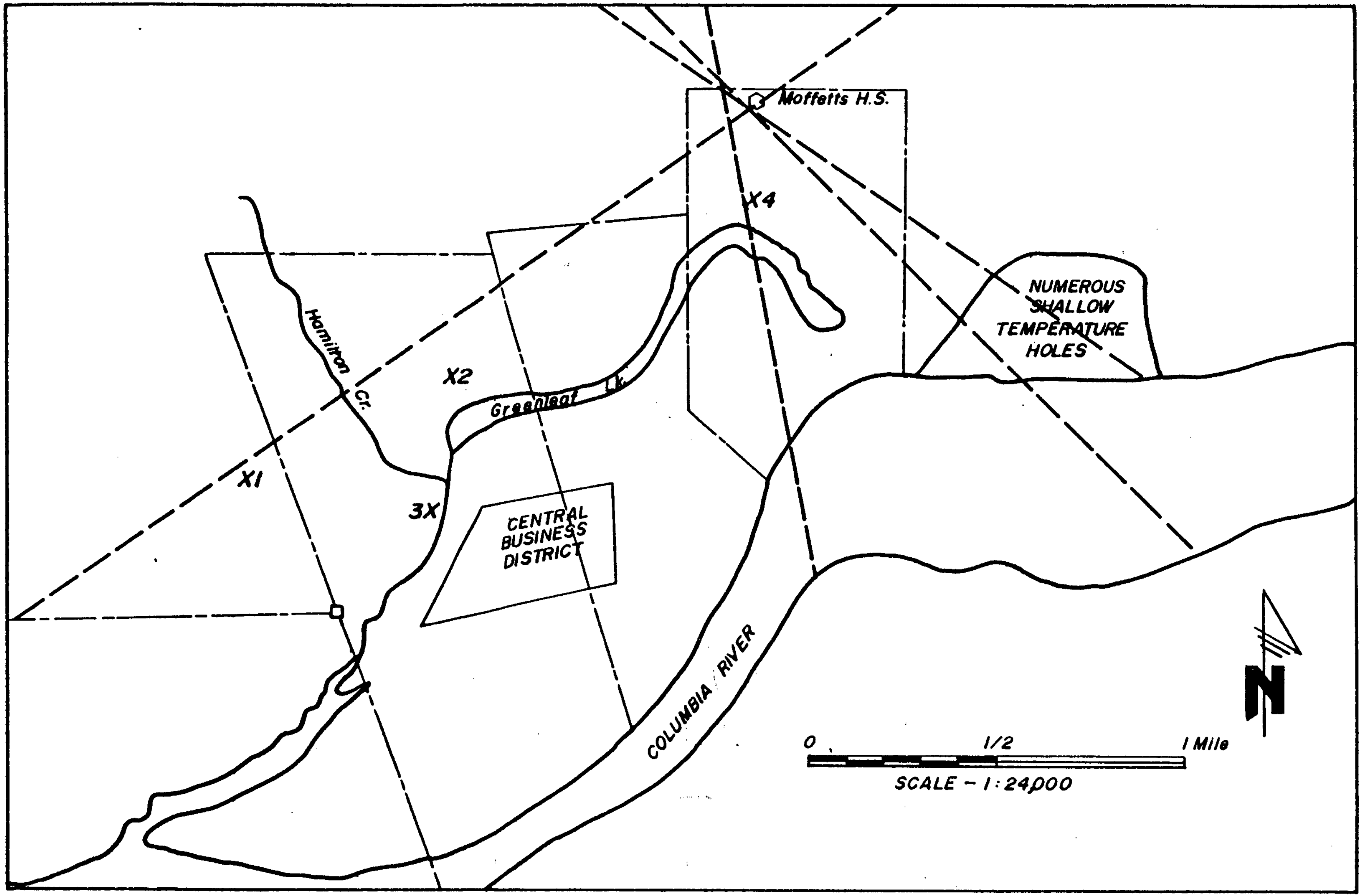


Figure 2 - Index map of N. Bonneville, Washington showing the locations of proposed thermal gradient holes.

proposed use. One of the principal purposes is to test the favorability of the main northeast-trending fault and determine its location and dip.

Site 1: The purpose of this hole is to test the favorability of the northeast-trending reverse fault or zone of faults. Geothermal waters found in this area could be used in the western portion of the city as well as the central business district. Proposed depth: 500 feet.

Site 2: Same purpose as hole #1. Proposed depth: 500 feet.

Site 3: The purpose of this hole is to test the favorability of the warm water source which was reported to exist prior to bridge reconstruction. This area is very close to the central business district which is the principal area of proposed use. Proposed depth: 500 feet.

Site 4: The purpose of this site is to test the geothermal potential along a zone of intersection of the northeast-trending reverse fault(s) and the Tanner Creek linear. As discussed previously, this intersection may be important in developing permeability along the fault zones which is required to transport appreciable quantities of thermal fluids. This hole may be located closer to Moffetts Hot Springs if desired. If this is done the exploration drilling may disrupt the flow of water at the resort. Proposed depth: 500 feet.

During this drilling program it is important that cuttings be collected at a minimum of ten-foot intervals. Careful logging of these cuttings will be important in updating the conceptual exploration model of the geothermal system. In addition to temperature logs, it would be advantageous to acquire SP, resistivity, and gamma logs of the holes. These are important in defining stratigraphy and structure as well as evaluating zones of fresh water and thermal water entries into the drill hole. In addition, fluid should be collected from the holes are regular intervals.

Data acquired during this test program should be synthesized and evaluated prior to the decision to site and drill a production hole.

Please do not hesitate to contact me if you have any questions about this program or the geothermal resource at North Bonneville.

Best regards,

Dennis L. Nielson

Dennis L. Nielson
Geologist/Project Manager

DLN:srm

cc: R. Bendixson, DOE
M. Korosec, WA-DNR
D. Struhsacker, ESL

GEOLOGIC INTERPRETATION OF THE GEOTHERMAL POTENTIAL OF THE NORTH BONNEVILLE AREA

REPORT TO:

Dennis L. Nielson
University of Utah Research Institute
Earth Science Laboratory
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

COMPILED BY:

Michael R. Moran
4121 N. E. 29th Avenue
Portland, Oregon 97211
(503) 287-7931

CONCLUSIONS:

Possible geothermal development for the township of North Bonneville, Washington is being investigated because of the proximity of the town to hot springs in a geologic province of good geothermal potential. Surface expression of geothermal resources is provided by conduits through an impermeable reservoir cap and is therefore generally structurally controlled.

Near North Bonneville the geologic formations that underlie potential drilling sites are the Eagle Creek Formation and the Ohanpecosh Formation. The Lower Miocene Eagle Creek Formation is composed of poorly consolidated volcanic conglomerates, sandstones, tuffs, and includes a few minor interbedded lava flows. The Eocene-Oligiocene Ohanapecosh (Weigle) Formation in its nearest exposures to North Bonneville is composed of volcaniclastics and lava flows. The Ohanapecosh has been altered to zeolites and clays and is therefore well consolidated and impermeable. The lack of permeability provides the necessary reservoir cap for any geothermal system that may be present at depth. This formation, to the northeast, in the Wind River drainage is greater than 19,000 ft. thick (Wise, 1970). Circulation of geothermally heated water from this thick sequence of impermeable strata must be associated with penetrating fracture zones.

Identifiable fractures and faults are lacking in the vicinity of interest primarily because large areas are covered either by landslides or alluvium. However, projection of lineations into the region and the alignment of geologic features provides some insight into the problem.

Intersecting lineations and the distribution of hot ground and hot springs suggest preliminary targets for gradient testing. Before a deep test hole is planned several gradient drill holes should be completed with potential sites as follows:

Northwest side of Bass Lake along Eagle Creek trend.

Located along lower Eagle Creek linear which displays reported hot ground on southeast side (P. Dickson, personal comm., 1979) of lake and hot ground at the juncture of the spillway coffer dam and the Washington shore (Holdredge, 1937). If the southeast side is not closed off due to construction at Bonneville Dam it might be a preferable location.

Tanner Creek trend and Washington shore.

Tanner Creek is a major trend and may mark the divide between the High Cascade and the Western Cascade provinces, in which case drill sites to the east of the trend may have higher heat flow.

Washington Highway 14 and bridge over Hamilton Creek.

Hot ground was reported during construction of new bridge (P. Dickson, personal comm., 1979). Individuals that have actually seen this feature should be questioned directly to acquire feel for quality of observation.

100-200m west of Moffetts Hot Springs along gas pipeline.

Intersection of 3-4 linears. This is the best target based on analysis of linears, however, potentially the worst politically due to the proximity to the existing development at the hot springs.

INTRODUCTION:

The central part of the Columbia River Gorge near the new town of North Bonneville is in the Cascade Range geologic province. Only Cenozoic stratigraphy is exposed and is entirely volcanic in origin except for alluvium and landslide deposits. Small intrusives in the form of volcanic necks and dikes are located nearby as well as a small Quaternary volcanic center and associated deposits. A geologic map was completed as a part of the study and is presented here as Plate I.

Structure in the area is represented by gentle folds and limited definable faulting. Minor topographic lineations, however, are fairly common and are presumed to represent major tectonic joints or faults with minimal displacement.

Moffetts Hot Springs and St. Martins Hot Springs to the east near the town of Carson have temperatures of 32° C and 49° C respectively. The hot springs are structurally controlled and are probably located at the intersection of more than one fracture trend. The Ohanapecosh Formation underlies the area and is considered to be an aquiclude due to postdepositional formation of zeolites and clays. Potential geothermal development, therefore, is viewed as being dependent upon fracture zones for water circulation.

Z. F. Danes is analyzing and modeling a recent gravity survey in the area and it is felt that the resulting data may substantiate the presence of subsurface fracture zones. Although it is somewhat premature to suggest a drilling site until the gravity data is made available potential good sites are 100-200m west of the development at Moffetts Hot Springs along the gas pipeline and an equally accessible but structurally less desirable location is at the intersection of the powerline and road about 400m southeast of Moffetts Hot Springs.

STRATIGRAPHY:

The bedrock stratigraphy of the Cascade Range in the Columbia River Gorge near the town of North Bonneville is composed of about 25,000 ft. of Cenozoic volcanic rocks. Three major stratigraphic formations account for nearly the entire section and include the Ohanapecosh Formation, the Eagle Creek Formation, and the Grande Ronde Basalt within the Yakima Basalt Subgroup of the Columbia River Basalt Group. The remainder of the area is underlain by small Quaternary Basalt occurrences and a few small intrusions. Much of the bedrock in the area is obscured by large landslides and recent alluvium.

Ohanapecosh Formation:

The oldest known formation in the vicinity of North Bonneville is the Eocene-Oligocene Ohanapecosh Formation (Plate I). Many older reports refer to this unit as the Weigle Formation. In the nearby Wind River drainage this formation is greater than 19,000 ft. thick (Wise, 1970) and is composed predominately of consolidated volcaniclastics and lesser amounts of lava flows. The upper portion of the section exposed nearest to North Bonneville possesses proportionately more lava flows and like the formation elsewhere is well consolidated due to postdepositional alteration which has led to the formation of zeolites and clays. Surface exposures indicate that this unit should behave as an aquiclude and thereby provide some confinement of any geothermal resource present at depth.

Eagle Creek Formation;

Overlying the Ohanapecosh Formation is the Lower Miocene Eagle Creek Formation (Plate I). This formation is composed almost entirely of volcaniclastics in the form of conglomerates, sandstones, and tuffs, and occasionally an interbedded lava flow. Unlike the Ohanapecosh the Eagle Creek is poorly consolidated and because of the nature of the abundant conglomerates may prove some problems for drilling. The Eagle Creek, in the area of North Bonneville, is the surface bedrock formation and because of its permeable character would tend to dissipate circulating fluids. Drill hole information from the USCE indicate that the base of the Eagle Creek Formation near Moffetts Hot Springs is probably less than 500 ft. from the surface.

Grande Ronde Basalt;

Unconformably overlying the Eagle Creek Formation is a Middle Miocene sequence of tholeiitic flood basalts greater than 1500 ft. thick. These basalts are the cliff formers of most of the Columbia River Gorge but they are topographically above any potential drilling site for this project and therefore are significant only in providing information concerning some of the regional structure.

INTRUSIONS AND YOUNGER BASALTS:

Intruding the Eagle Creek Formation on the south flank of Table Mountain are a small diabasic neck and associated dike. This rock has been relatively dated only as younger than Eagle Creek in age. However, its orientation and association with tectonic joints indicate that it may be younger than Grande Ronde Basalt. A regional fracture zone projected into the area from Tanner Creek-Blazed Alder Creek south of the Columbia River may be the controlling structure, in which case it may be Pliocene or younger.

Another diabasic body is exposed at the south abutment of Bonneville Dam Powerhouse. This rock is known only to be younger than Eagle Creek and covers a surface area of less than 1/4 mi^2. This unit has been described as intrusive in USCE reports, however it possesses some flow characteristics near its top and also displays locally abundant vesiculation and is therefore considered to be emplaced at or very near to the then existing surface.

Red Bluffs Basalts;

Probably the most important of the younger volcanic features in the area for the development of geothermal resources is the Red Bluffs olivine basalt volcanic complex. Covering an area of only about 2 mi^2, most of which has been displaced by the Bonneville Landslide, it possesses a relatively intact cinder cone which is indicative of an age probably no older than Pleistocene. The south trending face of Red Bluffs is a complex of basalt intermixed with cinder and is probably the approximate location of the vent. At the top of the landslide scarp is approximately 1/4 mi^2 of in situ basalt that probably represents nearly all of the basalt that was deposited in Greenleaf Basin. This volcanic field should be further studied by geophysical methods in an attempt to identify the presence of controlling structures. It should be accurately dated, especially if an associated structure can be located.

Sheridan Point Lava Flow;

A 30 ft. thick flow is exposed for about 1/4 mi. in road cuts at Sheridan Point that is of unknown extent and source. The flow rests on Columbia River Basalt talus and is overlain by landslide deposits. The known extent of this flow indicates that it probably was fairly limited in volume and extent upon emplacement and because it is felt that such a limited flow could not defeat and cross the Columbia River the most likely source for this basalt is south of Wauna Lake which marks the approximate south shore of the pre-slide Columbia River. The source may be in the present river channel or on the Oregon side of the Columbia.

Many other small volcanic centers are present on both sides of the Columbia River but are considered to be too distant from North Bonneville to have a direct bearing on potential geothermal resources for this community. Moreover, much of the area immediately surrounding North Bonneville is covered by the 700 year old Bonneville Landslide (Lawrence and Lawrence, 1958) and modern Columbia River alluvium thus requiring some speculation regarding the location of potential drill sites.

STRUCTURE:

Bedrock exposures in the region are somewhat limited by landslides, alluvium, colluvium, talus, and thick vegetation. This amount of cover coupled with formations that are difficult to correlate stratigraphically any distance has limited the number of identifiable structures, especially faults and tectonic joints. In general the area is represented by gentle folds with low structural relief and a regional southward dip averaging 10° north of the

Columbia River and 5° south of the river. Due to the general impermeability of the underlying Ohanapecosh Formation tectonic fractures, joints, and faults are deemed one of the more important geologic aspects for successful development of nearby geothermal resources.

Faults;

The only definable fault mapped in the study area is located on the south flank of Table Mountain and displaces Grande Ronde Basalt about 50 ft. down to the north on a vertical fault plane (Plate I). The trend of the fault, N70E, is representative of structural trends mapped to the east in the Klickatat River (J. L. Anderson, personal comm., 1979) and from the Wind River to the Klickatat River (P. E. Hammond, personal comm., 1980). Faults to the east that possess this trend tend to be in echelon systems that form regional zones trending N60E. Potential regional structural trends that define the N60E trend are the Red Bluffs-Grays Hot Springs lineation and the Moffetts Hot Springs-St. Martins Hot Springs trend. A strong linear correlation exists from the alignment of the saddle in Table Mountain, the 800 ft. scarp in the Eagle Creek Formation exposed in Red Bluffs, the position of Grays Hot Springs, and a small saddle above Carson Creek to the east. A parallel trend can be observed by constructing a line from Moffetts Hot Springs through St. Martins Hot Springs. This line defines the north shore of the pre-Bonneville Landslide Columbia River and follows the river to the southwest for more than 20 miles. SLAR imagery indicates the same trend in the Gorge walls on the Oregon side of the river. This persistant trend has displacements of over 300m to the east and may have a significant impact on the bedrock geology in this region, such as the unanticipated structural high in the Ohanapecosh Formation beneath the Bonneville Landslide.

Eagle Creek is the largest stream flowing north into the Columbia River between the Sandy River to the west and Hood River to the east. The lower 6 mi. of the creek is divided into 3 equal straight line segments that are believed to be structurally controlled (Plate I). The segment nearest the mouth and the segment furthest from the mouth intersect near Moffetts Hot Springs along trends of N55W and N45W, respectively. Tectonic breaks were found along neither of these trends. The middle trend possesses a pair of well developed vertical fractures with associated narrow breccia zones trending N25W.

The dominant northwest trend in the immediate area is the Tanner Creek-Blazed Alder Creek trend. Observed tectonic features are lacking in the Columbia River drainage side of this trend, however, in the Bull Run River drainage along Blazed Alder Creek this trend is observed to have narrow breccia zones and controls the emplacement of at least two small dikes. This trend is considered to be an area of extension along a diverging wrench zone and if it continues to Moffetts Hot Springs it could provide substantial water circulation through fractures.

HOT SPRINGS:

Moffetts Hot Springs is located about 2 mi. northeast of North Bonneville and has a surface temperature of 32^{o} C with a predicted reservoir temperature of less than 80^{o} C (Schuster, and others, 1978). Located about 11 miles northeast of North Bonneville is St. Martins Hot Springs with a surface temperature of 49° C and a predicted reservoir temperature of less than 80° C (Schuster, and others, 1978).

Hot ground was encountered during the construction of Bonneville Dam and is recorded to be 60° F when the ambient temperature was 20° F. Three areas of hot ground were observed, one near the upstream end of the navigation locks, the northeast abutment of the powerhouse on Bradford Island, and at the Washington shore and the downstream end of the north spillway coffer-dam (Holdredge, 1937). The northern most of the hot spots lies on the N55W linear Eagle Creek trend.

The State of Oregon Department of Geology and Mineral Industries drilled a 500 ft. geothermal gradient hole about 2 miles southwest of North Bonneville at the mouth of McCord Creek on the south shore of the Columbia. Bottom hole temperature was about 10° C and the calculated gradient about 50° C/Km is consistant with that of the region (J. Riccio, personal comm., 1980).

REFERENCES CITED

Holdredge, C. P., 1937, Fumaroles at Bonneville: Geological Soc. of the Oregon Country News Letter, v. 3, n. 9, p. 96-97.

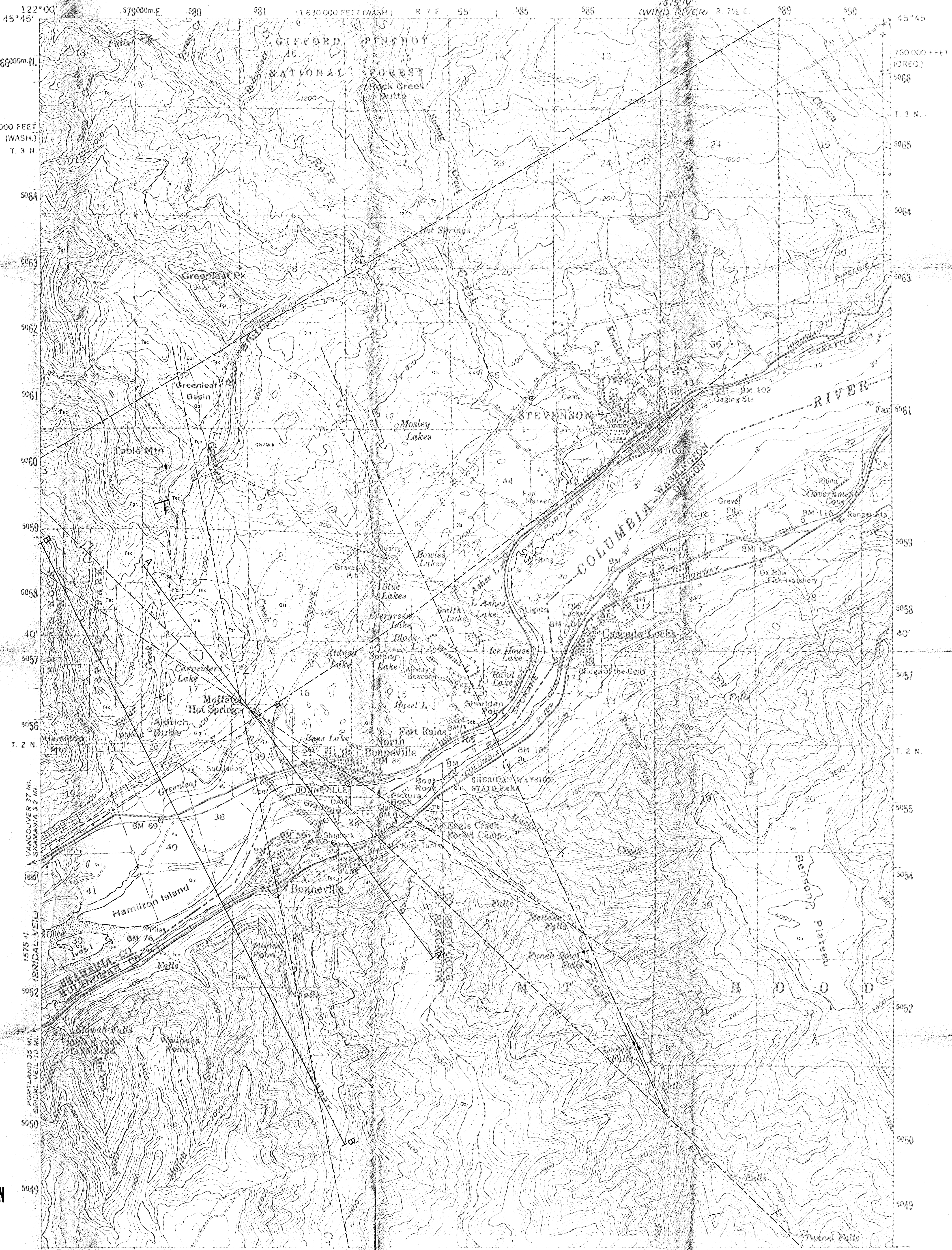
Lawrence, D. B., and E. G. Lawrence, 1958, Bridge of the Gods Legend, its origin, history, and dating: Mazama, v. 40, no. 13, p. 33-41.

Schuster, J. Eric, D. D. Blackwell, P. E. Hammond, and M. T. Huntting, 1978 Heat flow studies in the Steamboat Mountain-Lemi Rock area, Skamania County, Washington: Washington Division of Geology and Earth Resources Info. Cir. 62, 56p.

Wise, W. S., 1970, Cenozoic volcanism in the Cascade Mountains of Southern Washington: Washington Division of Mines and Geology Bull. 60, 45p.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

NW PORTION OF THE
BONNEVILLE DAM QUADRANGLE
Oregon-Washington
15'



EXPLANATION

QUATERNARY

- Qal — Alluvium
- Qls — Landslide
- Qob — Olivine-Basalt
- Qa — Andesite
- Qb — Basalt

TERTIARY

- Tgr — Grande Ronde Basalt
- Tec — Eagle Creek Fm.
- To — Ohanapecosh Fm
- Tib — Diabase and basalt intrusions

- Normal Fault (D/U)
- Joint
- Dip and Strike
- Contact
- Landslide Scarp
- Topographic Lineation
- Projected Lineation
- Hot Ground

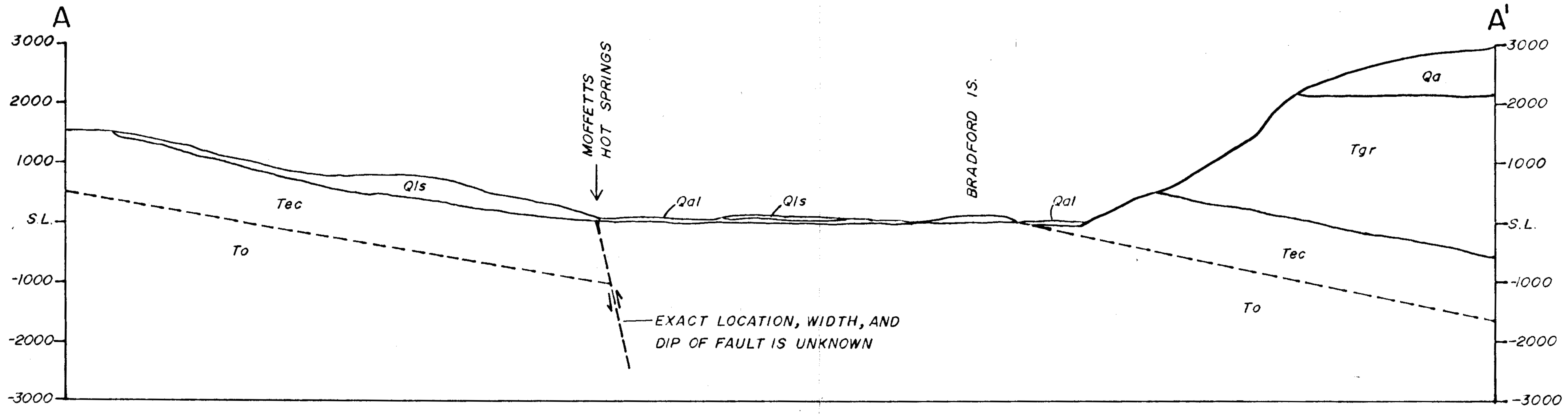
GEOLOGY OF NORTH BONNEVILLE, WASHINGTON AND VICINITY

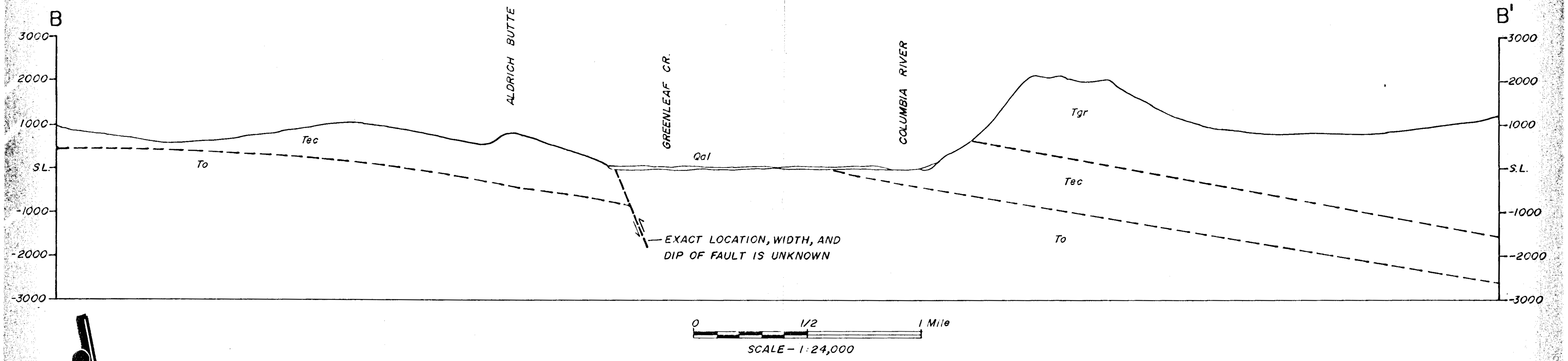
Compiled by Michael R. Moran, 1980

Geology after W. S. Wise, 1970
A. C. Waters, unpub. data
M. R. Moran, unpub. data

EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE

PLATE II





GEOLOGIC CROSS SECTIONS OF THE NORTH BONNEVILLE AREA, WASHINGTON AND OREGON

D.L. NIELSON, 1980