STATE OF WASHINGTON
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES
OLYMPIA, WASHINGTON 98504

# PRELIMINARY REPORT ON THE GEOLOGY OF THE GRANDE RONDE LIGNITE FIELD, ASOTIN COUNTY, WASHINGTON

by

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## ABSTRACT

The Grande Ronde lignite field is located in southeastern Washington and northeastern Oregon in the Grande Ronde River-Blue Mountains region. The lignite occurs within sediments intercalated with Miocene Columbia River Basalt Group flows, which were folded and faulted by regional arching during the Miocene and Pliocene.

During prolonged periods of volcanic quiescence in the waning stages of Columbia River Basalt Group volcanism (between 6 and 13.5 million years B.P.), sediments accumulated in streams, lakes, and swamps on the surface of basalt flows. This sand, silt, clay, diatomaceous earth, and peat (later converted to lignite) was then buried by subsequent basalt flows. All lignites of the Grande Ronde field are found within sedimentary interbeds between flows of the Saddle Mountains Basalt of the Yakima Basalt Subgroup of the Columbia River Basalt Group.

The present distribution of sedimentary interbeds in the Washington State portion of the Grande Ronde lignite field is the result of several Miocene-Pliocene depositional and erosional events. These events produced complex stratigraphic relationships between basalt flows and sedimentary interbeds, which must be understood before lignite reserves of the Grande Ronde field can be accurately estimated.

1. Pre-depositional events affecting sediment distribution

    a. Sediments were deposited in the developing Grouse Flat syncline, and are thickest along the axis of the synclinal basin and thin toward basin margins.

    b. Sediments were deposited on basalt flow surfaces of moderate local relief. The relief resulted from either near-vent constructional topography or erosional topography which developed prior to burial by sediments.

2. Post-depositional events affecting sediment distribution

    a. Sediments may have been partially eroded by stream activity before burial by subsequent basalt flows.

    b. Sediments were intruded by burrowing, invasive flows.

    c. Sediments may have been intruded by feeder dikes and sills near vents for subsequent flows.

    d. On the north border of the Grande Ronde lignite field, the sediments dip steeply on the flank of the Slide Canyon monocline and have been eroded away along the top of the structure.

    e. In response to regional uplift following volcanism, some interbed sediments were eroded, reworked, and deposited as stream terraces on benches, as the Grande Ronde River incised a deep canyon during post-Miocene time.

Although poorly exposed, outcroppings in springs, creeks, and roadcuts indicate that the thickest known Grande Ronde lignites (approximately 10 meters) occur near the base of the Grouse Creek sedimentary interbed and occasionally rest directly on Umatilla flow basalt. Deposition of the peats which formed these lignites were apparently preceded only by the deposition of diatomaceous earth beds or a brief influx of detrital sand and silt.

Analyses of Grande Ronde lignites range from 5,027 to 7,944 BTU/lb (as received), with low sulphur and moderate ash contents.

## LOCATION AND GEOGRAPHIC SETTING

The Grande Ronde lignite field is located in Asotin County in southeastern Washington and Wallowa County in northeastern Oregon. It lies along the southern slopes of the northeasternmost extension of the Blue Mountains and borders the Grande Ronde River canyon (fig. 1). The Washington State portion of the field stretches northeastward from Troy, Oregon for approximately 10 miles, and crops out on flat to gently rolling benches 1,300 to 2,300 feet (400 to 700 meters) above the Grande Ronde River (plate 1). These benches, which mark the stratigraphic position of thick sedimentary interbeds between basalt flows, have been deeply dissected into a series of smaller, isolated benches by the downcutting of Cottonwood and Menatchee Creeks. All lignites of the Grande Ronde lignite field are found within these sedimentary interbeds.

Each of the benches is accessible by well-maintained gravel roads. With the exception of a few scattered parcels of state-owned land, the benches are privately owned. In 1981, several tracts of land have already been leased for coal exploration, but other tracts remain which have not been leased.

## FIELD METHODS

Reconnaissance mapping of the Grande Ronde lignite field was completed during 6 weeks of field work during the summer of 1980. Staff members of the Division of Geology and Earth Resources plan additional mapping during the summer of 1981 in an attempt to answer questions raised in this preliminary report.

## REGIONAL GEOLOGIC SETTING

The Grande Ronde River-Blue Mountains region in southeastern Washington and northeastern Oregon lies within the Columbia Basin province (fig. 2)—one of the earth's youngest flood basalt provinces, which formed between 6 and 17 million years B.P. (McKee and others, 1977; McKee and others, in press). These basalt flows, which comprise the Columbia River Basalt Group, have been subdivided into five formations—the Imnaha Basalt, Picture Gorge Basalt, Grande Ronde Basalt, Wanapum Basalt, and Saddle Mountains Basalt, of Miocene age (fig. 3). The major source for the flows was the north-northwest trending Chief Joseph dike swarm of southeastern Washington, northeastern Oregon, and adjacent Idaho (fig. 4).

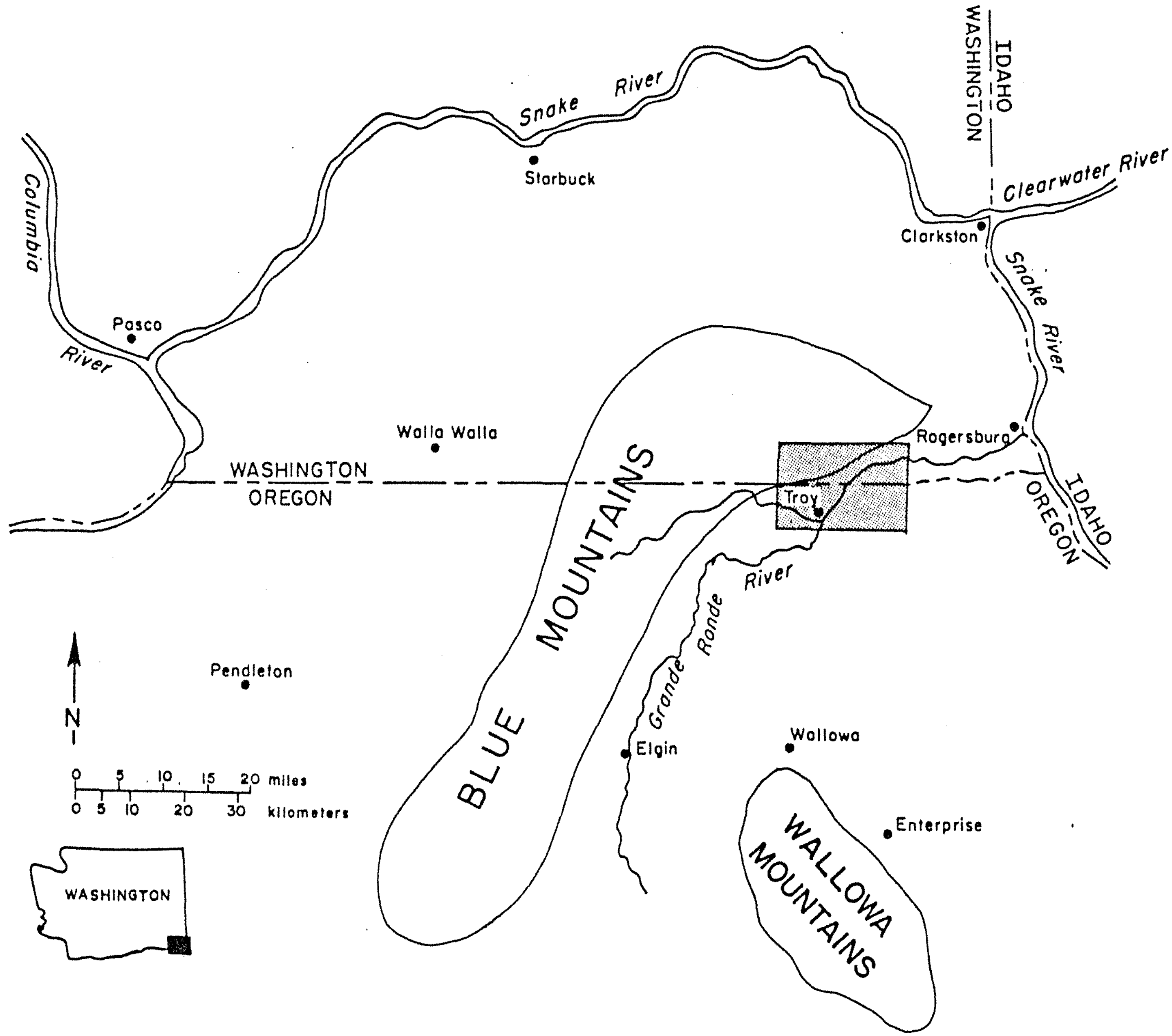



FIGURE 1.—Study area location (stippled) in the Grande Ronde River-Blue Mountains region of southeastern Washington.

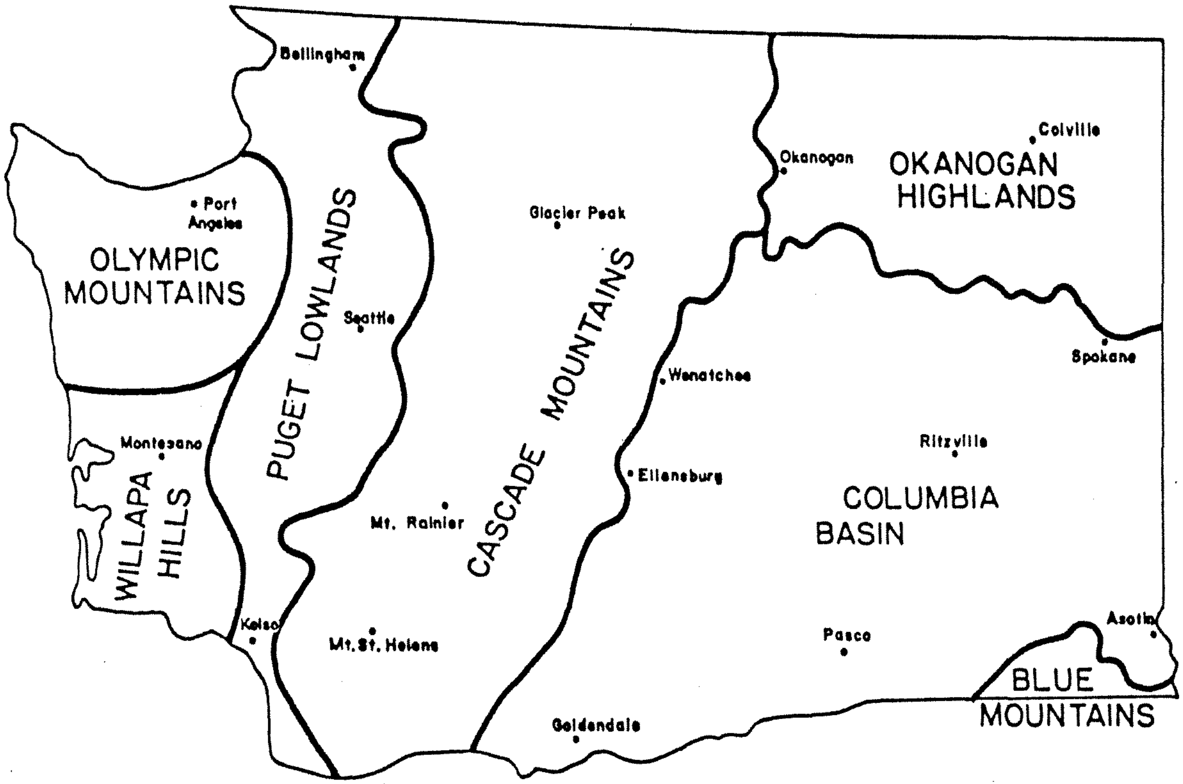
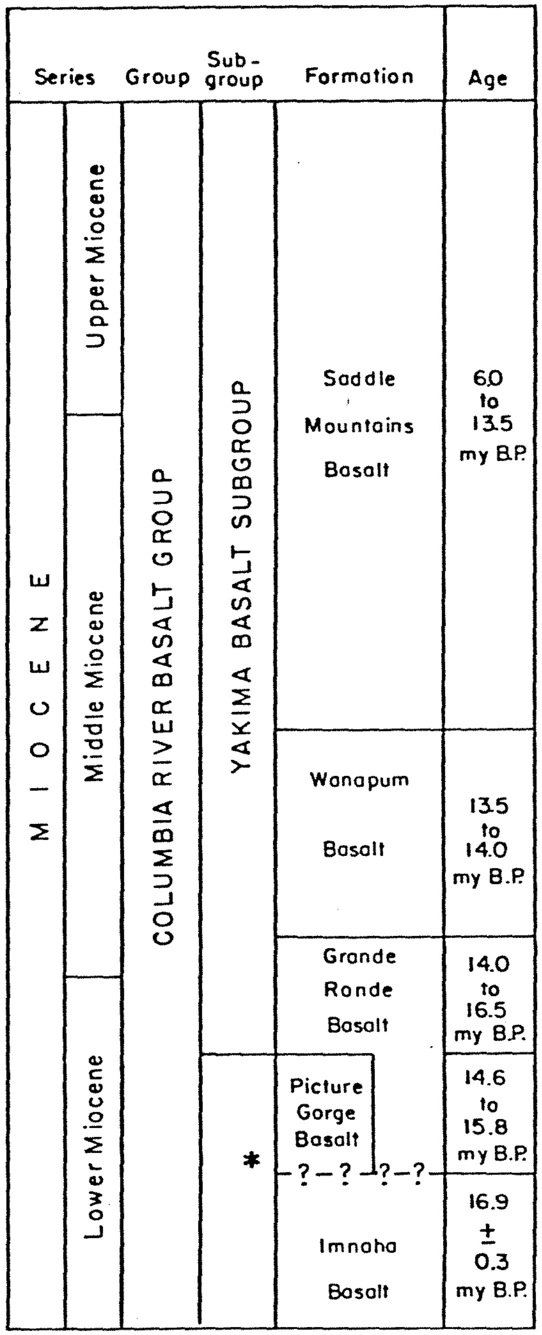



FIGURE 2.—Physiographic divisions of Washington State (after Weissenborn, 1978).




* The Imnaha and Picture Gorge Basalts are nowhere known to be in contact. Interpretation of preliminary magnetostratigraphic data suggests that the Imnaha is older.

FIGURE 3.— Regional Columbia River Basalt Group stratigraphic nomenclature (after Swanson and Wright, 1981; Imnaha Basalt age after McKee and others, in press).

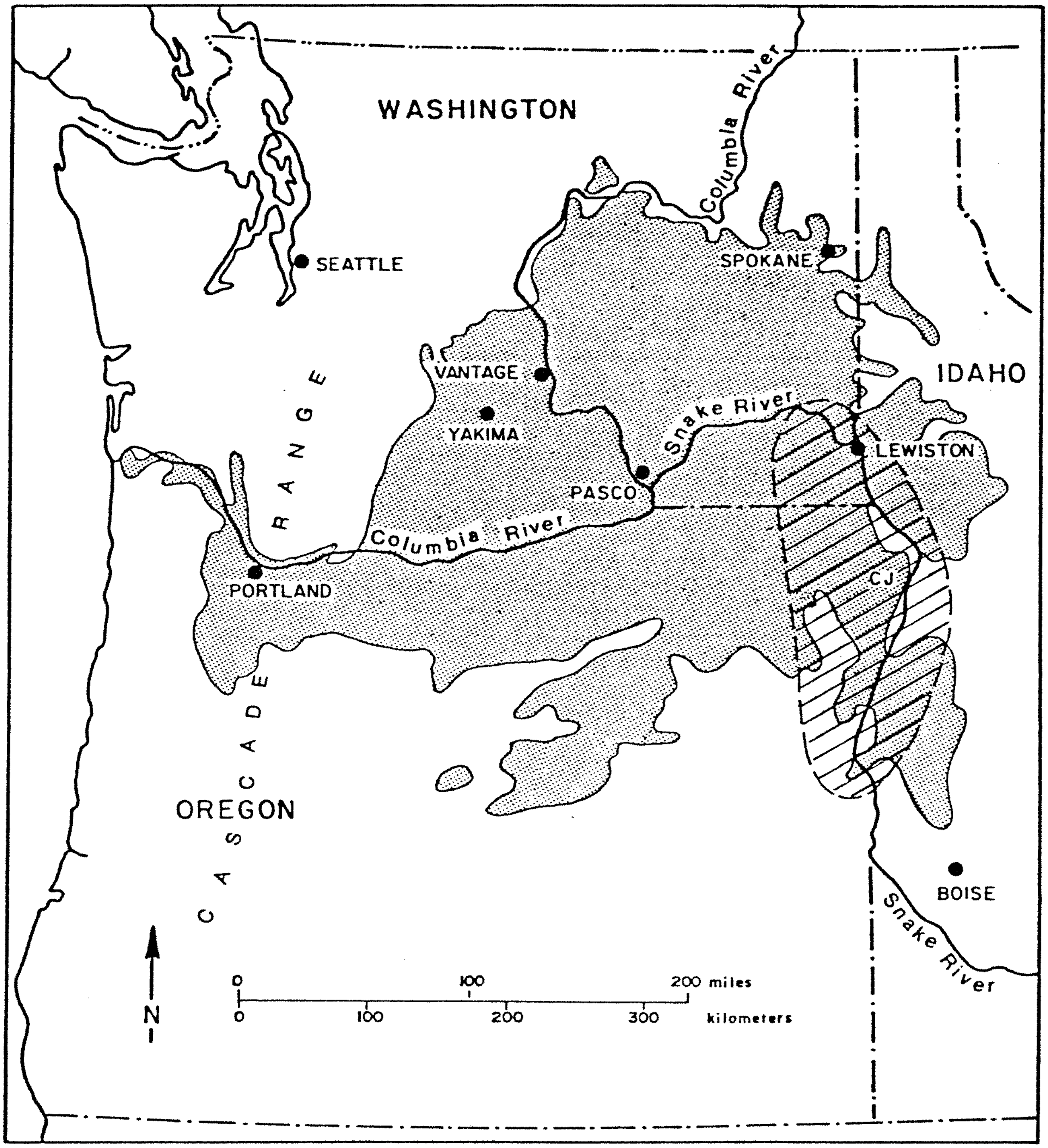



FIGURE 4.—Generalized map of Northwestern United States showing distribution of the Columbia River Basalt Group (stippled) and Chief Joseph dike swarm (lined) (after Myers and Price, 1979).

The Grande Ronde lignite field is located within the Blue Mountains portion of the Columbia Basin province. The Blue Mountains are a broad anticlinal arch which was uplifted in Miocene-Pliocene time, concurrent with the extrusion of the Columbia River flood basalts. The core of the Blue Mountains arch is composed of folded and faulted Paleozoic and Mesozoic metamorphic rocks (Swanson and others, 1980). Although these pre-Tertiary rocks form the core of the uplift, they are rarely exposed in the Grande Ronde River-Blue Mountains region.

In the northeasternmost portion of the arch, the axis of the uplift coincides with the Saddle Butte anticline—one of several major anticlines in the northeastern Blue Mountains (fig. 5). The Saddle Butte anticline, developed primarily in the Grande Ronde Basalt, generally has gently dipping limbs and a broad, flat hinge zone (fig. 6). However, the south limb of the anticline steepens to become the Slide Canyon monocline, which dips as much as 70° to the south (Ross, 1978). Maximum structural relief from the base of the monocline to the crest of the anticline is approximately 2,800 feet (850 meters).

A very broad syncline with gently dipping limbs, the Grouse Flat syncline, lies just south of the Slide Canyon monocline (figs. 5 and 6). Outcrops of the Wenaha and Buford flows (fig. 7), which are the youngest Columbia River Basalt Group flows in the Grande Ronde River region, are restricted to this syncline, indicating that it had already begun to form prior to the extrusion of the Saddle Mountains Basalt flows (Price, 1977).

## YAKIMA BASALT SUBGROUP STRATIGRAPHY IN THE GRANDE RONDE RIVER REGION

### Grande Ronde Basalt

The Grande Ronde Basalt is the oldest formation of the Columbia River Basalt Group exposed in the study area (fig. 7). Flows of this formation, which were extruded from north-northwest trending fissures in southeastern Washington and adjacent Oregon between 14 and 16.5 million years B.P., cover a large portion of Washington and Oregon (fig. 8). Thick sequences of Grande Ronde Basalt flows crop out along the inner canyon walls of the Grande Ronde and Wenaha Rivers and in many of the deeply incised creeks (fig. 9). The flows also crop out extensively in the Blue Mountains to the north, where arching and subsequent erosion has exposed them (fig. 6). Steeply dipping Grande Ronde Basalt flows on the flank of the Slide Canyon monocline form the northern limit on the Grande

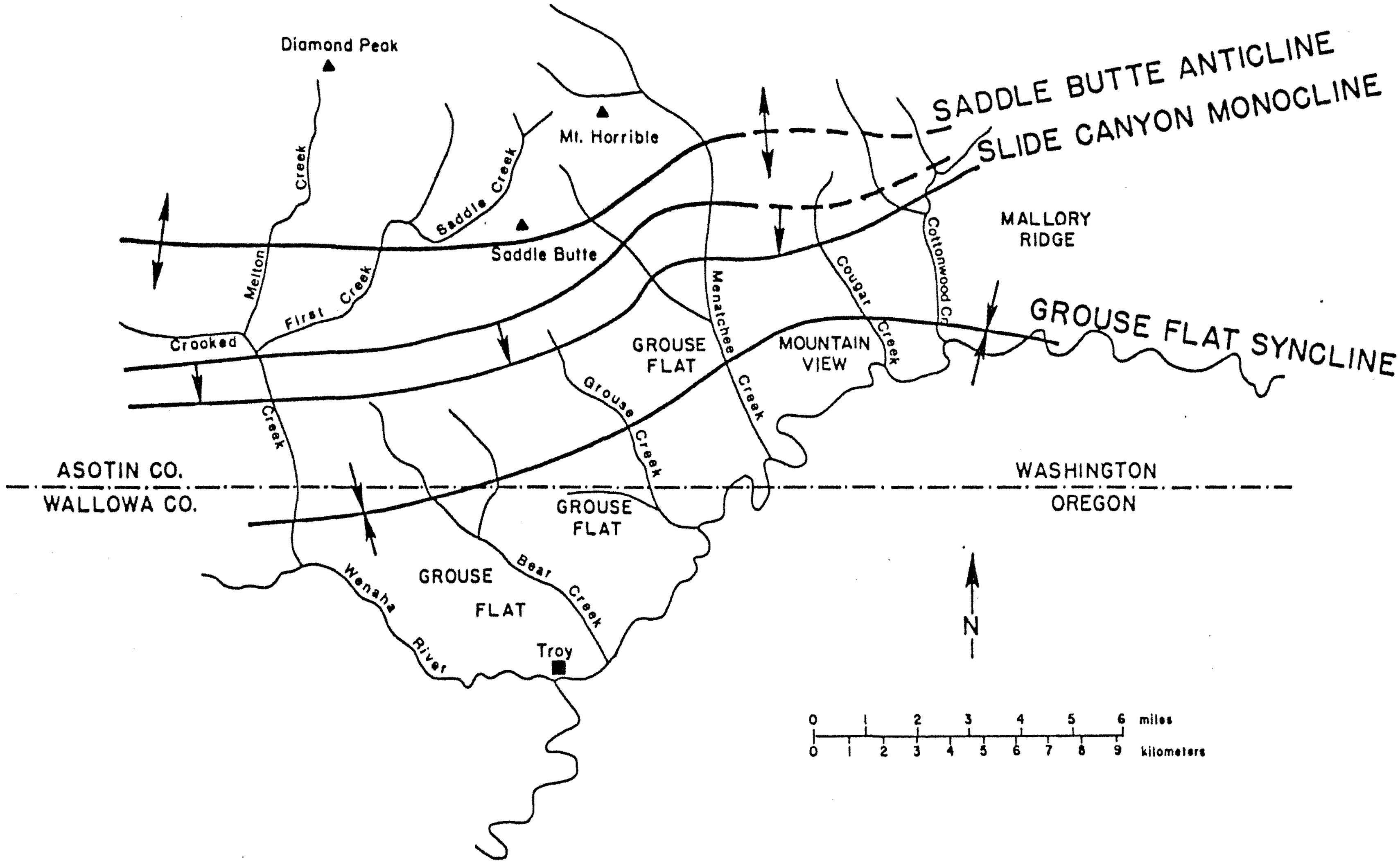



FIGURE 5.—Generalized location map of major structural features in the Grande Ronde River-Blue Mountains region in southeastern Washington (after Ross, 1978). See plate 1 for more precise location of structures.

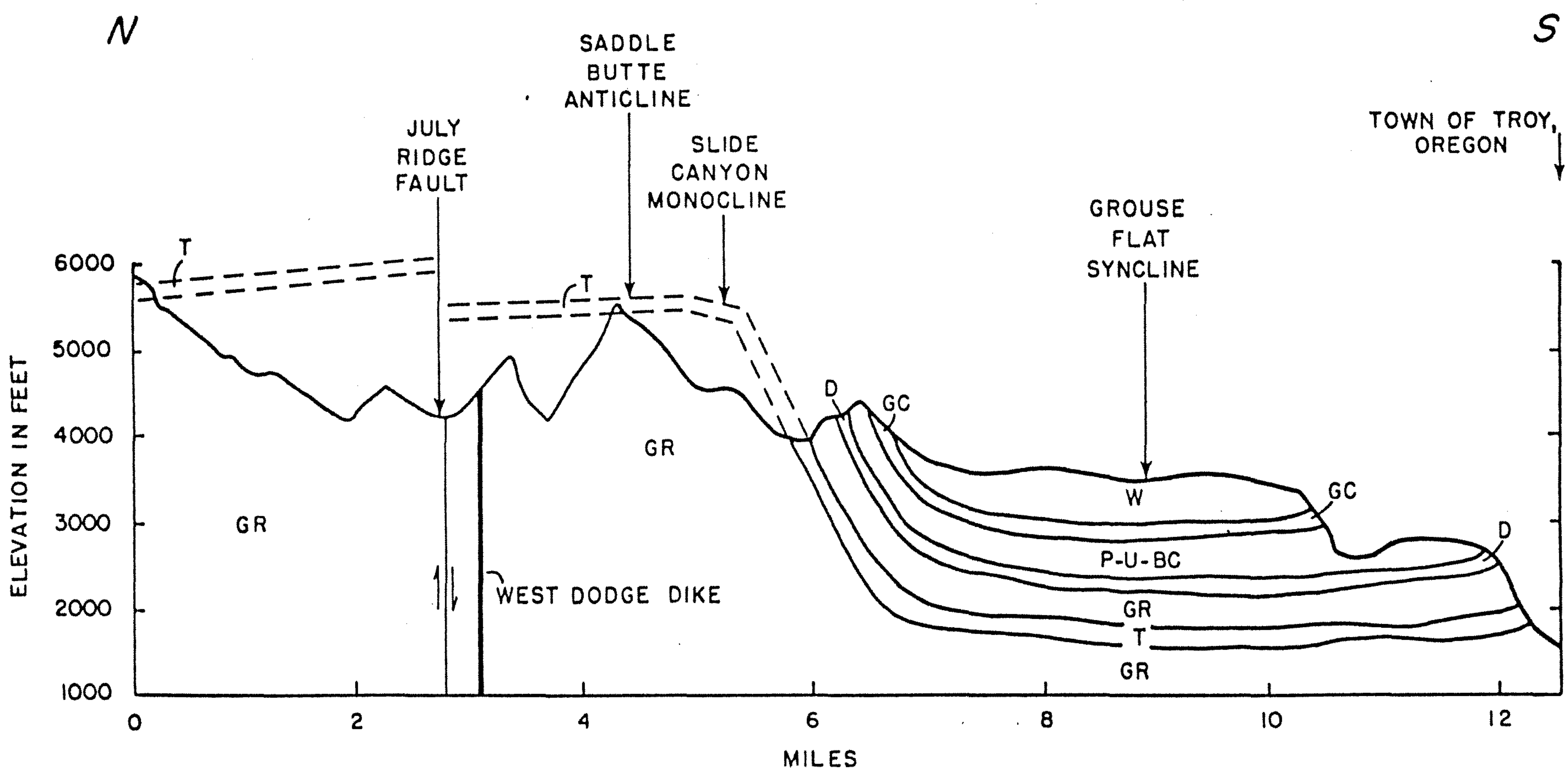



FIGURE 6.—North-south cross-section through the Grande Ronde River-Blue Mountains region, Units: GR=Grande Ronde Formation, T=Troy flow, D=Dodge flow(s), P=Powatka flow, U=Umatilla flow, BC=Bear Creek flow, GC=Grouse Creek sedimentary interbed, W=Wenaha flow (after Ross, 1978).

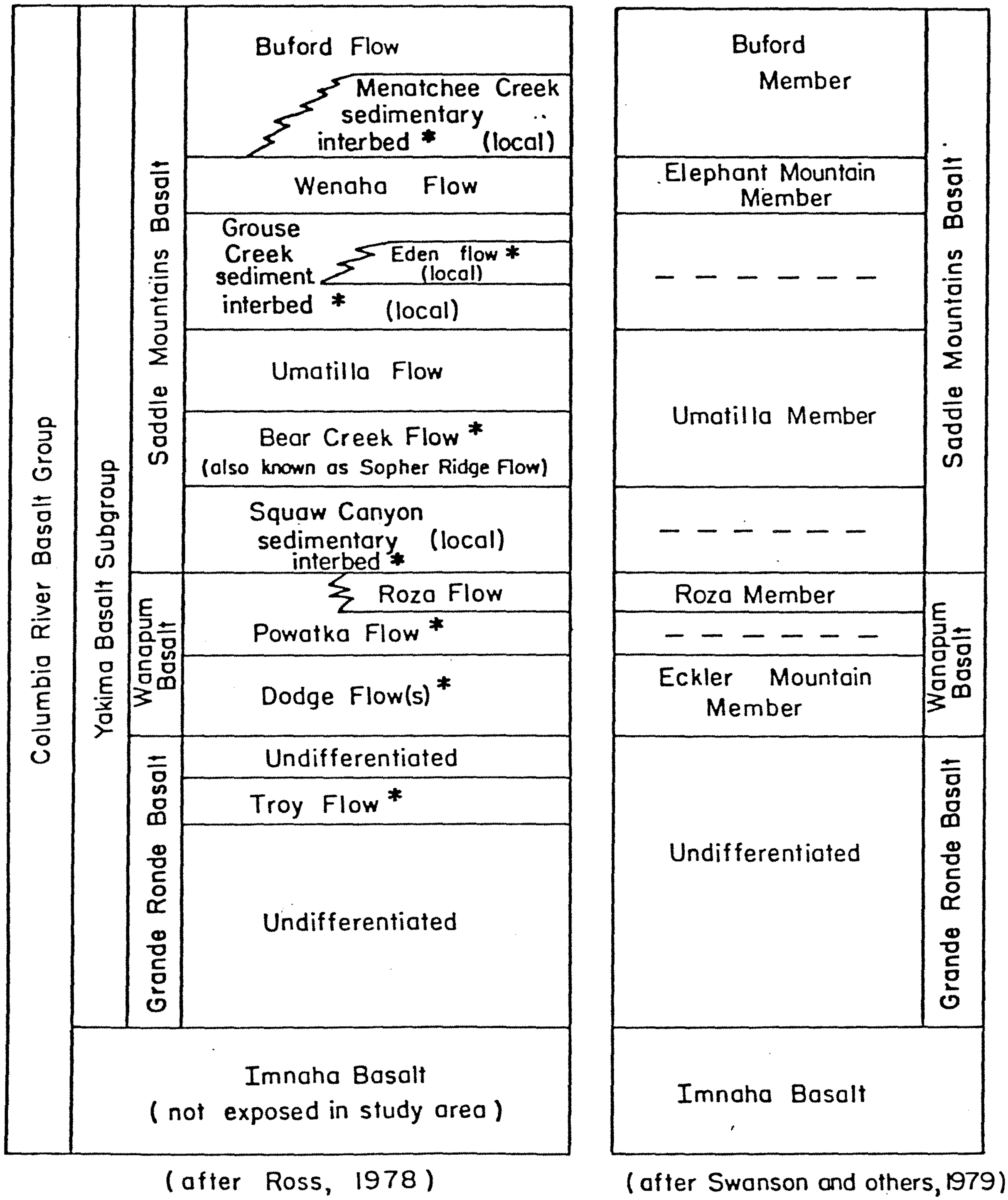



FIGURE 7.—Generalized stratigraphy of the Grande Ronde River-Blue Mountains region (left) correlated with formalized stratigraphic nomenclature of the Columbia River Basalt Group (right). Asterisk designates informal unit name. Dashed line indicates local Grande Ronde unit not correlative with formal Columbia River Basalt Group nomenclature.

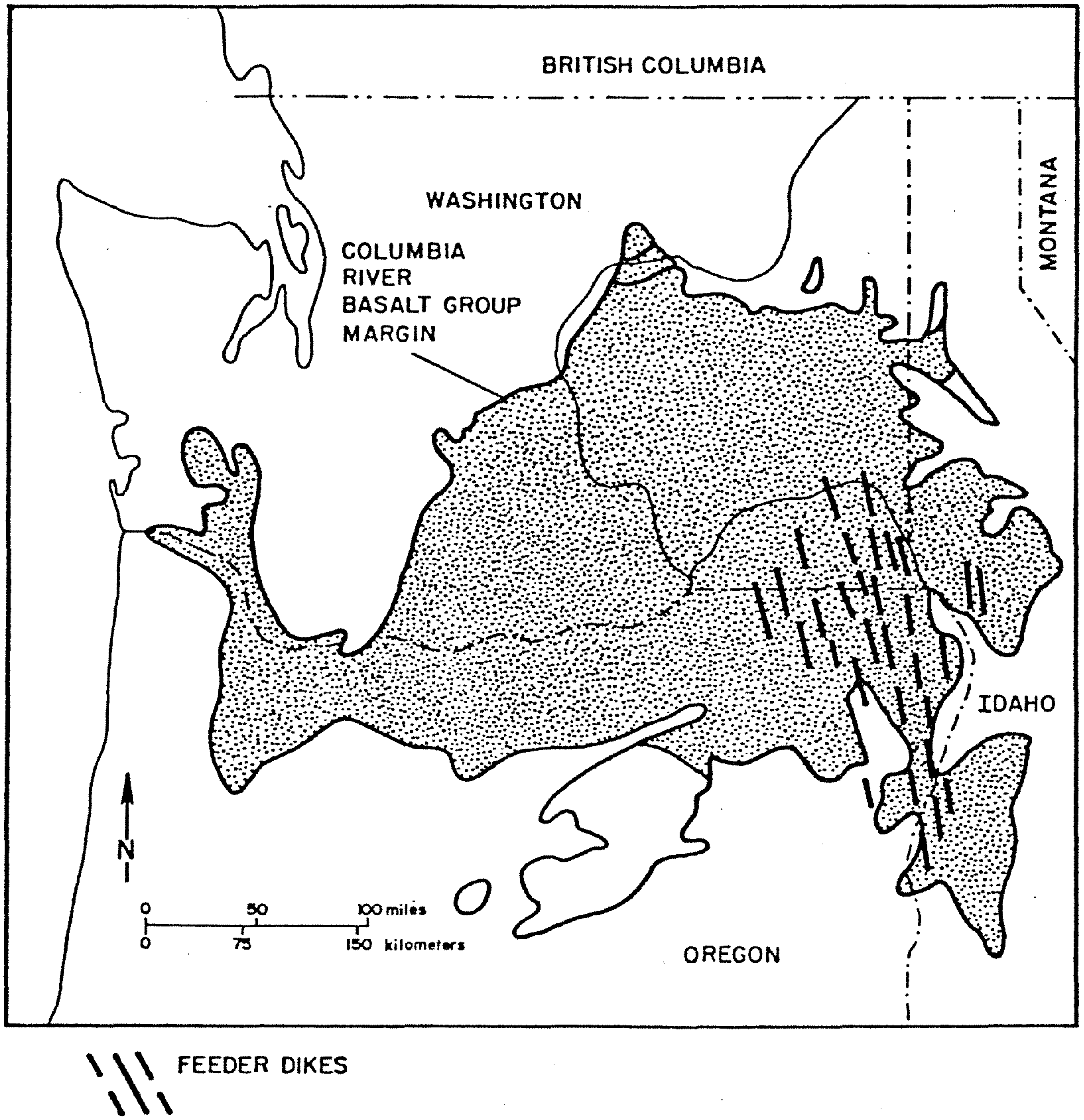



FIGURE 8.—Inferred original distribution of the Grande Ronde Basalt (stippled area) (from Myers and Price, 1979).

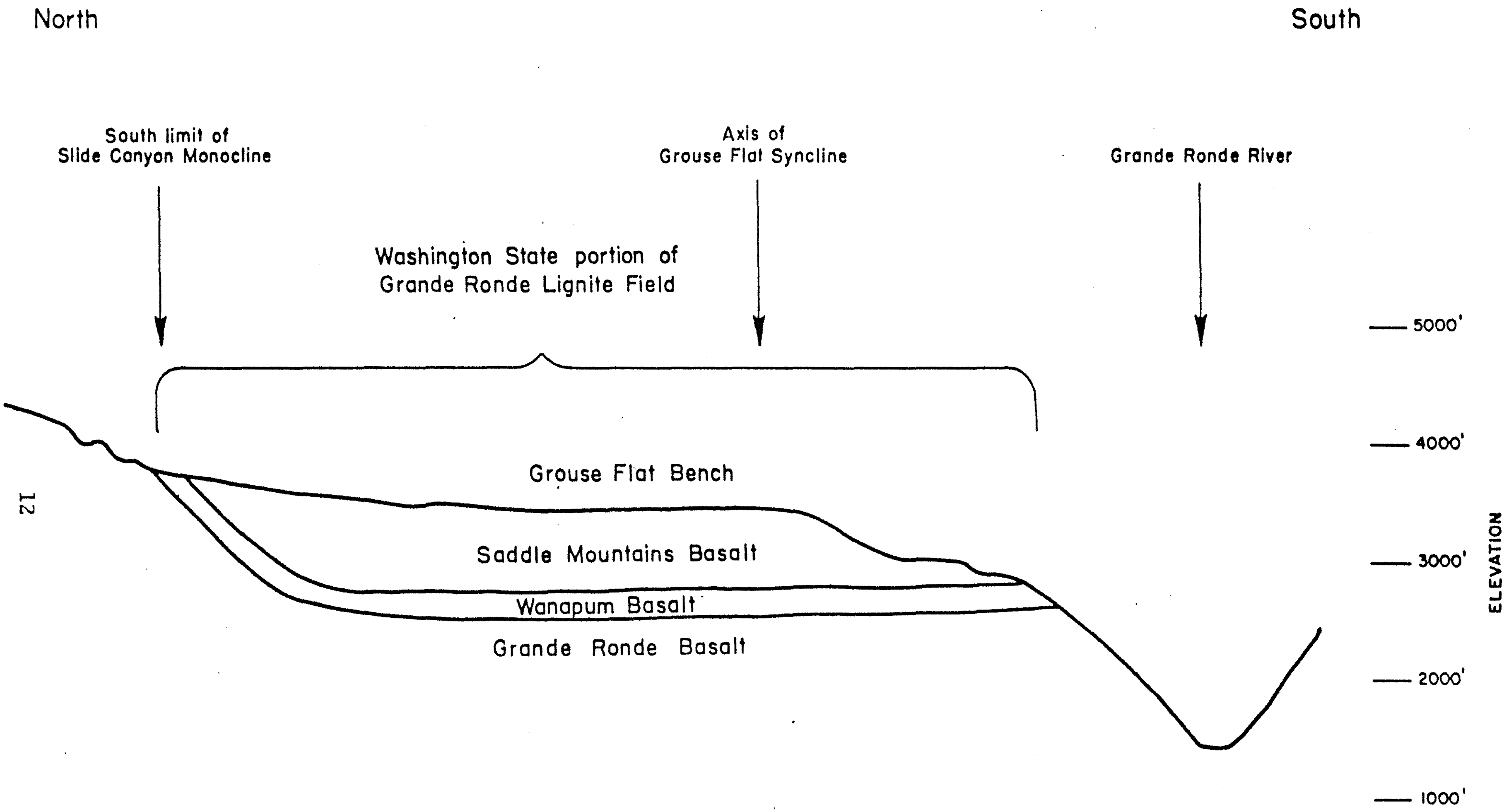



FIGURE 9.—Cross-section illustrating general outcrop localities of the three Yakima Basalt Subgroup formations in the Washington State portion of the Grande Ronde lignite field.

Ronde lignite field (fig. 9 and plate 1). The relatively uniform field, petrographic, and chemical characteristics of the flows make correlation difficult within the Grande Ronde Basalt.

## Wanapum Basalt

Flows of the Wanapum Basalt were extruded from fissures in southeastern Washington between 13.5 and 14 million years B.P., and also cover a large area in Washington and Oregon (fig. 10). In the study area, Wanapum Basalt flows are exposed near the top of the inner canyons of deeply incised rivers and creeks (fig. 9). The greatest number and the thickest section of Wanapum flows in the study area are found in the Grouse Flat syncline, indicating that development of the syncline began prior to or during the extrusion of Wanapum Basalt flows (Ross, 1978). Since individual flows of the Wanapum Basalt are identifiable by field and laboratory methods, the Wanapum Basalt can be easily correlated and mapped. The Grande Ronde Basalt and Wanapum Basalt are separated by a saprolitic soil throughout much of the study area, which also provides an excellent marker horizon and correlation tool (Ross, 1978).

## Saddle Mountains Basalt

During the late stages of Yakima Basalt Subgroup volcanism, between 6 and 13.5 million years B.P., basalt flows of the Saddle Mountains Basalt were extruded from fissures in south-central and southeastern Washington (fig. 11). This period of waning volcanism was accompanied by the accumulation of locally thick sedimentary interbeds between flows. In the study area, three major sedimentary interbeds—Squaw Canyon, Grouse Creek, and Menatchee Creek (fig. 7)—are intercalated with five flows. Grouse Flat, Mountain View, and Mallory Ridge benches are all cut into sedimentary interbeds between flows of the Saddle Mountains Basalt Formation (fig. 12 and Plate 1). As a result of accelerated downwarping during the upper Miocene, the thickest section of the Saddle Mountains Basalt coincides with the axis of the Grouse Flat syncline. The formation thins toward the synclinal basin margins and has been eroded away along the flank of the Slide Canyon monocline. Many of the individual flows of the Saddle Mountains Basalt are petrographically and(or) chemically distinct and can be correlated across wide areas (Swanson and others, 1980).

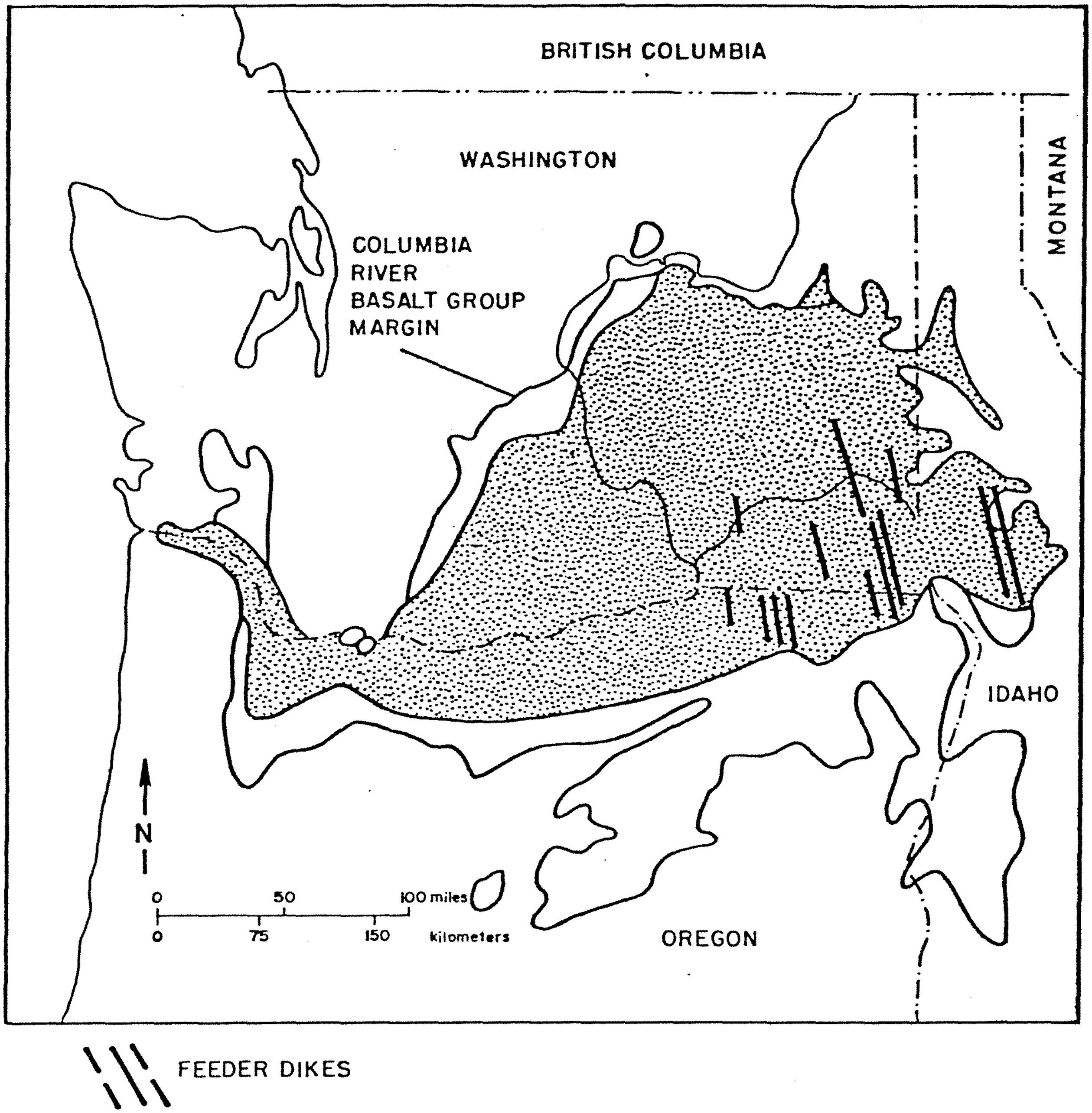



FIGURE 10.—Inferred original distribution of the Wanapum Basalt (stippled area) (from Myers and Price, 1979).

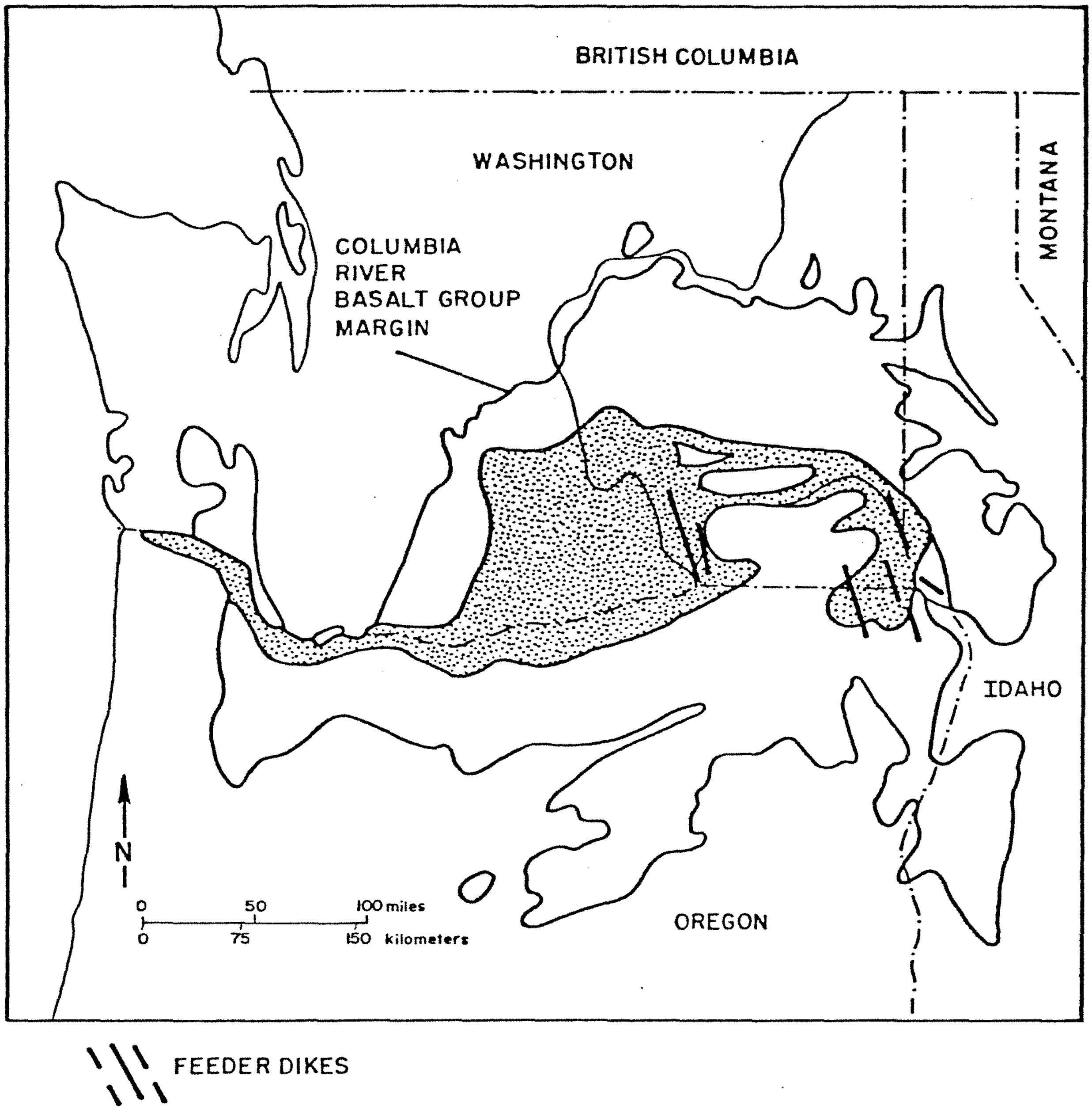



FIGURE 11.—Inferred original distribution of the Saddle Mountains Basalt (stippled area) (from Myers and Price, 1979).

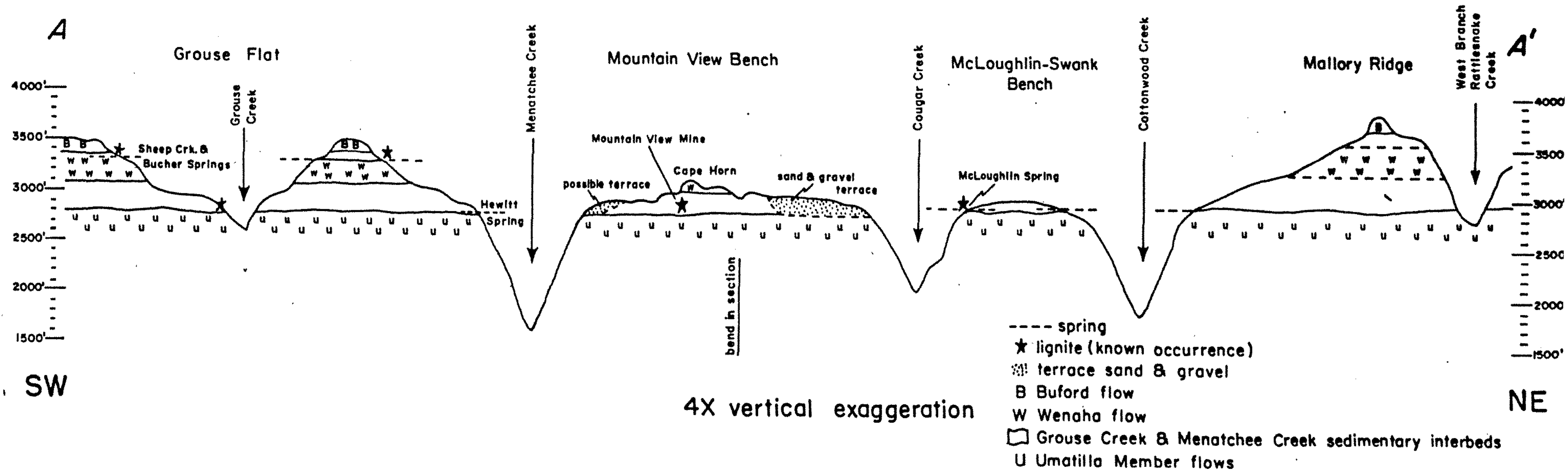



FIGURE 12.—Schematic cross-section parallel to the axis of the Grouse Flat syncline, showing benches underlain by sedimentary interbeds between flows of the Saddle Mountains Basalt. The slope of the basalt flow surfaces is an apparent slope, resulting from section line A-A' diverging from the trace of the synclinal axis and angling across the gently dipping north limb of the Grouse Flat syncline (see plate 1).

The lignite beds of the Grande Ronde lignite field are all located within sedimentary interbeds between flows of the Saddle Mountains Basalt (fig. 7). The remainder of this report describes the complex stratigraphic relationships between flows of the Saddle Mountains Basalt and the sedimentary interbeds. Using currently accepted stratigraphic nomenclature of the Columbia River Basalt Group, sedimentary interbeds between basalt flows should be assigned to either the Latah or Ellensburg Formations.

## GEOLOGIC HISTORY OF THE GRANDE RONDE LIGNITE FIELD

Only gross stratigraphic relationships are outlined in this history. Detailed descriptions of stratigraphic complexities are given in the section entitled "Complex Stratigraphic Relationships." The chronology outlined in this section is condensed from Price (1977), Ross (1978), and Swanson and others (1980) (see figs. 7 and 13).

The following is a brief chronology of geologic events that occurred in the Grande Ronde River region during the formation of the Saddle Mountains Basalt.

1. Following the cessation of Wanapum Basalt volcanism approximately 13.5 million years B.P. (McKee and others, 1977), an extended period of volcanic quiescence and local structural deformation occurred. Sediments were swept into the developing Grouse Flat synclinal basin from surrounding highlands and accumulated to a maximum thickness of 50 feet (15 meters). This sedimentary interbed is informally named the Squaw Canyon interbed.
2. The influx of sediments into the Grouse Flat synclinal basin was temporarily interrupted by the extrusion of the Bear Creek and Umatilla flows of the Umatilla Member of the Saddle Mountains Basalt. The Umatilla flow was extruded from a vent at Puffer Butte (secs. 16 and 21, T. 7 N., R. 45 E.) just northeast of the study area (Price, 1977).
3. The end of Umatilla volcanism was accompanied by continued structural deformation and renewed sediment influx into the synclinal basin. Quartzose and micaceous sandstones, micaceous and tuffaceous siltstones, claystones, carbonaceous shales, diatomaceous earth beds, and peats were all deposited in fluvial and lacustrine environments. Periodically, air-fall tuffs from more violent volcanic explosions outside of the study area were deposited in the basin. These sediments, which

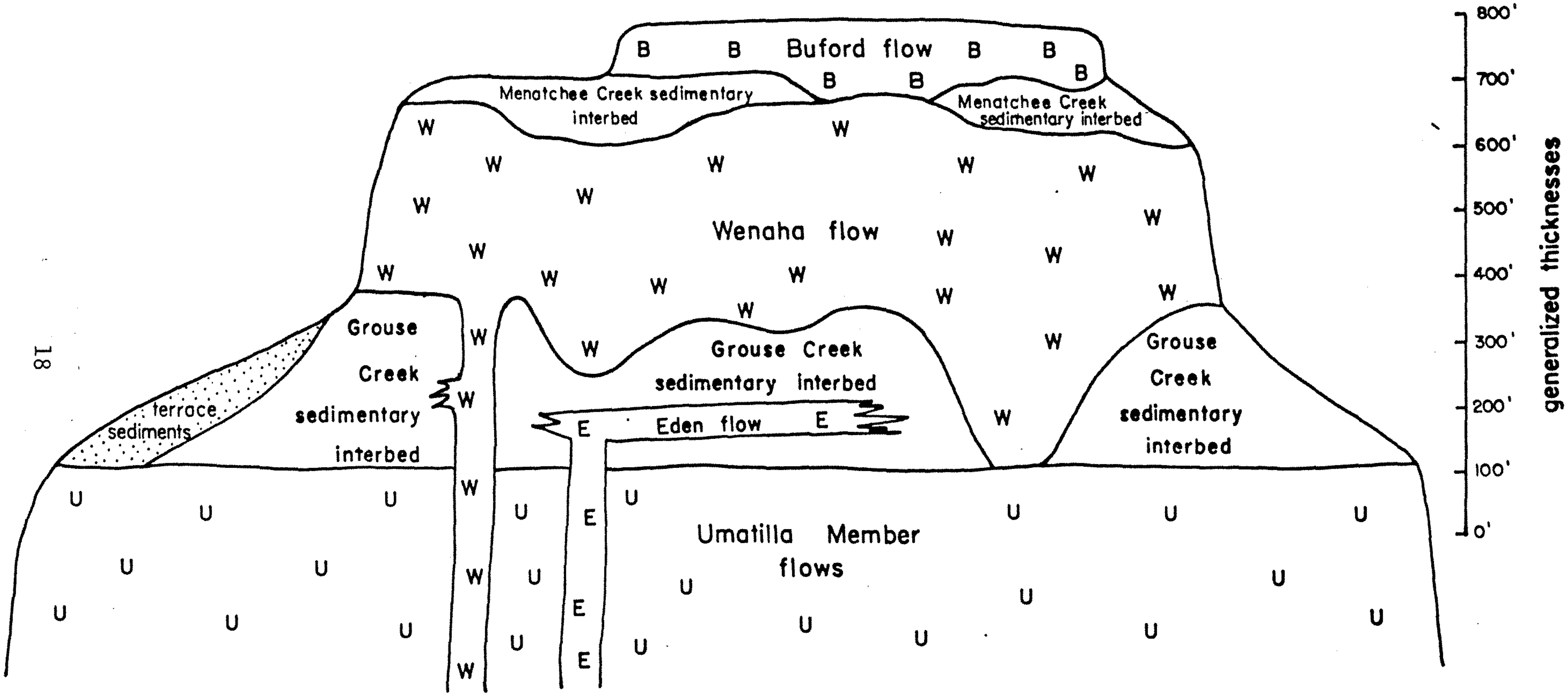



FIGURE 13.—Stratigraphic relationship of Saddle Mountains Basalt flows and intercalated sedimentary interbeds in the Grande Ronde River-Blue Mountains region.

accumulated to a maximum thickness of approximately 350 feet (100 meters) in the Grande Ronde River region, comprise what is informally named the Grouse Creek interbed.

4. Just southwest of the study area, deposition of the Grouse Creek sediments was interrupted by the extrusion of the Eden flow from a major vent southwest of Troy, Oregon (Peter Hooper, personal communication, 1981). Apparently, the Eden flow was a local flow which did not travel far from its vent. The Eden flow has not been mapped in the study area. Deposition of the Grouse Creek sedimentary interbed continued during and after the extrusion of the Eden flow. Because of their synchronous deposition, the Grouse Creek sediments have been mapped as a single interbed which interfingers with the Eden flow. In areas not inundated by the Eden flow the Grouse Creek sediments form one thick sedimentary unit.
5. Pillow-palagonite structures at the base of the Wenaha flow suggest that it either flowed into water or onto water-saturated sediments. Filling of the Grouse Flat synclinal basin by the Wenaha flow brought an end to the deposition of Grouse Creek interbed sediments approximately 10.5 million years B.P. (Swanson and others, 1980). The Wenaha flow was extruded from fissures along the present day Wenaha and Grande Ronde Rivers on the west side of Grouse Flat (Ross, 1978). In the Grande Ronde River region, the Wenaha flow was apparently restricted to the Grouse Flat synclinal basin and may have filled a channel of an ancestral Grande Ronde River (Price, 1977).
6. In the waning stages of volcanism in the Grande Ronde River region, deposition of sediments resumed. In the Grouse Flat-Mountain View area, sediments similar to those of the Grouse Creek sedimentary interbed were deposited on the surface of the Wenaha flow. These sediments, which accumulated to a maximum thickness of 100 feet (30 meters), are herein informally named the Menatchee Creek sedimentary interbed, for exposures on both sides of Menatchee Creek. In places where erosion has stripped the overlying Buford flow, the Menatchee Creek sediments crop out on the surface. These surficial Menatchee Creek sediments are probably areally extensive on Grouse Flat (plate 1).

7. The last gasp of volcanism in the Grande Ronde River region was the extrusion of the Buford basalt flow. This local flow, restricted to the Grouse Flat syncline, was extruded from a vent within the syncline. Erosional stripping has made reconstruction of the original distribution of the flow difficult. In the study area the Buford flow is present on Grouse Flat, Mountain View, and Mallory Ridge benches.
8. Following the conclusion of volcanism in the Grande Ronde River-Blue Mountains region, the Grande Ronde River established a meandering course upon the plateau surface. In response to regional uplift and continued erosion, the meanders became entrenched and a canyon began to form. When the easily erodable sedimentary interbeds were encountered, the river eroded laterally and formed benches. As lateral erosion occurred, interbed sediments were reworked and deposited as terraces of fluvial sands and gravels along the river banks (fig. 13). Once the river eroded through the interbed sediments, it again became entrenched into the basalt flows and cut the narrow, deep gorge of the inner canyon of the Grande Ronde River and its tributaries.

## COMPLEX STRATIGRAPHIC RELATIONSHIPS

Plate 1 is a preliminary outcrop map of the Grouse Creek and Menatchee Creek sedimentary interbeds in the Washington State portion of the Grande Ronde lignite field. The thin, poorly exposed Squaw Canyon interbed is not shown. Plate 1 simply shows the general area underlain by the two bench-forming sedimentary interbeds. Portions of basalt flows also crop out within these areas (see discussion which follows). Outcrop patterns of these two sedimentary interbeds will be better defined by mapping by Division of Geology and Earth Resources geologists during the summer of 1981.

Along the axis of the Grouse Flat syncline, approximately 250 feet (75 meters) of Grouse Creek interbed sediments are overlain by the Wenaha flow, which is in turn overlain by up to 100 feet (30 meters) of Menatchee Creek interbed sediments (fig. 13). During their formation, these sedimentary interbeds were subjected to several Miocene-Pliocene depositional and erosional events which controlled their distribution. These events produced complex stratigraphic relationships between basalt flows and sedimentary interbeds, which must be understood before lignite reserves of the Grande Ronde lignite field can be accurately estimated.

## Pre-depositional Events Affecting Distribution of Sedimentary Interbeds

Several Miocene geologic events which preceded the deposition of each of the sedimentary interbeds in the Grande Ronde River region controlled sediment deposition and must be considered when mapping the present distribution of sedimentary interbeds in the Grande Ronde lignite field.

1. Sediments of the Grouse Creek and Menatchee Creek sedimentary interbeds were deposited in the developing Grouse Flat synclinal basin, so the thickest sediments occur along the synclinal axis and sediment thickness decreases toward basin margins.
2. On a regional scale, the surfaces of the Umatilla and Wenaha flows are relatively flat and of low relief, parallel to the Grouse Flat synclinal axis in the study area (fig. 12). In contrast, in some areas the local relief on the surfaces of the flows is substantial (fig. 13). This relief is apparently the result of the following events:
   (a) Following the extrusion of the Umatilla and Wenaha flows in the study area, the Grouse Creek and Menatchee Creek sedimentary interbeds were deposited during long periods of volcanic quiescence. Weathering, erosion, and sediment deposition spanned more than 2 million years between extrusion of the Umatilla and Wenaha flows (Swanson and others, 1980), and probably lasted nearly that long between the extrusion of the Wenaha and Buford flows. Field identification of sediment-filled channels indicates that erosion on the surface of the Wenaha flow was extensive. This erosional relief can best be observed in outcrops at the head of Grouse Creek (SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 4, T. 6 N., R. 4 E.), where the Wenaha flow surface exhibits 200 feet (60 meters) of relief within one quarter of a mile. Thick soil profiles and subdued local relief suggest that weathering was more dominant than erosion on the surface of the Umatilla flow.

(b) Cinder and spatter cones and low shield volcanoes of lava cone complexes commonly surround vents, forming topographic relief. Price (1977) described a vent for the Umatilla flow at Puffer Butte, just northeast of the study area. It is a possibility that some of the relief on the Umatilla (Member) and Wenaha flow surfaces is constructional topography related to vent or near-vent features.

On Grouse Flat, the presence of the Bear Creek flow at higher elevations than the Umatilla flow caused Ross (1978) to map the Bear Creek flow stratigraphically above the Umatilla flow (fig. 7). However, recent work south of the Grande Ronde River (Peter Hooper, personal communication, 1981) has shown that, in fact, the Bear Creek flow underlies the Umatilla flow. If these flow units are correctly mapped, it seems probable that the presence of the Bear Creek flow at higher elevations on Grouse Flat results from the Umatilla flow lapping up against a topographic high composed of the Bear Creek flow (fig. 14). The Umatilla flow lapped up against this "high" but did not flow over it. Away from the "high," the Umatilla flow overlies the Bear Creek flow in normal stratigraphic position. This "high" may be the result of the extrusion of the Bear Creek flow from a vent in the Grouse Flat area, which could have produced a lava cone complex similar to that described by Price (1977).

Ross (1978) identified and mapped a north-northwest trend of Wenaha flow feeder dikes along the west edge of Grouse Flat (plate 1). These feeder dikes presumably mark the location of the Wenaha flow vent, which may account for some of the topographic relief on the Wenaha flow in the Grouse Flat vicinity.

Interbed sediments deposited on flows near topographically high vent areas are probably significantly thinner than away from vent areas. The Grouse Creek sedimentary interbed probably thins along the eastern limit of the Grande Ronde lignite field, near the Puffer Butte vent (source for the Umatilla flow), and possibly thins under Grouse Flat, near the

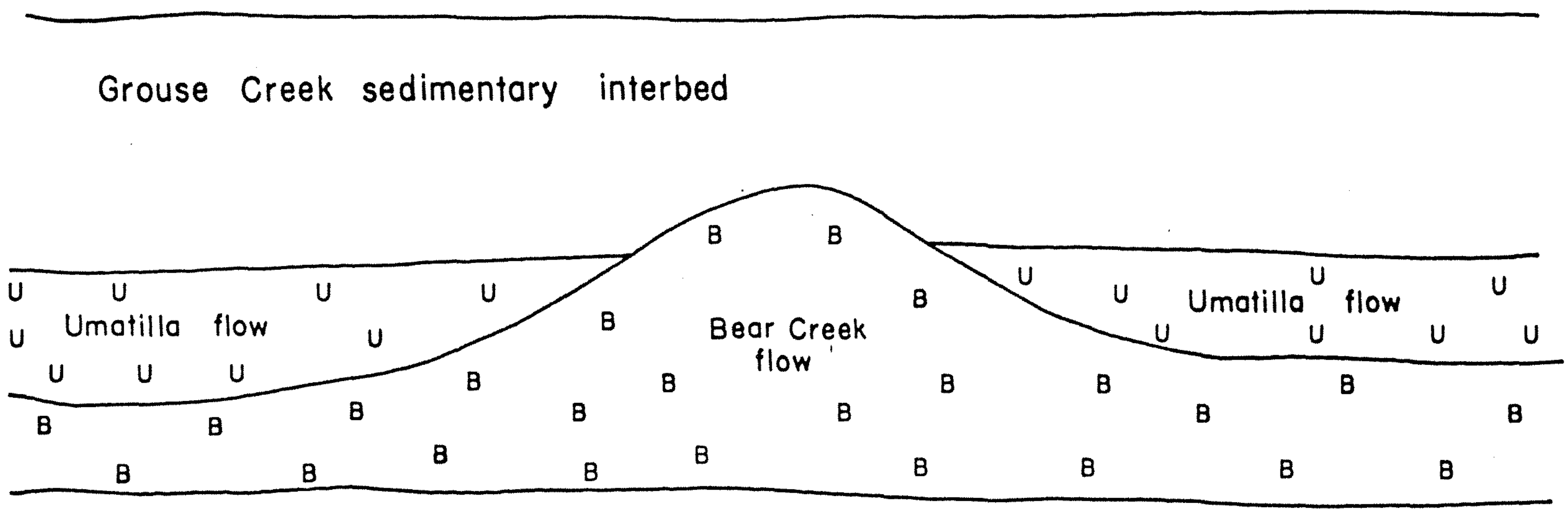



FIGURE 14.—Schematic cross-section of the apparent relationship of the Bear Creek and Umatilla flows (Umatilla Member) in the Grouse Flat vicinity.

suspected Bear Creek flow vent. The Menatchee Creek sedimentary interbed probably thins substantially on the west side of Grouse Flat, near the Wenaha flow vent.

## Post-depositional Events Affecting Distribution of Sedimentary Interbeds

Several Miocene-Pliocene geologic events followed the deposition of each of the sedimentary interbeds in the study area. These events, which significantly reduced the volume of interbed sediments (and enclosed lignites) deposited in the Grande Ronde lignite field, must also be considered when mapping the present distribution of the sedimentary interbeds.

1. Substantial relief on the bases of the Buford and Wenaha flows suggest that the surfaces of the Grouse Creek and Menatchee Creek sedimentary interbeds may have been modified by erosion prior to extrusion of subsequent basalt flows. The subsequent flows would have filled any erosional channels cut into the interbed sediments, producing basal relief on the basalt flows (fig. 13). If all of the basal relief on the Buford and Wenaha flows can be attributed to burrowing basalt flows (described below), then this cut-and-fill erosion on the surface of the sedimentary interbeds may not have occurred.
2. Numerous examples of nearly unfragmented flows which burrowed into interbed sediments are known on the Columbia Plateau (Schminke, 1964). Most of these flow intrusions form sheets, tongues, or globular masses, generally within coarse-grained sediments. Invasion of finer-grained sediments by burrowing, invasive flows commonly form basalt-sediment breccias known as peperites (Schminke, 1967). These mixtures of fragmented basalt and shattered sediments result from hot liquid lava churning up wet, unconsolidated sediments as it is intruded. An excellent example of a burrowing flow can be seen in a gravel pit in SW¼SW¼SW¼ sec. 8, T. 6 N., R. 43 E., where the Buford flow has burrowed into Menatchee Creek interbed sediments. Another exposure of a burrowing flow is located in SE¼SW¼SW¼ sec. 20, T. 7 N., R. 44 E., where a 3,040-foot roadcut exposes massive Wenaha basalt which grades

laterally into peperite and then sediments of the Grouse Creek sedimentary interbed.

Preliminary evidence suggests that in several places the Wenaha flow has burrowed completely through the Grouse Creek sedimentary interbed and is in direct contact with the Umatilla flow. This relationship can be observed best at the Medicine triangulation station (elevation 2,824 feet) on Hanson Ridge in NE¼SW¼SW¼ sec. 28, T. 7 N., R. 44 E., where it is believed that massive Wenaha flow basalt overlies scoriaceous Umatilla flow basalt. Likewise, field relationships suggest that in some places the Buford flow has burrowed completely through the Menatchee Creek sedimentary interbed. An excellent example can be seen in a roadcut (elevation 3,200 feet) in NW¼SE¼SE¼ sec. 4, T. 6 N., R. 43 E., where a 1-foot thick dike and sill of the Buford flow have invaded sandy sediment at the base of the Menatchee Creek sedimentary interbed.

3. Following deposition, the interbed sediments were folded during continued development of the Grouse Flat syncline-Slide Canyon monocline. The elevation of the sedimentary interbeds rises gently (approximately 3° dip) north and south of the synclinal axis (fig. 6). Along the north border of the Grande Ronde lignite field, the interbed sediments dip steeply on the flank of the Slide Canyon monocline and have been eroded away along the top of the structure.
4. In response to regional uplift following volcanism, the Grande Ronde River and its tributaries began downcutting through the basalt flows. When the easily erodable sedimentary interbeds were encountered, the rivers eroded laterally and formed benches. As lateral erosion occurred, interbed sediments were reworked and deposited as terraces of fluvial sands and gravels along the river banks (fig. 13). In some areas, especially on Mountain View bench, large volumes of interbed sediments (and enclosed lignites) have apparently been eroded and terrace sediments rest directly on basalt.
5. During the bench-forming episodes, lateral erosion by rivers undercut the cliffs at the back of the benches and produced landslides. The cliffs at the back of the benches have remained extremely susceptible to landsliding and are still active today. Recent landslide blocks which slid out onto the benches are easy to recognize, but older, partially

eroded landslide deposits on the benches are difficult to recognize since the basalt usually lacks bedding. Landslides have not significantly reduced the volume of interbed sediments present on the benches, but landslide deposits often obscure contacts and make mapping of the basalt-sediment contacts extremely difficult. A good example of a recent landslide can be seen in the N½ sec. 10, T. 6 N., R. 43 E., where a large landslide covers the contacts between the Umatilla, Wenaha, and Buford flows and the Grouse Creek and Menatchee Creek sedimentary interbeds.

## DISTRIBUTION AND DEPOSITIONAL ENVIRONMENT OF GRANDE RONDE LIGNITES

Since lignites in the Grande Ronde lignite field are poorly exposed, relatively little is known about their distribution and depositional environment. Nevertheless, lignite beds are exposed at springs, creeks, and roadcuts in outcrops of two different interbeds—the Grouse Creek and Menatchee Creek sedimentary interbeds.

Four exposures of lignite in the Grouse Creek sedimentary interbed are known:

1. Mountain View mine SW¼SW¼SW¼ sec. 31, T. 7 N., R. 44 E.
2. McGloughlin Spring NE¼NE¼SE¼ sec. 29, T. 7 N., R. 44 E.
3. Medicine Creek SE¼SW¼NE¼ sec. 30, T. 7 N., R. 44 E.
4. Sheep Creek NW¼NE¼NW¼ sec. 22, T. 6 N., R. 43 E.

Of these four localities, lignite thickness is known only from the Mountain View mine, where a 300-foot-long adit was driven to expose lignite at least 27 feet (8 meters) thick (Washington Division of Geology and Earth Resources unpublished data), and from McGloughlin Spring where an excavation exposed lignite at least 16 feet (5 meters) thick (Russell, 1901).

Where exposed in Washington State, lignites in the Grouse Creek sedimentary interbed commonly occur near the base of the sediments and occasionally rest directly upon Umatilla flow basalt. Deposition of the peats which formed these lignites appears to have been preceded only by the deposition of diatomaceous earth beds or a brief influx of detrital sand and silt.

Lignite beds are also known from two localities in the Menatchee Creek sedimentary interbed:

1. East Grouse Flat NE¼NE¼SE¼ sec. 3, T. 6 N., R. 43 E.
2. Grouse Creek SE¼SW¼NE¼ sec. 4, T. 6 N., R. 43 E.

These lignite beds are very poorly exposed, appear to be thin, and are intercalated with interbed sediments. No data is available concerning the quality of these lignites.

More information on the distribution and depositional environment of the Grande Ronde lignites in Washington State will come only from additional exploration and drilling programs. Drilling programs should be undertaken with the outlined stratigraphic complexities in mind. Staff members of the Division of Geology and Earth Resources have done additional mapping in the Grande Ronde lignite field during the summer of 1981, in an attempt to answer questions raised in this preliminary report.

## ANALYSES OF GRANDE RONDE LIGNITES

Analyses of six Grande Ronde lignites from scattered localities in the study area are given in table 1. All samples were analyzed by the U.S. Department of Energy except sample no. 1, which was analyzed by the U.S. Bureau of Mines.

Four of the samples (nos. 1, 2, 3, and 6) are lignites with a maximum BTU/lb value of 7,944 (as received) and a maximum (as received) fixed carbon value of 39.6 percent. Sulfur content is less than 0.5 percent in all four samples, while ash content ranges from 5.7 to 16.7 percent (as received).

Although the physical characteristics of the remaining two samples (nos. 4 and 5) were similar to the above lignites, analyses indicate they contain no fixed carbon and have no BTU value. Both samples contain over 90 percent mineral matter (moisture free analyses).

## TABLE 1—*Analyses of Grande Ronde lignites*

AR - as received

MF - moisture free

MAF - moisture and ash free

| | | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| PROXIMATE ANALYSIS | Moisture (AR) | 15.8 | 36.8 | 33.4 | 9.6 | 14.9 | 12.5 |
| | Volatile matter (AR) | 31.8 | 24.0 | 35.0 | 12.4 | 15.1 | 43.9 |
| | Volatile matter (MF) | 37.8 | 37.9 | 52.5 | 13.7 | 17.8 | 50.2 |
| | Volatile matter (MAF) | 44.6 | 51.5 | 57.4 | 262.8 | 196.8 | 60.9 |
| | Fixed carbon (AR) | 39.6 | 22.5 | 25.9 | 0.0 | 0.0 | 28.2 |
| | Fixed carbon (MF) | 47.0 | 35.6 | 38.9 | 0.0 | 0.0 | 32.1 |
| | Fixed carbon (MAF) | 55.4 | 48.5 | 42.6 | 0.0 | 0.0 | 39.1 |
| | Ash (AR) | 12.8 | 16.7 | 5.7 | 85.6 | 77.4 | 15.4 |
| | Ash (MF) | 15.2 | 26.5 | 8.6 | 94.8 | 91.0 | 17.7 |
| ULTIMATE ANALYSIS | Hydrogen (AR) | 4.4 | 6.0 | 7.0 | 1.9 | 2.8 | 5.4 |
| | Hydrogen (MF) | 3.1 | 3.1 | 4.9 | 0.9 | 1.4 | 4.6 |
| | Hydrogen (MAF) | 3.7 | 4.2 | 5.3 | 17.8 | 15.4 | 5.5 |
| | Carbon (AR) | 49.6 | 31.3 | 40.5 | 1.3 | 1.2 | 46.6 |
| | Carbon (MF) | 58.9 | 49.6 | 60.8 | 1.4 | 1.4 | 53.2 |
| | Carbon (MAF) | 69.5 | 67.4 | 66.5 | 27.5 | 15.3 | 64.6 |
| | Nitrogen (AR) | 0.6 | 0.4 | 0.4 | 0.0 | 0.1 | 0.5 |
| | Nitrogen (MF) | 0.7 | 0.6 | 0.6 | 0.1 | 0.1 | 0.5 |
| | Nitrogen (MAF) | 0.8 | 0.8 | 0.7 | 1.0 | 0.8 | 0.7 |
| | Sulfur (AR) | 0.3 | 0.1 | 0.2 | 0.1 | 0.1 | 0.4 |
| | Sulfur (MF) | 0.4 | 0.2 | 0.3 | 0.1 | 0.1 | 0.4 |
| | Sulfur (MAF) | 0.4 | 0.2 | 0.3 | 1.5 | 0.7 | 0.5 |
| | Oxygen (AR) | 32.2 | 45.4 | 46.2 | 11.0 | 18.5 | 31.7 |
| | Oxygen (MF) | 21.6 | 20.1 | 24.8 | 2.7 | 6.2 | 23.6 |
| | Oxygen (MAF) | 25.5 | 27.3 | 27.2 | 52.2 | 68.2 | 28.6 |
| | Ash (AR) | 12.8 | 16.7 | 5.7 | 85.6 | 77.4 | 15.4 |
| | Ash (MF) | 15.2 | 26.5 | 8.6 | 94.8 | 91.0 | 17.7 |
| Btu/lb | BTU (AR) | 7,815 | 5,027 | 6,697 | None | None | 7,944 |
| | BTU (MF) | 9,263 | 7,949 | 10,053 | None | None | 9,078 |
| | BTU (MAF) | 10,953 | 10,809 | 10,998 | None | None | 11,024 |

1 (DGER #5-76) SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 30, T. 7 N., R. 44 E. - Medicine Creek
2 (DGER #8-77) SW$\frac{1}{4}$NE$\frac{1}{4}$ sec. 30, T. 7 N., R. 44 E. - Medicine Creek
3 (DGER #9-77) NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 29, T. 7 N., R. 44 E. - McGloughlin Spring
4 (DGER #9-80) NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 9, T. 6 N., R. 43 E. - Grouse Creek
5 (DGER #10-80) SE$\frac{1}{4}$SE$\frac{1}{4}$ sec. 26, T. 6 N., R. 44 E. - Buford Creek, Oregon
6 (DGER #11-80) NE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 35, T. 6 N., R. 44 E. - Buford Creek, Oregon

## REFERENCES


McDonald, G. A., 1972, Volcanoes: Prentice-Hall, Englewood Cliffs, New Jersey, 510 p.

McKee, E. H.; Hooper, P. R.; Kleck, W. B., 1981, Age of Imnaha Basalt—Oldest basalt flow of the Columbia River Basalt Group, Northwest United States: Isochron—West, no. 31 [in press].

McKee, E. H.; Swanson, D. A., 1977, Duration and volume of Columbia River Basalt volcanism, Washington, Oregon, and Idaho: Geological Society of America Abstracts with Programs, v. 9, no. 4, p. 463-464.

Myers, C. W.; Price, S. M., 1979, Geologic studies of the Columbia Plateau—A status report: Rockwell Hanford Operations Report RHO-BWI-ST-4.

Price, S. M., 1977, An evaluation of dike-flow correlations indicated by geochemistry, Chief Joseph Swarm, Columbia River Basalt: University of Idaho Ph. D. thesis, 320 p.

Ross, M. E., 1978, Stratigraphy, structure, and petrology of Columbia River Basalt in a portion of the Grande Ronde River-Blue Mountains area of Oregon and Washington: Rockwell Hanford Operations Report RHO-SA-58, 460 p.

Russell, I. R., 1901, Geology and water resources of Nez Perce County, Idaho, U.S. Geological Survey Water Supply Paper 54, p. 125-127.

Schminke, H. U., 1964, Petrology, paleocurrents, and stratigraphy of the Ellensburg Formation and interbedded Yakima Basalt flows, south-central Washington: Johns Hopkins University Ph. D. thesis, 426 p.

Schminke, H. U., 1967, Fused tuff and peperites in south-central Washington: Geological Society of America Bulletin, v. 78, no. 3, p. 319-330.

Swanson, D. A.; Wright, T. L.; Helz, R. T., 1975, Linear vent systems and estimated rates of magma production and eruption for the Yakima Basalt on the Columbia Plateau: American Journal of Science, v. 275, p. 877-905.

Swanson, D. A.; Wright, T. L.; Hooper, P. R.; Bentley, R. D., 1979, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457G, 59 p.

Swanson, D. A.; Wright, T. L.; Camp, V. E.; Gardner, J. N.; Helz, R. T.; Price, S. M.; Reidal, S. P.; Ross, M. E., 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Map I-1139, scale 1:250,000.

## REFERENCES—Continued


Swanson, D. A.; Wright, T. L., 1981, Guide to geologic field trip between Lewiston, Idaho and Kimberly, Oregon emphasizing the Columbia River Basalt Group. In Johnston, D. A.; Donnelly-Nolan, Julie, editors. Guides to some volcanic terranes in Washington, Idaho, Oregon, and northern California: U.S. Geological Survey Circular 838, p. 1-28.

Taubeneck, W. H., 1970, Dikes of Columbia River Basalt in northeastern Oregon, western Idaho, and southeastern Washington. Gilmour, E. H.; Stradling, D., editors: Proceedings of the second Columbia River Basalt symposium, Eastern Washington State College Press, p. 73-96.

Walker, G. W., 1979, Reconnaissance geologic map of the Oregon part of the Grangeville quadrangle, Baker, Union, Umatilla, and Wallowa Counties, Oregon: U.S. Geological Survey Map I-1116.

Washington Division of Geology and Earth Resources unpublished data, various dates.

Weissenborn, A. E., 1978, Geology of Washington: Washington Division of Geology and Earth Resources Reprint 12, 51 p.

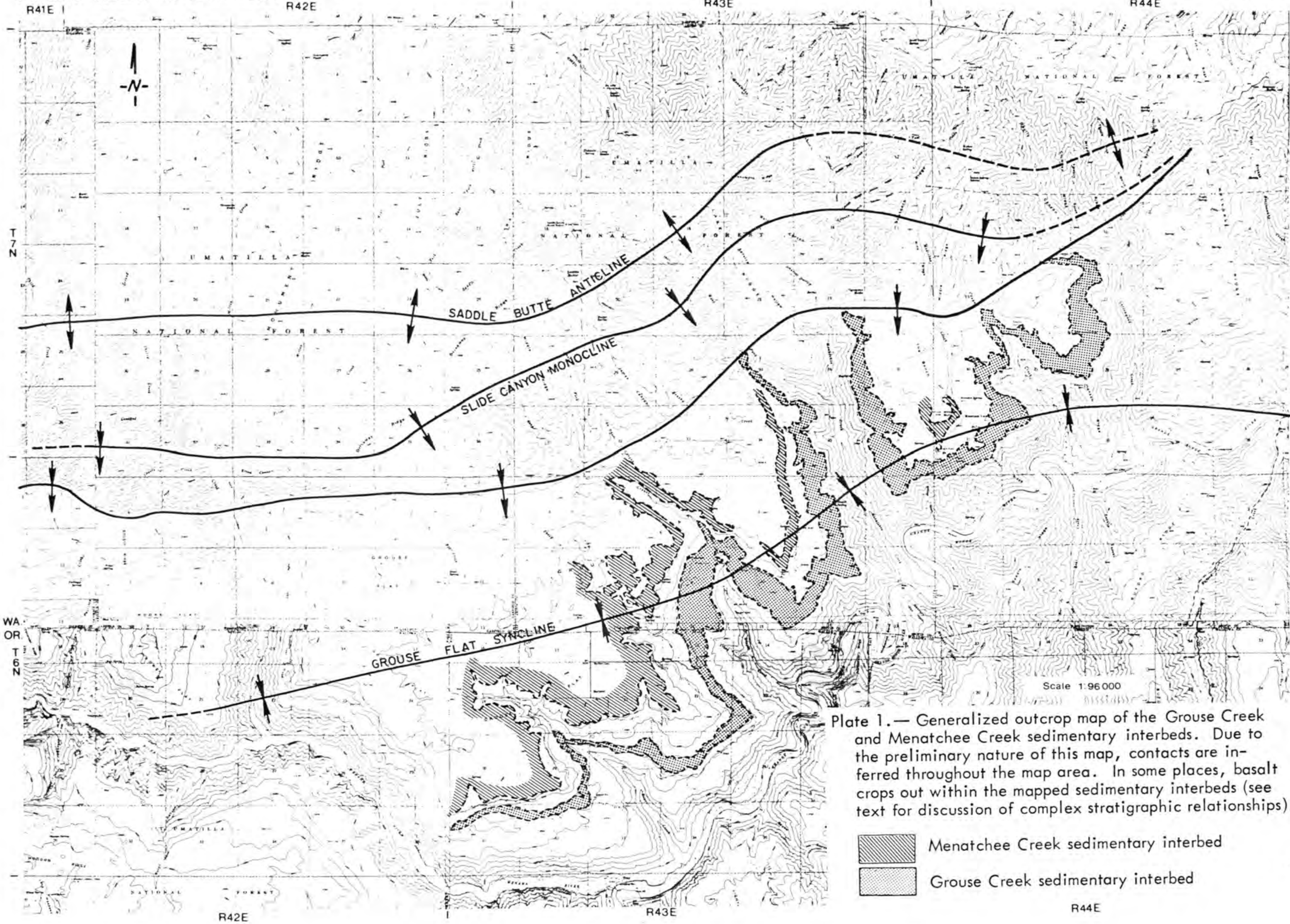



Plate 1.— Generalized outcrop map of the Grouse Creek and Menatchee Creek sedimentary interbeds. Due to the preliminary nature of this map, contacts are inferred throughout the map area. In some places, basalt crops out within the mapped sedimentary interbeds (see text for discussion of complex stratigraphic relationships).

Menatchee Creek sedimentary interbed

Grouse Creek sedimentary interbed