TOBACCO ROOT GEOLOGICAL SOCIETY
11th ANNUAL FIELD CONFERENCE 1986

CENOZOIC GEOLOGY OF MOSCOW IDAHO AND SURROUNDING AREAS

MOSCOW, IDAHO

AUGUST 6-9, 1986

PATRICIA C. BEAVER, EDITOR

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9:40 - 10:15	Geophysical Investigations of Southeastern Washington by Richard Thiessen
10:25 - 11:00	The Miocene Clarkia System by Charles J. Smiley
11:00 - 11:30	A Middle Cenozoic Climate Change in Northern Idaho by Robert Jorstad
11:30 - 12:00	Tertiary Vertebrates of the Rockland Valley Southeastern Idaho by William Akersten
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1:30 - 2:00	Lake Missoula Floods in the Northern Borderlands of the Columbia Plateau by Dale F. Stradling
2:00 - 2:30	The Scabland Features of the Rathdrum Prairie and Spokane Valley, Northern Idaho and Eastern Washington by John McKiness
2:30 - 3:00	Late Quaternary Geology of the Upper Kootenai River Valley, Northwestern Montana by Bruce Cochran
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3:30 - 4:00	Hypabyssal Intrusions in the Chiwaukum Graben Near Wenatchee, Washington by Lawrence Ott
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Thursday, August 7, 1986 (continued)

6:00 - 7:00	No-Host Cocktails
7:00 - 9:00	Annual Banquet (included in registration fees)

Friday, August 7, 1986

8:00 am	Field Trip participants assemble in the west parking lot of the University Inn. Field Trip includes a sack lunch and soft drinks. Field trips 1 and 2 depart at the same time. Vans will be labeled with field trip number.
8:30 pm	Annual Business Meeting of the TRGS - all members are urged to attend.

Saturday, August 8, 1986

8:00 am	Same as above for field trips 3, 4, and 5.

TERTIARY VERTEBRATES OF THE ROCKLAND VALLEY, SOUTHEASTERN IDAHO

by William A. Akersten, H. Gregory McDonald, and James M. Soiset
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ABSTRACT

Trimble and Carr (1976) assigned all post-Paleozoic outcrops in the Rockland Valley to the Starlight Formation or younger units. Four fragmentary vertebrate specimens were reported from a gravel pit in the upper member of the Starlight Formation about 10 miles (16 km) south of Rockland. A partial mandible of a short-jawed mastodon lacking lower tusks (IMNH 1000) was tentatively identified as *Pliomastodon*. We consider it too fragmentary for generic assignment. Other specimens in the USGS collections were tentatively assigned to an advanced species of *?Hipparion* and to *?Megatylopus* sp. Mollusks from both the upper and lower members of the Starlight Formation appeared most similar to those from middle Pliocene (= late Miocene of current usage) deposits. This agrees with radiometric dates of 6.5 and 7.7 mya (Armstrong *et al*., 1975) and does not conflict with interpretations of the above vertebrates.

However, one small, isolated outcrop about three miles southeast of Rockland has yielded a partial cranium (IMNH 18450) assignable to *Mesoreodon* sp., known elsewhere from latest Oligocene through earliest Miocene (about 21 to 28 mya) deposits, including the Lemhi Basin near Leadore, Idaho (Nichols, 1976). While the Rockland specimen may not be correctly identified (it is crushed and incomplete and oreodonts have undergone considerable parallelism), a more likely explanation is that the Tertiary record of the Rockland Valley is longer and more complex than previously thought.

Armstrong, R.L., W.P. Leman, and A.P. Malde, 1975, K-Ar Dating. Oligocene and Miocene Volcanic Rocks of the Snake River Plain, Idaho. *American Journal Science*, 275: p. 225-251.

Nichols, R., 1976, Early Miocene Mammals from the Lemhi Valley of Idaho. *Journalist Tebiwa*, 2: p. 9-47.

Trimble, A.B. and W.J. Carr, 1976, Geology of the Rockland and the Arbon Quadrangles, Power County, Idaho. *U.S. Geological Survey Bulletin*, 1.99, 115 pp.

A COMPARISON OF PLATE INTERACTIONS IN THE PACIFIC OCEAN AND THE PLUTONIC-VOLCANIC HISTORY OF IDAHO FROM THE CRETACEOUS TO THE PRESENT

by Earl H. Bennett
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University of Idaho

ABSTRACT

Opening of the North Atlantic occurred approximately 120 m.y.a. initiating movement between the North American and oceanic plates in the Pacific. A comparison of recent K/Ar and Ar39/40 dates for the Idaho Batholith with the timing of plate motions in the Pacific Ocean shows a close correlation. The Quiet Zone of the Pacific Plate lasted roughly from 120 to 72 m.y.a., an interval spanning the entire magmatic history of the Cretaceous batholith. Although quiet in regard to the development of major transform faults, a major change probably occurred in Pacific Plate motion from westerly to northwesterly at 100 m.y.a., as recorded by the trace of the MacDonald Seamount and Sala Y Gomez Hot Spots.

Plutonic rocks of the Cretaceous batholith consist of border zone tonalite, estimated to be 85 to 95 m.y.a., intruded by biotite granodiorite grading to two-mica granite, dated at 75 to 72 m.y.a. The two-mica granite is tightly constrained at 72 m.y.a. and marks the end of Cretaceous plutonism. The older tonalite magmatic event is roughly concordant with the 100 m.y.a. plate change. The 72 m.y.a. date corresponds to the next plate reorientation, when the trace of the Hawaiian Hot Spot changed from the northwest-trending Obruchev Rise, to the more northerly directed Emperor Chain.

No further plutonic or volcanic activity occurred in Idaho until the onset of Challis volcanism about 55 m.y. At this time a major reorganization between the Farallon, Kula, and Pacific Plates is recorded in sea floor magnetics south of Alaska. The convergence between the Farallon Plate and the North American Plate increased to 75 mi/m.y. (120 km/m.y.), with a related flattening of the subduction zone beneath western North American and the development of the Challis Arc.

The end of Challis volcanism is synchronous with the well-known shift in the Pacific Plate direction recorded by the dogleg in the

Emperor-Hawaiian chain about 40 m.y. ago. At the end of Challis time, regional extension affected the area from the eastern Snake River Plain to British Columbia, with the formation of core complexes, bimodal volcanism, related grabens, and anorogenic granites. This extension was in part related to the Kula-Farallon spreading center that was totally subducted about 40 m.y. ago.

A slowdown between the North American and Farallon Plates to 25 mi/m.y. (40 km/m.y.) occurred at the end of Challis time. A thinner, hotter Farallon Plate changed from positive to negative buoyancy, and subduction steepened and stepped westward to the Cascades.

The intersection of the Pacific-Farallon spreading center with North America occurred about 30 m.y. ago, with resulting Basin and Range extension beginning at 20 m.y. ago. The Yellowstone Hot Spot located on the Kula-Farallon spreading ridge was overridden by the pre-Basin and Range extended North American Plate. When the hot spot intersected the edge of continental crust near McDermitt, Oregon, and Silver City, Idaho about 16 m.y. ago, voluminous rhyolitic volcanism associated with the eastern Snake River Plain began. Alkaline magmas were generated from accreted terrane (McDermitt) and calcalkaline rhyolite magmas from old continental crust (Silver City and southwest Oregon).

Voluminous basaltic volcanism related to back-arc rifting and Yellowstone Hot Spot activity began in the Columbia River Basin 17 m.y. ago. The basalts flooded an area of thin or absent continental crust, possibly filling a hole created by the northward movement of the Kootenai terrane.

A series of volcanic eruptions extending from southeastern Oregon to the Newberry Volcano resulted from volcanism along the southern edge of the remnant Farallon Plate. The Brothers, Eugene-Denio, and McLoughlin Fault zones and possibly the Olympic-Wallowa lineament probably formed above old transforms in the thin Farallon (Juan de Fuca) Plate.

Basin and Range faulting continues in Idaho today as a result of both the Yellowstone Hot Spot, and the intersection and northward migration of the Pacific plate in California. The potential is high for future volcanism and related seismic activity.

LATE QUATERNARY GEOLOGY OF THE UPPER KOOTENAI RIVER VALLEY, NORTHWESTERN MONTANA

by Bruce Cochran
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University of Idaho

ABSTRACT

Detailed stratigraphic studies of late Quaternary deposits in the upper Kootenai River Valley of northwestern Montana yield new information pertaining to the age of the stagnation and decay of the Kootenai ice lobe and the gradational history of the Kootenai River during the last 11,000 years. Compacted till records the last advance of continental ice (Vashon State) which reached its maximum about 15,000 years ago and decayed by 12,000 years ago. About 12,000 years ago the Kootenai River was flowing southward through drainageways near Troy, Montana and Elmira, Idaho. Soon after this time the Kootenai Valley was occupied by Glacial Lake Kootenai. The co-occurrence of Mount St. Helens Set J. (ca. 11,700 yrs. B.P.) and Glacier Peak Layer G (ca. 11,300 yrs. B.P.) volcanic ashes in the upper 7 ft. (2.0 m) of the lacustrine deposits furnish an upper limiting age of Glacial Lake Kootenai. After 11,000 years ago the river began to erode and remove former valley fill. Between ca. 8,100 yrs. B.P. and today, four alluvial cycles (I-IV) are represented by four distinctive alluvial units of different radiocarbon age. Age of these aggradational-degradational episodes bracket between pre 8,100 to pre 6,700 yrs. B.P. (I); pre 6,700 to post 4,800 yrs. B.P. (II); post 4,800 to ca. 2,300 yrs. B.P. (III); and post 2,300 yrs. B.P. to modern times (IV).

CHARACTER OF ORGANIC-RICH CENOZOIC SEDIMENTARY DEPOSITS IN THE REPUBLIC GRABEN, NORTH-CENTRAL WASHINGTON

by David R. Gaylord
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ABSTRACT

The Columbia Plateau is one of the last true oil and gas exploration frontiers in the continental United States. However, exploration for potential hydrocarbon-bearing strata in this area is severely limited by the thick and extensive Columbia River Basalt. Details of the character and extent of underlying sedimentary rocks must be inferred from examination of sedimentary rocks exposed peripherally to the Basalt.

A sequence of potential hydrocarbon-producing volcaniclastic and siliciclastic Cenozoic sedimentary rocks are preserved in the Republic Graben, one of a series of en echelon structural depressions that adjoin the Columbia River Basalt in north-central Washington. Sedimentary and volcanic fill in this 6-10 mi (10-16 km) by 50 mi (80 km) Eocene extensional feature exceeds 9,850 ft (3,000 m), and includes deposits of the O'Brien Creek Formation, Sanpoil Volcanics, and the Klondike Mountain Formation. Pyroclastic flows and falls are common in the O'Brien Creek Formation but decrease up-section. Sedimentary rocks are concentrated in the upper Sanpoil Volcanics and Klondike Mountain Formation, and include thick and highly fossiliferous pyroclastic flows and falls. Lack of compositional and textural maturity, abundant load and slump structures, prevalence of graded beds, and exceptional preservation of plant, fish, and insect fossils attest to periodically high sedimentation rates. Sedimentary deposits coarsen upward from the middle to the upper part of the Sanpoil Volcanics, and from the lower to the middle of the Klondike Mountain Formation. In both cases lacustrine, deltaic, and fluvial sediments are capped by debris flow deposits, as former lake basins were filled. Sedimentary facies in the Sanpoil Volcanics and Klondike Mountain Formation are difficult to trace laterally due to pervasive intragraben faulting. However, available stratigraphic data suggests that filling was dominantly from the north and west. Organic-rich sedimentary rocks in the Klondike Mountain Formation are 985-1315 ft. (300-400 m) thick and have total organic carbon values and production indices that suggest promise as hydrocarbon sources. Because structural trends and gravity data suggest

that the Republic Graben extends beneath the Columbia River Basalt, the potential for buried hydrocarbons appears promising.

Documenting depositional trends and patterns of the principal Cenozoic sedimentary units in the Republic Graben may have significance in locating preferred sites of gold and silver mineralization. There is a close association between sites of economic gold and silver mineralization and preserved sites of thick sedimentation (e.g., the Klondike Mountain Formation). Details of this association, through presently enigmatic, may have important implications for future exploration.

ERUPTION OF THE COLUMBIA RIVER BASALT

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ABSTRACT

From 17.5 m.y. to 6.0 m.y. (Middle to Late Miocene) unusually large volumes of basalt erupted from NNW-SSE orientated fissures close to the borders between western Idaho and eastern Washington and Oregon. 47,990 mi^3 (200,000 km^3) to 71,990 mi^3 (300,000 km^3) of lava poured out in about three million years, after which activity decreased greatly but sputtered on for another 8 million years. There is no historical equivalent of continental fissure eruptions on this scale. Individual eruptions of 168 mi^3 (700 km^3) formed single flows that covered most of the 61,780 mi^2 (160,000 km^2) of the Columbia Plateau and some erupting in western Idaho, travelled about (372 mi) 600 km down the existing drainage systems to the Pacific coast.

Fissure systems from which the flows extruded, now represented by dikes, are up to 90 mi (150 km) long and include numerous low angle volcanic cones. The Roza system for example, has had over 20 such cones identified along its 90 mi (150 km) length just west of Lewiston. Two Roza flows, totalling 340 mi^3 (1,400 km^3), erupted from these fissures and for each eruption we must envisage a wall of fluid lava 98 ft (30 m) high, 60 mi (100 km) long, advancing westwards at an approximate rate of 3 mph (4.8 kmph).

Previous estimates suggest about 150 basalt flows of substantial size forming the Columbia Plateau. This means that, on average, each flow had a volume of 360 mi^3 (1,500 km^3) to 480 mi^3 (2,000 km^3) and one such major eruption occurred every 20,000 years. More probably there are up to 300 major flows with half of the above volumes which were erupted at 10,000 year intervals.

The magma in each eruption is very homogeneous, although they have undergone substantial crystal fractionation dominated by plagioclase removal. This indicates very large magma reservoirs close to the crust-mantle boundary (20 mi/32 km depth). All basalt is derived from the mantle, and the geochemical and isotopic data require two or three different mantle sources. We envisage this magma migrating to the crust-mantle boundary beneath the thin accreted terranes of the Blue

Mountains Province. Here it was held in a density trap, fractionating first olivine and pyroxene, then predominantly plagioclase. Some assimilation of the crustal roof of the reservoir occurred at this stage, but there is considerable disagreement as to the relative importance of crustal assimilation versus a variable mantle source.

The eruption was triggered by either simple back-arc spreading or the migration of the North American Plate over the Yellowstone Hot Spot. In either case, it was localized along the old suture where weaker and thinner oceanic crust was accreted to the old cratonic margin. The form of the fissure eruption was controlled by regional tectonic stresses associated with back-arc spreading. Deformation associated with regional stress on the evolving Columbia Plateau can be traced in detail, as can the evolution of drainage patterns.

A MIDDLE CENOZOIC CLIMATE CHANGE IN NORTHERN IDAHO

by Robert B. Jorstad
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ABSTRACT

The documentation of a Middle Cenozoic climate change in northern Idaho is based on assemblage analysis of palynological data from sediments found in the drainage basins of Oviatt Creek and the St. Maries River near Clarkia. Early Miocene palynomorph assemblages from the Clarkia Fossil Site can be interpreted as having components of a valley floor Mixed-Mesophytic Forest (mild climate) with an inferred gradual elevation based floristic change to an upland cool climate Mixed-Coniferous Forest. Assemblage analysis of the Middle Miocene Oviatt Creek Basin palynomorphs shows the lack of an upland floristic component, but clearly documents an Early Miocene climate change.

Uniformitarianism allows extrapolation of specific thermal and precipitation conditions for the two Clarkia forests as well as for pollen assemblages from the Oviatt Creek Basin sites. Specific inferred paleoclimatic changes from the Early Miocene Clarkia Basin to the Middle Miocene Oviatt Creek Basin assemblages include: (1) slightly warmer summers in the Middle Miocene; (2) cooler winters in the Middle Miocene; (3) a greater mean annual temperature range during the Middle Miocene, and (4) a slightly drier climate during the Middle Miocene. The magnitude of the Early Miocene climate change in Idaho is roughly analogous to comparing the modern climates of the Southern Appalachian Mountains and Milwaukee, Wisconsin.

THE SCABLAND FEATURES OF THE RATHDRUM PRAIRIE AND SPOKANE VALLEY, NORTHERN IDAHO AND EASTERN WASHINGTON

by John Paul McKiness
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University of Idaho

ABSTRACT

The Rathdrum Prairie and eastern Spokane Valley were a major flood path for Glacial Lake Missoula's outburst floods during the Fraser Glaciation. The last flood or floods that traversed this route occurred after a Mount St. Helens Set S ash fall event.

The outburst floods extensively modified the lower flanks of the Mt. Spokane and Mica Peak uplands and the valley's outwash plain surface. The maximum flood surface elevation on the southern flank of the Mt. Spokane uplands and the northern flank of the Mica Peak uplands appears to have been approximately 2700 feet (823 meters). The most intense flood scouring occurred below 2600 feet (792.5 meters) in elevation in this region. During these floods the valleyward flanks of the uplands retreated laterally leaving minor tributary valley mouths hanging above intensely scoured bedrock surfaces; spurs were faceted; and divide crossings were incised across the lower spurs and ridges. The outwash plain was channeled and overall degraded, creating flood erosional landforms that are difficult to distinguish from depositional landforms.

Three distinct types of scabland resulted from the outburst floods in the Rathdrum Prairie and Spokane Valley: gneissic scabland, basalt flow/clay bed scabland, and outwash plain scabland. Due to variations in local flood intensity, duration, and/or number of floods that affected a surface, scabland surfaces vary from intensely to indistinctly scoured.

HYPABYSSAL INTRUSIONS IN THE CHIWAUKUM GRABEN NEAR WENATCHEE, WASHINGTON

by Lawrence E. Ott and Peter L. Siems
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University of Idaho

ABSTRACT

Whole rock analysis and K-Ar age determinations are used to differentiate Tertiary igneous events within the southeast part of the northwest-trending Chiwaukum Graben of central Washington. Intrusive rocks in the area belong to the calcalkaline suite and range in age from 50.9 m.y.b.p. to 28.2 m.y.b.p.

Three distinct episodes of intrusive activity have been identified. Hornblende andesite porphyry and gabbro were emplaced as dikes and sills between 50.9 and 48.0 m.y.b.p. These intrusions were emplaced before or very early in the formation of the Chiwaukum Graben. Biotite rhyodacite prophyry with vitrophyric and perlitic borders was emplaced as intrusive domes along a northwest-trending zone east of the early Eocene hornblende andesite. The rhyodacite was emplaced during the latest stages of graben development between 44 and 41 m.y.b.p. The final intrusive event is represented by a sill of hornblende andesite which was emplaced between 28.2 and 34.2 m.y.b.p. and post-dates graben formation.

LATE CENOZOIC GEOLOGY AND THE TENMILE GRAVEL NEAR LUCKY PEAK DAM, IDAHO

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ABSTRACT

Interpreting the geologic and geomorphic record near Lucky Peak Dam may help to better limit and define the Tenmile Gravel. The Tenmile Gravel is a thick accumulation of coarse gravel deposited by the Boise River. It underlies Tenmile Ridge, and remnants extend west to the Snake River. Morphology of Tenmile Ridge, weathering of gravel, and relationships with faulting and Tertiary basalt suggest that the maximum age of the Tenmile Gravel may be as early as Miocene. The "upper" part of the Tenmile Gravel may be equivalent to the Tuana Gravel, which was deposited between 2.06 and 2.18 million years ago. The minimum age of the Tenmile Gravel is limited by the timing of the development of Pleistocene alluvial terraces of the Boise River. Three distinct intracanyon basalts of the Boise River cap three terraces in the canyon downstream from Lucky Peak Dam. K-Ar dates, paleomagnetic polarities, and possible correlation with the first and second canyon stages of the Bruneau Formation suggest that these lavas flowed onto terraces, whose origin resulted from successive incision of the Boise River between 1.67 and 2.06 million years ago.

THE MIOCENE CLARKIA SYSTEM

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ABSTRACT

Miocene fossil beds near Clarkia, Idaho, occur as flat-lying valley-fill that was deposited along 19 miles (30 km) of the St. Maries River Valley. Highly fossiliferous, micaceous silts and clays, with volcanic ash interbeds, have been intensively studied at site P-33 near Clarkia. The basin was then, as now, topographically confined, except at the down-drainage end toward the northwest. The hill-and-valley topography and drainage system were established on the mica schist basement prior to basalt damming of the valley to form Miocene Clarkia Lake. At site P-33 occurs a 30-33 ft. (9-10 m) thick section that appears to be an essentially complete cycle of lake deposition. At the base there is a turbidite unit, probably representing soil slump at the initiation of lacustrine conditions. The middle is laminated, with unoxidized silty clays and ashes representing the bulk of sedimentary infilling. The upper beds are poorly laminated, oxidized silts and ashes of late lacustrine infilling.

Fossils of diverse organisms are abundant and exceptionally well preserved. These include (1) limnetic: fish, aquatic insect larvae, sponges, thecamoebians, dinoflagellates (?), diatoms, chrystophyte algae, and (2) terrestrial: megafossils and microfossils of a luxurient vegetation of conifers and angiosperms, with associated ferns, mosses and a rich fungal flora; and a diverse insect fauna dominated by forest-floor and lake-border taxa. Quality of preservation is exemplified by (1) leaves that occur as intact cellular tissue retaining original pigmentations, chemical constituents such as steriods and flavonoids, intracellular microstructures, phytoliths, fungal infestations, and insect teratology, (2) forest beetles with original bright colorations, and (3) carbon-coated impressions of undisturbed fish carcasses showing intact skeleton, eyes, and scale patterns. Inferred environment was a meromictic lake in a hilly area; a warm, humid, stormy climate; and rapid burial of fossils in anoxic lake-bottom conditions.

LAKE MISSOULA FLOODS IN THE NORTHERN BORDERLANDS OF THE COLUMBIA PLATEAU

by Eugene P. Kiver and Dale F. Stradling
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ABSTRACT

The late Wisconsin catastrophic flood record in the valleys and adjacent areas north of the Channeled Scablands indicates a complex record of flood paths and numerous floods flowing into glacial lakes whose elevations decreased with time.

Late Wisconsin glaciers in the Pend Oreille River Valley were sufficiently withdrawn, such that catastrophic floods not only flowed south to Spokane through the Purcell Trench as previously recognized, but were also able to flow westward and northward to the Newport area, where they spilled across divides into the broad Little Spokane River Basin. Most floodwater spilled directly southward into the Spokane River Valley near Ninemile Falls, but some flowed westward across the Loon Lake Divide into the Colville-Chamokane Valley.

The levels of the glacial lakes in the Spokane and Columbia River Valleys were controlled by the position of the Okanogan Ice Lobe and the elevation of the bedrock lip at Grand Coulee. An early flood preceded glacial Lake Columbia (LC) and the high stand of LCI (2400'; 730 m) was followed by LCII (1700'+; 520 m) after the Okanogan ice withdrew from the Grand Coulee. Varved lake sediments, interrupted by catastrophic flood sediments, record a minimum of 27 late Wisconsin floods in the Hawk Creek area. Flood erosion of the bedrock lip at Grand Coulee lowered the base level and a prominent terrace formed at the 1560' (475 m) level. Subsequent LCIV (1400'; 425 m) and LCV (1360'; 415 m) terrace levels were controlled by downstream ice or sediment dams.

Decreasing late Wisconsin lake levels provided greater storage capacity and moderated the effects of overland floods. Three or more very late floods were confined to the lower parts of the valleys. Thus, at least 31 late Wisconsin floods occurred.

GEOPHYSICAL INVESTIGATIONS OF SOUTHEASTERN WASHINGTON

by Richard L. Thiessen, Gregory B. Mohl, and J.B. Lim
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ABSTRACT

Recognition of accreted terranes in northeastern Oregon and adjacent portions of Idaho and Washington, concerns of tectonic stability and potential for resource development has led to a need to better determine the tectonic setting of southeastern Washington. Cover by Miocene flood basalts makes the utilization of geophysical techniques attractive. We have compiled and collected 1500 Bouguer gravity measurements in southeastern Washington. In addition, 11 paleomagnetic sites in the Pomona Basalt Flow (12 m.y.o.) were sampled. Six major gravity anomalies are recognized in the study area. Three of these features are minima which align with pre-basalt topographic highs where the relatively less dense basement is close to, or at the surface.

A major maximum trending east-west parallels the postulated location of the cratonic margin (based on strontium isotope analyses). This feature is paralleled by an aeromagnetic maximum, and is intepreted to be caused by ultramafic material caught in the suture zone. This feature, combined with a parallel minimum to the north creates a paired gravity anomaly which is typical of suture zones. In the eastern portion of the study area, this feature parallels the Lewiston structure, a major fault/monocline system in the basalts. Paleomagnetic drilling near the Lewiston Structure indicates up to 10.3 degrees of clockwise rotation. In the western portion of the study area, the gravity maximum bends to the north. South of Washtucna, this feature appears to separate a domain of northwest-trending lineaments (to the east) from a domain of northeast-trending ones west of the gravity maximum. Paleomagnetism of the Pomona Flow shows less than 5 degrees of rotation in this vicinity.

A northeast-trending linear anomaly transects the maximum, the southern end of which coincides with the Hite Fault and the suspected western margin of the Seven Devils accreted terrane. The northern portion

of this anomaly is subdued, but does indicate the presence of the Hite Fault north of the cratonic margin.

A major minimum, centered over the Snake River, appears to be associated with up to 12.8 degrees of clockwise rotation. No major folds or faults have been mapped which could account for this rotation, although there is a concentration of lineaments along its western edge. This feature may be a thickened portion of cratonic crust, a buried extension of a pre-basalt ridge, or a buried sedimentary basin.

Future goals for this project include acquisition of data in west-central Idaho in order to better study the suture zone between the craton and accreted terranes.

ROAD LOG FOR FIELD TRIP ALONG PORTIONS OF THE SNAKE, CLEARWATER AND POTLATCH RIVERS, WASHINGTON AND IDAHO

by

JOHN BUSH
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University of Idaho

Generalized Geologic History Moscow Area

Moscow is located on the eastern edge of the Columbia River Plateau, near the western slope of the Rocky Mountains. Major geologic units consist of Precambrian metasediments and metamorphics of the Belt Supergroup, Cretaceous-Tertiary intrusives of the Idaho Batholith, Miocene volcanics and sediments of the Columbia River Basalt Group and Pleistocene loess of the Palouse Formation (Fig. 1). Lesser units include Eocene? rhyolites and breccias generally restricted to the Deary-Bovill area; Pleistocene flood deposits located at lower elevations along the Snake and Clearwater drainages; and Pliocene? clay deposits in the Troy-Bovill area.

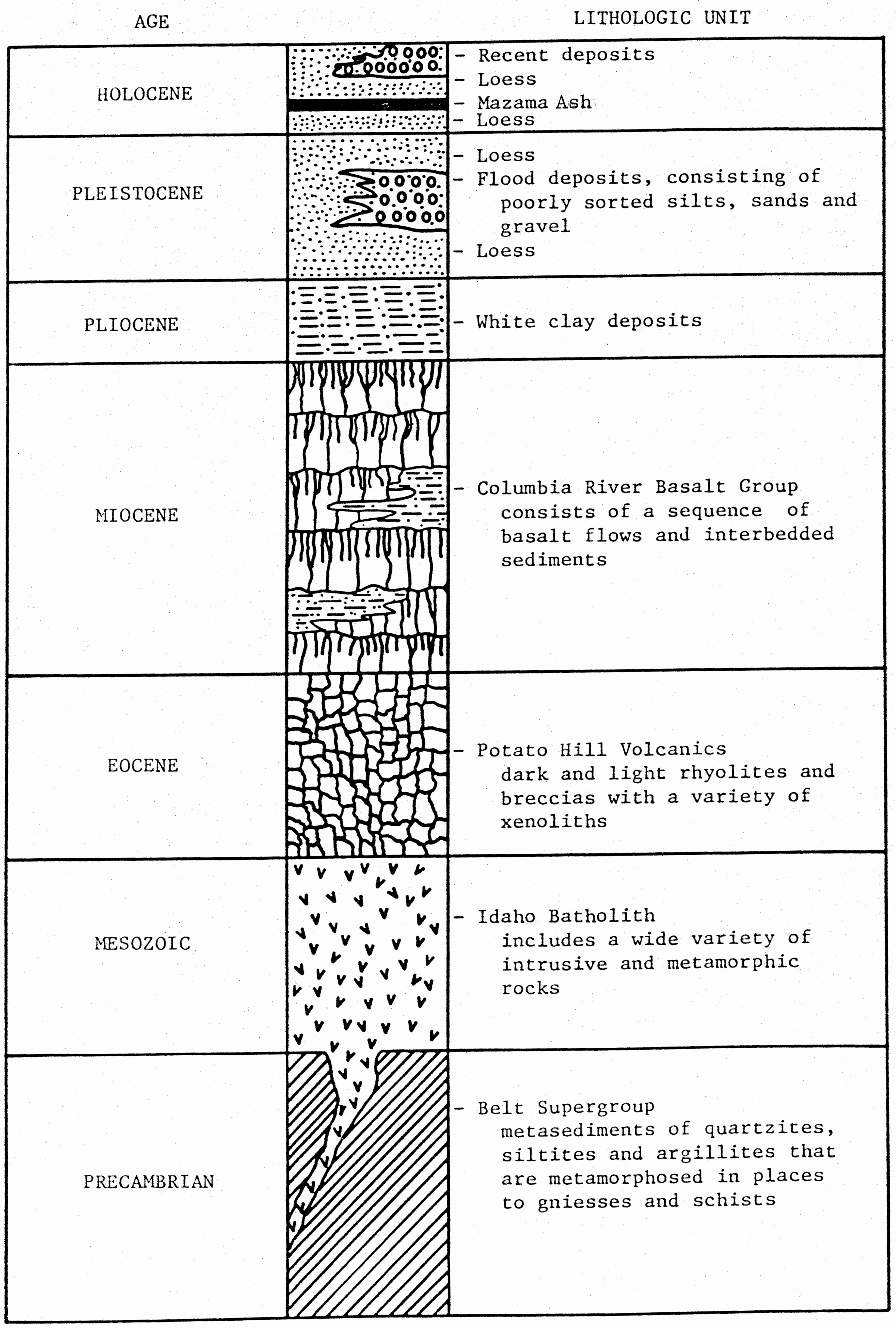
Precambrian rocks of the Belt Supergroup exhibit features common to low-grade regional metamorphism, and consist mostly of quartzites, argillites and siltites. Outcrops contain relict cross-beds, ripple marks, bedding laminations and other sedimentary features. However, at numerous localities within Latah County, Belt rocks are metamorphosed to phyllites, schists, and gniesses.

Along with Mesozoic intrusives, the Precambrian units form most of the mountains and topographic highs in the Moscow area. Exceptions could be Steptoe, Kamiak and associated buttes. Steptoe and Kamiak Buttes consist of coarse-grained, recrystallized quartzites. Savage (1973) considered these to be Precambrian, and a coarse grained equivalent of Belt rocks. However, Hooper and Webster (1982) tentatively correlated these quartzites with similar Cambrian quartzites of northeast Washington. Paradise Ridge and Bald Butte, south of Moscow, also contain outcrops of similar quartzites.

Intrusive rocks in the Moscow area belong primarily to the Cretaceous-aged Idaho Batholith, and commonly range in composition from quartz monzonite to granite and quartz diorite. Locally, tonalite, gabbro and syenites are common. The Palouse Range which rims Moscow to the north and northeast, consists of undifferentiated Idaho Batholith rocks.

Accompanying and following the intrusion of the Idaho Batholith was a period of extensive erosion. Near Moscow, the pre-basalt relief was considerable, while to the west over southeastern Washington, the relief was less and a broad flat plain may have existed. The lower areas were filled in by basalts that erupted from fissures during an 11-million-year period in the Miocene between 17 million and 6 million years ago (Hooper, 1982). The flows filled up local canyons and flowed primarily westward into a rapidly subsiding basin in the Pasco area. Along the edges of the Plateau, lava dams formed across canyons; lake sedimentation occurred and preservation of fossils was common.

The basalts belong to the Columbia River Basalt Group, which during the past twenty years has been studied in petrographic, chemical and magnetic detail (Hooper, 1982; Swanson and others, 1979). This work has



AGE	LITHOLOGIC UNIT
HOLOCENE	- Recent deposits - Loess - Mazama Ash - Loess
PLEISTOCENE	- Loess - Flood deposits, consisting of poorly sorted silts, sands and gravel - Loess
PLIOCENE	- White clay deposits
MIOCENE	- Columbia River Basalt Group consists of a sequence of basalt flows and interbedded sediments
EOCENE	- Potato Hill Volcanics dark and light rhyolites and breccias with a variety of xenoliths
MESOZOIC	- Idaho Batholith includes a wide variety of intrusive and metamorphic rocks
PRECAMBRIAN	- Belt Supergroup metasediments of quartzites, siltites and argillites that are metamorphosed in places to gniesses and schists

Figure 1. Generalized stratigraphic section for the Moscow-Pullman area.

produced a stratigraphic terminology for the basalts, generally accepted for use throughout the Columbia River Plateau (Fig. 2).

Beneath Moscow, the Columbia River Group is over 1310 ft (400 meters) in thickness, and represents a filled paleo-valley between the Palouse Range to the north and Paradise Ridge to the south. In general, the sequence beneath Moscow consists of three thick sediment sequences alternating with basalts. The uppermost flows, which outcrop in isolated areas in the Moscow area, are remnants of the Saddle Mountains Formation. Most outcrops along the main highways and in the lower elevations belong to the Priest Rapids Member of the Wanapum Formation. The contact between Wanapum and Grande Ronde Basalts is approximately 65-100 ft (20-30 meters) beneath the surface and the lowermost exposed flows in the Moscow area.

At least 95 percent of the enormous volume of basalt accumulated in the first 3.5 million years (Hooper, 1982), and after this major eruptive event the major drainage areas of the nearby Snake, Clearwater and Julietta began to reestablish themselves. In addition to being influenced by continuing sporadic vulcanism, the river courses were also influenced by post-Wanapum deformation. In the Moscow area this deformation is best expressed along the Snake and Clearwater Rivers in the vicinity of Lewiston, Idaho, where two east-west major structures dominate. The Lewiston Basin syncline is approximately 21 mi (34 km) in length and its axis is located just south of Lewiston and Clarkston. Paralleling the Lewiston Syncline is a complex, asymmetric and faulted, east-west anticline which has been mapped in detail by Camp (1976). The basalts directly beneath Moscow are considered to be primarily horizontal, with a slight westerly dip.

Pleistocene loess of the Palouse Formation mantles the bedrock in the Moscow area. The sources for this wind-blown soil has been debated considerably in recent years.

During the Pleistocene, an ice dam near the Idaho-Montana border east of Sandpoint, Idaho, produced a large lake that covered much of western Montana. This lake broke frequently during interglacial times, producing catastrophic flooding over much of southeastern Washington (Waite, 1980). The water stripped away much of the loess in flooded areas and produced dry stream channels (coulees) in southeastern Washington. The Pullman and Moscow area stood high and dry and was not effected by these raging flood waters. However, the water did wash up the Snake River from central Washington to points upstream from Lewiston. This backwash deposited flood gravels and silts along the Snake River and its tributary streams. Some of these flood silts can be found near the bottom of Wawawai Canyon, southwest of Pullman.

Field Trip Route And Objectives

The field trip was designed for the Tobacco Root Geological Society meetings in August of 1986. The trip leaves Moscow and travels westward to Pullman, and then southwestward and down Wawawai Canyon to the Snake River in Washington (Fig. 3). From that point, the trip trends primarily eastward along the Snake River to Lewiston, Idaho, where the Snake and Clearwater Rivers join. After a brief side trip to the top of the Lewiston Grade, the trip continues eastward along the Clearwater and Potlatch Rivers. The direction of travel provides an east-west cross-

		FORMATION	MEMBER	MAGNETIC POLARITY	K/Ar DATES
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	Saddle Mountains Basalt	Lower Monumental	N	6 my
			Ice Harbor	N_1 R	
			Buford	R	
			Elephant Mountain	N_1 T	
			Pomona	R	12 my
			Esquatzel	N	13.5 my
			Weissenfels Ridge	N	
			Asotin	N	
			Willow Creek	N	
			Umatilla	N	
		Wanapum Basalt	Priest Rapids	R_3	14.5 my
			Roza	T_1 R_3	
			Frenchman Springs	N_2	
			Eckler	N_2	
		Grande Ronde Basalt		N_2	16.5 my
		Picture Gorge Basalt	R_2	R_2	
			N_1	N_1	
				R_1	
		Imnaha Basalt		T	17.0 my
				N_0	
				R_0?	

Figure 2. Stratigraphic succession of the Columbia River Basalt Group. N_1 normal magnetic polarity, R_1 reversed magnetic polarity, T transitional magnetic polarity. Data from numerous sources but primarily modified from Hooper, 1982.

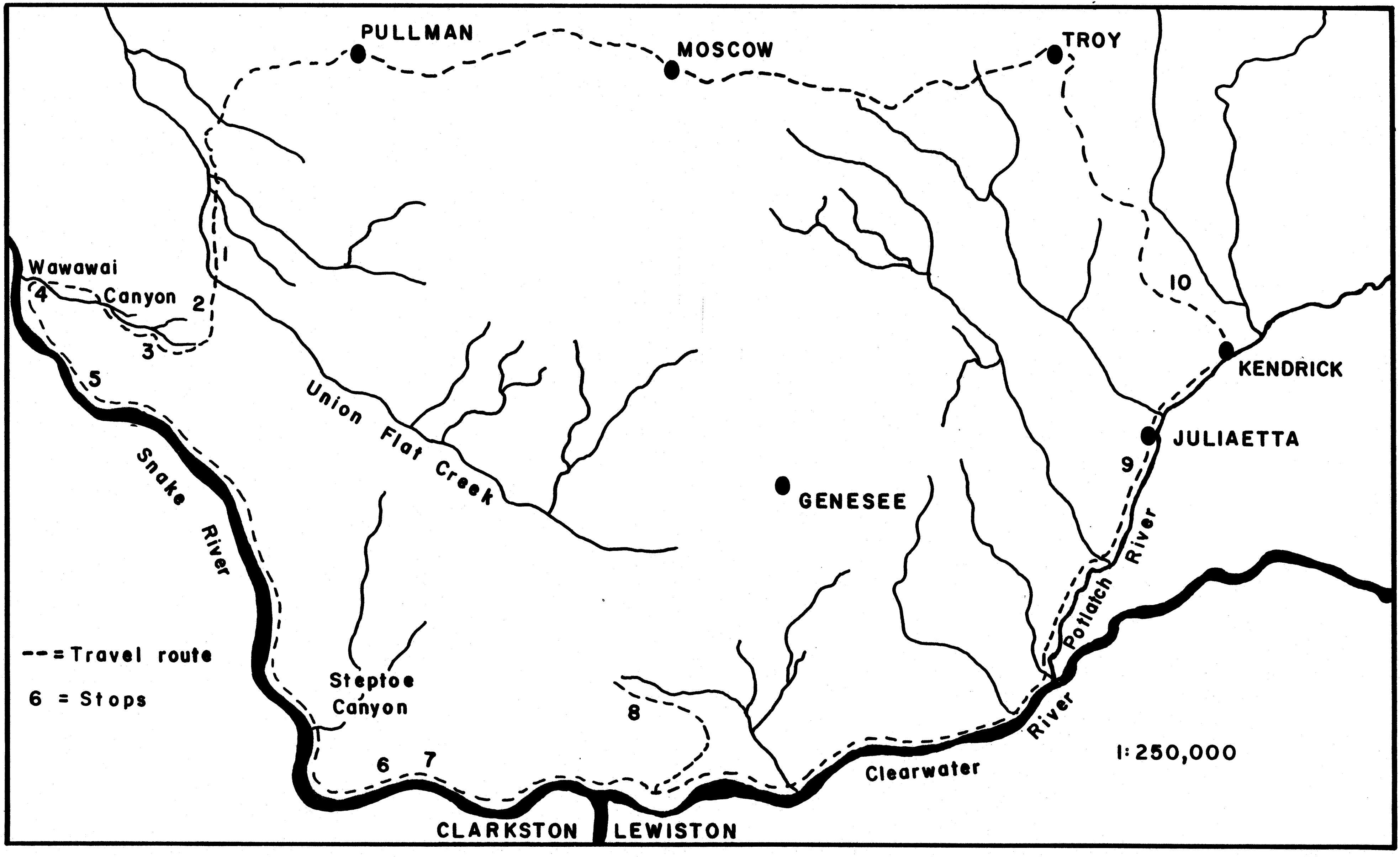


Figure 3 - Location map for Field Trip Stops.

sectional view of the Columbia River Plateau as it approaches the eastern foothills.

The primary objectives of the field trip are as follows:

1) To briefly examine field differences in the Columbia River Basalt.
2) To examine and discuss the relationship between basement rocks, Columbia River basalts and their contained interbeds.
3) To examine the broad structural features of the Lewiston area.

Mileage And Descriptive Log

Mileage

Cumulative/Difference

0.0	0.0	Juncture of Line Street and Pullman Highway. Proceed towards Pullman.
2.5	2.5	Small roadcuts in basalt. The vesicular nature of these exposures suggests that these outcrops are near the top of a flow. These flows are correlative with non-porphyritic Wanapum flows.
3.7	1.2	Basalt quarry on the south side of the highway. The Pullman test well (1060 ft/324 meters deep) was drilled approximately 490 ft (150 meters) west of the county road on the north side of the creek. Chemical analysis of well chip samples indicated that the Wanapum-Grande Ronde contact was encountered at a depth of 100 ft (30 meters) (Brown, 1976). The interval is marked by a predominantly clay interbed 12 ft (3.5 meters) thick.
7.1	3.4	Major quarry operation on south side of highway exposes Wanapum flow equivalent to the Priest Rapids Member.
8.1	1.0	Entrance to Washington State University.
8.9	0.8	Juncture with Lewiston-Colfax highway, turn right.
9.0	0.1	Juncture with Route 195, turn left to Colfax. Outcrops of basalt at top of grade are Priest Rapids Member. Along the north (side) of the valley, a few meters above the valley floor, are exposures of siltstones with plant debris. This thin interbed (approximately 10 ft/3 meters) separates the Wanapum and Grand Ronde Formations in the Pullman area.
9.7	0.7	Turn left off State Highway at the Hilltop Restaurant onto the Wawawai-Pullman Road.
11.5	1.8	Juncture with Lewiston Highway U.S. 195, proceed straight ahead.
15.6	4.1	Highway follows Union Flat Creek on the right.

17.2 1.6 STOP ONE: Outcrops of Saddle Mountains Basalt on left. The Priest Rapids Member of the Wanapum forms the valley floor of Union Flat Creek. Saddle Mountains and Wanapum flows can be individually mapped using chemistry, field criteria and paleomagnetics. For the purposes of this trip it should be noted that Saddle Mountains and Wanapum basalts can generally be distinguished in the field from the underlying Grande Ronde flows by the presence of abundant to sparsely scattered plagioclase and/or olivine phenocrysts. Look closely at hand samples here so that we can compare them with Grande Ronde basalts at Stop 3. In terms of volume and thickness, the Saddle Mountains and Wanapum flows only form a thin skin over the underlying Grande Ronde flows.

21.3 4.1 STOP TWO: Small pull-off at entrance to gravel road at top of ridge. The ridge is the drainage divide between Union Flat Creek, a mature system and Wawawai Canyon, a youthful system. Walk approximately 500 ft (150 meters) up the gravel road. On a clear day, numerous high peaks can be seen in the distance. Due north is the cone shaped Steptoe Butte, N 20 E is Kamiak Butte, N 50 E is the Palouse Range (Moscow Mountain), and due east is Bald Butte. The basalt flow beneath this locality is one of the youngest Saddle Mountains flows on the Plateau proper. From the view it is possible to develop a "feel" for how the older metamorphics and intrusives rise above the loess mantled Columbia River Basalts. The highway from this point decends rapidly to the Snake Canyon, going down section through Wanapum and a major portion of the Grande Ronde.

22.0 0.7 Juncture with Wawawai Road, turn right.

23.0 1.0 STOP THREE: Outcrops on left with red oxidized flow top. Good exposure of Grande Ronde flows, which are consistently dark and aphanitic. Groups of Grande Ronde flows can be correlated using a combination of recognizing high titanium, low magnesium, high magnesium flows and magnetostratigraphy. Grande Ronde flows outcrop all the way to the river.

24.6 1.6 The white material exposed across the drainage (west) is a reworked deposit of Mazama Ash dated at approximately 6,700 m.y.

26.7 2.1 Note large granite boulder in cobble and silt matrix along the right side of the road.

27.8 1.1 STOP FOUR: Entrance to Wawawai County Park. Proceed ahead to restrooms and park vehicle. Note view of basalt flows directly ahead on the south side of the river. Similar to the north side, most of the sequence consists of Grande Ronde, with a thin-skin of Wanapum flows at the very top. Saddle Mountains was not mapped on the top of the Plateau along its southern edge directly ahead (Swanson and others, 1980). Wawawai County Park is built on Pleistocene Spokane flood sediments, which were deposited in many of the side drainages of the Snake

River between here and Lewiston. Walk approximately 500 ft (150 meters) northwest across grassy hills to a nearly overgrown south-facing gravel pit exposing 10 ft (3 meters) of flood sediments. Note at least six "packages" or "cycles" consisting of coarse granules at the base, fining upward to fine loess caps. Locally, these are cross-cut by small clastic dikes.

28.6 0.4 Return to park entrance and turn right.

29.4 0.8 Wawawai landing and recreational area on right.

30.1 0.7 Note gentle westward dip of Grande Ronde Basalts along south side of river.

31.4 1.3 STOP FIVE: Pull-off to right along outcrops of light-colored rocks. The area is locally referred to as Granite Point. The bulk of the rocks at Granite Point are coarse grained and of granitic composition (Hooper and Rosenberg, 1970). Crystals of quartz and light-colored potassium feldspar of greater than average size can be seen in hand specimens, the latter exhibiting distinct marginal zones reminiscent of rapakivi texture (Hooper and Rosenberg, 1970). Biotite is very abundant and occurs in vague bands which are partially responsible for the slight foliation, which is characteristic of the rock. The foliation is enhanced by feldspar elongation and orientated "sheet-like" segregation of biotite, hornblende, small crystals of apatite and deep red-brown sphene. The granite is overlain by Grande Ronde Basalt (N_2) and contains a weathered horizon that is exposed along the north side of the railroad tracks. It appears that these rocks are the most westerly member of a series of hills and ridges of pre-basalt granitic Cretaceous-aged rocks that extend into eastern Washington from Idaho south of Moscow.

34.0 2.6 Highway mileage marker 19.

37.3 3.3 Blyton Landing on right.

37.8 0.5 Basalt pillows and zones of palagonite exposed along railroad tracks over the next six miles (10 km). Pillows and interbasalt sediments are rare in Grande Ronde Basalts in the central portion of the basin. The flows were extruded in a relatively short period of time. As we travel eastward towards the paleotopographic highs, the Grande Ronde flows thin, pinch out, and sediments become increasingly common between flows. This eastward pinching and thinning was caused by the rapid basin of the Plateau over the Tri-Cities area in south-central Washington, as the basalt flows attempted to fill up the "pot". The Grande Ronde Basalt poured out over a period of 2 million years and over 60 flows were erupted at a rate of one every 10,000 years at the peak of activity (Hooper, 1982).

40.9 3.1 Note radiating columns forming two large circular-shaped features in the flow above railroad tracks. The origin of these features could be irregular pre-flow channels, irregular pockets of gas forming different cooling surfaces or they may represent filled lava tubes.

43.9 3.0 Nisqually Landing

44.4 0.5 Highway crosses railroad tracks

46.4 2.0 Juncture with Steptoe Road, turn right and note change in the dip of flows south side of the river.

47.7 1.0 Moses Railroad Landing. From this point the Vista Fault crosses the Snake River and extends into the canyon directly south of the river. The landing is located at the northwestern end of the Lewiston Basin where the east-west Vista Fault of Swanson and others (1980) and the Lewiston Structure of Camp (1976) suddenly change directions and swing southwestward. The Lewiston Structure includes an anticlinal wedge pushed up between a vertical fault to the south and a high angle reverse fault to the north (Camp and Hooper, 1981).

50.1 2.4 STOP SIX: Excellent view of the Lewiston Structure. The anticlinal wedge exposes Imnaha Basalts along the highway. These flows can be traced to where they dip southward beneath the hogbacks of Grande Ronde Basalt, visible directly ahead. Imnaha Basalts weather to a distinctive light gray color. On fresh surfaces they are medium to coarse grained, are plagioclase phyric with phenocrysts between 0.2 and 1.0 in. and (5 and 25 mm) in length.

52.4 2.3 STOP SEVEN: Pre-Saddle Mountains paleo-Snake River channel exposed to the southeast across the Snake River. On the east end of the outcrop are flows of Elephant Mountain and Pomona, which fill in an irregular surface cut into Grande Ronde Basalts. Numerous workers, Camp (1976), Hooper and Camp (1981), Camp and Hooper (1981) have referred to similar outcrops from the Lewiston area westward to Pasco. These features show that the Lewiston Structure and Basin began to form after Wanapum extrusion, which ended approximately 13.5 m.y. ago. The Snake River drainage reestablished itself, and up until 6 m.y. ago basalt flows poured into and out of the Lewiston Basin. At times these flows traveled down the Snake River all the way to Pasco, Washington.

53.6 1.2 On the south side of the river, flows can be seen dipping gently eastward and southward into the Lewiston Basin.

55.5 1.9 Juncture with Clarkston Bridge. Continue directly ahead.

58.7 3.2 Junction with Spiral Highway. Turn right.

59.5 0.8 Turn left onto Highway 12 east.

59.6 0.1 Stop, turn left on Highway 12 and remain in left lane.

59.8 0.2 Bear left to Moscow.

61.8 2.0 Three roadcuts over next kilometer (mile) expose the eastern extension of the Lewiston Structure. The highway curves westward after crossing the structure and continues upward in normal stratigraphic sequence.

64.3 2.5 Small reverse fault exposed on right, in red flow top, within a Grande Ronde flow.

64.5 0.2 The brown zone exposed on the right is a saprolite, representing the contact between Wanapum basalts overlying Grande Ronde flows.

65.6 1.1 Red clays on right mark the contact between a Wanapum flow overlying a Saddle Mountains flow.

65.7 0.1 Turn left and left, and retrace route back down grade to scenic overlook.

66.5 0.8 STOP EIGHT: Pull over to scenic overlook with Lewiston-Clarkston below at the junction of the Clearwater and the Snake Rivers. Hells Canyon of the Snake River is due south and the Clearwater Canyon is due east. The small buttes in the distance, capping the plateau to the southwest, are remnant cones of the Roza Member. The basalts to the north (across highway) are nearly horizontal. Looking due west, the axis of the Lewiston Structure is visible between horizontal basalts to the north and the hogbacks which dip steeply southward. After stop continue down the grade.

71.5 5.0 Juncture with Route 12, bear left on Route 12 to Missoula.

72.6 1.1 Potlatch River on south side of Clearwater River.

76.2 3.6 Outcrops over the next few miles are complex due to faulting and in places, landsliding. For details of the area see Bond (1963).

78.9 2.7 Juncture of Route 12 and Route 95, bear right on Route 12 to Missoula.

84.0 5.1 Juncture of 12 and Route 3, turn left from left lane, following signs to Juliaetta.

88.1 4.1 STOP NINE: Small pull-off on right approximately 100 ft (30 meters) past the 4 mile (6.5 km) marker. The light-colored rocks are claystones and siltstones of a sediment sequence between Imnaha and Grande Ronde flows. This interbed contains occasional imprints of shrubs and trees. Similar interbeds in the region contain entire preserved leaves, fish and insects.

The sediments were deposited in ponds, lakes and streams. These interbeds increase as you go eastward toward more mountainous country, underlain with Idaho Batholith and Belt Supergroup rocks. There were a considerable number of lakes and ponds created as a result of the damming of drainage systems by extruding basalts. The types of leaves found in the interbeds are similar to dicots presently found in southeastern United States, which indicates that the climate in northern Idaho was milder and more humid 16 million years ago.

91.7 3.6 Entering Juliaetta, continue straight ahead.

96.6 4.9 Entering Kendrick.

96.9 0.3 Juncture with Route 99 to Troy, turn left and proceed up grade. Note columns in basal Grande Ronde flow dipping in numerous directions, probably caused by the flow filling in channels and irregularities developed on Precambrian units which occur in the subsurface beneath Kendrick. The highway goes upward through 980 ft (300 meters) of basalt to the top of the plateau.

98.0 1.1 One of several interbeds in Grande Ronde exposed on right.

99.3 1.3 Brown weathered zone in sapprolite represents Wanapum-Grande Ronde contact.

102.5 3.2 STOP TEN: (optional) Small pull-offs on right on the top of plateau. Moscow Mountain visible to northwest, Toner and Bald Butte visible to west. Other highs of Precambrian and Mesozoic basement rocks visible to north and east.

109.1 6.6 Juncture with Route 8, turn left and enter Troy. Continue ahead to Moscow.

120.8 11.7 Moscow City limits.

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ROAD LOG FOR MIOCENE FOSSIL FIELD TRIP CLARKIA AREA, IDAHO

by

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General Background

The presence of Miocene fossil plants in sediments interbedded with the Columbia River Basalts have been known for many decades (Knowlton, 1926). Numerous sites have been reported primarily around the edge of the Columbia River Plateau in Idaho, Washington and Oregon. This road log focuses on sites near Clarkia, Idaho where exposures of richly fossiliferous, finely laminated lacustrine deposits have been under study by Smiley and Rember (1979). The sediments examined on this trip are considered to have formed in a lake created by outpourings of Columbia River Basalt which dammed the St. Maries River (Smiley and Rember, 1979). The Proto-St. Maries had established a drainage in Precambrian and Cretaceous aged metamorphics and intrusives. The lake sediments filled in most of the steep-sided drainages resulting in the flat valley floor that is still evident in the Clarkia area.

The preservation of plant megafossils is so excellent in places that the leaves are complete cellular compressions and can be lifted intact from bedding surfaces for microscopic examination. More than 100 species of ligneous (woody) plants are known to occur as fossils in the Clarkia Lake deposits (Smiley and Rember, 1979). The plant cover that formed around Miocene Lake Clarkia was a mixed mesophytic forest of hardwoods and conifers. Several taxa appear to have been woody vines (Siane) that probably were climbers on other plants of the forest. Some of the smaller plants of the forest were royal and polypody ferns, mosses, horetails and cattails (Smiley and Rember, 1979). Plants dominate the fossils but insects, fish, and diatoms have also been collected. Smiley and Rember (1979) used the numerous taxa and recognized three major habitats: swamp, floodplain-slope and drier slope.

The Clarkia Lake deposits are closely associated with the Columbia River Basalt Group. In the past twenty years the basalts have been examined in petrographic, chemical, paleomagnetic and stratigraphic detail by numerous researchers. Swanson et al. (1979) and Hooper (1982) discuss the details of the stratigraphic succession of the Columbia River basalts.

As Hooper (1982) points out, in most cases individual flows and stratigraphic position can be determined by chemical and magnetic examination of outcrops. Figure One represents the stratigraphic terminology for the basalts.

Field Trip Route And Objectives

This field trip, scheduled in conjunction with the August 1986 Tobacco Root Geological Society meeting in Moscow, follows routes 8 and 3

		FORMATION	MEMBER	MAGNETIC POLARITY	K/Ar DATES
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	Saddle Mountains Basalt	Lower Monumental	N	6 my
			Ice Harbor	N_1 R	
			Buford	R	
			Elephant Mountain	N_1 T	
			Pomona	R	12 my
			Esquatzel	N	13.5 my
			Weissenfels Ridge	N	
			Asotin	N	
			Willow Creek	N	
			Umatilla	N	
		Wanapum Basalt	Priest Rapids	R_3	14.5 my
			Roza	T_1 R_3	
			Frenchman Springs	N_2	
		Grande Ronde Basalt	Eckler	N_2	
				N_2	16.5 my
		Picture Gorge Basalt	R_2	R_2	
			N_1	N_1	
				R_1	
		Imnaha Basalt		T	17.0 my
				N_0	
				R_0?	

Figure One. Stratigraphic succession of the Columbia River Basalt Group. N_1 normal magnetic polarity, R_1 reversed magnetic polarity, T transitional magnetic polarity. Data from numerous sources but primarily modified from Hooper, 1982.

eastward through the logging towns of Troy, Deary, Bovill and Clarkia (Fig. Two). Major geologic units are noted with emphasis on stops related to the fossil sites. The road log is somewhat generalized and is meant to act primarily as a guide. Supplemental data can be obtained from Smiley and Rember (1979).

The objectives of the trip are as follows:

1) To examine and collect plant fossils from sediments of Miocene Lake Clarkia.

2) To examine and discuss the relations between Columbia River Basalt flows and the Clarkia sediments.

3) To discuss the Miocene climatology and paleogeography.

Mileage And Descriptive Log

Mileage

Cumulative/Difference

0.0	0.0	Juncture of U.S. Highway 95 and Idaho Highway 8, South Main Street, Moscow. There are only a few isolated highway exposures of basalt over the first 10 miles (17 kilometers). These basalts belong to the Priest Rapids Member of the Wanapum Formation and fill in valleys between the surrounding hills of Idaho Batholith and Precambrian rocks. The hills and valleys are mantled by Pleistocene loess referred to as the Palouse Formation.
12.1	12.1	Troy city limits, proceed straight ahead. Clay for A.P. Green Refractories Company is mined from nearby clay deposits. Most of the clays are pre-Pleistocene in age.
12.9	0.8	Juncture of Idaho Routes 99 and 8 - turn left on Highway 8 to Deary.
13.9	1.0	Basalt outcrops overlying baked sediments on right belong to the Wanapum Formation. Wood fragments have been collected from this locality.
16.8	2.9	Road cut exposes contact between two flows near road level from which a silicified tree log has been collected and identified as sweet gum. At the top of the outcrop of Priest Rapids Basalt is a channel occupied by white clay. The deposits are considered to be transported in origin and were derived from weathered soils developed on batholith-related granitics.
20.8	4.0	Directly ahead is a view of Potato Hill which is composed primarily of light pink to gray rhyolite and dark purple to black volcanic breccia. The sequence has not been accurately dated. Breccias contain xenoliths of "Belt-like" metamorphic

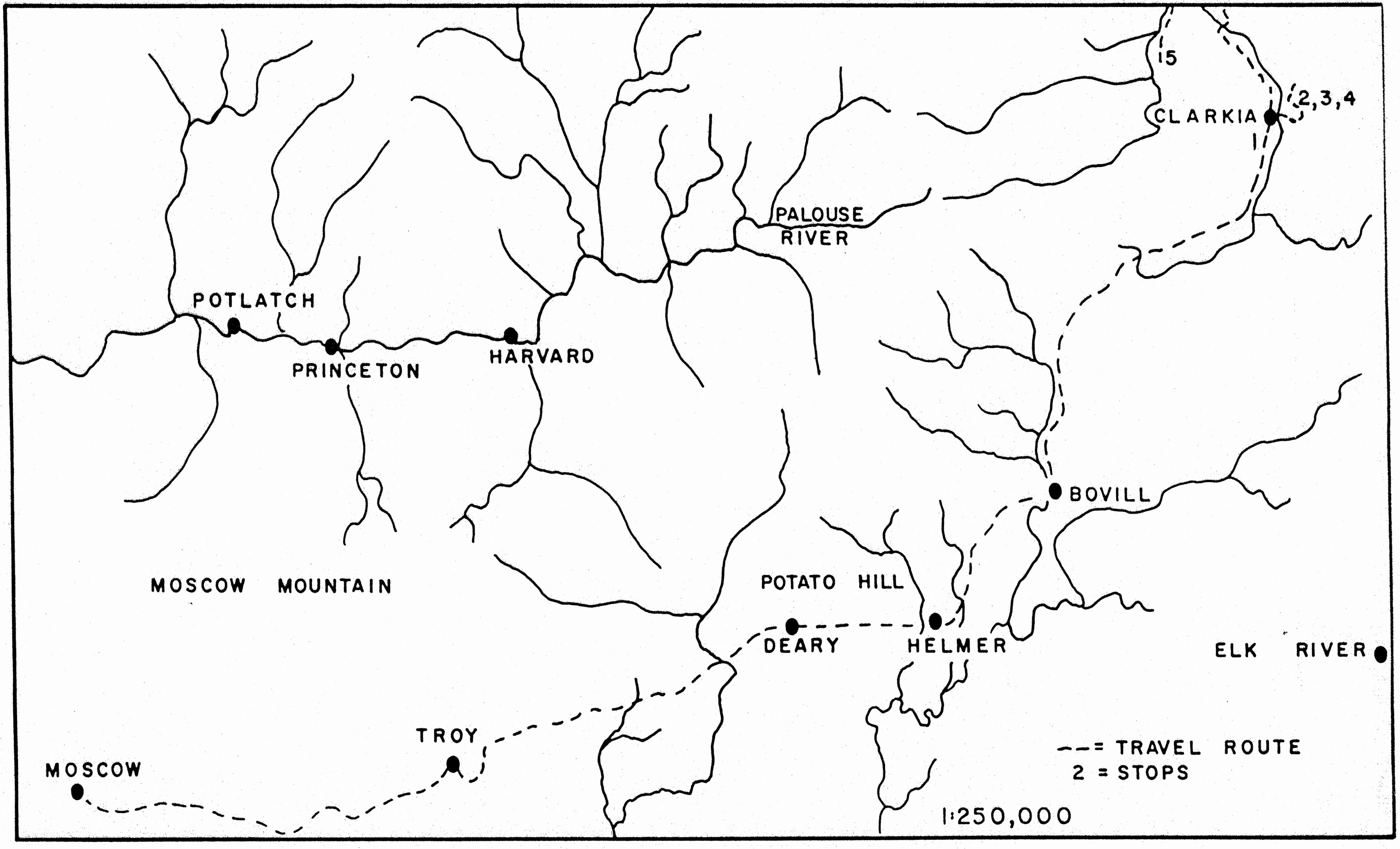

Figure Two. Map Showing Travel Route and Location of Field Trip Stops.

rocks and "Idaho Batholith-like" igneous rocks. No xenoliths of Columbia River Basalt have been noted and field relations suggest that they are overlain by Miocene Columbia River Basalt. Rember and Bennett (1979) list the age of the Potato Hill Volcanics as Eocene to Oligocene.

24.3	3.5	Juncture Route 91 and Route 8, continue straight ahead.
24.6	0.3	Deary city limits, continue straight ahead.
26.1	1.5	Outcrops along railroad tracks, on left are Potato Hill volcanics.
29.3	3.2	Town of Helmer, located on Columbia River Basalt. White clay deposits crop out just east of town.
31.4	2.1	Hog Meadow on left, believed to be underlain by lacustrine sediments (Smiley and Rember, 1979).
34.2	2.8	White clay pits barely visible to left. Simplot originally developed these pits which extend for a couple of miles north from here just west of Bovill. These clays are high in aluminum and have been used for refractory bricks.
35.5	1.3	Juncture with Highway 3, turn left into Bovill and proceed straight through town.
37.8	2.3	Roadcuts are in weathered garnetiferous mica schists of the Precambrian Belt Supergroup that underlies the region.
38.8	1.0	Small roadcuts on right are Precambrian rocks that rim the Cretaceous-aged granitics that core the east-west ridge directly ahead.
40.4	1.6	Roadcuts to the top of pass consist of weathered Cretaceous granitic rocks which are intruded into underlying Precambrian units. The pass is part of a ridge which served to delimit the southern extent of Clarkia Lake.
44.5	4.1	Top of pass.
45.2	0.7	Latah-Shoshone County line.
47.0	1.8	Highway mile post 50.
47.4	0.4	Roadcuts in Precambrian gniesses on the north flank of the granite-cored ridge.
48.1	0.7	Flat valley floor underlain by Clarkia deposits near the south end of Miocene Clarkia Lake.

49.3	1.2	STOP ONE: Type locality for Clarkia "fossil beds" on left of highway on the north curve of the Fossil Bowl Race Track owned by Frances Kienbaum. The south end of the track is cut into a hill of weathered Precambrian schist. This location contains the best fossils in the Clarkia area and details are too numerous to summarize here. You are referred to Smiley and Rember (1981, 1985a, 1985b), Gray (1985), and Lewis (1985). Permission for collecting must be obtained from Mr. Kienbaum.
50.8	1.5	On left, roadcut exposes the nose of a spur of Precambrian rocks along the edge of Clarkia Valley.
51.3	0.5	Townsite of Clarkia. Turn off Highway 3 and proceed through town.
51.6	0.3	Turn left at Trading Post General Store.
52.1	0.5	Rock quarry. Precambrian rocks cut by a diorite dike. Turn left (west).
52.4	0.3	STOP TWO: Road juncture. Walk approximately 4 miles (6 km) north to a small rock quarry cut. Enroute are roadcuts through Precambrian basement rocks. The exposures at the quarry are interpreted as a Miocene volcanic vent and contain basalt flows, volcanic ash, scoreaceous cinders and bombs and charred wood.
52.6	0.2	STOP THREE: Rock quarry and small roadcut. Pillow basalts overlying coarse volcanic ash containing a Clarkia florule. White pebbles and boulders in the area represent later deposits that can be located in places throughout the region. Common fossils are false beech, chestnut, hazelnut, alder, oak and bay.
53.3	0.7	STOP FOUR: Roadcut of sand, silt, and laminated clays, with lenses of sand indicating scour and fill activity during the time of deposition. The thin basalt sheet seems to be a sill associated with the thicker dike at right where the sediments are blackened. Common fossils are false beech, bald cypress, poplar, willow, alder, magnolia, bay, sycamore, cherry and oak. Return to Idaho Highway 3.
55.3	2.0	Juncture with Highway 3. Turn right (north) on Idaho Highway 3, down the valley of the St. Maries River, enroute to Emerald Creek fossil beds in a west embayment of the Miocene Clarkia Lake.
55.7	0.4	National Forest Work Center.
56.3	0.6	On left, roadcut through pillow basalts of a Priest Rapids flow.

59.2	2.9	On right, a roadcut in Precambrian rocks. This is another example of a knoll of basement rock that was above the level of the Miocene valley sediments and basalts.
61.2	2.0	Garnet sand shipping point. Turn left (west) here to Emerald Creek fossil beds and garnet collecting area. Exposures east of road juncture are a Priest Rapids flow over fossiliferous baked sediments.
61.3	0.1	Bridge over St. Maries River at juncture with Emerald Creek. Directly ahead is a Priest Rapids flow over sediments.
64.5	3.1	Road juncture at confluence of East and West Emerald Creeks. The garnet sand separating mill is on the left. Take right fork across the bridge and continue to bear left at road junctions over next 0.2 mile (0.3 km).
64.8	0.3	One of the fossil sites is off the road to the right. Sunshine Mining Company restored the valley bottom after commercial dredging for garnet sands. The surrounding hilly terrane is on Precambrian basement rocks and the flat valley floor is underlain by Miocene lacustrine deposits. This has been termed the Emerald Creek Embayment of Clarkia Lake (Smiley and Rember, 1979).
65.7	0.9	<u>STOP FIVE</u>: Roadcut on National Forest land containing fossil site. Common fossils are dawn redwood, bald cypress, pine, poplar, alder, birch, chestnut, oak, false beech, monreed, tulip tree, magnolia, bay, sweet gum, sycamore, maple, honey or water locust, black locust and tupelo.

End of Trip - Return to Moscow

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ROAD LOG FOR COLUMBIA RIVER BASALT VENT TRIP SOUTHEASTERN WASHINGTON

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Background Discussion

The Columbia River Basalt erupted from fissures over an 11 million year period during the Miocene (17 million to 6 million years ago). Over 95 percent of the volume of basalt accumulated in the first 3.5 million years and covers an area of 61,800 mi^2 (160,000 km^2), including most of eastern Washington, much of northern Oregon, and significant parts of west-central Idaho (Hooper, 1982) The accessibility of the Columbia River Basalts make them amenable to detailed stratigraphic, chemical and petrographic study.

Most Columbia River Basalt flows may be identified by their chemical composition. It is now technically and economically feasible to analyze many samples from a group of flows and provide the analyses rapidly enough for field geologists to use them as they map. Furthermore, a fluxgate magnetometer permits the magnetic polarity of each flow to be determined in the field. Together with field mapping and microscope petrography, the new techniques of rapid analysis and magnetic polarity have established a detailed stratigraphic succession of the Columbia River Basalt Group (Fig. 1). With the established stratigraphy, it has been possible to clarify the physical and chemical evolution of the basalt magma, to correlate individual flows with their feeder dikes, and to reconstruct the magnitude of the eruptions.

The maximum observed thickness of the Columbia River Basalts is 4,925 ft (1,500 meters), but basaltic rocks have been reported from drill cores as deep as 9850 ft (3,000 m) near the center of the plateau; the total thickness of the basalts, based on estimates of the greatest known thickness for each formation, is more than 8,200 ft (2,500 m). The Columbia River Basalts fill a shallow basin; they are thickest at the center (Pasco Basin) and wedge out toward the margin of the basin. Rough calculations imply a total basalt volume of more than 48,000 mi^3 (200,000 km^3) and the number of flows ultimately identified on the plateau will probably be between 120 and 150 (Hooper, 1982) Individual flows range in thickness up to 400 ft (120 m); with an average thickness of 50 ft to 100 ft (15 to 30 m); and their aerial extent varies from small spatter cones at source vents to major flows that cover a significant part of the Columbia Plateau, with volumes as large as 170 mi^3 (700 km^3). The flows were erupted from north-northwest to south-southeast fissures concentrated in the southeast part of the plateau, where dikes cut through older lava flows and the surrounding prebasaltic rocks (Swanson and others, 1975)

		FORMATION	MEMBER	MAGNETIC POLARITY	K/Ar DATES
COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	Saddle Mountains Basalt	Lower Monumental	N	6 my
			Ice Harbor	N_1 R	
			Buford	R	
			Elephant Mountain	N_1 T	
			Pomona	R	12 my
			Esquatzel	N	13.5 my
			Weissenfels Ridge	N	
			Asotin	N	
			Willow Creek	N	
			Umatilla	N	
		Wanapum Basalt	Priest Rapids	R_3	14.5 my
			Roza	T_1 R_3	
			Frenchman Springs	N_2	
			Eckler	N_2	
		Grande Ronde Basalt		N_2	16.5 my
		Picture Gorge Basalt	R_2	R_2	
			N_1	N_1	
				R_1	
		Imnaha Basalt		T	17.0 my
				N_0	
				R_0?	

Figure One. Stratigraphic succession of the Columbia River Basalt Group. N_1 normal magnetic polarity, R_1 reversed magnetic polarity, T transitional magnetic polarity. Data from numerous sources but primarily modified from Hooper, 1982.

Field Trip Plans and Objectives

This field trip, scheduled in conjunction with the August 1986 Tobacco Root Geological Society meeting in Moscow, Idaho provides an examination of Columbia River Basalt features in the eastern portion of the Columbia River Plateau (Fig. 2 and 3). The trip will generally be on top of the Plateau where most of the flows belong to the Wanapum Formation. However, a portion of the trip in the vicinity of Granite Dam along the Snake River travels through outcrops of the Grande Ronde Formation.

The trip extends over a portion of the north-northwest trending vent areas as defined by Swanson and others (1975). The same loop travels over the area where the Wanapum flows onlap Grande Ronde flows (Fig. 4).

The objectives of the trip are as follows:

1) To examine and discuss regional stratigraphic, chemical, and structural relations.

2) To examine and identify some of the field features used to distinguish individual flows and flow groups.

3) To examine some of the features outlined by Swanson and others (1975 and 1976) and to identify vent and near-vent areas for the Columbia River Basalts.

Mileage

Cumulative/Difference

0.0 0.0 Junction of Line Street and Pullman Highway. Proceed towards Pullman.

2.5 2.5 Small roadcuts in basalt. The vesicular nature of these exposures suggests that these outcrops are near the top of a flow. These flows are correlative with the Lolo Flow of the Priest Rapids member of the Wanapum Formation.

3.7 1.2 Basalt quarry on the south side of the highway. The Pullman test well (1,060 ft/324 meters deep) was drilled approximately 490 ft (150 meters) west of the county road on the north side of the creek. Chemical analysis of well-chip samples indicated that the Wanapum-Grande Ronde contact was encountered at a depth of 100 ft (30 meters) (Brown, 1976). The interval is marked by a predominantly clay interbed 12 ft (3.5 meters) thick.

7.1 3.4 Major quarry operations on south side of highway exposes the Lolo Flow.

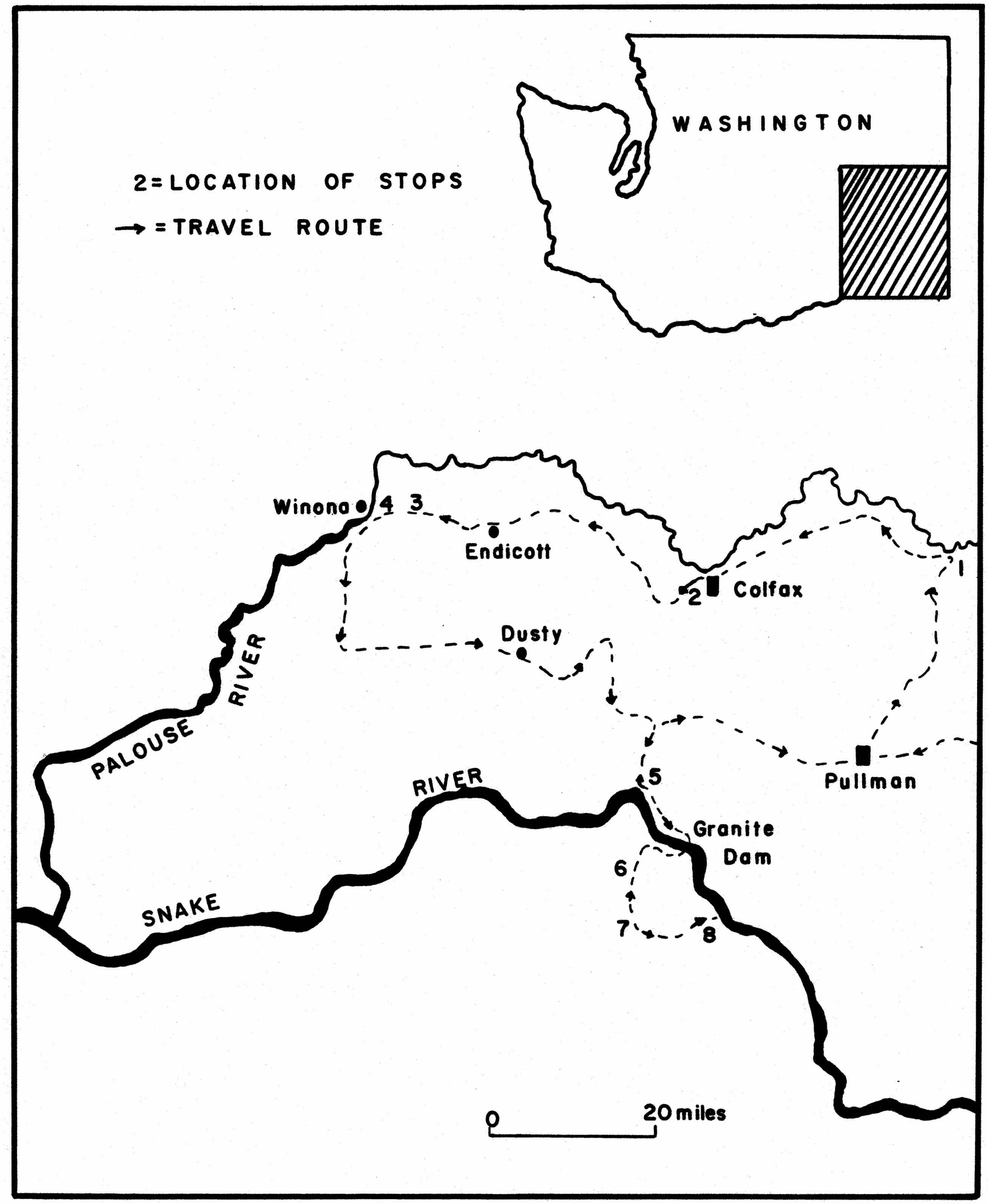

Figure Two. Index map illustrating route of travel and location of stops for the basalt vent trip.

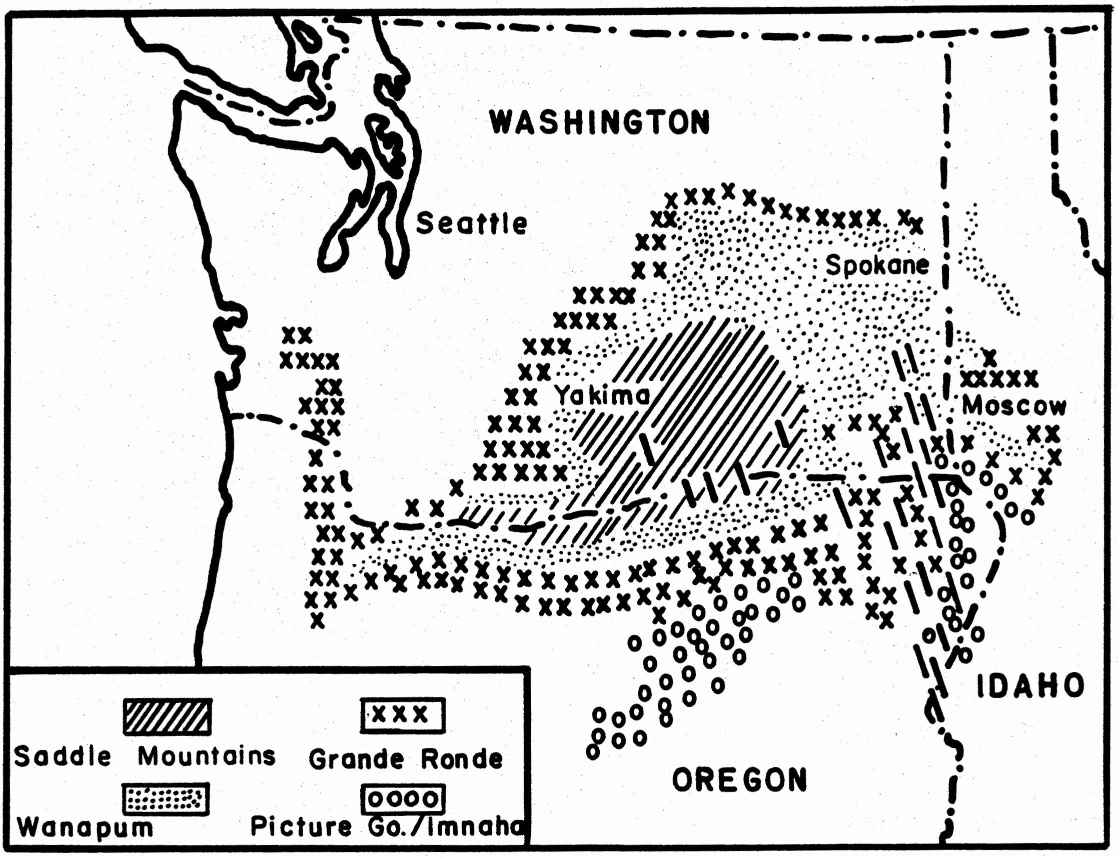

Figure Three. Generalized geologic map of Columbia River Basalt Group.

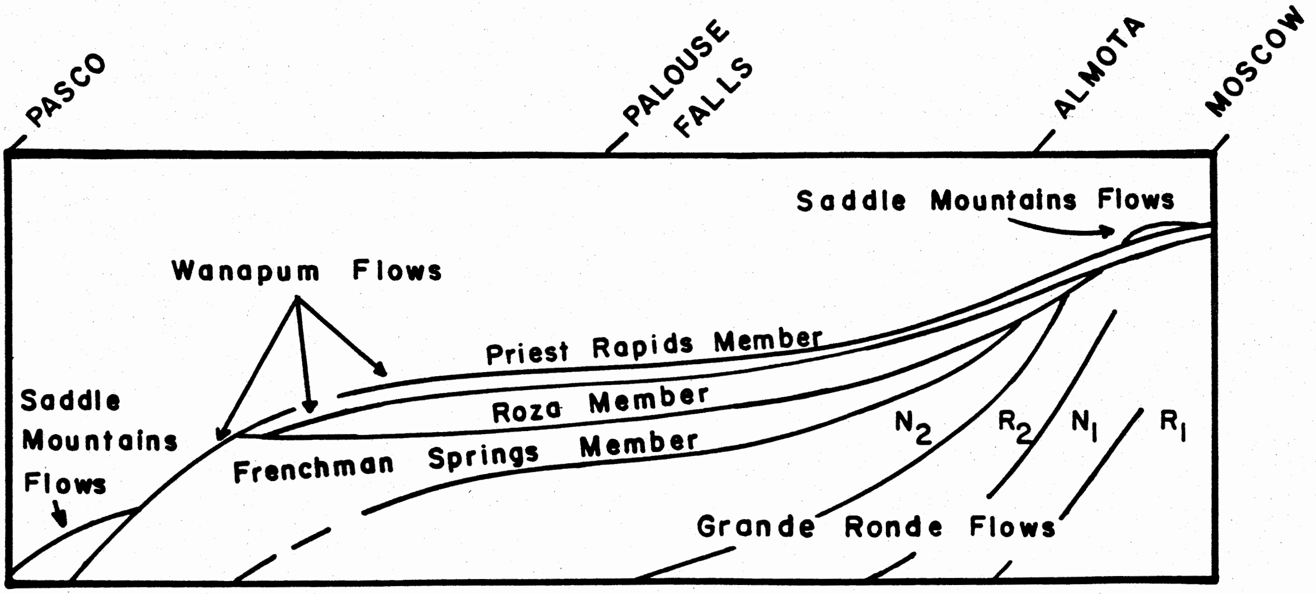

Figure Four. Schematic cross-section across the Columbia River Plateau from Pasco to Moscow. Diagram illustrates the onlap relations between Almota and Moscow (modified from Swanson and others, 1976).

Mileage

Cumulative/Difference

7.8 0.7 Juncture with Johnson Road. Turn off and continue to bear left. Sign points to Spillman Agriculture Farm.

8.3 0.5 STOP ONE: Outcrop of Priest Rapids Member (Lolo Chemical Type) on north side of highway. In the eastern 1/3 of the exposure is a 10 to 13 ft (3 to 4 meters) wide basalt dike. Similar to many Columbia River Basalt dikes, it is not immediately apparent. Upon close inspection of the dike, chill margins can be identified as the smaller columns. Chemical data has shown that it is not similar to the Lolo Flow that it cross-cuts. In addition its magnetic polarity is normal, whereas the Lolo Flow is reversed.

8.4 0.1 Road juncture and railroad tracks. Turn around and return to main highway.

9.0 0.6 Juncture with main highway. Turn left towards Pullman.

9.3 0.3 Entrance to Washington State University.

10.1 0.8 Junction with Lewiston-Colfax Highway, turn right.

10.2 0.1 Junction with Route 195, continue straight ahead toward Palouse. Exposures are poor in downtown Pullman, but drill hole data and examination of exposures just west of town indicate that the street is on the Wanapum-Grande Ronde contact. In Pullman, the Lolo Flow is separated from the underlying Grande Ronde by a thin interbed of sand and clay, and the Roza and Frenchman Springs Members are missing.

10.9 0.7 Red light, continue straight ahead toward Palouse.

18.0 7.1 Kamiak Butte is visible to the west. Kamiak Butte is comprised of poorly bedded quartzite. They tend to strike east-west, and the southern slope is essentially a dip slope modified by minor faulting. Savage (1973) considers these quartzites to be Precambrian, equivalent to some portion of the Ravalli group of the Belt Supergroup. He believed that Kamiak Butte is basically a block which lies in a major northwest-southeast trending disturbed belt, which cuts across Benewah, Kootenai, Latah, Whitman, and Spokane counties.

Hooper and Webster (1982) tentatively correlated the quartzites with similar Cambrian quartzites of northeast Washington. It is distinct from the impure laminated quartzites of the Belt Supergroup found further east in Idaho.

22.4 4.4 Turn off to Kamiak Butte State Park.

Mileage

Cumulative/Difference

25.3 2.9 Outskirts of Palouse.

25.7 0.4 Junction with Route 272, turn right towards Potlatch.

26.1 0.4 STOP TWO: Pull over and park in small pullout to the right, just after crossing railroad tracks. The basalts here belong to non-porphyritic Wanapum Formation. There are at least four major lithologic units exposed in the roadcut opposite the pullout. These are listed in Table One from oldest unit one to youngest unit two. In addition to the roadcut, examine exposures in the small pit across the county road and exposures along the railroad tracks. This locality is interpreted to be very near a vent for non-porphyritic Wanapum Basalt. The interpretation is based primarily on the nature of the material (bombs, splatter, pumice) exposed at the south end of the exposure. The palagonite breccia which overlies the interbed contains near-vent material. Thus, the roadcut is interpreted as a cross-section of a small low-lying Wanapum spatter cone.

TABLE ONE -- Major units in small roadcut - Palouse, Washington.

Unit One:	Highly weathered, partly consolidated pumice, spatter, cinders, bombs, etc.
Unit Two:	Upward fining sequence of light colored fine sand, silt, and clay. Scattered pieces of plant debris can be found at the top.
Unit Three:	Plagonite breccia, poorly bedded, containing bombs, pumice, scoria, and angular basalt fragments.
Unit Four:	Fine-grained, gray basalt typical of non-porphyritic Wanapum flows. At the north end of the exposure, these basalts exhibit typical columnar features. Note that Unit Four unconformably overlies Units One through Three.

Mileage

Cumulative/Difference

26.5 0.4 Return to Junction, with Route 27, turn right.

26.7 0.2 Make a left turn to Colfax.

27.4 0.7 Outcrops along Palouse River are the Priest Rapids Member.

29.4 2.0 Small quarry operations in the Priest Rapids Member.

Mileage

Cumulative/Difference

37.8 8.4 Junction with road to Glenwood. The road to Glenwood goes down stratigraphic section from the Priest Rapids and Roza Members of the Wanapum Formation, and into underlying Grande Ronde. The Roza, which is missing at Pullman, is approximately 100 ft (30 meters) thick at this locality. Continue straight ahead.

42.0 4.2 Highway begins to depart from the plateau proper and descends into Colfax. The outcrops at the top of the grade are the Priest Rapids Member.

42.8 0.8 Outcrops of the Roza Member. The Roza Member is 213 ft (65 meters) thick in Colfax and cropouts all the way to the base of the grade.

43.0 0.2 Junction with Highway 195, turn right, stay in left-hand lane.

43.7 0.7 Junction with Highway 127, turn left to Walla Walla.

43.8 0.1 STOP THREE: Park near stop sign wherever possible. The outcrops directly ahead are Grande Ronde, which are overlain by 10 ft (3 meters) of sand, silt, and clay, which are in turn overlain by the Roza Member of the Wanapum Formation. Examine Grade Ronde outcrops then walk up Green Hollow Road to a small quarry, where pillows of Roza Member are in contact with the interbed.

44.6 0.8 Large quarry ahead is in the Roza Member.

47.7 3.1 Turn off to Winona, turn right.

63.1 15.4 Town of Endicott. Outcrops along road are the Priest Rapids Member.

67.3 4.2 Reworked Mazama Ash exposed along creek banks.

68.9 1.6 STOP FOUR: The roadcut east of Winona corresponds to locality 5 of Swanson and other (1975, Table One). Bedded Roza pumice and spatter, comprising relics of cones and ramparts, are seen here. Narrow dikes cut the pumice deposit. Roza flow caps the outcrop, and thin flows are interbedded with the pumice. It may be necessary to walk from Stop Four to Stop Five.

69.4 0.5 STOP FIVE: Railroad cut across the Palouse River from Winona. Walk across railroad bridge from small parking area. This outcrop corresponds to locality 4 of Swanson and others (1975, Table 1). Here relic spatter cones and ramparts of Roza lithology are scoured and highly modified in shape by "bulldozer action" of the thick, overlying Roza flow. Note the basaltic pumice, some fresh enough to float in the Palouse. It is easy to imagine how quickly such tephra could be eroded away, were it not for a protective capping of some sort (in this case, thick flows). Probably cones and tephra deposits like these were formed at most Wanapum vents, only to be removed before being covered by the next flow. According to Swanson and Wright (1976), these localities are about 12 mi (7.5 km) south of the northernmost known Roza vents, while the most southernmost known Roza vents are 120 mi (75 km) away, near the Oregon border. Swanson and Wright (1976) calculate the eruption rate for the Roza Member to be 0.24 mi^3/day/mi; (1km^3/day/km). They base this on observed dimensions of the vent system and the Shaw and Swanson (1970) rheologic model.

Take the paved road to LaCrosse south. A right turn from the small railroad parking area.

70.1 0.7 Small outcrop of Priest Rapids Member (Lolo Chemical Type), which overlies the Roza everywhere in this area.

72.7 2.6 Three way road junction, bear to the right.

73.6 0.9 Road is located on the easternmost scabland channel in this area. Isolated islands of loess can be seen ahead at 11:00 o'clock.

74.2 0.6 Sharp left turn across railroad tracks. The road from here to LaCrosse is located near the Priest Rapids-Roza contact.

81.3 7.1 Entrance to LaCrosse, continue through the town, following the signs to Dusty.

83.4 2.1 Junction with Route 26, turn left.

95.8 12.4 Junction to Walla Walla, continue east on 127.

104.2 8.4 Junction with secondary paved road, turn right (south) to Boyer Park.

104.3 0.1 Outcrops along road are the Roza Member.

106.0 1.7 Outcrops in quarry are the Roza Member. Note platy jointing very similar to Roza outcrops at other localities in southeastern Washington.

108.5 2.5 Small intersection, bear to the right toward Boyer Park.

113.6 5.1 Small intersection, turn right to Almota and Boyer Park.

114.5 0.9 Small roadcut in Priest Rapids flow.

Mileage

Cumulative/Difference

115.8 1.3 Roadcuts in Roza Member, and according to Swanson and Wright, (1976) three flows are present.

117.5 1.7 Roadcut shows Roza Member resting on tuffaceous sedimentary rocks that overlie saprolite developed on the Wanapum Formation. No Frenchman Springs Flows are present.

117.7 0.2 Sequence of the Grande Ronde flows. Outcrops all the way to the base of the grade are in the Grande Ronde Formation.

121.0 3.3 Railroad underpass at base of grade.

STOP SIX: It is necessary to park along near the underpass and proceed on foot. Exposed along the road are outcrops of a flow top. Take a close look at this material. Can you tell these deposits from near vent material? This flow top can be traced for several miles (km) along the Snake River. As you drive past it later, note how it rises in elevation.

122.5 1.5 Entrance to Boyer Park.

124.6 2.1 Sharp right turn toward Lower Granite Dam. Note the exposures to the north just before the turn. Several different types of columnar basalt are exposed here. The flow you have been following is composed of a basal columnade, which grades upward into an upper flow top, without an entabulature. However, the overlying flow exhibits a classical basal columnade, with overhanging entabulature, which is typical of many Grande Ronde flows.

124.8 0.2 Entrance to Granite Dam. Traffic is generally allowed to cross during daylight hours.

125.4 0.6 Small "Y" intersection, bear to the left.

127.9 2.5 Road begins up a grade of large gravel deposit.

129.5 1.6 Excellent view of Grande Ronde basalts along both sides of the river.

129.9 0.4 Outcrop on ridge at 10:00 o'clock is a remnant of the lower Monumental flow, an intercanyon basalt flow of the Saddle Mountains Formation.

131.1 1.2 Road takes a sharp left and begins to climb up a grade.

132.1 1.0 Three dikes with plagioclase phenocrysts are exposed within 985 ft (300 meters). According to Swanson and Wright (1976) two are Roza chemistry and a third has a composition unlike most other flows.

Mileage

Cumulative/Difference

132.4 0.3 Thin Grande Ronde flows. Some with very oxidized flow tops.

133.4 1.0 Roza dike exposed along highway.

133.6 0.2 STOP SEVEN: Small pullouts on left, park on first one which is safe. Walk back to examine Roza, dike which corresponds to locality 9 of Swanson and others (1975, Table 1). Swanson and Wright (1976) believe the thin Grande Ronde flows at this locality may imply nearby sources.

134.1 0.5 Exposure of the Grande Ronde-Wanapam contact here, defined by a brown saprolite zone, overlain by Frenchman Springs flows, which are 65 to 82 ft (20 to 25 meters) thick here.

134.3 0.2 Two Frenchman Springs flows, with scattered phenocrysts of plagioclase are exposed at this locality.

134.5 0.2 Outcrops of the Roza Member, which are separated from the Frenchman Springs by a thin, discontinuous siltstone.

134.6 0.1 Small pullout on left, at the end of guardrails.

STOP EIGHT: Walk back to examine Roza and Frenchman Springs.

135.1 0.5 Roadcut consists of two thin flows of the Roza Member, which according to Swanson and Wright (1976) are separated by welded spatter material, and corresponds to locality of Swanson and others (1975, Table 1).

135.7 0.6 Downtown Mayview.

138.1 2.4 Sharp right curve, junction with two roads, turn left on Tramway Road. The road was not marked in 1986.

139.5 1.4 STOP NINE: Park at white steps. The quarry is in Priest Rapids basalt. Walk over to Tramway Road to view stratigraphic relationships. The Roza is present in the cliffs below, but the Frenchman Springs Member is absent. On a good day Granite Point can be seen, as well as the extensive nature of the Grande Ronde flows in this area.

END OF LOG. Shortest way home (50 miles/80 km) is back across Granite Dam.

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A CHANNELED SCABLAND FIELD TRIP, EASTERN WASHINGTON -- A ONE-DAY FIELD TRIP FROM MOSCOW, IDAHO

by

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Introduction

Formation and Age

The field trip detailed in this road log focuses primarily on the Cheney-Palouse Tract of the channeled scablands. The Cheney-Palouse Scabland Tract in east-central Washington is one of three major channels that was occupied by flood water originating from glacial Lake Missoula (Bretz and others, 1956; Baker and Nummendal, 1978). Nested within this scabland tract are deposits and landforms whose origin challenges the imagination. The formation of high elevation giant gravel bars, stream divide crossings, and anastomosing stream channels were produced by an event or events of catastrophic proportions. Hydrodynamically formed loess islands and erosional scarps, as well as giant ripple marks and deep plunge pools are features indicative of fluvial origins (Bretz, 1923, 1929, 1932, 1959; Bretz and others, 1956).

Rhythmically bedded deposits exhibiting upstream current directions are found in many tributaries draining into the Cheney-Palouse tract. In the Pasco Basin and Vantage area of south-central Washington primary airfall deposits of single and multiple Mount St. Helens Set S volcanic ash are contained in similar rhythmically bedded sediments which Flint (1938) called the Touchet Beds. Mullineaux and others (1978) attribute these deposits to the last major scabland flood originating from glacial Lake Missoula. The age of multiple volcanic ashes attributed to set S tephra date between 13,650±400 years B.P. (W-3136; Mullineaux and others, 1978) and 11, 900±300 years B.P. (W-2866; Mullineaux and other, 1975). The occurrence of set S volcanic ash in these fine clastic sediments provides an age for the event(s) that produced them (Fig. 1).

Similar rhythmically bedded deposits are found in the Snake, Tucannon, and Clearwater River Valleys and in tributaries to these rivers. If the rhythmically bedded deposits in the Snake, Tucannon, and Clearwater Valleys are co-eval to the Touchet Beds in the Pasco Basin and Vantage region then they furnish an age of the last flooding event that occupied the Cheney-Palouse Scabland Tract.

At the confluence of the Snake and Clearwater Rivers near Lewiston, Idaho the rhythmically bedded deposits unconformably overlie set S tephra. Near Spalding, Idaho the ca. 11,200 years B.P. Glacier Peak layer B volcanic ash overlies coarse alluvium that unconformably overlies the rhythmically bedded sediments. The occurrence of these two tephra beds provide lower and upper limiting ages on the rhythmically bedded sediments in this area and the event that emplaced them. We attribute the fine clastic, rhythmically bedded deposits in the Lewiston, Idaho area to a late Pleistocene

		14 C yrs. B.P. Appx.	Deposit	Event
HOLOCENE			Several weak soils developed on loess	Neoglacial aeolian deposition with intermittant periods of soil formation
		6,700	Mazama Ash moderate soil developed on loess	Multiple Mazama eruptions postglacial loess deposition
PLEISTOCENE	LATE	11,000	Glacier Peak Ash	Multiple Glacier Peak eruptions
		13,000	Rhythmically bedded deposits Mount St. Helens Set S Ash Flood Gravels	Last major flood Mount St. Helens eruption
		20,000	Alluvium Mount St. Helens Set S Ash Moderate soils developed on various loess sheets	Mount St. Helens eruption At least two advances and two retreats of Pinedale ice sheets
	EARLY	? 120,000	Flood gravels Moderate to strong petrocalcic soils on weathered loess	Pre-Pinedale ice advances and recessions
			Weathered flood gravels	Earliest known flood

Figure 1. Generalized stratigraphic column for the Cheney-Palouse scabland tract.

catastrophic flood originating from northern Idaho and northwestern Montana.

History of Investigations

The following discussion is a brief overview of the history of controversy pertaining to formation of deposits and geomorphic features in the Cheney-Palouse Scabland Tract. It is not a comprehensive review. For a detailed review the reader is referred to Baker and Nummedal (1978).

J. Harlen Bretz (1923, 1924, 1928ab, 1929, 1932, 1959, 1969) proposed that the erosional and depositional features in the Channeled Scablands of eastern Washington were produced by short-lived floods of catastrophic proportions. In his earlier investigations Bretz (1923, 1925, 1928ab) could not account for a source of flood water other than to speculate upon a combination of events that included rapid melting of glacial ice combined with torrential rainfall. By 1930 the origin of the flood water had been solved. From Pardee's (1910) field study of glacial Lake Missoula, Bretz (1930) became convinced that catastrophic outbursts from Glacial Lake Missoula explained the features in the Channeled Scablands of eastern Washington.

Allison (1933) formulated a different model and speculated that the Columbia River between Columbia Gorge and Wallula Gap became blocked by ice jams. These ice jams would have blocked normal stream and flood discharge and thereby produced ponding and additional headward blockage into the Channel Scablands. This headward growing blockage would have raised the base level and would have allowed streams to anastamose, cross high divides, and produce high elevation gravel bars. Subsequent failure of the Columbia Gorge Ice Jam would have permitted the Columbia and Snake Rivers to remove much of the fill yet retaining the deposits and geomorphic features in the Channeled Scablands.

Flint (1938) proposed a fill and cut hypothesis to explain the features in the Cheney-Palouse Scabland Tract. He believed that streams of normal discharge were temporarily graded to higher base levels. This rise in base level and rapid infilling of sediment was caused by Lake Lewis. Flint (1938) suggested that the Touchet Beds are the products of Lake Lewis, an interpretation challenged by Bretz and others (1956), Baker (1973), and Waitt (1980, 1985). Lake Lewis was considered to have filled the Pasco Basin to approximately 1,100 ft (335 meters) in elevation. Normal rivers entering from the north and east rapidly filled the Pasco Basin with a thick mantle of fluvial-lacustrine silt. In the transition zones, streams deposited coarser sediment. The high elevation divide crossings were explained as a result of normal streams "rising on their own fills and overtopping the divides that confined them" (Flint, 1938; p. 510).

Flint's (1938) fill and cut hypothesis was finally discredited by Bretz and others (1956) who found giant ripple marks on benches or terraces through the use of aerial photography. Allison's (1933) ice-jam theory lacked supportive field evidence. Bretz's (1930) flood theory for the scabland features combined with Pardee's (1942) evidence of catastrophic emptying of Glacial Lake Missoula supported a catastrophic origin of many of the features found in the Channeled Scabland of eastern Washington. However, many problems pertaining to the interpretation of the Touchet Beds and Touchet-like sediments and their age and stratigraphic relations to large gravel bars, and giant ripple fields outside the Pasco Basin remain unresolved. Other questions that remain unanswered pertain to the number of catastrophic flooding events during the late Pleistocene.

Waitt (1980, 1984) agrees with the flood hypothesis but does not agree that the Touchet Beds and other rhythmically bedded deposits resulted from surges or pulses within a single flooding event as proposed by Bretz (1929), Baker (1973), and Bjornstad (1980). According to evidence cited by Waitt (1984) the rhythmically bedded deposits, including the Touchet Beds, record at least 40 glacial lake outburst floods. One rhythmite represents one flooding event. If this is true, then the rhythmically bedded deposits located in the Lewiston Basin of Idaho and along the lower Cheney-Palouse Scabland Tract and in the Tucannon River drainage, represent multiple floods of the same or similar magnitude that date between ca. 13,000 and ca. 11,000 years B.P.

This road log and field trip focuses on the Cheney-Palouse Channeled Scabland Tract in eastern Washington and in several backflooded areas in the Tucannon drainage system. Should time permit, several exposures of gravel and rhythmically bedded deposits near Lewiston, Idaho will be investigated. These exposures, however, are not documented in this road log. The field trip is designed to generate controversy and questions pertaining to the number and magnitude of flooding events that inundated the Channeled Scablands of eastern Washington during the latest Pleistocene.

Road Log for One-Day Scablands Field Trip

Introduction

The scablands "story" involves a large geographic area. However, a part of the story can be easily understood by studying the sediments and geomorphic features in the Cheney-Palouse Tract (Fig. 2). This tract, 75 miles (120 km) long and up to 25 miles (40 km) wide, extends southwest from the vicinity of Cheney, Washington to the Snake River. The Cheney-Palouse Tract is an excellent place to examine and test Bretz's (1959) theory of glacial flood origin for scabland topography. Mapping in this tract shows more than 75 loess islands and at least ten major westward spillovers (divide crossings) into the Grand Coulee-Quincy Basin drainage system.

The Cheney-Palouse tract cuts across a pre-glacial drainage. Several semiparallel creek valleys converge to join the Palouse River in the southern part of the tract. The Palouse River enters the tract near its midpoint from an unviolated drainage to the east. The pre-glacial pre-flood Palouse River followed a route through the Hooper and Washtucna area and down the present streamless Washtucna Coulee to where it joined the Snake River about 50 miles (80 km) to the southwest. The flood waters, however, crossed a divide between Washtucna Coulee and the Snake River during peak flooding and beheaded the Washtucna Coulee. The new path is 50 miles (80 km) from the old path and drops 900 ft. (274 meters) in only 10 miles (16 km) from Hooper to the Snake River.

The field trip is designed so that we will generally follow the movement of flood waters. We will enter the Cheney-Palouse Tract near Winona on the north and follow the water path southward to its junction with the Snake River where the water split and some flowed eastward up the Snake River. Our trip will follow that eastward surge up the Tucannon Creek until its end near Dodge, Washington. Thus, we can imagine ourselves "surfing" the frontal waves as the waters

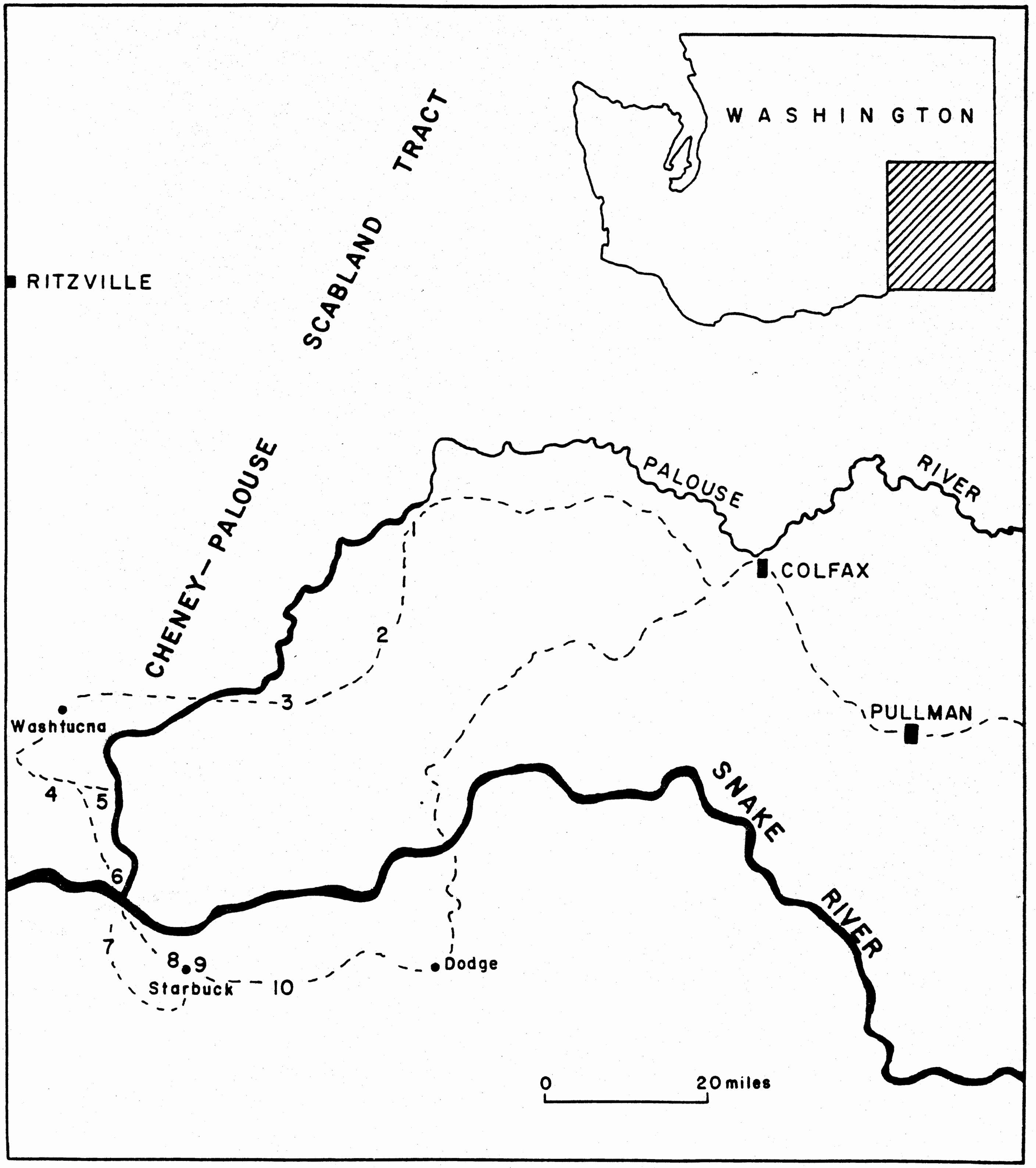

Figure 2. Index map of Cheney-Palouse Scablands Tract in Eastern Washington showing stops on field trip. Dashed line indicates travel route.

crossed stream divides, swashed in eddies, crashed against canyon walls, and scraped against loess hills.

Mileage

Cumulative/Difference

0.0 0.0 Junction of Line Street and Washington Highway 270. Proceed toward Pullman.

2.5 2.5 Small roadcuts in basalt. These flows are correlative with nonporphyritic flows of the Wanapum Formation of the Miocene Columbia River Basalt Group (Fig. 3).

7.1 4.6 United Paving Company quarry south side of road. Loess cover on the basalt ranges from about 15 to 30 feet (5 to 9 meters) or more. The thickness of the loess is greater here because the pit is on the northern slope of a buried basalt hill. The loess has drifted into protected north slopes of the preloessial topography, and the loess cover normally is thinner on the southfacing slopes and thicker on the northfacing slopes.

8.1 1.0 Entrance to Washington State University.

8.9 0.8 Junction with Lewiston-Colfax Highway. Turn right.

9.0 0.1 Junction with U.S. Highway 195. Turn left to Colfax.

10.0 1.0 Junction. Turn right on U.S. Highway 195 toward Colfax. For the next several miles you will have a good view of the strong asymmetry of the loess hill topography. The very gentle slopes face south and the rather steep slopes face north.

23.1 13.1 Entering Colfax. Until we reach Palouse Falls later in the day, we will be traveling over gently southwestward - dipping flows of the Wanapum Formation, which thickens from about 256 feet (78 meters) near Colfax to over 500 feet (153 meters) at Palouse Falls. Follow Highway 195 through downtown Colfax. Most of the basalt outcrops along the valley floor of Colfax belong to a porphyritic flow of the Wanapum Formation referred to as the Roza Member.

26.0 1.6 Junction with Washington Highway 127. Bear left to Walla Walla.

29.9 3.9 Junction with secondary highway near Fairgrounds. Turn right to Winona.

34.8 4.9 Town of Diamond.

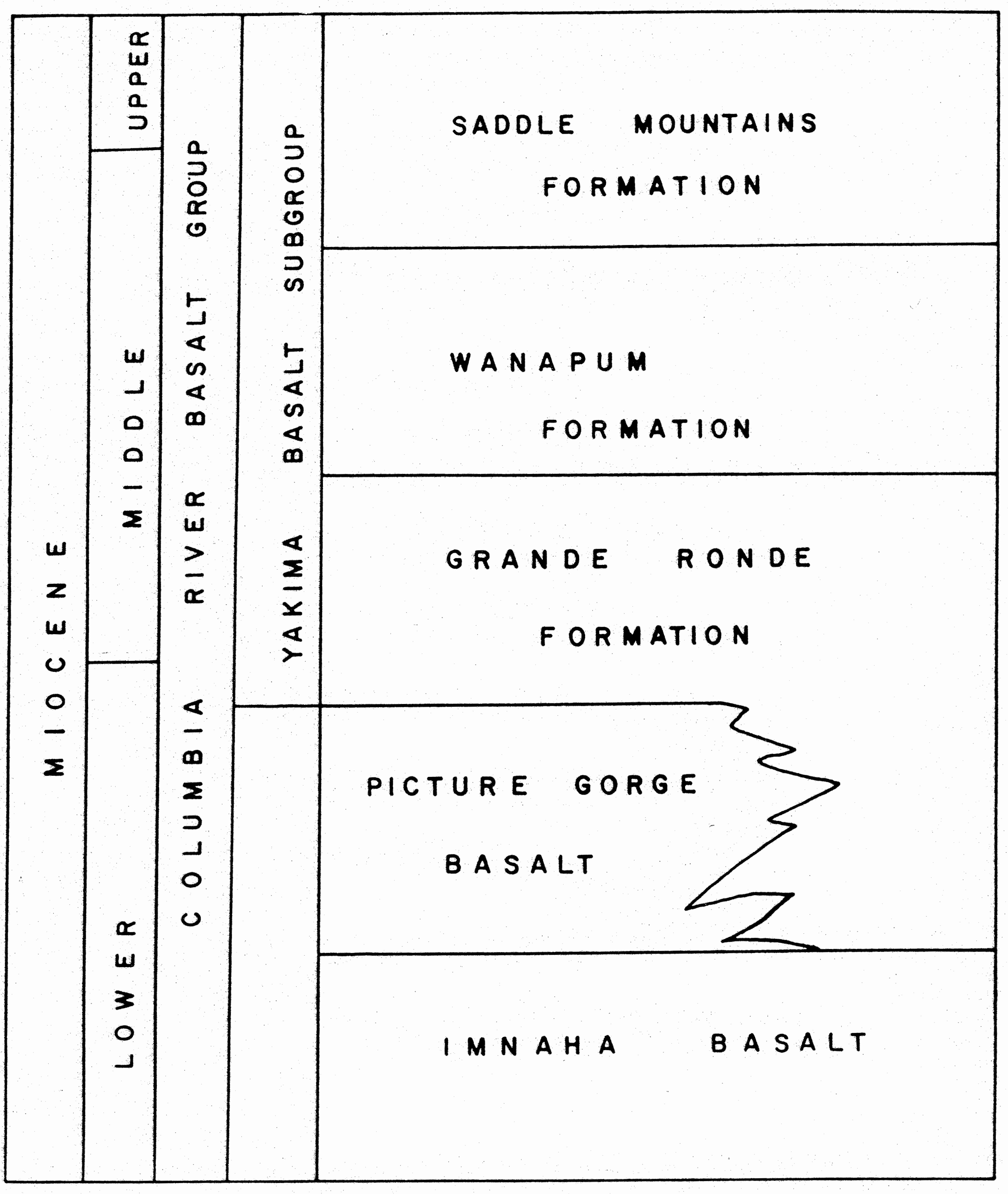

Figure 3. Generalized stratigraphic section for the Columbia River Basalt Group.

45.3 15.4 Town of Endicott.

49.5 4.2 Exposures along creek banks exhibit reworked Mazama Ash, underlain by early Holocene alluvium.

51.6 2.1 Town of Winona. Turn left to Lacrosse. Winona lies on the eastern edge of the Cheney-Palouse Tract. The cinderlike outcrops have been interpreted as near-vent material for one of the Columbia River Basalt Flows.

54.6 3.0 Three-way road junction. Keep to the right.

56.1 0.6 Sharp left turn across railroad tracks. Park on gravel road ahead for STOP ONE.

STOP ONE: Orientation and discussion of trip agenda. From this locality on the eastern edge of the tract, isolated islands of loess can be seen on clear days. From this locality to STOP THREE we will be traveling parallel to water movement.

63.0 6.9 Entrance to Lacrosse.

STOP TWO: Brief restroom stop at city park. Continue through the town following signs to Dusty.

63.6 0.6 Junction with U.S. Highway 26. Turn right. From here to STOP THREE we will be driving over and through deposits of Willow Creek Bar.

69.6 6.0 STOP THREE: Small pullout on left (south) side of road, just beyond mile post 99. Necessary to cross fence and walk to east on old road bed. Features of interest at this point include thin postflood loess, cobble- to boulder-sized gravel, battered basalt columns, soft sediment deformation features, silt boulders, poorly developed graded beds, and foreset beds, which indicate both eastward and westward current direction.

ADDITIONAL DISCUSSION: The deposits here are believed by Baker (1973) to be eddy bar deposits which formed in the mouths of the tributary valleys, marginal to the high-velocity sections of flooded channels. At this locality, eddy bar deposits blocked the mouth of Willow Creek. Eddy bars contain a wide range of grain sizes and bedding structures. Interfingering occurs between poorly sorted boulder gravels, laminated silts, cross-bedded granule gravel, and graded silt layers. Although not obvious at any one locality, the mixture of sediment types occurs in crudely upward-fining couplets that as a group also fine upward. Poorly defined foresets in the boulder gravels mostly dip away from the main scabland channel. However, the smaller foresets in the granule gravels dip back toward the main scabland channel. Giant current ripples are rarely found associated with the eddy bars. It is believed that these deposits are a result of poorly understood macroturbulent phenomena as described by Matthis (1947) and most recently rediscussed by Baker (1973).

In summary, Willow Creek Bar deposits are believed to have been formed by eddies, with the stronger currents carrying the coarsest flood debris up the tributary valley and the weaker return currents depositing the finer granule gravels. The method of deposition is open to controversy and we welcome your comments.

These deposits extend kilometers (miles) upstream from this locality. However, the abundance of coarse materials decreases as sand and silt increases. As the sediments fine away from the blockade at the tributary mouth, they are termed slackwater deposits.

69.6 6.0 Proceed westward on U. S. Highway 26. We will be traveling across the Cheney-Palouse Tract through typical scabland topography.

76.1 6.5 Pillow basalts exposed in Wanapum Flows.

81.2 5.1 To the south the Palouse River makes a right-angle turn across the pre-glacial Palouse-Snake Divide. Our route continues westward down the pre-glacial valley of the Palouse River.

85.2 4.0 Junction with Washington Highway 260 at Washtucna. Turn left and proceed through the center of town. Most of the eastern part of Washtucna is built on a point bar made of flood gravels. Several deposits of flood gravels are easily seen in and above railroad cuts along the east side of Washtucna Coulee for the next 5 miles (8 km). Only a few deposits of flood gravel are found along the west side of the Coulee. The flood waters traveled down this coulee to the area of Connell, 24 miles (38 km) to the west, where they joined with waters from other scabland tracts. Simultaneously, water was spilling over drainage divides through shorter routes where the present Palouse Falls Park and Devils Canyon are located.

91.7 6.5 McAdam Junction. Turn left on Washington Highway 261 to Lyons Ferry.

92.1 0.4 Gravel bar, which obstructs the mouth of a tributary valley, is visible on the right.

92.6 0.5 Exposures of Mazama Ash.

97.5 4.9 STOP FOUR: View of H & U cataract. Necessary to cross fence at gate opening on south side and walk 985 feet (300 meters) for view of cataract. Please respect property rights. The large cataract forms the head of Davin Coulee, which leads to the Snake River 4.0 miles (6.4 km) to the south. The cataract is approximately 308 feet (94 meters) from the brink to the bottom of the plunge basin. There are numerous cataracts like this within the Columbia River Basin. Stops 4 through 7 are illustrated on Figure 4.

From this point, joint-controlled drainage valleys and steep plow-pointed loess islands are visible. Return to vehicles.

99.7 2.2 View of smooth-shaped loess islands to the right. Bretz and others (1956) interpreted these hills as fluvially eroded loess islands. Baker (1973) has shown that many of these hills were eroded subfluvially, by pointing out that the streamlined shapes bear a close resemblance to airfoils, thus supporting Bretz's contention that they were streamlined by a rapid flowing fluid.

101.3 1.6 Junction. Turn left onto road to Palouse Falls.

103.7 2.4 STOP FIVE: Lunch. Palouse Falls State Park. Palouse River now flows over an old flood cataract recessional scarp 200 feet (61 meters) high. The course of the Palouse River is joint controlled and remarkably angular (Fryxell and Cook, 1964). Even the small tributary canyons are along joints. This canyon was a flood shortcut to the Snake River, from which the Palouse River never rejoined its old channel west of Washtucna. The top of the waterfall marks the approximate contact between Wanapum basalts above, and Grande Ronde basalts below.

106.1 2.4 Return to main Washington Highway 261. Turn left to Lyons Ferry.

107.0 0.9 View of lower Palouse Canyon.

107.9 0.9 STOP SIX: Optional. View of confluence of Palouse and Snake Rivers from beneath the railroad trestle. The basalt knob on the south side of the Snake River split the flood waters (Fig. 4). The water that was diverted downstream along the Snake River deposited the gravel bar to the west of the knob. The bar is covered with giant current ripples whose asymmetry clearly indicates that flood waters flowed down the Snake River Valley. The water which was directed upstream deposited Midcanyon Bar (visible ahead to the southeast) that is covered by giant ripples whose asymmetry clearly indicates movement up the Snake River Valley. Our direction of travel will be across the bridge to Midcanyon Bar. From there, we will take a side trip following the water movement through the saddle illustrated on Figure 4 and then to the top of the knob in order to look down on the unnamed gravel bar.

109.2 1.3 Turn right across railroad tracks on Deruwe Road.

111.2 2.0 Turn right immediately before power lines. At this point, we will be following the water movement as it was attempting to return to the Snake River.

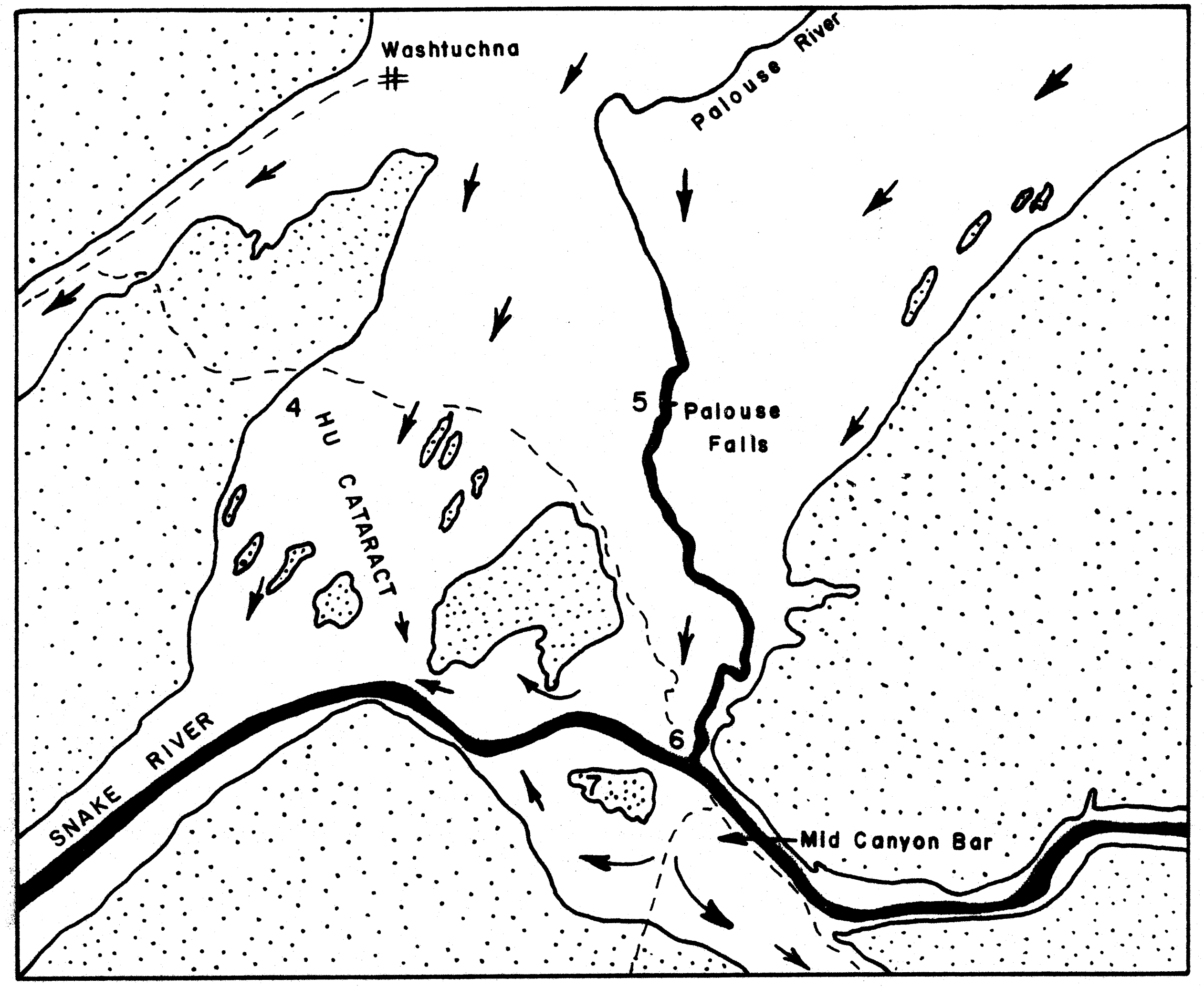

Figure 4. Generalized location map of the confluence of the Cheney-Palouse floodwaters with the Snake River in eastern Washington. Pattern shows unscoured loess-covered areas. Inferred paleo-flow directions are shown by arrows. Dashed lines are paved roads, and numbers are STOPS on roadlog.

111.4 0.2 Turn right on poorly defined road towards old water tank. Proceed on this road until Snake River becomes visible.

112.2 0.8 STOP SEVEN: View of the confluence of Palouse and Snake Rivers, the unnamed bar below with giant ripples, and the mouth of Davin Coulee. The current direction of the ripples can easily be seen from this vantage point. Gravel was taken from the bar to build an unsuccessful protective dike around the Marmes Rockshelter located along the Palouse River upstream from its confluence with the Snake River.

An interesting sidelight concerning the Marmes Rockshelter is repeated from Webster and others (1976, p. 18).:

"This archaeological site received worldwide attention in the spring of 1968 when human remains were discovered in situ 24 feet beneath the surface of the modern flood plain. These remains were established reliably as being at least 10,000 years old -- the oldest well documented human remains in the New World. Numerous artifacts, cultural features, and animal bones were associated directly with the human remains."

115.2 3.0 Return to junction with Washington Highway 261. Turn right. Road will cross Midcanyon Bar. The gently undulating ridges and swales cut by the road are giant current ripples, 10 feet (3 meters) in height and 246 feet (75 meters) between crests. Mouth of Tucannon River. The Tucannon has eroded through the bar of flood gravel that originally blocked this tributary valley. The road cuts on the opposite bank of the river show poorly sorted boulder and cobble gravel containing large rip-up silt clasts. Junction with the road to Powers. Note the flood gravels on the crest of the ridge to the left as we proceed on Washington Highway 261 towards Starbuck. We will be following the path of water as it traveled up the Tucannon drainage. The next three stops will be in slackwater sediments, each stop being further from the mouth of the Tucannon River, and further from the source of the flood water.

120.3 5.1 STOP EIGHT: Junction with Little Goose Dam Road. Park and walk back to road cut on left exposing backwater deposits. This stop and stops 9 and 10, feature flame structures, ball and pillow structures, clastic dikes, and lateral changes in relative grain size. Webster and others (1976) have described the next three stops in detail. Most of our descriptions are modified versions from their field guide.

ADDITIONAL DISCUSSION: Preflood tributaries to the Cheney-Palouse Scabland Tract recorded surges from the main channel back up the tributary valleys. The evidence for this is recorded in erratic boulders, sand, and loess-derived flood silts transported kilometers up the tributaries. Most of the cross bedding in the deposits indicates up-valley currents. Moreover, grain sizes of the sediment decrease up the tributaries, away from the scabland channels. Bretz (1969) suggested that these slackwater deposits might contain a record of successive flooding; however, he emphasized that the mechanics of slackwater deposition is poorly understood.

Locally the graded sand-silt intervals of the slackwater deposits may be divided into the following vertical sequence:

(1) a basal layer of structureless coarse sand and granules.
(2) horizontally stratified medium and fine sand.
(3) current ripple bedding in the uppermost fine sands and lowermost coarse silts.
(4) parallel laminations in the medium and fine silts.

Occasionally, this sequence will overlie an even lower layer of poorly sorted, angular flood gravel. Few of the coarser members of the sequence are present in the upper Tucannon Valley. Return to vehicles and proceed to Starbuck.

121.2 0.9 STOP NINE: Optional. Road cut exposure on left of backwater deposits with ice rafted boulders and clastic dikes.

The graded sand-silt intervals of the Tucannon Valley show considerable evidence of deformation. This deformation occurs as local settling and as sediment-filled fissures called clastic dikes. Lupher (1944) believed that the melting of buried ground ice was largely responsible for the clastic dikes. He suggested, however, that a few fissures might have been formed by landslides. All the clastic dikes, he believed, were filled from above by cycles of lake advances and retreats. Alwin and Scott (1970) concluded that the dikes represent filled crevices of permafrost origin.

122.1 0.9 Road cut on left exposes more slackwater deposits.

124.3 2.2 Road cut shows silt with only minor amount of basalt sand. Similar slackwater deposits are in most road cuts for the next 4 miles (6.8 km).

128.2 3.9 STOP TEN. Junction with U.S. Highway 12. Turn left. The road cut exposes very fine-grained slackwater deposits. Similar deposits are visible in the few road cuts for the next 5 miles (8 kilometers).

SUMMARY: Baker (1973) offered a unified hypothesis to explain the slackwater facies of Missoula Flood sedimentation. The preflood tributary valleys, such as the Tucannon River, behaved as settling basins adjacent to main flow channels. Any disturbance of the water level in the main scabland channels was propagated up these tributaries as transient surges (water surface waves). Such surges would bring into the tributary valleys a mixture of main channel flood sediments as either density flows or turbidity currents. The coarsest material would be deposited as an eddy bar at the junction of the tribuatary and the main channel. Further up the valley, sands and silts would settle out as an upward-fining turbidite. The proportion of silt versus sand would increase up-valley. Reverse, down-valley transients, analogs of reflected waves in stilling basins, might initiate weaker,down-valley turbidity flows. Further changes in the main channel's water surface could initiate new up-valley surges.

The result of successive surges would be a vertical sequence of numerous turbidites as seen along the Tucannon valley. The vertical units would result from the attenuation of the successive surges. The slumping of sediments deposited in earlier surges could account for the clastic dikes, faulting, and other deformation of the slackwater deposits.

Waitt (1980, 1984) would interpret each rhythmite as representing one catastrophic flood. The current ripples, parallel laminations, and inclusion of exotic lithologies in the lower part of each rhythmite is evidence for a single flooding event (Waitt, 1984). Furthermore Waitt (1980, 1984) concludes that the massive silt and very fine sand units which cap most individual rhythmites, represents a period of subaerial exposure characterized by eolian activity.

136.8 8.6 Dodge Junction. The shortest route to Moscow is on U.S. Highway 295 to Dusty. Proceed straight ahead at Dodge Junction.

END OF LOG.

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A FIELD TRIP GUIDE TO THE CENOZOIC INTRUSIVE ROCKS OF THE IDAHO BATHOLITH ALONG U.S. HIGHWAY 12, IDAHO COUNTY, IDAHO

by Terry Hayden
Department of Geology and Geological Engineering

Introduction

The Bitterroot Lobe of the Idaho Batholith is part of a large plutonic complex that occupies much of the central part of Idaho. Emplacement of the various plutonic bodies began in the Late Cretaceous and continued episodically until mid-Tertiary. Armstrong (1975) noted that the compiled dates for the Bitterroot Lobe are all less than 70 m.y. Bickford and others (1981) believe the granite of the Bitterroot Lobe to be about 55 m.y.

Intrusive rocks of the batholith are in general more mafic to the west and become progressively more felsic eastward. The Bitterroot Lobe is divided into three broad intervals or sectors. For purposes of this field-trip: a western sector with northwest trending steeply dipping, primary flow foliation; a central sector with west-northwest trending, steeply dipping primary flow foliation, in places; and an eastern sector with west trending steep dipping primary flow foliation. Overprinting the primary flow foliation in all thin sectors is a secondary foliation-lineation which describes a broad arch across the Bitterroot Lobe of the Idaho Batholith.

In all three sectors granite and granodiorite occur in approximately equal amounts with much smaller amounts of quartz monzonite, quartz monzodiorite, tonalite, diorite, and anorthoite plus various dike rocks also being present. All the above plutonic rocks belong to the Bear Creek Pluton (defined by Toth, 1981). For brevity sake, only granite and granodiorite will be discussed. For more detailed data see Reid (1984).

The northern part of the Bitterroot Lobe is dissected by the Lochsa River, along a northeast-southwest trend. U.S. Highway 12 follows the Lochsa River and provides easy access to observe the three sectors of the Lobe of the Idaho Batholith.

Acknowledgements

This field-trip guide is based on a revision of Reid and others (1979). Additional data was added from Reid (1984).

Emplacement and General Structure

Studies by Nold (1968) and Hietenan (1962, 1963) show that the rocks intruded by the batholith decrease in age towards the batholith, or have fold axes plunging towards the batholith (suggesting underflow on at least the northeastern and western margins of the batholith).

The major intrusive rocks of the Bitterroot Lobe, tonalitic gneisses, and meta sedimentary rocks all contain similar accessory mineral suites, suggesting considerable assimilation of the wall rocks by the batholithic magma.

A secondary foliation suggests that the Bitterroot Lobe has been deformed into a broad general arch as indicated in Figure 1.

A compilation of average measurements of flow directions in the granite rocks is shown in Figure 2. The flow trends include primary and secondary flow features, as well as the trend of blastomylonite where it has developed. The flow trends form a fan-shaped array opening out to the southeast. Flow lines plunge 30° northwesterly, become horizontal near the Bitterroot Arch, and then plunge 30° southeast in the Bitterroot gneissic front.

Figure 1 shows the disposition of secondary flow lineation across the studied interval. The intensity of the strain fabric lessens to the west and is structurally higher in the pluton as shown in the cross-section. The mylonite zone at the east margin of the pluton is removed by erosion at its western edge and is not seen again further west.

Granite And Granodiorite Bitterroot Lobe

Western Sector

The western part of the Idaho Batholith is characterized by zones of granite and granodiorite with primary flow foliation interspersed with zones of massive granite. Screens of migmatite involving lit-par-lit gneisses and meta sedimentary material up to one (1.6 mi) kilometer-thick parallel the primary flow orientation.

The granite and granodiorite at Stop One is medium-grained, gray, has a hypidiomorphic granular texture and moderate, well developed primary flow foliation trending northwest (320° az). The flow foliation is expressed mostly by biotite or microcline bands, and less commonly by biotite-rich schlieren. Roughly one-third of the rocks from the western sector display a foliation that is only recognizable at the outcrop and is not visible in hand-specimens or in thin sections. However, there are certain fabric elements that impart a secondary, subtle foliation. This secondary foliation is expressed by flattened quartz and feldspar grains (visible in stained slabs and measured locally in the field).

Sodic plagioclase (An 15-32, oligoclase) has normal zoning and equant to prismatic, subhedral to euhedral form. Other minerals include quartz, K-feldspars, biotite, and minor late muscovite. Accessory minerals include zircon, baddeleyite, apatite, magnetite, sphene, thorite, allanite, and leucoxene, with magnetite being more abundant than all other accessories lumped together. No sphene was found in the granodiorite of the western section.

Shear joints have east to northeast trends and are generally slickensided with the slickensides raking to the northeast and southwest. Secondary joints have a random orientation, widely varied in both strike and dip.

Migmatite in the northern part of the Bitterroot Lobe forms large sheets (screens) trending west to northwest and is relatively abundant. Foliation in the migmatite closely parallels primary flow foliation. The migmatite screens are composed of quartzite, calc-silicates, granitic gneisses, or amphibolitic rocks.

Several exposures of blastomylonite are present with an average attitude of 320° az, 40° SS.W. Lineations in the blastomylonites trend 30°, 290° az.

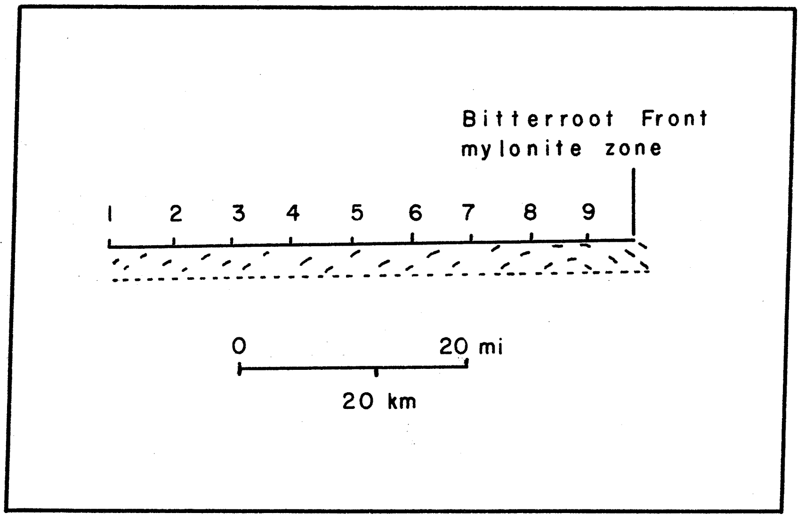

Figure 1: Diagrammatic structure cross section (53 mi/85 km long) across the Bitterroot Lobe of the Idaho Batholith, showing the disposition of secondary flow lineation trending about 290°-110°az. Relief is generalized except at the Bitterroot front, where the slope on the myolite zone is shown approximately. The base of the section is about 10 mi (6 km) below the surface; data are extrapolated from surface exposures. Numbers on the section refer to 7 1/2 quadrangles as follows: (1) Huckleberry Butte; (2) Greenside Butte; (3) Fish Lake; (4) McConnel Mountain; (5) Hungary Rock; (6) Cedar Ridge; (7) Jeanett Mountain; (8) Blodgett Mountain; (9) Printz Ridge. (After Reid, 1984).

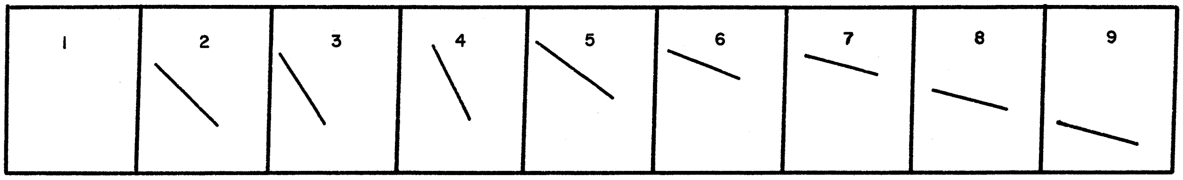

Figure 2. Average flow directions in granitic rocks across the Bitterroot Lobe of the Idaho Batholith. Numbers on the diagram refer to 7 1/2 quadrangles as in Figure 1.

Central Sector

The granite and granodiorite of the central part of the Bitterroot Lobe is massive for the most part, however, there are zones displaying primary flow foliation - having a northwest trend with moderate to steep dips. In the west part of the central sector approximately two-thirds of the rock is massive, whereas in the eastern part, two-thirds of the rock is foliated/lineated.

The foliation is expressed by oriented biotites (as parallel biotite grains, biotite streaks, biotite-rich band, or schlieren), or by platy xenoliths oriented parallel in flow. Foliation is also expressed by parallel K-feldspar phenocrysts in some locations (this foliation plan dips more steeply than does the biotite foliation in the same rock). Rarely, feldspar phenocrysts form a lineation in the foliation. In places the primary flow foliation is crossed or destroyed by a northwest-trending secondary foliation which is expressed by flattened quartz and feldspar grains. A secondary lineation in the secondary foliation is expressed by linear biotite streaks in schlieren, minor fold axes, and linear biotite arrays in xenolith of biotite quartzites and schists. Both massive and foliated rocks are locally porphyritic with K-feldspar phenocrysts comprising from 1 to 20 percent of the rock.

The granite and granodiorite of the central sector is fine to medium-grained hypidiomorphic granular. Plagioclase has equant prismatic subhedral form and is normally zoned. Other major minerals are K-feldspar, quartz, and biotite. The accessory minerals are apatite, epidote, sphene, allanite, thorite, baddeleyite, zircon, magnetite, beta-zoisite, and monazite.

Some areas of the central sector are intensely, randomly jointed and altered (Stop Five). The alteration involves silicification and chloritization, which impart a pink coloration.

The central zone is cut by fine-grained blastomylonitic schistosity or zones of blastomylonite up to 14 in. (35 cm) in thickness. The blastomylonitic fabric partly parallels and partly cross cuts flow foliation. The blastomylonitic shears vary widely in their orientations.

Eastern Sector

Granite and granodiorite in the eastern part of the Bitterroot lobe is much less brecciated and altered than rocks in the central sector. Approximately 20 percent of the rocks are porphyritic, with no sharply defined contacts between porphyritic and non-porphyritic rocks.

Most of the rock in the eastern sector is foliated, with the foliation expressed by parallel arrangment of biotite grains, flattened or rodded quartz and feldspar grains, parallel schlieren, feldspar crystals partly parallel to the flow planes, parallel slabby xenoliths of biotite quartzite, fine-grained biotite schists, and by biotite-rich bands.

Foliation relations are more complex in the eastern sector with much of the foliation being secondary in character. Much of the foliation in the eastern part of the east sector appears to cut across early primary flow foliation. Lineations are near horizontal (as compared to 30°NW in the west and central sectors). This change in lineation attitude reflects a lineation arch across the eastern sector, from westerly plunges on the west to easterly plunges on the east.

The east part of the eastern sector is part of the Bitterroot frontal gneiss zone and has foliation dips at shallow angles to the east. The foliation becomes stronger from west to east in the eastern sector, with feldspar grains being flattened in the foliation and the rocks being strongly lineated in places on the same general trend as that in the rocks to the west. The lineation is described by elongate biotite grains, trains of small biotite flakes, rodded quartz and feldspar grains, and minor fold axes in biotite-quartzite xenoliths. Some zones more than several hundreds of meters in thickness display lineation, but no foliation. The above is a generalized view of the eastern sector, for detailed information see Reid (1984).

Petrographically the eastern sector is quite similar to the other sectors, however, the eastern sector has fewer total accessory minerals.

Blastomylonite is relatively scarce in the western part of the eastern sector, but is present in amounts larger than those of the central sector, and becomes more abundant yet to the east. The mylonites are flat lying and contain a lineation oriented in the 110°az - 290° sector.

ROAD LOG

From Moscow, take U.S. Highway 95 south to its junction with U.S. Highway 12 at Lewiston. Follow U.S. Highway 12 east along the Clearwater River to Lowell, Idaho (approximately 95 miles, 153 km). Continue east on Highway 12 to mile 111.6.

Mileage Cumulative/Difference		
111.6		STOP ONE: First turnout past the bridge at Split Creek. Western Sector: Primary gneiss (granodiorite) in the marginal zone of the Bitterroot Lobe has a moderately strong primary flow foliation oriented 305°az, 75°NE. A basalt dike intrudes the batholith.
115.5	3.9	STOP TWO: Macaroni Creek. Western Sector: Massive granite of the Bitterroot Lobe.
117.5	2.0	STOP THREE: Western Sector: Lit-par-lit gneiss in a migmatite screen (similar to several near mile 112.5). The gneisses are tonalitic to granodioritic in composition with an internal foliation trend averaging about 300°az, and having a vertical dip. The trend of the screen probably parallels that of the flow foliation.
124.8	7.3	STOP FOUR: No-See-Um Creek. Central Sector: Granite with shallow-dipping primary flow foliation. The granite has widely spaced joints and is relatively unaltered.

Mileage

Cumulative/Difference

132.2	7.4	STOP FIVE: (Optional) About one mile (1.6 km) east of Castle Creek. Central Sector: Jointed, altered granite, with silicified shears and intense alteration along jointing. Near this stop is a vertical fault striking 325°az with related vertical extension joints trending 360°az. The fault has horizontal slickensides indicative of strike-slip movement. Joints suggest that the maximum principal stress was oriented 360° and was horizontal - suggesting right-lateral motion. Vertical slickensides overprint the horizontal slickensides, suggesting later dip-slip movement.
142.0	9.2	STOP SIX: East of Weir Creek. Central Sector: Granite, moderately to intensely jointed, brecciated and altered to a pink color (K-feldspar rich?) with associated epidote and chlorite alteration. Andesite and more mafic dikes are highly sheared, mylonitized, chloritized and altered to pink along fractures.
145.0	3.0	STOP SEVEN: One-half mile east of Post Office Creek. Eastern Sector: Brecciation and alteration much less intense than at Stop Six. Primary flow foliation trends 290°az with an average dip of 80° SW in foliated granite. Andesite dike cuts granite.
160.7	15.7	STOP EIGHT: (Optional) About 1.2 miles (2 km) west of turn off to the Powell Ranger Station. Eastern Sector: Granite with three to thirty feet (one to ten meters) diameter xenoliths of calc-silicate quartzite near the eastern contact of the Bitterroot Lobe. Quartzite bedding is little disrupted (025°az, 65°NW) and the quartzite may form more of a septum than isolated xenoliths.

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