NATURAL RESOURCES

Geologic Map of the Mead 7.5-minute Quadrangle, Spokane County, Washington

by Robert E. Derkey

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES

Open File Report 97-3
June 1997

U.S. Geological Survey STATEMAP Program
Contract No. 1434-HQ-96-AG-01524

Location of quadrangle

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands
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Geologic Map of the Mead 7.5-Minute Quadrangle, Spokane County, Washington

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INTRODUCTION

The Mead quadrangle is named for the community of Mead near the southwest corner of the quadrangle, 8 mi northeast of downtown Spokane. Suburban (two or three homes per acre) and hobby farm (10-acre or smaller lots) development has been extensive in the vicinity of Mead in recent years. This development has resulted in adverse impacts on ground water and potentially limited mineral resource development.

Shallow ground water has become a local problem. No homes in the quadrangle are served by a city or county sewer system; homes rely on individual septic systems or local community sewer systems. Low permeability of silt and clay-rich sediments in some areas in the quadrangle creates shallow, unconfined perched aquifers that have resulted in basement and surface flooding as wastewater is added to the permeable surficial sediments.

Restrictions on surface- and ground-water use have increased. Most of the more densely developed areas in the quadrangle obtain their water from a community provider that draws its water from gravels underlying the Little Spokane River drainage basin. In order to maintain a minimum streamflow of 115 cfs in the Little Spokane River, the Department of Ecology will no longer issue permits to commercial providers to pump water from the Little Spokane River drainage basin (Covert, 1997). However, wells drilled into the local aquifer for individual home use do not need an Ecology permit.

Mineral-resource issues are not currently perceived as urgent. However, as development continues, it is inevitable that local mineral resources, such as sand and gravel, will become scarce or inaccessible.

This mapping project focused on providing geologic information useful for addressing ground-water and mineral-resource issues. Aerial photography interpretation, field mapping, and water-well and mineral exploration drilling logs were used to determine the spatial distribution of surface and subsurface geologic units.

New or refined information developed during the course of this mapping includes:

- Mass-wasting deposits, generated primarily by deep-seated landslides, are more widespread than previously thought. The landslides extend into the pre-Pleistocene buried valleys and are covered by lacustrine sediments.
- Clay interbeds in glaciolacustrine deposits apparently restrict downward percolation of surface water. The surface and subsurface distribution of the glaciolacustrine deposits is described and illustrated.
- The Miocene Latah Formation is thicker and more extensive than previously thought.
- Pre-Miocene intrusive bedrock units are much less extensive than previous reconnaissance mapping had indicated. Some areas mapped as bedrock proved to be sites where numerous large ice-rafted boulders, cobbles, and pebbles were deposited.
- Flood-gravel deposits of the Little Spokane River valley contain a higher proportion of sand than do the flood gravels beneath the Spokane River valley; excessive amounts of sand limit the economic exploitation of the resource.

GEOLOGIC HISTORY OF THE SPOKANE AREA AND THE MEAD QUADRANGLE

Spokane lies in an area of high-grade metamorphic rocks of the Spokane dome of the Priest River metamorphic core complex. Core complex rocks have been intruded by Mesozoic and early Tertiary muscovite-biotite bearing, dike- to batholith-scale granitic rocks. Some of the granitic rocks were deformed and have various intensities of foliation, suggesting they were intruded during metamorphism and core complex development (Joseph, 1990). Priest River metamorphic rocks are bounded and cut by major mylonitic fault zones, including at least one major decollement (Harms, 1982). A detailed description of the Priest River metamorphic core complex and related intrusive rocks can be found in Rehrig and others (1987) and Armstrong and others (1987). There are no high-grade metamorphic rocks and only limited exposures of Mesozoic and early Tertiary granitic rocks in the Mead quadrangle. These rocks are referred to as the pre-Miocene granitic rocks in the remainder of this report.

During the Miocene, basalt of the Columbia River Basalt Group began to fill the Columbia Basin. The ancestral Columbia and tributary rivers were blocked by the basalt flows, and shallow lakes formed in the Spokane area (Pardee and Bryan, 1926). The topographic relief of the area at the time was similar to that of today. The Miocene was also a period of deep weathering and extensive soil formation on the pre-Miocene rocks of the area. Abundant clay minerals were formed at this time. The Latah Formation, a thick sequence of clay, silt, and fine sand, was deposited by streams and in lakes in the Spokane area (Robinson, 1991; Boleneus and Derkey, 1996). The Latah is estimated to be more than 1,000 ft thick in the Mead quadrangle, but it did not completely cover the pre-Tertiary terrain.

Hills of pre-Miocene granite locally protrude above the highest elevation of the Latah Formation in the Mead quadrangle. Most exposures of the granite have an extensive weathered zone consisting of grus. Although there are excellent exposures of pre-Miocene granitic rocks in the Spokane area, they are limited in the Mead quadrangle and many of those are

covered by grus, especially in the northeast corner of the quadrangle.

Basalt capped the Latah Formation as the lava continued to fill the Columbia Basin. Observations in the Spokane area show that the Grande Ronde Basalt, the first local sequence of flows, is distributed to a maximum elevation of approximately 2,200 ft. The second series of flows, the Priest Rapids Member of the Wanapum Basalt, covered the area above 2,200 ft, but also filled valleys cut into the older Grande Ronde Basalt and Latah sediments, thereby resulting in locally reversed stratigraphy (Pardee and Bryan, 1926; Joseph, 1990). With one exception, all basalt in the Mead quadrangle is above 2,200 ft and is part of the Priest Rapids sequence. The exception is a Priest Rapids Member valley fill.

Sediments from two events dominate the Quaternary (Pleistocene) deposits in the Spokane area. They are extensive flood sands and gravels from repeated catastrophic glacial outburst floods and fine-grained lacustrine sediments from glacial lakes.

Glacial Lake Missoula, which existed in western Montana, was impounded by ice dams that intermittently blocked the Clark Fork River near Clark Fork, Idaho (summarized in Molenaar, 1988). Periodically, these dams broke, and enormous volumes of water rushed through the Spokane area en route to the Columbia River. Flood waters inundated the entire Spokane area to a maximum elevation of 2,700 ft. (The highest point in the Mead quadrangle is 2,400 ft.) Two primary local floodwater channels have been identified, the Spokane River and the Little Spokane River channels. Water sweeping down the Spokane River channel was moving very fast, and its sediment-carrying capacity was tremendous—car-size boulders are common constituents of the valley fill. The energy of the floodwaters in the Little Spokane River channel was apparently lower, and the sediment deposited in the channel contains relatively less coarse gravel and more sand than the Spokane River channel.

Quaternary glacial lakebeds are also extensive in the Mead quadrangle. Glacial Lake Columbia (Atwater, 1986) formed when glaciers blocked the Columbia River downstream from the present Coulee Dam area. At least two periods of lake formation are known. The first lake reached an elevation of about 2,400 ft, and a second lake reached about 1,700 ft (Atwater, 1986). Because no part of the Mead quadrangle is as low as 1,700 ft elevation, the lakebeds in the quadrangle must be from the earlier glacial Lake Columbia.

PREVIOUS GEOLOGIC MAPPING IN THE SPOKANE AREA

Geologic mapping in the Spokane area consists of the Mount Spokane 15-minute quadrangle (Weissenborn and Weis, 1976) immediately east of the Mead quadrangle and the Greenacres quadrangle (Weis, 1968) southeast of the Mead quadrangle. Reconnaissance or compiled geologic maps at 1:1,00,000 scale or smaller include the Spokane (1:100,000-scale) quadrangle (Joseph, 1990), the west half of the 1° x 2° Spokane (1:125,000-scale) quadrangle (Griggs, 1966), and a surficial geologic map of the Washington portion of the Spokane (1:250,000-scale) quadrangle (Kiver and others, 1979). The 250,000-scale geologic maps, based upon reconnaissance or compiled geologic maps, are Griggs (1973) and Stoffel and others (1990). In 1993–94, the Division of Geology and Earth Resources completed a detailed study of Quaternary deposits that form the Spokane sole-source aquifer; that 1:50,000-scale map is available in a digital form from the Spokane County Water Quality Management Program in the Public Utilities Department.

PHYSIOGRAPHY OF THE MEAD QUADRANGLE

The Mead quadrangle can be divided into five physiographic areas. These are (1) the bluffs, (2) the southwestern and northeastern highlands, (3) slopes, (4) the lower prairies, and (5) the Little Spokane River flood channel (Fig. 1). A brief summary of their unique geomorphic features and underlying geology and geologic history is included here.

The Bluffs

The bluff areas in the Mead quadrangle consist of three basalt-capped mesas that are 400 to 500 ft above the surrounding landscape. The northernmost bluff is Orchard Bluff. Green Bluff is near the center and east center of the quadrangle, and Pleasant Prairie is near the southeast corner of the quadrangle and extends farther into the adjacent North Spokane quadrangle. The basalt is covered by unconsolidated weathered basalt, flood sand, ice-rafted gravel, and loess. It is underlain by Miocene Latah Formation.

Loess is less than 2 ft thick on Orchard Bluff; abundant cobbles are plowed up in fields, and granitic boulders as much as 3 ft in diameter are stacked at the edges of some fields. The material underlying loess on Orchard Bluff may be till, or the cobbles and boulders may be ice rafted. There are no similar rocks on recently plowed fields on Green Bluff and Pleasant Prairie, suggesting that they are covered by thicker loess or that underlying sediments contain fewer such rocks. The only cobbles and pebbles observed on Green Bluff are basalt fragments, suggesting that unconsolidated material between loess and basalt bedrock is fine flood deposits or weathered basalt. Although no cobbles were observed on top of Pleasant Prairie, several granitic cobbles are piled along the bluff edge. Because this bluff is underlain by about 60 ft of basalt and several hundred feet of Latah Formation, these cobbles were probably deposited by ice rafting.

The Southwestern and Northeastern Highlands

The southwestern and northeastern highlands are areas where pre-Miocene granitic rocks crop out or are known from water-well logs to be at shallow depths. These rocks are surrounded by deposits of the Latah Formation. Outcrops of pre-Miocene rocks in the southwestern highlands are fresher than those of pre-Miocene rocks in the northeastern highlands, presumably because Quaternary floods and Holocene erosion have removed the weathered granite in the southwest.

Slopes

Sloped areas lie between the bluffs and the lower prairies and the Little Spokane River flood deposits. Most of the slope area on Figure 1 consists of deep-seated landslides involving Latah Formation and basalt cap rock. Intermixed in the landslides is basalt rockfall shed from the rimrock of the bluffs and debris flows extending down into the valleys. Because of the mixed character of these deposits, they are referred to as mass-wasting deposits. Water-well and mineral exploration drilling logs for the area (Boleneus, 1978; Boleneus and Derkey, 1996) show that the mass-wasting deposits are widely distributed beneath the lakebeds of the lower prairies. The landslide de-

Figure 1. Physiographic areas of the Mead quadrangle.

posits were emplaced before or during early Pleistocene glaciation and flooding in the region. These landslide features are geomorphically expressed as large headscarps as much as a mile wide with backward rotated slump blocks and slump earthflows. Toe deposits are conspicuously missing, suggesting either burial or removal by erosion. The presence of basalt blocks in, and mass-wasting materials below, lake and flood deposits supports a relatively greater age for the deep-seated phases of mass-wasting deposits than for the lake deposits and also indicates that these landslides were partially buried (rather than eroded) by flood and lake sediments.

The Lower Prairies

Peone and Valley Prairies, located just south and just north of Green Bluff and its related slope deposits respectively, are referred to as the lower prairie areas. Deadman Creek, which flows eastward across Peone Prairie, maintains year-round flow. Little Deep Creek, which extends northeastward through Valley Prairie, is intermittent. Headwaters of both streams are northeast of the quadrangle near Mount Spokane. The lower prairie areas are underlain by fine sand, silt, and clay deposits of glacial Lake Columbia. The floor of the lake (at or near 1,900 ft elevation) in these two prairies coincides with the present prairie surface. During and after draining of the lake, an extensive drainage network was developed in the basin; more than 60 ft of relief has been measured along Deadman Creek. A few small intermittent drainages extend above 1,900 ft elevation. Lakebed surfaces are veneered by less than 2 ft of loess eroded from slopes, and loess has been redeposited in the lower areas along the courses of intermittent streams. Below the lakebeds of Peone and Valley Prairies are mass-wasting deposits and (or) Latah Formation.

The Little Spokane River Flood Channel

The deepest known part of the Little Spokane River flood channel is filled with more than 500 ft of gravel and sand deposited by the numerous catastrophic floods from glacial Lake Missoula. These sediments are important as a host of ground water in the Spokane area. The modern course of the river in the Mead quadrangle is at or near the west edge of the extensive flood channel deposits. A profile of the ancestral channel of the Little Spokane River (prior to deposition of the flood deposits) was generated during a reflection seismic survey along Colbert Road (shown on cross section E–E′, Plate 2) conducted by the Washington Department of Natural Resources for the Spokane County Water Quality Management Program (Palmer and Derkey, 1996). The most probable course of that older channel in the Mead quadrangle is shown in Figure 2. Several terraces, characterized by level surfaces, lie at elevations above the present-day flood plain and are prominent geomorphic features along the Little Spokane River in the Mead quadrangle.

DESCRIPTION OF MAP UNITS

Quaternary Sediments

Qa **Alluvium (Holocene)**—Stream deposits consisting of silt, sand, and gravel in present-day stream channels and on flood plains. In the eastern two-thirds of the quadrangle, the alluvium is dominantly sand and silt derived from the underlying Pleistocene lacustrine deposits, loess, and the Latah Formation. In the western one-third of the quadrangle, the alluvium is predominantly sand and gravel derived from the underlying Missoula flood deposits.

Alluvium along Little Deep Creek ends in sec. 8, T27N, R44E, near the northeast corner of the map. A dam at this location was shown on the reconnaissance geologic map in Pardee and Bryan (1926); however, the dam, remnants of which suggest it was no more than 10 or 12 ft high, was removed more that 40 years ago. Upstream from the former dam, a fairly small volume of lake sediment covers the Pleistocene lacustrine deposits of the Little Deep Creek drainage, obscuring the former channel of the creek.

Mineral resource considerations: Although alluvium in the Spokane area contains sand and gravel, the deposits in the Mead quadrangle are small and restricted to active streams. Therefore, sand and gravel extraction probably would not be compatible with maintenance of riparian, wetland, or other critical areas.

Qs **Sand deposits (Holocene and Pleistocene)**—Windblown deposits of predominantly fine, well-sorted, sub- to well-rounded sand. Grains are predominantly lithic fragments that range from medium gray to nearly white. Deposits consist of a 10- to 20-ft-thick vegetated blanket; some dunes locally rise as much as 60 ft. Much of the sand probably is reworked from underlying flood sediments. Most weathered exposures of this unit are tan to brown; fresh exposures, such as in borrow pits, are medium to light gray, but because of the mixture of medium-gray and white lithic fragments, many exposures appear speckled.

Mineral resource considerations: Locally referred to as the Mead sand (because of its abundance in the Mead area), the sand is used to make finishing concrete. Rounded sand grains are more desirable for that product than angular grains of similar size derived from rock crushing operations.

Ql **Loess (Holocene and Pleistocene)**—Light- to medium-brown (darker where wet or recently plowed), unstratified, windblown silt and clay, locally including small amounts of fine sand and volcanic ash. The major minerals are quartz, feldspars, hornblende, and micas (Busacca, 1991). The loess is interspersed with sand in areas adjacent to unit Qs in the southwest portion of the map; contacts between the two units are gradational. Although loess is as thick as 75 ft in Spokane County, it rarely exceeds 2 ft in the Mead quadrangle; exceptions are in depressions where loess has washed down from the surrounding slopes. Some loess can typically be found on all soils in the Mead quadrangle, but it is mapped as a separate unit only on the tops of the bluffs. Loess deposits of the Columbia Basin are considered mostly Pleistocene; however, small amounts of loess are being redeposited by present-day dust storms.

Qgl **Glaciolacustrine deposits of glacial Lake Columbia (Pleistocene)**—Very light gray to pinkish or yellowish gray, predominantly silt and sand deposits. The silt and coarser fractions of the lacustrine deposits, like the Latah Formation, consist of quartz, micas, and feldspar with 4- to 6-in.-thick clay interbeds; scattered ice-rafted boulders, and some sand and gravel lenses, which may be eddy deposits from the Missoula floods or debris-flow deposits from the surrounding highlands. Lacus-

Figure 2. Location of the major drainages of the Mead quadrangle. The probable course of the ancestral Little Spokane River is also shown.

trine sediments underlie the lower prairie areas of Peone and Valley Prairies and are veneered by 1 to 2 ft of loess. The best exposures of lakebeds are along Bruce Road, which extends north–south across the center of Peone Prairie. For example, across the road from the Peone Cemetery, south of Deadman Creek (sec. 1, T26N, R43E), three 4- to 6-in. beds of predominantly clay are separated by 3 to 4 ft of silt and fine sand with subordinate clay.

Hosterman (1969), in an analysis of 14 auger holes (mostly 70–100 ft deep) in glacial lake deposits on Peone Prairie, found that the clay fraction of the sediments consists of 60 percent montmorillonite, 20 percent kaolinite, and 20 percent illite. Clays of the Latah Formation are predominantly kaolinite with lesser amounts of illite. An exception is a clay pit near Shelley Lake in the Spokane Valley where the ratio is 50 percent montmorillonite, 30 percent kaolinite, and 20 percent illite, nearly the same as the Peone Prairie glaciolacustrine deposits. The montmorillonite component is considered to be derived from volcanic ash (Hosterman, 1969). Assuming that montmorillonite in the glacial lakebeds is also of volcanic origin and Cascade volcanism was likely not contributing ash of the amount in the lakebeds, the montmorillonite must have been derived from older rocks. The likely source is the Latah Formation, similar to the Shelley Lake deposits; some clay may have its source in the surrounding uplands.

Mineral resource considerations. Clayey silt in the lacustrine deposits of Peone Prairie has been used as a clay resource for brick manufacture. A small brick plant operated more than 50 years ago in NW1/4 sec. 2, T37N, R43E. A more extensive description of the glaciolacustrine deposits of Peone Prairie and their resource potential can be found in Hosterman (1969).

Qfg **Missoula flood deposits (Pleistocene)**—Light-brown to yellowish-gray, poorly to moderately well-sorted, massive to thick-bedded, stratified mixture of boulders, cobbles, pebbles, and sand. Boulders, cobbles, and pebbles are predominantly granite, gneiss, or quartzite similar to bedrock units north and east of the area. Boulders may comprise as much as one-half the material in the unit. Matrix is mostly sand with some pebbles. In the Mead quadrangle, the majority of this unit lies just east of the present-day channel of the Little Spokane River. A hatched pattern indicates the general distribution of coarser gravels that contain more and larger clasts (6- to 12-in. boulders). Missoula flood deposits are locally interspersed (as eddy deposits) in glacial lake beds of Peone Prairie and in mass-wasting deposits, but these occurrences are too small to show on the geologic map.

A small exposure of coarse gravel is present near the northeast corner of the quadrangle (Plate 1), more than 3 mi from any similar coarse gravel. The deposit contains clasts of several different granitic rocks and quartzite, most of which are not present elsewhere in the Mead quadrangle. This gravel may be ice-rafted debris. It is in a low-lying gap that, if it had been covered by only a few tens of feet of flood water and if winds were right, could have accommodated iceberg transport of that volume of gravel to the area (E. P. Kiver and D. F. Stradling, Eastern Washington Univ., oral commun., 1997).

Mineral resource considerations: Missoula flood deposits are the principal source of construction sand and gravel (aggregate) in Spokane County. In the Spokane Valley along the course of the Spokane River, flood gravels were deposited by very high energy flood waters. The deposits are hundreds of feet thick and consist of pebbles, cobbles, and boulders as much as 10 ft in diameter. Gravel mines in the Spokane Valley have exposed a thick, nearly continuous sequence of coarse gravel containing fairly little sand. Sand is brought in for blending with the Spokane Valley aggregate for making concrete.

Missoula flood deposits in the Little Spokane River valley consist of only local pockets of coarse gravel like that in the Spokane Valley. Deposits in the Mead quadrangle along the Little Spokane River were laid down by flows of lower energy than those in the Spokane Valley; they have fewer boulders and cobbles and relatively more sand and pebble-size clasts. The pockets of gravel typically grade laterally and vertically into flood deposits having less than 1 percent of clasts coarser than sand. Gravel mining operations about 10 mi north of the quadrangle confirm this gradation and suggest that any gravel deposit in the quadrangle could not be mined to great depth before penetrating sand or fine glaciolacustrine deposits such as those found near the Colbert landfill (section G–G′). Although sand is an integral ingredient in gravel used for aggregate, a disproportionately large amount of sand results in excess reject. However, when mining large gravel deposits over the Spokane aquifer in the Spokane Valley is no longer possible, mining the deposits in the Mead quadrangle may become viable. Residential development tends to limit where gravel can be mined, and as development continues in the quadrangle, mineable resources will dwindle.

Groundwater resource considerations: The channel of the ancestral Little Spokane River (locally more than 500 ft deep near Colbert Road) lies east of the present channel (Fig. 2). This is the host for the lower end of the Little Spokane River aquifer, which appears to be producing water at capacity on the basis of streamflow measurements at the gaging station at Dartford (Covert, 1997). The aquifer has been the focus of at least two recent ground-water studies (Boese and Buchanan, 1996; Ader, 1996). The ancestral channel was identified by a reflection seismic survey along Colbert Road in the west-central portion of the quadrangle (Palmer and Derkey, 1996) and by well logs. The most logical projection of this channel is southward and then westward to intersect the present bedrock-confined course of the Little Spokane River. Upstream from Colbert Road, the results of extensive drilling at the Colbert landfill site suggest that the channel is located west of the westernmost drill hole, which reached bedrock at 400 ft below the surface.

The aquifer in flood deposits underlying the Little Spokane River is not as productive as the Spokane aquifer in the Spokane Valley, as is shown by the restrictions on pumping from the Little Spokane River when streamflow drops below 115 cfs (Covert, 1997). A much greater volume of water is being pumped from the Spokane aquifer. The availability of water in the Little

Spokane River aquifer may be influenced by the finer gravels in the deposits and (or) by the smaller overall size of the aquifer and the smaller recharge area for this aquifer relative to that for the Spokane aquifer, which extends to Lakes Pend Oreille and Coeur d'Alene in Idaho.

Qmw **Mass-wasting deposits (Holocene to Pliocene?)**—Consists of heterogeneous broken deposits of Latah Formation, lesser amounts of Wanapum Basalt (Priest Rapids Member), and catastrophic flood deposits. The irregular or hummocky topography suggests mass-wasting deposits are predominantly deep-seated, very large (>1 mi wide) composite landslides. Debris-flow and rockfall deposits have also been identified. Cohesive landslide blocks of the Latah Formation, the unit in which most of the mass-wasting deposits occur, are typically very light gray to yellowish gray; where blocks are more extensively broken, they commonly are stained yellow-orange to brown and rusty brown by limonite. Basalt clasts range from blocks as much as 25 ft across to cobbles and pebbles; they are gray to dark gray and mostly angular. Because at least some of the landsliding occurred during catastrophic flooding, small, irregular lenses of coarse sand and pebble gravel are locally interspersed with the mass-wasting deposits. Clasts in the sand and gravel are angular and well sorted, and consist of fragments derived from basalt and older granitic rocks. The much smaller and less numerous debris flow deposits, consisting of angular sand- to pebble-size materials and cobbles of basalt, are dark brown to reddish brown.

Mass-wasting deposits are older than some of the flood deposits of the Little Spokane River and glaciolacustrine deposits of the lower prairie areas. Extensive drilling in the vicinity of the Colbert landfill (section G–G′, Plate 2) indicates mass-wasting deposits (apparently from Orchard Bluff to the east) were deposited directly over bedrock, but this sequence of deposits does not extend beneath the river. They are overlain by flood gravels, which in turn are overlain by an apparent remnant of glaciolacustrine deposits, and finally by a later sequence of flood gravels (Landau Associates, Inc., 1991). The contact between older and younger flood deposits shown by Landau Associates, Inc. (1991) is not shown on section G–G′. Small pockets or areas of flood gravel also occur on mass-wasting deposits west of the Little Spokane River along the western border of the map.

Water-well and mineral-exploration drilling logs suggest that the mass-wasting unit is present between overlying glaciolacustrine deposits and underlying Latah Formation in most of Peone Prairie (sections A–A′, B–B′, C–C′, E–E′, and I–I′, Plate 2). The most compelling evidence that mass-wasting deposits are present is basalt and clay mixtures in mineral-exploration (Boleneus, 1978) and water-well logs of the area. For example, a water well (no. 111; Plate 1 and section B–B′, Plate 2) intercepted material described as "dirty basalt" from 165 to 180 ft depth. A mineral-exploration drill hole (no. 97, Plates 1 and 2) less than 200 ft from hole 111 did not intercept any basalt. The contact between mass-wasting deposits and underlying Latah Formation was difficult to determine. Therefore, the depiction of mass-wasting deposits beneath glaciolacustrine deposits of Peone Prairie is somewhat arbitrary.

Tertiary Volcanic and Sedimentary Rocks

Mvw **Wanapum Basalt, Priest Rapids Member, Columbia River Basalt Group (middle Miocene)**—Fine-grained, dense, dark-gray to black, aphyric basalt flows of reversed magnetic polarity (Joseph, 1990). Petrographic analysis indicates that mineral grains consist of plagioclase, pyroxene, and minor olivine. The matrix is predominantly glass (30–50 percent). Water-well logs on all three bluff areas indicate the basalt is between 20 and 75 ft thick (average about 40 ft) and is underlain by Latah Formation. The basal contact of the basalt on the bluffs is above 2,200 ft elevation. A small area of Wanapum valley-fill basalt is at the west-central edge of the map.

Mineral resource considerations: Priest Rapids flows form the "rimrock" and have well-developed columns in the Spokane area. This basalt unit is the principal source of crushed rock used by county and state highway departments for highway surfacing, by private companies for construction purposes, and by the railroad for fill/ballast. The basalt columns are also used for decorative and landscaping purposes. The county maintains a pit for crushed rock for road surfacing on Green Bluff less than a mile from the east-central border of the quadrangle. A private company operates a quarry northwest of Mead about a mile from the west border of the quadrangle in the adjacent Dartford quadrangle. Priest Rapids Basalt is in that quarry.

Mcl **Latah Formation (middle Miocene)**—Light-gray to yellowish gray, poorly indurated deposits of finely laminated siltstone, claystone, and minor sandstone (Pardee and Bryan, 1926; Hosterman, 1969). When weathered, this unit is commonly brownish yellow with stains, spots, and seams of limonite. The formation is a laterally equivalent to and coeval with Columbia River Basalt Group rocks of the Columbia Basin. Clay minerals most likely formed by weathering of the pre-Miocene gneiss and granitic rocks in the highlands east of the quadrangle. The principal source mineral was probably feldspar; Hosterman (1969) noted kaolinite pseudomorphs after feldspars in the Latah Formation in the Mica area.

Although plant fossils are common in the Latah Formation, none were found during this study in the Mead quadrangle. Descriptions of the Latah flora can be found in Knowlton (1926) and Berry (1929).

More than 550 ft of Latah was penetrated in a water well near the north-center boundary line of sec. 32, T27N, R44E. The elevation at the bottom of this well is about 1,730 feet. A mineral-exploration drill hole in glaciolacustrine deposits, mass-wasting deposits, and Latah Formation beneath Peone Prairie (no. 97, Plate 1; cross section B–B′, Plate 2) reached bedrock at just above 1,000 ft elevation. On the basis of water-well data, the maximum elevation of the basalt–Latah Formation contact on adjacent Green Bluff and Pleasant Prairie is 2,290 ft, suggesting that more than 1,200 ft of Latah Formation was present prior to deposition of the Columbia River basalt.

Almost all exposures of Latah Formation in the Mead quadrangle are large blocks in the mass-wasting deposits and are mapped as part of unit Qmw. On Plate 1, the contact between unit Qmw and the Latah Formation has been placed between the smoother contour lines of the upper slope and irregular contour lines typical of mass-wasting deposits. Latah Formation is inferred from well logs to underlie headscarp areas above the mass-wasting deposits but is nowhere exposed because it is so easily eroded or covered by newer deposits. The Latah is commonly blanketed with a cover of colluvial and residual soils and rockfall.

Mineral resource considerations: Spokane County is one of the largest producers of clay products in Washington. Although clay from other formations has been used, only clays from the Latah Formation are now being quarried. The highest quality clay products are made from material containing predominantly kaolinite and much less illite or montmorillonite (Hosterman, 1969). A homeowner in sec. 13, T27N, R43E reported that clay from Latah Formation in a nearby exposure of mass-wasting deposits was used to produce bricks. However, there was no pit or excavation to indicate any significant quarrying had occurred in the area.

Mesozoic and Older Intrusive Rocks

TKi **Granitic rocks (Tertiary and Cretaceous)**—Medium-grained (1–3 mm), light gray on fresh exposures; yellow limonitic staining on weathered surfaces. Consist of quartz (20–40%) and feldspar (50–70%) with the remainder (≤10%) being biotite and muscovite. Feldspar consists of plagioclase and potassium feldspar at a ratio of about 3:2. Accessory minerals include garnet, apatite, zircon, and rutile. In thin section, most plagioclase, in even the freshest samples, displays at least a small degree of alteration/weathering. Texture is typically hypidiomorphic-granular. Some bodies and phases in exposed granite bodies consist almost exclusively of feldspars and quartz and are considered leucocratic granites or alaskite. The alaskites typically have varied grain sizes ranging from aplitic to pegmatitic. Exposures of grus are common in the northeast corner of the quadrangle.

All pre-Miocene rocks of the Mead quadrangle are intrusive and, with the exception of the two smaller exposures in the southwest portion of the map, correspond to a combination of Weissenborn and Weis' (1976) biotite-muscovite quartz monzonite or alaskite units. Outcrops of weakly to moderately altered or weathered granite are restricted to scattered exposures amounting to less than 2 mi^2 in the entire quadrangle.

Associated with most of the granites are narrow (1–6 in. wide) aplite and pegmatite dikes; boundaries of the dikes with the host granitic rocks are commonly sharp, in places they are diffuse. Because exposures are limited and aplite and pegmatite veins are small and dispersed in the available exposures, they are not mapped as a separate unit.

Foliation, indicative of emplacement prior to final deformation of the metamorphic core complex, is weak to absent. Weak foliation is present in the small exposure of granitic rock near the southwest corner of the map (sec. 15, T26N, R43E).

Mineral Resource Considerations. Uranium mines in the adjacent Mount Spokane 15-minute quadrangle have produced 90,000 lb of U_3O_8 (Weissenborn and Weis, 1976). All occurrences of uranium in the Mount Spokane quadrangle are in, or contiguous to, alaskite bodies. The granite in sec. 25, T27N, R43E is alaskite and is the only location with known uranium mineralization in the Mead quadrangle. No commercial grade uranium mineralization has been identified with this occurrence. Radiation and radon gas are typically associated with such rocks.

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REFERENCES CITED

Ader, M. J., 1996, Hydrogeology of the Green Bluff plateau, Spokane County, Washington: Washington Department of Ecology Open File Technical Report 96-03, 27 p., Appendices A-D.

Armstrong, R. L.; Parrish, R. R.; van der Heyden, P.; Reynolds, S. J.; Rehrig, W. A., 1987, Rb-Sr and U-Pb geochronometry of the Priest River metamorphic complex—Precambrian X basement and its Mesozoic–Cenozoic plutonic-metamorphic overprint, northeastern Washington and northern Idaho. *In* Schuster, J. E., editor, Selected papers on the geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 15-40.

Atwater, B. F, 1986, Pleistocene glacial-lake deposits of the San Poil River valley, northeastern Washington: U.S. Geological Survey Bulletin 1661, 39 p. 3 pl.

Berry, E. W., 1929, A revision of the flora of the Latah Formation: U.S. Survey Professional Paper 154-H, p. 225-266.

Boese, R. M.; Buchanan, J. P., 1996, Aquifer delineation and baseline groundwater quality investigation of a portion of north Spokane County, Washington: Spokane County Public Works Department Water Quality Management Program, 104 p.

Boleneus, D. E., 1978, The Peone uranium target: Evaluation of drilling information and recommendations for exploration: Rexcon Inc., 36 p.

Boleneus, D. E.; Derkey, R. E., 1996, Geohydrology of Peone Prairie, Spokane County, Washington: Washington Geology, v. 24, no. 1, p. 30-39.

Busacca, A. J., 1991, Loess deposits and soils of the Palouse and vicinity. *In* Baker, V. R.; Bjornstad, B. N.; and others, Quaternary geology of the Columbia Plateau. *In* Morrison, R. B., editor, Quaternary nonglacial geology—Conterminous U.S.: Geological Society of America DNAG Geology of North America, v. K-2, p. 216-228.

Covert, J. J., 1997, Water rights/water availability in the Little Spokane River watershed water resource inventory area 55, Washington [abstract]: Inland Northwest Water Resources Conference Program and Abstracts, [unpaginated].

Griggs, A. B., 1966, Reconnaissance geologic map of the west half of the Spokane quadrangle, Washington and Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-464, 1 sheet, scale 1:125,000.

Griggs, A. B., 1973, Geologic map of the Spokane quadrangle, Washington, Idaho, and Montana: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-768, 1 sheet, scale 1:250,000.

Harms, T. A., 1982, The Newport fault—Low-angle normal faulting and Eocene extension, northeast Washington and northwest Idaho: Queen's University (Kingston, Ontario) Master of Science thesis, 157 p., 3 pl.

Hosterman, J. W., 1969, Clay deposits of Spokane County, Washington: U.S. Geological Survey Bulletin 1270, 96 p.

Joseph, N. L., 1990, Geologic map of the Spokane 1:100,000-scale quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-17, 29 p., 1 pl., scale 1:100,000.

Kiver, E. P.; Rigby, J. G.; Stradling, D. F., 1979, Surficial geologic map of the Spokane quadrangle, Washington: Washington Division of Geology and Earth Resources Open-File Report 79-11, 1 sheet, scale 1:250,000.

Knowlton, F. H., 1926, Flora of the Latah formation of Spokane, Washington and Coeur d'Alene, Idaho: U.S. Geological Survey Professional Paper 140-A, p. 17-81.

Landau Associates, Inc., 1991, Colbert Landfill remedial design/remedial action, Spokane County, Washington; Final Phase 1 engineering report: Landau Associates, Inc., 1 v.

Molenaar, Dee, 1988, The Spokane aquifer, Washington—Its geologic origin and water-bearing and water-quality characteristics: U.S. Geological Survey Water-Supply Paper 2265, 74 p.

Palmer, S. P.; Derkey, R. E., 1996, Seismic reflection profiling and well velocity surveying along Colbert Road, Spokane County, Washington: Washington Division of Geology and Earth Resources [under contract to] Spokane County, 10 p., plus appendix.

Pardee, J. T.; Bryan, Kirk, 1926, Geology of the Latah formation in relation to the lavas of the Columbia Plateau near Spokane, Washington: U.S. Geological Survey Professional Paper 140-A, p. 1-16.

Rehrig, W. A.; Reynolds, S. J.; Armstrong, R. L., 1987, A tectonic and geochronologic overview of the Priest River crystalline complex, northeastern Washington and northern Idaho. *In* Schuster, J. E., editor, Selected papers on the geology of Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 1-14.

Robinson, J. D., 1991, Stratigraphy and sedimentology of the Latah Formation, Spokane County, Washington: Eastern Washington University Master of Science thesis, 141 p.

Stoffel, K. L.; Joseph, N. L.; Waggoner, S. Z.; Gulick, C. W.; Korosec, M. A.; Bunning, B. B., 1991, Geologic Map of Washington—Northeast quadrant: Washington Division of Geology and Earth Resources Geologic Map GM-39, 3 sheets, scale 1:250,000, with 39 p. text.

Weis, P. L., 1968, Geologic map of the Greenacres quadrangle, Washington and Idaho: U.S. Geological Survey Geologic Quadrangle Map GQ-734, 4 p., 1 pl., scale 1:62,500.

Weissenborn, A. E.; Weis, P. L., 1976, Geologic map of the Mount Spokane quadrangle, Spokane County, Washington and Kootenai and Bonner Counties, Idaho: U.S. Geological Survey Geologic Quadrangle Map GQ-1336, 1 sheet, scale 1:62,500. ■