Surficial Geologic Map of the Lewiston Orchards North Quadrangle and Part of the Clarkston Quadrangle, Nez Perce County, Idaho

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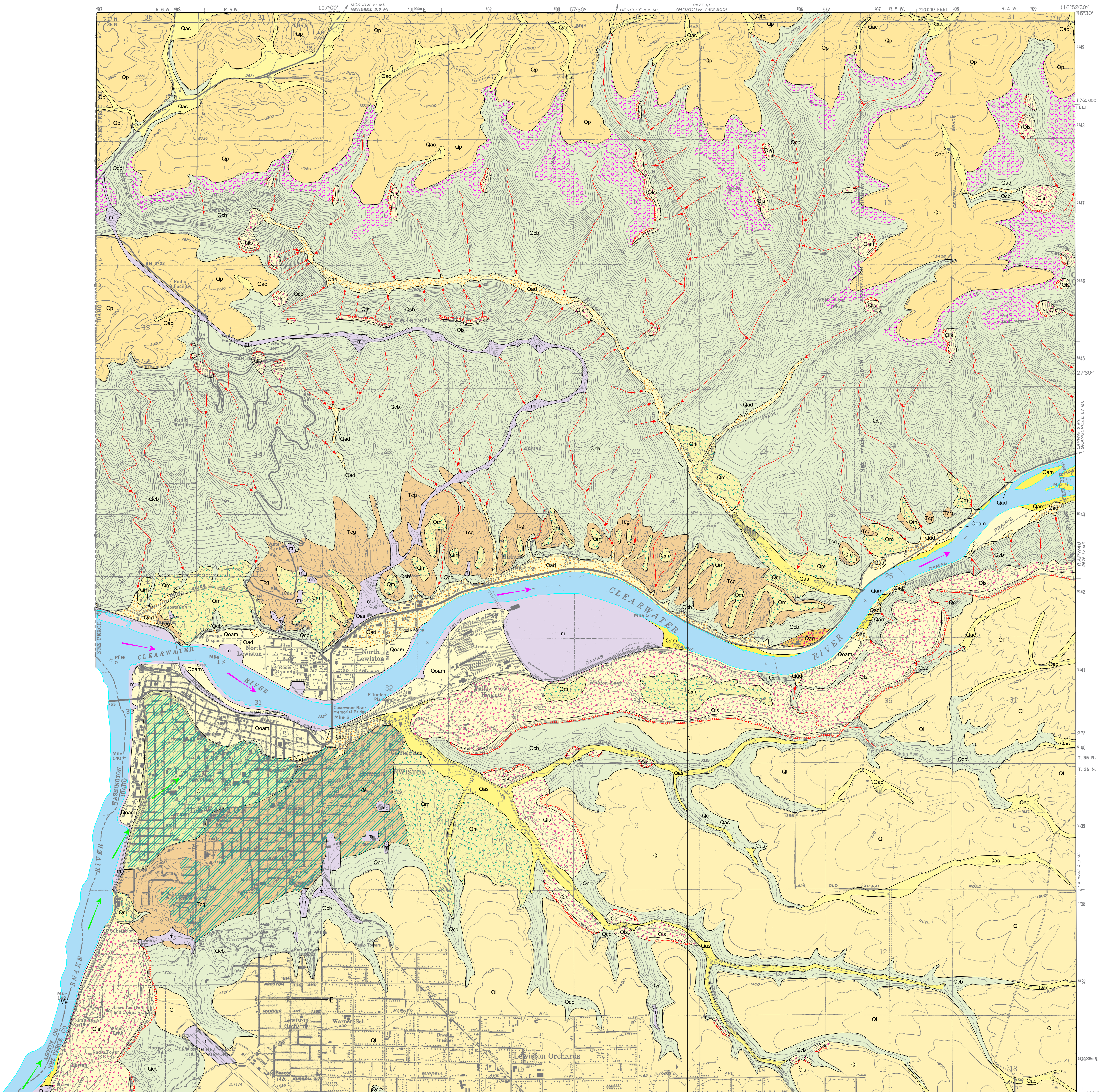
2003



Base map from USGS digital raster graphic 1971 (Clarkston), 1972 (Lewiston Orchards North).

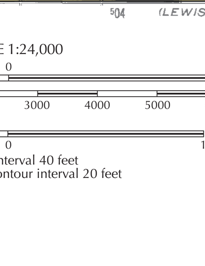
Topography by photogrammetric methods from aerial photographs taken 1966. Field checked 1967.

1927 North American Datum.

Projection and 10,000-foot grid ticks based on Idaho coordinate system, west zone.

1000-meter Universal Transverse Mercator grid ticks, zone 11.

National geodetic vertical datum of 1929.



UTM Grid and 1971 Magnetic North Declination at Center of Map

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

Contour interval 40 feet
Supplementary contour interval 20 feet

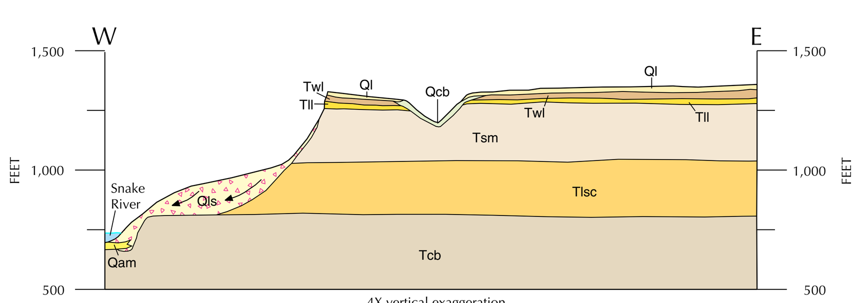
Field work conducted 2001.

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program.

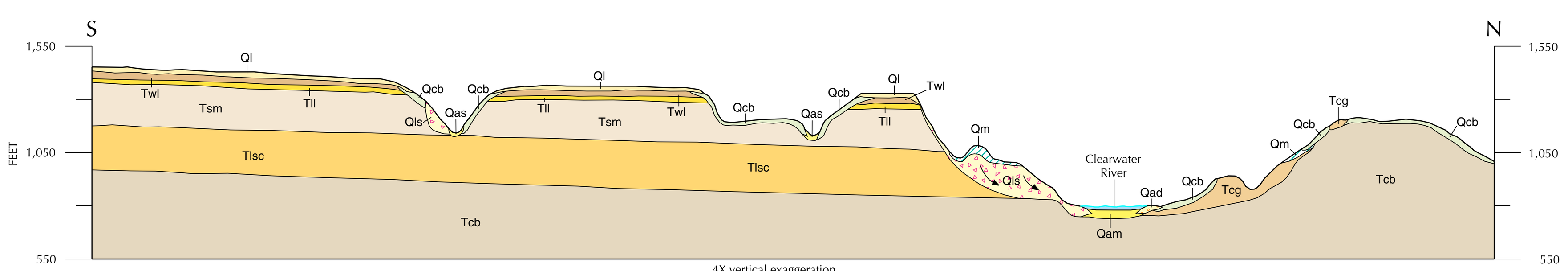
Reviewed by Terry Howard.

Digital cartography by B. Benjamin E. Studer, Loudon R. Stanford and Jane S. Freed at the Idaho Geological Survey's Digital Mapping Lab.

Map version 7-9-2004.

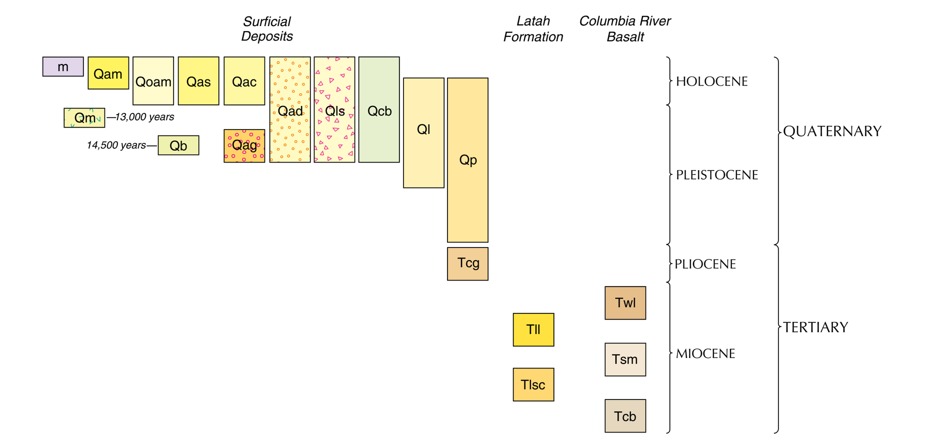


4X vertical exaggeration



4X vertical exaggeration

CORRELATION OF MAP UNITS



INTRODUCTION

The surficial geologic map of the Lewiston Orchards North and part of the Clarkston quadrangles identifies earth materials on the surface and in the shallow subsurface. It is intended for those interested in the area's natural resources, urban and rural growth, and private and public land development. The information relates to assessing diverse conditions and activities, such as slope stability, construction design, sewage drainage, solid waste disposal, and ground-water use and recharge.

The geology was intensively investigated during a one-year period. Natural and artificial exposures of the geology were examined and selectively sampled. In addition to field investigations, aerial photographs were studied to aid in identifying boundaries between map units through photogeologic mapping of landforms. In most areas map-unit boundaries (contacts) are approximate and were drawn by outlining well-defined landforms. It is rare that contacts between two units can be seen in the field without excavation operations which are beyond the purpose and scope of this map. The contacts are inferred where landforms are poorly defined and where lithologic characteristics grade from one map unit into another. The precision of a contact with respect to actual topography also depends on the accuracy and scale of the topographic base. Details depicted at this scale, therefore, provide an overview of the area's geology. Further intensive analyses at specific locations should be arranged through independent geotechnical specialists.

The city of Lewiston and the Lewiston Hill are the prominent features on the map. Lewiston is located near the boundary between the Columbia Plateau and the Northern Rocky Mountains. The physiography is dominated by the Lewiston basin, a crustal depression between the Northern Rocky Mountains, the Blue Mountains, and the Palouse portion of the Columbia Plateau. Miocene basalt flows of the Columbia River Basalt Group are folded and faulted into the Lewiston basin. Sediments of the Latah Formation are interbedded with basalt flows in the basin, reflecting the effect of tectonic deformation on the drainage system, including placement of the present courses of the Snake and Clearwater Rivers which join at the city of Lewiston. In the late Pleistocene the Snake and Clearwater Rivers were inundated by both Bonneville and Lake Missoula Floods. Giant gravel bars deposited by the Bonneville Flood are prominent features along the Snake River. Multiple catastrophic floods from the emptying of Glacial Lake Missoula reversed the flow of the rivers depositing silt, sand, and ice-rafted cobbles and boulders in the valleys. Rhythmically bedded sediments typical of Lake Missoula Flood backwater deposits mantle portions of the landscape to 500 feet above the present river levels. The cooler and dryer climate of the Pleistocene brought on the cyclical deposition of wind-blown silt that forms the thick loess of the Palouse hills north of the Lewiston Hill. Thinner loess caps the basalt flows on the gently sloping surfaces of Lewiston Orchards and east toward Lapwai. The hummocky block and flow topography and head-wall escarpments of large landslides form the valley side south along the Snake River and the south side of the Clearwater River valley. These large landslides occur where major sedimentary interbeds have been exposed along valley sides.

The map on the bedrock geology of the Lewiston Orchards North quadrangle by Garwood and Bush (2001) details the Columbia River basalt flows and the folds and faults that have deformed the rocks.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

m **Made ground (Holocene)**—Large-scale artificial fills composed of excavated, transported, and emplaced construction materials of highly varying composition, but typically derived from local sources. Includes the Corps of Engineers' levee system, the Potlatch Corporation landfills and water-treatment area, and the large fills in highway right-of-ways. Many smaller areas of made ground in the urban areas are too small to map at this scale.

Qam **Alluvium of mainstreams (Holocene)**—Channel and flood-plain deposits of the Clearwater and Snake rivers that are actively being formed on a seasonal or annual basis. Two grain-size suites are typically present: Well-sorted and rounded sandy gravel of river bars and islands, and coarse sand forming thin shoreline deposits. Clearwater River gravel clasts include granitic and metamorphic rocks derived from the Northern Rocky Mountains, and a large component of Columbia River Basalt from more local sources. Snake River gravel clasts are similar but also include metamorphic and felsic volcanic rocks derived from Hells Canyon. Water-well logs adjacent to the Clearwater River indicate gravel thicknesses of 40-60 feet over a presumed river-cut surface in basalt. Soils developed in mainstream alluvium are mostly riverwash-aquents (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qoam **Older alluvium of mainstreams (Holocene)**—Fine- to coarse-grained bedded sand and silty sand overlying river channel gravel. These alluvial deposits form one or more levels of old point bars and flood plains that are younger than the Lake Missoula Floods backwater deposits, but older than alluvium of the present rivers. Surface heights above present mean water level range from 15 to 30 feet. Relative heights and soil characteristics suggest a late Holocene age, and the lower of these surfaces may have been inundated by the highest seasonal flood waters before the stream flows were controlled by upstream dams. The sand overlying channel gravel is 6-15 feet thick. Water-well logs and test wells near the Clearwater River indicate gravel thickness of 20-60 feet over a presumed river-cut surface on basalt. Soils developed in older mainstream alluvium are mostly the Wistona series, but include the Lapwai and Bridgewater series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qas **Alluvium of side streams (Holocene)**—Channel and flood-plain deposits of tributaries to the Clearwater River. Primarily coarse channel gravel deposited during high-energy stream flows. Subrounded to rounded pebbles, cobbles, and boulders of basalt in a sand matrix. Moderately stratified and sorted. Includes intercalated colluvium and debris-flow deposits from steep side slopes. Soils developed in side-stream alluvium include the Bridgewater and Lapwai soil series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qac **Alluvium and colluvium (Holocene)**—Stream, slope-wash, and gravity deposits. Predominantly beds of silt, clay, and sand derived from erosion of adjacent units. Stream deposits typically are thin and interfinger with laterally thickening deposits of slope wash and colluvium derived from local loess deposits and weathered basalt. Soils developed in these deposits include the Broadax and Slickpoo series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qad **Alluvial-fan and debris-flow deposits (Holocene and Pleistocene)**—Primarily crudely bedded, poorly sorted brown muddy gravel shed from canyon slopes of basalt colluvium. Gravel is composed of subangular and angular pebbles, cobbles, and boulders of basalt in a matrix of granules, sand, silt, and clay. May include beds of silt and sand derived from reworked loess, Mazama ash, and Lake Missoula Flood backwater deposits. Thickness varies, but typically ranges 6-50 feet. Fans composed of alluvium and debris-flow deposits commonly occur in canyon bottoms below steep debris-flow chutes (see Symbols).

Qls **Landslide deposits (Holocene and Pleistocene)**—Poorly sorted and poorly stratified angular basalt cobbles and boulders mixed with silt and clay. Landslide deposits include debris slides as well as blocks of basalt, sedimentary interbeds that have been rotated and moved laterally. Debris slides mainly composed of unstratified, unsorted gravel rubble in a clayey matrix. In addition to the landslide deposit, the unit may include the landslide scarp and the headwall (steep area adjacent to and below the landslide scarp) from which material broke away (see Symbols). The headwall area may include large areas of fill from landslide movement. Location of landslide deposits in canyons is controlled by the presence of sedimentary interbeds and the hydrogeologic regime. The largest landslides occur where canyon-cutting has exposed the landslide-prone Sweetwater Creek sediments (*Tlsc*) to steep topography. Slope failures have occurred where the fine-grained sedimentary interbeds are saturated by ground water moving toward the valleys. This relationship is so prevalent that the major sedimentary interbeds may be traced by locating landslide deposits along the valley sides. The landslides range in age from ancient, relatively stable features, to those that have been active within the past few years. The factors that cause landslides have been prevalent in the region for thousands of years. The frequency of landsliding may have been greater in the Pleistocene. Landslide activity in the Clearwater and Snake River valleys may have been induced by the catastrophic rising and lowering of river water during the Bonneville and Lake Missoula Floods. Today, initiation and reactivation of landslides is closely tied to unusual climatic events and land-use changes. Even small landslide activity on the upper parts of canyon slopes can transform into high-energy debris flows that endanger roads, buildings, and people below (see *Debris-flow chute* under Symbols). Landslide debris is highly unstable when modified through natural variations in precipitation, artificial cuts, fills, and changes to surface drainage and ground water.

Qcb **Colluvium from basalt (Holocene and Pleistocene)**—Primarily poorly sorted brown muddy gravel composed of angular and subangular pebbles, cobbles, and boulders of basalt in a matrix of silt and clay. Emplaced by gravity movements on steep-sided canyons and gullies cut into Columbia River basalt. Includes outcrops of basalt that are common on steep, dry, southerly aspects where colluvium is thinner and the more erosion-resistant basalt flows form laterally traceable ledges. More gently sloping areas are mantled with thin loess (typically 1-5 feet thick), especially near boundaries with loess (*Ql* and *Qp*). Distribution and thickness of colluvium is dependent on slope aspect, upper and lower slope position, basalt and sediment stratigraphy, and association with landslides. Colluvium is thin and associated with many basalt outcrops on dry, southerly facing slopes, and may exhibit patterned-ground features (see Symbols). Colluvium is thicker on north- and east-facing slopes, and is associated with landslides (*Qls*) and debris-flow chutes (see Symbols), especially where moisture is retained and where sedimentary interbeds are present. Areas of thicker colluvium have fewer outcrops of basalt, and the surface may have a patterned ground of crescent-shaped lobes of colluvium, probably relicts of Pleistocene solifluction. Unit includes landslides too small to map separately, and talus below cliffs and ledges of basalt. Colluvium typically increases in thickness toward the base of slopes where it interfingers with alluvium in valley bottoms. May include all of valley-bottom sediment where streams have little discharge or are ephemeral. Soils developed in basalt colluvium include the Almota, Alpowa, Athena, Hatwai, Kettenback, Lickskillet, and Linville soil series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qm **Lake Missoula Floods backwater deposits (Pleistocene)**—Rhythmites deposited when Lake Missoula Floods backwaters inundated the Clearwater and Snake River valleys. Similar depositional environment, sedimentology, and age as Lake Missoula Floods rhythmites of eastern Washington (Smith, 1993; Waitt, 1980, 1985). In eastern Washington, Mount St. Helens tephra forms a 13,000-year time line in Missoula Floods rhythmites. Primarily alternating thin beds of gray and pale brown silts. Cross-bedded, dark-gray, basalt-rich granule gravel and coarse sands common at the base. Includes cut and fill structures and sandy clastic dikes. The clastic dikes are common features in the deposits and may follow coarser, sand and gravel facies. Where rhythmites mantle Clearwater Gravel and basalt, the clastic dikes cut deep into the gravel and follow joints and normal faults down into the basalt. Rhythmites are typically capped by 1-3 feet of loess and commonly reworked into sandy, silty colluvium. Found locally up to 1,200 feet in elevation, the approximate maximum flood level. In the Snake River valley, Lake Missoula Floods backwater deposits overlie Bonneville Flood gravel, and are mapped as a diagonal line pattern where rhythmites mantle the Bonneville Flood expansion bar (*Qb*) and Clearwater Gravel (*Tcg*). In the Clearwater River drainage, Bonneville Flood deposits have not been recognized. Lake Missoula Floods rhythmites mantle Pleistocene alluvial gravel of the Clearwater River (*Qag*). Lake Missoula Floods temporarily reversed the course of the Clearwater River within the area of backwater inundation (see *flow direction* in Symbols). The Chard series is the most common soil developed in Lake Missoula Flood deposits (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qb **Bonneville Flood gravel (Pleistocene)**—Gravel and sandy gravel of the giant expansion bar that forms the Lewiston bench ("Normal Hill"), and the giant point bar informally named Tammany Bar (O'Connor, 1993, Figure 48) just south of the Clarkston quadrangle (see the surficial geologic map of the adjoining Asotin quadrangle by Othberg and others, 2002). The gravel pit in the north end of Tammany Bar exposes details of the growth of the giant point bar as it was formed. According to Jim O'Connor (written communication, 2001), Bonneville Flood gravels overlie sand deposits that he interprets as pre-Bonneville Snake River alluvium. Organic material from the sandy alluvium has a radiocarbon age of 27,860 ± 345 years before present (University of Arizona radiocarbon date AA4774). The giant expansion- and point-bar deposits are poorly sorted and bedding consists of large cross-beds and crude layers of alternating bouldery gravel and sand. Minor calcium-carbonate cementation minimizes unraveling in steep exposures. The sand and fine gravel clasts are predominantly very angular basalt fragments probably derived from the Snake River canyon just upstream. Non-basalt pebbles and cobbles are generally well rounded. Coarse-gravel clast lithologies reflect a Hells Canyon source with at least half basalt and the remainder mostly granitoids and greenschist facies volcaniclastics (Hooper and others, 1985). Includes clasts of Sweetwater Creek interbed silt, probably associated with upstream exposures where large landslides are located. The Lewiston bench gravel, especially well exposed near the Clarkston bridge, exhibit large foreset beds dipping down the Snake River and up the Clearwater River. Lewiston bench is capped with 2-20 feet of Lake Missoula Flood sand and silt rhythmites (*Qm*) that thicken to the east.

The Bonneville Flood originated at Red Rock Pass where approximately 14,500 years ago Lake Bonneville spilled over the divide between the Great Basin and the Snake River drainage. O'Connor (1993) describes the hydrology, hydraulics, and geomorphology of the flood, providing a more complete picture of the history and character of the flood and the many landforms and deposits resulting from the flood. Of importance in the Lewiston area is the typical stepwise nature of the flood's profile at its maximum discharge. The catastrophic stream flows were great to be accommodated within the many narrow canyons of the Snake River, and caused hydraulic ponding in many reaches. The constriction five miles downstream from the Clearwater River confluence probably caused ponding within the Lewiston-Clarkston valley. O'Connor's modeling of the Bonneville Flood ends at Tammany Bar, but his graph suggests a water-level altitude of approximately 1,040 feet at the north end of Tammany Bar. It is likely that ponding at Lewiston was about that high during the maximum flood discharges.

Qag **Alluvial gravel (Pleistocene)**—Well-rounded pebble and cobble gravel of remnant point bar about 80 feet above the Clearwater River. Gravel poorly exposed owing to mantle of Lake Missoula Floods backwater sediments (*Qm*). Interfingers with colluvium and debris-flow deposits at toe of canyon slope. The gravel was deposited by the ancestral Clearwater River prior to the latest Lake Missoula Floods and may have formed during periodic greater discharges of the river during the Wisconsin glaciation. Soils mapped in areas of Pleistocene alluvial gravel include the Chard series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Ql **Loess (Holocene and Pleistocene)**—Calcareous wind-blown silt; sandy near Lake Missoula Floods deposits. Exposures show one to several layers of loess that represent periods of rapid deposition of air-borne dust. Thickest layers may have formed immediately after Lake Missoula Floods backwater events in the Clearwater and Snake River valleys. Buried soils mark the tops of loess depositional units. Forms cap on youngest Lake Missoula Floods deposits and blankets the relatively flat dip-slope surface of basalt. Partly correlates with the Palouse Formation, but lacks the distinctive Palouse Hills of the eastern Columbia Plateau, and unlike the Palouse Formation, is predominantly composed of a single late Pleistocene deposit. Thickness 5-20 feet based on well logs, field observations, and map relationships. In some areas apparent thickness based on topography may be misleading, and relief is due to erosion of underlying basalt surface before loess deposition. Thickness may be greater than 20 feet on some north-facing slopes where it is thickened by primary wind drift and where vegetation prevents subsequent erosion. Loess is thinnest on steep, south-facing slopes where sheet wash erosion is common. Thin loess overlies Holocene soil development caps Lake Missoula Floods backwater sediments, and probably represents rapid deposition following the Lake Missoula Floods at the end of the Pleistocene. Loess less than 5 feet is not included in this unit, but thin loess is a common soil parent material throughout the map area (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999). Soils developed in loess include the Broadax, Hatwai, and Olliphant series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Qp **Palouse Formation (Holocene and Pleistocene)**—Silty and clayey loess of the Palouse hills. Remnants of Palouse hills occur in the north part of the quadrangles, but are mostly found in adjoining areas to the north where the Palouse Formation blankets Miocene basalt flows of the eastern Columbia Plateau and forms hills of loess up to 200 feet thick (Othberg and others, 2001a, 2001b). In the Palouse hills, many layers of loess represent periods of rapid deposition from air-borne dust transported into the Palouse from the Pasco basin. Buried soils mark the tops of most depositional units, which form complex surface and subsurface patterns that are discontinuous and difficult to map. Thicker loess includes middle- to early-Pleistocene deposits that are locally exposed through erosion or in artificial cuts. Where loess is thin, it is mostly Holocene and late Pleistocene in age. Previous usage mostly restricted the Palouse Formation to the Pleistocene (see Newcomb, 1961; Keroher, 1966; Richmond and others, 1965; Ringe, 1968; Griggs, 1973; Foley, 1982; Schuster and others, 1997). Holocene loess, however, was included in the Palouse Formation by Hooper and Webster (1982) and Hooper and others (1985). Along boundaries between Palouse hills and canyon slopes, thick loess gradually thins into a patterned ground formed in basalt colluvium (*Qcb*) at the upper surface of basalt units (see Symbols). The soils developed in the Palouse Formation form a pattern that reflects the complex interaction of erosion and deposition of loess throughout the Quaternary. These soils include the Athena, Naff, Palouse, and Thatuna series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Tcg **Clearwater Gravel (Pliocene)**—Primarily mainstream channel gravel and sand that form a dissected terrace. Terrace surface remnants, from east to west, range from 1,080 feet to 1,050 feet in elevation; an alluvial-fan facies forms remnant slopes graded to the terrace. The terrace remnants are capped by thin Lake Missoula Floods rhythmites. Sources of the gravel are similar to the present Clearwater River. Foreset cross-bedding and cobble imbrication indicate a westward current like the present Clearwater River (Webster and others, 1982; Hooper and others, 1985). The gravel and sand are more weathered than Quaternary deposits, and have yellow to brown iron oxides in the matrix, local cementation, and softening of some gravel clasts. Some exposures are faulted with minor normal offsets. A low-angle thrust fault that places Grande Ronde Basalt over Clearwater Gravel is mapped by Garwood and Bush (2001). Webster and others (1982) and Hooper and others (1985) informally subdivide the unit into a lower gravel, a middle sand, and an upper gravel, based primarily on Kuhns' (1980) description of a section near the base of the Lewiston grade. In that description, the gravel is comprised of approximately fifty percent non-basalt clasts. Our observations suggest more complex facies in the unit, reflecting interaction of mainstream and side-stream sources. Part of the colluvium unit mapped by Hooper and others (1985) is an alluvial-fan facies of all basalt clasts that interfingers with and partly caps the Clearwater-source mainstream facies. These deposits and their stratigraphic relationships can be seen in exposures uphill from the site described by Kuhns (1980), in the POE Asphalt gravel in north Lewiston, and three miles to the east in a gravel pit adjacent to Groundcovers, Incorporated. As described by Kehew (1977), Webster and others (1982), and Hooper and others (1985), the Clearwater Gravel, and its downstream correlative Clarkston Heights Gravel, represent a major aggradational event in which an ancestral valley was filled to about an elevation of 1,150 feet (alluvial-fan facies extend higher on old valley-side remnants). Stream incision cut a deep valley and the Lower Monumental Member of the Saddle Mountains Basalt was emplaced into the stream channel. Sometime later, the valley was aggraded, probably in response to a rising base level downstream. Webster and others (1982) suggest the Clarkston Heights Gravel, and therefore the Clearwater Gravel, predate the early Pleistocene or late Pliocene capture of the Snake River drainage into the Columbia River drainage. They also suggest equivalency to the Middle Ringold Formation, which is early to middle Pliocene and formed in response to a base level event near the outlet of the Pasco Basin in Washington State. Therefore, the Clearwater Gravel is probably Pliocene in age. Soils mapped in areas of Clearwater Gravel include the Chard and Tammany series (U.S. Department of Agriculture, Natural Resources Conservation Service, 1999).

Note: The following units are shown only in cross section:

LATAH FORMATION

The Latah Formation sedimentary rocks were deposited along the margins of and within the Columbia basin during middle- to late-Miocene time. The Latah Formation comprises the sedimentary interbeds within the Columbia River Basalt Group. Their presence represents time intervals between eruptions of lava when sediments accumulated in lakes, streams, and local basins.

Tll **Lewiston Orchards sediments (Miocene)**—Beds of clay, silt, and sand that are unconsolidated to weakly consolidated and not well exposed. Best seen in roadcuts and headwalls of large landslides. Exposures and water-well logs indicate the sediment is capped by the basalt of Lewiston Orchards (*Twl*) and has a thickness of approximately 10 feet. Full extent unknown. Probably represents an early phase of subsidence of the Lewiston basin into which streams flowed and sediment was deposited.

Tlsc **Sweetwater Creek sediments (Miocene)**—Thick sequence of bedded silt and clay and minor sand. Named for exposures in the canyon of Sweetwater Creek, but traceable as a thick interbed at the base of the Saddle Mountains Basalt throughout the Lewiston basin. Deposited on the downwarped surface of the Priest Rapids Member following minor subsidence in the Lewiston basin. Although poorly exposed, logs from water wells indicate its thickness is 220-240 feet thick, thickening toward the center of the Lewiston basin. The distribution of the Sweetwater Creek sediments controls most of the landslides in the area. Ground water moving into the Lewiston basin and toward the Snake and Clearwater Rivers saturates the silts and clays, and may be confined by them. Unstable slopes commonly occur where the rivers have cut their valleys to elevations lower than the base of the Sweetwater Creek sediments.

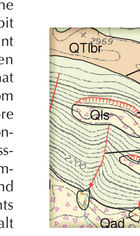
COLUMBIA RIVER BASALT GROUP

Twl **Weissenfels Ridge Member, Lewiston Orchards flow (Miocene)**—Single basalt flow that forms the nearly flat upland of the Lewiston Orchards. Thickness 15-25 feet, but the flow pinches out to the east. Exposures and water-well logs indicate it overlies a fine-grained sedimentary unit, probably Lewiston Orchards sediments (*Tll*), which is typical for this member (Hooper and others, 1985). Gentle subsidence in Saddle Mountains time continued to direct drainage into the Lewiston basin, and this flow probably followed stream courses into the basin where it formed a thin sheet basalt.

Tsm **Saddle Mountains Basalt (Miocene)**—Comprises flows of the Asotin and Wilbur Creek Members. Well logs indicate unit is 200-300 feet thick.

Tcb **Columbia River Basalt, Undifferentiated (Miocene)**—Comprises flows of the Priest Rapids Member and the R_2 magnetostratigraphic unit of the Grande Ronde Basalt.

SYMBOLS



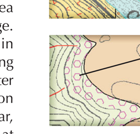
Contact: Line showing the approximate boundary between one map unit and another. The apparent ground width of the line representing the contact is about 80 feet at this scale (1:24,000).

Landslide scarp and headwall: Ticks show top of scarp.

Debris-flow chute in canyons. High-energy, short duration floods and debris flows may occur in these chutes in response to severe climatic conditions, such as thunderstorms and rain-on-snow events. Debris flows can also be triggered by landslides. These events are historically infrequent, dependent on weather, with a recurrence cycle on the order of years to decades. The most prominent debris-flow chutes are shown on the map, but any steep-gradient valley sides and canyon bottoms have the potential for these catastrophic events. Thin and discontinuous alluvial-fan and debris-flow deposits (*Qad*) may be present, but are not mappable at this scale.

Flow direction of Bonneville Flood.

Flow direction of Lake Missoula Floods backwater inundation.



Patterned ground associated with the weathered, differentially eroded surface of basalt. Pattern consists of regularly spaced, subround fracture system in basalt with silty mounds between fractures. Silty mounds give way to fractured basalt downslope, but thicken upslope where they gradually obscure the fracture pattern and merge with loess deposits or weathered basalt. Probably formed by stripping of loess from the basalt surface through Pleistocene periglacial processes. Original patterned-ground features destroyed by field plowing in many locations.

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