Late Cenozoic Gravels in Hells Canyon and the Lewiston Basin, Washington and Idaho

by

Gary D. Webster*, Mary J. Pankratz Kuhns2, and Gail L. Waggoner3

ABSTRACT

Six late Cenozoic gravels mapped in the Lewiston basin are attributable to a Snake, Salmon, or Clearwater River origin on the basis of preliminary studies of cobble lithology. The oldest, the North Lewiston Gravel, is between 12.0 and 6.0 million years in age, occurs below the Lower Monumental Member, contains 95 percent basalt clasts, and is derived from the ancestral Clearwater River drainage. The Clearwater Gravel, deposited above the Lower Monumental Member, is between 6.0 and 2.0 million years old, contains a higher percentage of nonbasaltic igneous and older metamorphic rocks, and is also derived from the Clearwater drainage. A gravel believed to be coeval with the Clearwater Gravel but derived from the ancestral Salmon River is the Clarkston Heights Gravel. The Clarkston Heights Gravel is distinguished by the abundance of red and green volcaniclastic rocks derived from the Seven Devils Group. The Clarkston Heights Gravel and the Clearwater Gravel are probably the upstream equivalent of the Middle Ringold gravels.

The Clarkston Gravel is restricted to a gravel underlying the northeastern part of Clarkston, Washington. This gravel is derived from the ancestral Salmon River and is believed to be late Pliocene or early Pleistocene in age. It is distinguished from the Clarkston Heights Gravel by the coarser cobble size and the clay interbeds. Deposits coeval with the Clarkston Gravel are believed to be present in the Snake River canyon below Clarkston.

Gravel deposits of the Bonneville Flood (14,000-15,000 years ago) are widespread in the Lewiston basin and reported for the first time from the lower Salmon and Grande Ronde canyons.

All of the late Cenozoic gravels provide clues to the regional erosional and depositional history of the Lewiston basin.

INTRODUCTION

Gravel deposits, older than 12,000 years, are found downriver from Hells Canyon along the Snake River and Clearwater River at Lewiston, Idaho, and Clarkston, Washington (Figure 1). They are diverse in character and origin. Many have been quarried as a source of aggregate and continue to be economically significant. They are the sedimentologic key to the late Cenozoic geologic history of the area.

PREVIOUS WORK

The Snake River and Clearwater River gravels have been the subject of several studies during the past fifty years. Working in the Channeled Scablands of southeastern Washington, Bretz (1929) recognized backwater deposits of the Missoula Flood both upstream and downstream from Lewiston. MacKenzie (1942) made counts of the coarser cobbles attempting to discriminate the diverse gravels of the Lewiston area. Lupher (1945) described a “Clarkston Stage” of the Pleistocene and included sands and gravels, here considered of diverse origin and character, in one unit that he designated the Clarkston Gravels. Stearns (1962) reported gravels attributed to the Bonneville Flood at the Brownlee Dam site above Homestead, Oregon, and several localities in and downstream from Hells Canyon. Furthermore, Stearns (1962) incorrectly considered some of the backwater deposits described by Bretz (1929) in the vicinity of Lewiston to be of Bonneville
Bonneville Flood Deposits

- Back-eddy bar
- Expansion bar
- Point bar
- Missoula Flood
- Backwater deposits

Figure 1. Index map and map showing location of Bonneville Flood and Missoula Floods deposits.

Regional Geology

The Lewiston basin and Hells Canyon area lie within the most eastward extension of the Columbia Arc (Taubeneck, 1966). The arc is composed of a series of calc-alkaline volcanic and volcanoclastic units of predominately andesite composition belonging to the Seven Devils Group and associated ophiolitic sequences of Permian-Triassic age (Vallier, 1974, 1977; Avé Lallemant and others, 1980). These units are overlain by clastic sediments of Jurassic age and intruded by granites of Jurassic to Early Cretaceous age. The arc rocks probably formed southwest of their present location and were accreted to the western margin of the American Plate in the Permian-Triassic (Hamilton, 1976) or the Cretaceous (Davis and others, 1979, Avé Lallemant and others 1980). To the east of the suture zone in the Whitebird-Riggins valley, the Idaho batholith of Cretaceous and early Cenozoic age intrudes rocks of the Precambrian old continental basement and Belt Supergroup. The old continental basement rocks contain a variety of augen gneisses, orthogneisses, pelitic schists, and amphibolites. Rocks of the Belt Supergroup are metamorphosed to the amphibolite facies. Originally they were sandstones, siltstones, and impure carbonate rocks.

The Miocene age Columbia River Basalt Group filled the post-Tertiary terrain that was deeply dissected by westward-flowing rivers (Figure 2).

The present Clearwater River system drains a large area of the Idaho batholith and older quartzite and gneiss. The Salmon River also heads in the Idaho batholith but cuts through the Seven Devils Group in Hells Canyon. All major drainages have cut deeply into the Columbia River Basalt Group.

Gravel Stratigraphy

Gravels preceding Holocene fluvial deposits within the Lewiston basin include six recognizable units. They range in age from late Miocene to late Pleistocene (Table 1). Their stratigraphic relationships are rather complex and include the following: (1) the oldest gravel is overlain by an intracanyon basalt flow; (2) the four oldest gravels are not in direct contact with one another; (3) most gravels are laterally in contact with basalt; and (4) the two youngest gravels directly overlie or are in lateral contact with most older gravels. Recognition of each of the six gravels is based upon cobble lithologies (Table 2) and stratigraphic relationships.

North Lewiston Gravel

As described by Kuhns (1980), the North Lewiston Gravel crops out approximately parallel to
the present course of the Clearwater River in the lower Clearwater River valley. It is a fluvial gravel confined between 750 to 850 feet (229 to 259 meters) in elevation. The best exposures are found along Hatwai Road and at the base of the old Lewiston grade (Figure 3), where the gravels occur 10 to 80 feet (3 to 24 meters) above the present river level.

Cobbles of the North Lewiston Gravel (based on a count of 1,000 clasts) consist primarily of basalt clasts having approximately 95 percent subrounded basalt and only 5 percent well-rounded igneous and metamorphic rocks. Igneous lithologies present include 0.4 percent mafic dike porphyry. Metamorphic rocks inside 1.1 percent banded biotite gneiss and 0.8 percent banded gneiss.

Partially consolidated silt to medium sand-sized quartz and basalt grains constitute the characteristically oxidized, bright orange matrix. Primary matrix minerals are 40 percent quartz, 30 percent basalt fragments, 15 percent plagioclase, 4 percent potassium feldspar, 2 percent biotite, 1 percent hornblende, and a trace of olivine in the 0.0 and 1.0 phi size intervals. Traces of muscovite, augite, and magnetite appear in the 2.0 and 3.0 phi size grades. The darker appearance of this gravel is due to the abundance of basalt fragments in the cobbles and matrix.

Imbrication, which is well developed in many of the outcrops, is two directional at some localities suggesting back-eddy deposition. Other directional indicators such as cross-bedding were not observed.

The North Lewiston Gravel is at least 6 million years old because it underlies the 6 million year old Lower Monumental Member (McKee and others, 1977) of the Saddle Mountains Basalt Formation. The maximum age of these gravels is post canyon cutting which is post-Weissenfels Ridge Member (between 14.0 and 12.0 million years) to pre-Pomona.
Member (12.0 million years) time (Swanson and others, 1979).

The name North Lewiston Gravel is used informally since the total extent of the unit is unknown. The gravels may be the result of aggrading conditions in the lower Clearwater River valley resulting from filling of the ancestral Snake River canyon below Lewiston by the Pomona or Elephant Mountain (10.5 million years) Members.

CLARKSTON HEIGHTS GRAVEL

The Clarkston Heights Gravel is herein informally defined as those sands and gravels extending in a northwest direction from the SE¼, sec. 8, T. 10 N.,

Table 1. Stratigraphic sequence and age of late Cenozoic gravels and basalts in the vicinity of Lewiston, Idaho. All basalts members belong to the Yakima Basalt subgroup of the Columbia River Basalt Group (Swanson and others, 1979).

<table>
<thead>
<tr>
<th>Stratigraphic Unit</th>
<th>Age</th>
<th>Basalt Stratigraphy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modern alluvium</td>
<td>12,000 to present</td>
<td></td>
</tr>
<tr>
<td>Missoula Flood deposits</td>
<td>14,000-15,000 to 12,000</td>
<td></td>
</tr>
<tr>
<td>Bonneville Flood deposits</td>
<td>14,000-15,000</td>
<td></td>
</tr>
<tr>
<td>Clarkston Gravel</td>
<td>Late Pliocene? or early Pleistocene?</td>
<td></td>
</tr>
<tr>
<td>Clearwater Gravel</td>
<td>Late Miocene to Pliocene (6 m.y. to 2 m.y.)</td>
<td></td>
</tr>
<tr>
<td>Clarkston Heights Gravel</td>
<td>Late Miocene to Pliocene (6 m.y. to 2 m.y.)</td>
<td></td>
</tr>
<tr>
<td>North Lewiston Gravel</td>
<td>Late Miocene (12 m.y. to 6 m.y.)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Comparison of major rock types, given as percent of 1,000 cobbles, recognized in modern gravel bars of the Clearwater, Salmon, and Snake Rivers and ancient gravel deposits in the Lewiston basin. Several distinct lithologies are recognizable within each of the four major rock groupings. Data are probably insufficient to be statistically evaluated.

Table 2.

<table>
<thead>
<tr>
<th>GRAVEL DEPOSIT</th>
<th>Columbia River Basalts</th>
<th>Seven Devils Group</th>
<th>Igneous Rocks Nonbasalt</th>
<th>Older Metamorphic Rocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slate Creek, Salmon River</td>
<td>43.9</td>
<td>34.8</td>
<td>5.5</td>
<td>15.8</td>
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<tr>
<td>China Bar, Salmon River</td>
<td>56.3</td>
<td>12.0</td>
<td>17.8</td>
<td>13.9</td>
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<td>Lochsa River</td>
<td>---</td>
<td>---</td>
<td>31.0</td>
<td>65.2</td>
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<tr>
<td>South Fork, Clearwater River</td>
<td>84.6</td>
<td>---</td>
<td>10.1</td>
<td>9.2</td>
</tr>
<tr>
<td>North Fork, Clearwater River</td>
<td>22.7</td>
<td>---</td>
<td>33.9</td>
<td>42.6</td>
</tr>
<tr>
<td>Pittsburgh Landing, Snake River</td>
<td>39.1</td>
<td>34.3</td>
<td>18.7</td>
<td>7.9</td>
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<tr>
<td>Asotin Bar, Snake River</td>
<td>74.3</td>
<td>19.5</td>
<td>3.8</td>
<td>2.4</td>
</tr>
<tr>
<td>North Lewiston Gravel (Ancestral Clearwater)</td>
<td>95.6</td>
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<td>2.2</td>
<td>2.2</td>
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<td>Clearwater Gravel, lower unit (Ancestral Clearwater)</td>
<td>53.7</td>
<td>---</td>
<td>25.8</td>
<td>19.7</td>
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<td>Clearwater Gravel, upper unit (Ancestral Clearwater)</td>
<td>58.4</td>
<td>---</td>
<td>26.3</td>
<td>20.2</td>
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<td>Clarkston Heights Gravel, Loc. 1 (Ancestral Salmon)</td>
<td>57.5</td>
<td>16.1</td>
<td>16.2</td>
<td>10.2</td>
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<td>Clarkston Heights Gravel, Loc. 2 (Ancestral Salmon)</td>
<td>70.8</td>
<td>10.3</td>
<td>9.1</td>
<td>9.9</td>
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<td>Clarkston Gravel, Loc. 1 (Ancestral Salmon)</td>
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<td>6.8</td>
<td>10.1</td>
<td>3.4</td>
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<tr>
<td>Clarkston Gravel, Loc. 2 (Ancestral Salmon)</td>
<td>58.5</td>
<td>12.3</td>
<td>19.0</td>
<td>9.2</td>
</tr>
</tbody>
</table>

1Kuhns, 1980
2Waggoner, 1981
Webster and others—Gravels in Lewiston Basin

FIGURE 3. North Lewiston Gravel underlying Lower Monumental Basalt; base of old Lewiston grade. Note rounded metamorphic, igneous, and basalt clasts. Lower Monumental Basalt in place in upper right corner of photograph.

R. 46 E., to the NW ¾, sec. 24, T. 11 N., R. 45 E. (Washington). It is restricted to the southwest side of the northwest-trending band of Saddle Mountains Basalt flows between Clarkston and Clarkston Heights (Figure 2). Excellent exposures are present in road cuts and gravel pits along Critchfield Road to the southeast (Figures 4 and 5) and Evans Road to the northwest. The unit is named for the suburb of Clarkston Heights which it underlies. The Clarkston Heights Gravel is a minimum of 337 feet (103 meters) thick according to water well logs from the area. Lupher (1945) considered them an undesignated part of his Clarkston Gravels and reported a maximum thickness of more than 400 feet (122 meters) based on topographic relief.

Cobble lithologies in this gravel as reported by Waggoner (1981) average 64 percent basalt, 13 percent red and green volcaniclastic rocks of the Seven Devils Group, 13 percent igneous rocks (mostly granitics and porphyries), and 10 percent metamorphic rocks (mostly quartzite and gneiss). All clasts are well rounded. The matrix is a bimodal, pebbly medium-grained sand or sandy pebble which alternates vertically between sand and pebble dominance. The alternating sand and pebble dominance of the matrix results in a recognizable rhythmic bedding in the upper part of the unit. Small boulders are present in the upper parts of this gravel. The matrix is partly cemented and oxide stained. The degree of weathering of the basalt and granitic cobbles is intense, many cobbles crumbling to the touch. Sedimentary structures are not common in the unit; however, imbrication and foreset cross-bedding indicate paleocurrent directions to the northwest, which is the trend of the gravel unit. Sand stringers and lenses of the same composition as the matrix sand in the gravel occur in the upper part of the unit.

The gravel is fluvial in origin. The cause of the aggradation is unknown. No glacial striations or ice-rafted erratics were found in these deposits to support a glacial origin as proposed by Lupher (1945). Lupher also speculated that the aggradation might be the result of some unrecognized downstream structural or sedimentologic feature.

The Clarkston Heights Gravel fills a canyon cut into the Pomona Member (12.0 million years) of the Saddle Mountains Basalt. It is overlain by modern loess, colluvium, and remnants of the Touchet Beds. The canyon filled by the Clarkston Heights Gravel was described by Lupher and Warren (1942) as the Asotin Canyon of the ancestral Snake River formed during the Asotin Stage of probably early Pleistocene time. However, the higher percentage of derived andesitic porphyries and older metamorphic rocks in these gravels implies an origin of Salmon River drainage rather than Snake River. Therefore, we propose that this canyon is of the ancestral Salmon and predates capture of the Snake River. If the proposal by Wheeler and Cook (1954) that the Snake River was not diverted to the north until early Pleistocene time is correct, then the Clarkston Heights Gravel is older than early Pleistocene. The Asotin Stage of Lupher and Warren (1942) must be late Miocene in age, since the intracanyon flows of the Saddle Mountains Basalt formed within the ancestral canyon.

The older age limit of the Clarkston Heights Gravel is uncertain. The Clarkston Heights Gravel overlies and must be younger than basalts of the Pomona Member (12.0 million years, McKee and others, 1977). It is here proposed that the Clarkston Heights Gravel is coeval with the Clearwater Gravel,
Figure 5. Clarkston Heights Gravel overlain by fine-grained Touchet Beds. Note imbrication in gravels, indicating a northwest current flow, and roundness of clasts. Housing excavation, north side of Critchfield Road, Clarkston, Washington.

As described below, because it is aggraded to the same elevation of 1,150 feet (351 meters), shows the same degree of deep weathering of basalt and granitoid clasts, is similarly iron stained, has a similar degree of cementation, and shows increasing sand stringers and lenses in the upper part. The ancestral Salmon and Clearwater Rivers merged immediately downstream from the northwest extent of the Clarkston Heights Gravel. Although easily separated on the basis of cobble lithologies, reflecting the different provenance of the two drainages, the number of similarities of sedimentologic features and concordance of aggradation seem to imply a coeval time of formation in response to a downstream change of base level. The Clearwater Gravel overlies the Lower Monumental Member (6.0 million years) as discussed below. If our proposal of time contemporaneity of the two units is correct, then both the Clarkston Heights Gravel and the Clearwater Gravel are between 6.0 million years and early Pleistocene in age. The age of the Clarkston Heights Gravel is certainly between 12.0 million years and 13,000 years. But the present evidence clearly favors an age between 6.0 million years and early Pleistocene.

CLEARWATER GRAVEL

The Clearwater Gravel forms a prominent terrace which in profile ranges in elevation from 800 to 1,150 feet (244-351 meters) along the lower Clearwater River valley. This gravel is well exposed in road cuts along the new Lewiston grade (U.S. Highway 95), Central Grade Road, the Northwest Aggregates quarry (SW¼NE¼NE¼, sec. 29, T. 36 N., R. 5 W.), south side of 16th Street (W½SE¼, sec. 1, T. 35 N., R. 6 W.) in Lewiston, and numerous small abandoned quarries between Lewiston and Lewiston Orchards. The Clearwater Gravel is informally recognized herein and the reference section is the exposure along the lower part of the new Lewiston grade (U.S. Highway 95) from the top of the Lower Monumental Member (NW¼SW¼, sec. 29, T. 36 N., R. 5 W., Idaho; Figure 6) to the ash bed exposed in the road cut along the north side of the runoff ramp in the NW¼NW¼, sec. 29, T. 36 N., R. 5 W. (Idaho).

As described by Kuhns (1980), the Clearwater Gravel consists of two gravel sequences separated by a sand. Maximum thickness of the lower gravel is 300 feet (91 meters), the intermediate sand 35 feet (11 meters), and the upper gravel 100 feet (30 meters). All units are light tan to yellow-brown with ferric oxide staining common. Current directions, indicated by foreset cross-bedding and cobble imbrication, show a westward flow parallel to that of the modern Clearwater River.

The lower gravel unit consists of well-rounded cobbles of approximately 50 percent basalt and 50 percent igneous and metamorphic lithologies. Igneous rock types include 6.7 percent quartz monzonite, 6.2 percent quartz latite porphyry, 4.4 percent pegmatite, 3.2 percent mafic porphyry, and 2.4 percent granodiorite. Metamorphic lithologies are 11.6 percent quartzite, 6.2 percent gneiss, and 1.4 percent argillite. The matrix is locally oxidized and generally unconsolidated. Major constituents of the matrix in the 0.0 and 1.0 phi size ranges are 60 percent quartz, 17 percent plagioclase, 6 percent hornblende, 5 percent potassium feldspar, 5 percent muscovite, 3 percent biotite, and traces of sphene, grossularite garnet, phlogopite, chlorite, and magnetite. The mineralogy becomes more diverse with decrease in grain size to 2.0 and 3.0 phi. Traces of additional igneous accessories such as augite, apatite, spessartite garnet, zircon, topaz, and tourmaline appear in the 2.0 phi fraction. This mineral suite is augmented in the 3.0 phi size range by gypsum, beryl, olivine, chromite, scapolite, calcite, serpentine, pyrite, chalcocopyrite, and pyrrhotite.

The sand sequence between the upper and lower gravel units is variable in thickness but present in all outcrops where the complete section is exposed. It is quartz-rich and white on fresh exposed surfaces. It weathers light tan, red, or brown from iron oxidation. This sand commonly shows foreset cross-bedding, in many places in reverse direction to that of the imbrication and foreset cross-bedding of the gravels suggesting back-edges and "behind the bar" development.
Well-rounded cobbles of the upper gravel unit consist of approximately 56 percent basalt and about 43 percent igneous and metamorphic rocks. Individual percentages of the igneous and metamorphic rock types include 9.7 percent quartz latite porphyry, 5.8 percent quartz monzonite, 5.8 percent pegmatite, 2.3 percent mafic dike porphyry, 2.0 percent granodiorite, 12.9 percent quartzite, and 5.7 percent gneiss. The matrix is the same composition as that in the lower gravel but generally one phi size coarser. Sand stringers similar to the middle sand unit are common at most localities. Westward current directions indicated by imbrication and cross-bedding are similar to those of the lower gravel.

Clastic dikes filled with sediment which can be followed upward into the Touchet Beds are present in some exposures of the Clearwater Gravel. Generally these are restricted to the upper gravel unit, but in the Northwest Aggregate quarry, east of the new Lewiston grade, they extend through the sand unit into the lower gravel unit. Small caliche-filled fractures, some of which show reverse offset of a few centimeters, trend north-northeast in the Clearwater Gravel. These fractures seem to be continuous from one exposure to another. A normally faulted clastic dike is exposed in the quarry west of Hatwai Creek near the eastern extent of the Clearwater Gravel. The dike has been offset about 3 inches (7.6 centimeters). The north-south fault can be traced through the gravel outcrop as a thin, bright red, oxidized band in the matrix. The Clearwater Gravel is a fluvial deposit formed in response to an unknown event which caused a temporary change in base level.

The Clearwater Gravel is deposited on top of the Lower Monumental Member (6 million years) and overlain by colluvium and Touchet Beds. A 6 inch (15.2 centimeters) thick volcanic ash layer in a sequence of lake beds and fine alluvial sediments immediately above the Clearwater Gravel was found in the road cut for the runoff ramp at the top of the gravel exposure along the new Lewiston grade. The ash was analyzed by Rockwell International but was so deeply weathered that it could not be characterized or dated (Ann Tallman, personal communication, 1980). On the basis of intense weathering, an age greater than 35,000 years is speculated for this ash. Thus the precise age of the Clearwater Gravel is uncertain, but stratigraphic relationships confine their age between 6 million years and 35,000 years. As discussed under the Clarkston Heights Gravel, the accordant summit of aggradation of the Clarkston Heights Gravel and Clearwater Gravel, a similar degree of oxidation and cementation and degree of weathering of the clasts suggest a similar age for these two deposits.

If the Clearwater Gravel and Clarkston Heights Gravel are time equivalent, then the 6-million-year maximum age is provided by the Lower Monumental Member and the early Pleistocene minimum age is provided by the Snake River diversion.

The similar sedimentologic characteristics of the Clearwater Gravel and Clarkston Heights Gravel are also typical of the gravels in the Middle Ringold Unit as defined by Tallman and others (1979) in the Pasco Basin and Ringold sheet gravels (probably Middle Ringold equivalents) along the lower Snake River southeast of Pasco described by Richman (1981). The Middle Ringold has been dated at 5.12 to 3.32 million years (Myers and Price, 1979). Webster (in Rigby and Othberg, 1979) considered the Ringold gravels to be of ancestral Salmon and Clearwater origin. The similarity of sedimentary features as discussed under the Clarkston Heights Gravel may be more than repetition of a sedimentary environment at different times. The Clearwater Gravel and Clarkston Heights Gravel may be coeval with the Middle Ringold. If this correlation is correct, then the change in base level which caused the aggradation may have been a base level event near the outlet of the Pasco Basin.
Cobbles are well rounded and average 69 percent basalt, 9 percent greenstones of the Seven Devils Group, 15 percent igneous rocks (mostly porphyry and granite), and 6 percent quartzite. Small boulders are common in this gravel. Matrix sands and pebbly sands are bimodal consisting of pebbles and medium-grained sand which is uncremented. There are thin clayey interbeds, and well logs indicate a basal clay. The Clarkston Gravel is not rhythmic or cyclic like the Clarkston Heights Gravel and has a coarser average cobble size. Sedimentary structures are not common but include imbrication and foreset cross-bedding, indicating a northwest current direction.

The Clarkston Gravel is interpreted as a point bar. It might have been built either during a major flood or over a period of time by a northeastward migrating meander of the ancestral Salmon drainage. The presence of the thin clay stringers and lenses support the latter interpretation. This meander migration truncated the Clearwater Gravel on the east as shown on the geologic map (Figure 2). The Clarkston Gravel is easily distinguished from the North Lewiston Gravel and Clearwater Gravel by the presence of the red and green metamorphosed volcaniclastic rocks of the Seven Devils Group. The abundance of small boulders and thin clay interbeds distinguish them from the Clarkston Heights Gravel. Waggoner (1981) speculated that the Snake River diversion is recorded within the Clarkston Gravel based on some variation in cobble counts within the unit. Better exposures and more data are needed to verify this speculation.

Numerous gravel bars along the Snake River canyon below Clarkston including Wilma Bar, opposite Clarkston, are probably equivalent to the restricted Clarkston Gravel as suggested by Lupher (1945). These downstream equivalents were mapped by Hammatt (1976) in the Lower Granite Reservoir area, as "Scabland flood bar gravel" following the suggestion of Bretz (1929). A sedimentologic study of four of these bars by Wheeler (1980) showed that they are point, lateral, and expansion bars with the concordant upper limits between 120 and 140 feet (37 and 43 meters) above the pre-dam river level. Furthermore, he demonstrated that they were deposited by down canyon currents, proving that they are not reworked traction gravels deposited by an up canyon surge of the Missoula backwater flooding. Wheeler's (1980) cobble lithologies are also primarily Salmon River-derived.

If all of these bars are of the same origin, they require a major fill or aggradation within the ancestral Salmon River canyon preceding the diversion of the Snake River to the north. Basalt and granitic clasts, although deeply weathered, are not as intensely weathered as those in the Clearwater Gravel and Clarkston Heights Gravel. This would imply a younger age and support the suggestion that the Clarkston Gravel at Clarkston is a point bar deposited as the ancestral Salmon River migrated eastward eroding Clearwater gravels.

The age of the Clarkston Gravel is thus confined as post-Clearwater Gravel and post-Clarkston Heights Gravel and pre-Snake River diversion to the north, probably very late Pliocene or earliest Pleistocene. Lupher (1945) suggested a Pleistocene age for his unrestricted Clarkston deposits and reported glacial erratics and glacially striated cobbles in them. The Pleistocene age may be supported by Wheeler (1980) based on the discovery of sedimentary features of glacial origin on quartz sand-size grains in the deposits downstream from Clarkston. If they are glacially derived they could form either from overloading of streams during an early Pleistocene glaciaion in the upper Salmon River drainage or from a catastrophic glacial discharge. However, if such glacial conditions are the cause one might expect similar deposits, presently unknown, in the Clearwater drainage. Additional study of the gravels in the lower and upper Salmon drainage and upper Clearwater drainage is needed to help solve this problem.

BONNEVILLE FLOOD DEPOSITS

The Bonneville Flood across the Snake River Plain of southern Idaho was clearly documented by Malde (1968). The age of this flood is 14,000 to 15,000 years (Scott and others, 1982 this volume). Obviously, the Bonneville Flood continued down the Snake River through Hells Canyon and the Lewiston basin to the Columbia River.

Bonneville Flood gravels are common deposits along the Snake River below Oxbow Dam (Figure 1). Webster (1980) reported expansion and back-eddy deposits of Bonneville Flood origin at several locations between Sluice Creek and Lewiston, Idaho. The Bonneville Flood deposits in the Lewiston basin are generally gray to dark gray or gray-green containing an abundance of angular to subangular Columbia Plateau basalt and Triassic Seven Devils Group volcaniclastic rock. Well-rounded pebbles and cobbles of quartzite make up a small percentage of the clasts. One-half mile above the mouth of Tammany Creek and on the western edge of Clarkston, abundant volcanic ash clasts are present in the Bonneville gravel.

On the basis of occurrence and grain size the Bonneville Flood deposits may be subdivided into three types of bars. Point bars occur on the inner...
side of gentle to sharp bends in the canyon and contain gravel dominated by cobbles and small boulders. Expansion bars occur where the canyon abruptly widens. The expansion bars contain boulders slightly over 2 meters in maximum diameter and become finer downstream. Expansion bars grade into lateral bars (not designated on Figure 2) in some parts of the canyon. Back-eddy bars are present at the mouth of tributary drainages where upstream currents developed. These deposits are a mixture of gravel, generally less than 6 inches (15 centimeters) in diameter, and sand (Figures 7 and 8). In the lower part they are mostly cross-bedded and lack matrix. In the upper part the matrix is a sandy silt to clay. Sandy silt containing floating pebbles and small cobbles may dominate the sediment.

Point bars and expansion bars occur up to 120 to 200 feet (37-61 meters) above the modern flood plain. Back-eddy bars are up to 425 feet (130 meters) above the modern flood plain. They provide an upper minimal water level for the Bonneville Flood. Although Bonneville Flood deposits in the Lewiston area have been discussed briefly by Stearns (1962) and Kehew (1977), no sedimentary analysis of these deposits was made. Lupher (1945) referred to the Bonneville Flood gravels near the mouth of Tammany Creek as reworked Clarkston Gravel between Touchet Beds and his older "Clarkston" gravels. Lupher and Warren (1942) were unaware of the Bonneville Flood and referred (Bonneville) gravels on the west side of the mouth of Ten-Mile Creek, above Asotin, to the Asotin Stage.

Most deposits mapped as scabland eddy deposits by Hammatt (1976) are Bonneville back-eddy deposits. Bonneville back-eddy bars at the mouth of Ten-Mile Creek and Couse Creek upstream from Asotin were incorrectly interpreted as Missoula Flood deposits by Bretz (1929).

No Bonneville Flood point or expansion bars are recognized in the Snake River canyon below Clarkston. Bonneville Flood gravel probably overlies the Clarkston Gravel in the southwestern part of the city of Clarkston, but no exposures are known showing the contact. Touchet Beds overlie the Bonneville deposits in northwestern Clarkston and upstream from the mouth of Tammany Creek.

MISSOULA FLOOD DEPOSITS—TOUCHEt BEDS

Sequences of alternating medium gray and tan, thin- to medium-bedded rhythmite deposits are common in many parts of the Lewiston basin. These deposits cap the terraces that Clarkston and Lewiston are built upon. Excellent exposures are common in quarries, roadcuts, and construction excavations throughout the Lewiston basin. Each rhythmite consists of a basal medium gray basalt dominated (greater than 80 percent) pebble and granule gravel which generally has foreset or trough cross-beds indicating a current flow upstream. These gravels grade upward into fine sands and in some deposits show up-valley ripple drift overlain by planar bedding. The upper part of each rhythmite consists of very fine sand and grades upward into silt with planar laminations. Ripple drift and wavey bedding is rare. The upper surface is somewhat wavey and locally may be channeled (Figure 9). The sediments are uncremented and commonly cut by sandstone dikes. The thickness of individual rhythm-
mites in sequences becomes thinner upward in nearly all exposures. Sediments become finer grained upstream. Six to ten rhythmites are common in most exposures in the Lewiston area. A maximum of seventeen rhythmites occurs in the abandoned quarry one-half mile above the mouth of Tammany Creek (Figure 2), and a minimum of ten rhythmites is present in the roadcut above the junction of Joseph Creek with the Grande Ronde River. Eight rhythmites, each lacking an easily defined basal part (consisting only of medium sand), are present along the lower Salmon. The rhythmite sequences occur as discrete deposits from Riparia Bar below Little Goose Dam approximately 65 miles (105 kilometers) below Lewiston to the lower parts of the Clearwater, Grande Ronde, and Salmon River valleys. They are best developed between 850 feet (259 meters) and 1,050 feet (320 meters) but occur at elevations of approximately 1,200 feet (366 meters) at Lewiston and in the lower Grande Ronde River valley.

In the Lewiston area the rhythmite sequences were first recognized as backwater deposits of the Missoula Floods by Bretz (1929). Lupher (1945) recognized the Touchet Beds above older gravels along the lower part of the Lewiston grade. The deposits above the mouth of Tammany Creek were discussed by Webster and others (1976). Hammatt (1976) mapped them as scabland slackwater deposits in the Lower Granite Reservoir area.

The method of deposition of these units has been interpreted as backwater deposits by Bretz (1929) and slackwater deposits by Hammatt (1976). Baker (1973) considered them to be turbidites. Waitt (1980) convincingly argued for traction and suspension deposition of the Touchet Beds in the Walla Walla valley and elsewhere in the Pasco Basin. The deposits in the Snake River canyon closely resemble those of the Walla Walla area, contain similar sedimentary structures, and are believed to have formed by traction and suspension deposition.

Bretz (1928) postulated that the discharge of the Missoula Floods passed across the channeled scablands of southeastern Washington and entered the Snake River canyon at the mouth of the Palouse River approximately 85 miles (137 kilometers) downstream from Lewiston. The discharge was so great that some of the Missoula Flood waters surged up the Snake River canyon. The initial surge incorporated some of the pebbles and small cobbles from older gravel deposits and reworked them into the dominantly basalt pebble and cobble traction gravels recognized as the basal Missoula Flood deposits in the Snake River canyon. The updrainage traction sediments of each flood form the lower half of a rhythmite.

The discharge of the Missoula Flood waters was so large that it ponded at Wallula Gap resulting in Lake Lewis which flooded the Pasco Basin and surrounding areas to an elevation of 1,150 feet (350 meters) (Bretz, 1929; Waitt, 1980). Preceding the Wallula Gap ponding, hydraulic damming of the Snake River drainage occurred at the mouth of the Palouse River. The hydraulic damming at the mouth of the Palouse and the formation of Lake Lewis ponded the surge up the Snake River canyon and the normal discharge of the Snake River. The highest elevation of these hydraulically formed lakes in the Lewiston area is recognized at 1,325 feet (404 meters) by the presence of ice-rafted erratics brought in with the Missoula Flood waters (Lupher, 1940). During the period of ponding of each flood, some finer sediment carried in suspension in the upstream surge was deposited to form the upper half of a rhythmite. The duration of the ponding was short and has been estimated from perhaps a few days to two weeks (Bretz, 1959; Baker, 1973).

Although Lupher (1945) called the Missoula Flood deposits the Touchet Beds, some geologists working in this area have been hesitant to use the term. Kuhns referred to the deposits along the lower Clearwater valley as "Touchet type beds," and Waggoner (1981) called the deposits in the Clarkston area Missoula Flood deposits. Because they obviously are a Snake River canyon facies of the Pasco Basin deposits, we believe they should be referred to as Touchet Beds.

Waitt (1980) interpreted each rhythmite in the Touchet Beds to represent a single flood from the breaching of the ice dam which formed glacial Lake Missoula in western Montana. The excellent ex-
The St. Helens tephra has not been found in the part of the Columbia Plateau establishes an age of rhythmites of the Touchet Beds in the southwestern the Mount St. Helens tephra within the upper (Scott and others, 1982 this volume). The above data between 19,000 and 12,000 years old. Bonneville (1980) considered the age of the Touchet Beds to be localities at Asotin, Lewiston, and Clarkston. Waitt immediately overlie the Bonneville gravel at several including the intracanyon flows. Erosion or channeling through seven rhythmites is present in the deposits at the mouth of Tammany Creek. Erosion or channeling through 1 or 2 rhythmites is seen at several localities in the Snake River canyon.

In the Lewiston basin the Touchet Beds overlie all older gravels and many of the flood basalts, including the intracanyon flows. The Touchet Beds immediately overlie the Bonneville gravel at several localities at Asotin, Lewiston, and Clarkston. Waitt (1980) considered the age of the Touchet Beds to be between 19,000 and 12,000 years old. Bonneville Flood sediments in the American Falls area of southern Idaho have recently been dated to have been deposited between 14,000 and 15,000 years ago (Scott and others, 1982 this volume). The above data suggest that the Touchet Beds are between 14,000 to 15,000 years and 12,000 years in age.

As summarized by Waitt (1980) the occurrence of the Mount St. Helens S tephra within the upper rhythmites of the Touchet Beds in the southwestern part of the Columbia Plateau establishes an age of 13,000 years for the upper part of the Touchet Beds. The St. Helens S tephra has not been found in the Touchet Beds in the Lewiston basin. It is possible that only older rhythmites of the Touchet Beds are present in the Lewiston basin.

HOLOCENE GRAVELS

Holocene gravel bars in each of the Snake, Salmon, and Clearwater Rivers above their confluences reflect the provenance of the upstream drainage basin. The Clearwater River drains a part of the Idaho batholith before entering the Clearwater embayment of the Columbia Plateau. The Salmon River also begins in the Idaho batholith, with the lower Salmon River drainage in mixed terrains of (1) western pods of the Idaho batholith, (2) major parts of the eastern bulge of the Columbia Arc containing late Paleozoic and Mesozoic volcanioclastic and carbonate rocks and Jurassic plutons, and (3) the southeastern edge of the Columbia Plateau. Sediments from the Snake River drainage come from several provenances including the Idaho batholith, northern Great Basin, Snake River Plain, and Columbia Arc before entering the Columbia Plateau. However, most of these sediments are trapped in the lakes impounded by dams built on the Snake River during the 1900s.

To better understand the gravels in the Lewiston basin, cobble counts were made upstream in each of the major drainages. Kuhns (1980) made cobble counts at three localities: (1) Lochsa River, just above the confluence with the Selway River; (2) South Fork of the Clearwater River, just above the confluence with the Middle Fork of the Clearwater River; and (3) North Fork of the Clearwater River, 35 miles (56 kilometers) above the confluence with the main Clearwater River. Webster made cobble counts at four gravel bar locations: (1) Salmon River, 1 mile (1.6 kilometers) below the mouth of Slate Creek; (2) Salmon River, one-half mile (0.8 kilometer) below the mouth of China Creek; (3) Snake River, one-half mile (0.8 kilometer) below Pittsburg Landing; and (4) Snake River, 2½ miles (4 kilometers) above Asotin.

At each locality a line was laid out across the modern gravel bar, and the first 1,000 adjacent clasts of pebble or coarser size touching the line were identified for lithology and size information. These data have been summarized into four major lithologic groups reflecting provenance. Lithologic counts from the ancient gravel deposits were then summarized, and both sets of data were compared (Table 2).

The most obvious differences in the data presented in Table 2 are the lack of Seven Devils Group lithologies in the Clearwater River drainage and the absence of Columbia River basalts in the Lochsa River drainage. A small exposure of the Seven Devils Group along the South Fork of the Clearwater River yields a few clasts of the characteristic red and green volcanioclastic lithologies, but downstream they disappear rapidly from abrasion. Although no Seven Devils Group lithologies were found in the cobble counts, a careful search of both modern and ancient gravel bars downstream of the exposure on the South Fork will yield an occasional clast. The absence of Columbia River basalts in the modern Lochsa gravels would be expected, since the Lochsa drainage is east of the Columbia Plateau.

Seven Devils Group strata are most abundantly represented in clasts in the modern gravel bars of the Salmon River at Slate Creek and the Snake River at Pittsburg Landing. Both localities are immediately downstream from outcrops of the Seven Devils.
Group. Most of these rock types are greenschist facies of siltstones, claystones, and volcanioclastic rocks. The rapid decrease of these lithologies in clasts downstream is reflected in the cobble counts of both recent and ancient gravels and suggests that they are nonresistant to fluvial transport and weathering.

Dilution and loss of both nonbasalt igneous and older metamorphic rocks downstream were also noted. The Snake River drainage area has a relatively low percentage of both of these rock types. The 18.7 percent nonbasalt igneous rocks (mostly quartz diorite and diorite) at Pittsburg Landing are derived from a small pluton within 5 miles (8 kilometers) upstream. Gravels derived from the Snake River may be best characterized by low percentages of older metamorphic rocks combined with a low percentage of nonbasaltic igneous rocks.

The North Lewiston Gravel has an extremely high percentage (95.4) of basalt clasts. It is uncertain if this reflects the influence of a local tributary, or other unknown factors.

During the cobble count studies many distinct lithologies were found. The source area for many of these lithologies is not known. Reference sets are presently being compiled, and studies of cobble source areas are being initiated.

LATE CENOZOIC HISTORY

The stratigraphy of the Columbia River Basalt Group in southeastern Washington was summarized in a series of maps by Swanson and others (1980, plate 1). After the outpouring of the Umatilla Member (between 14 million and 12 million years ago), the Lewiston basin was downwarped. Downwarping in the Lewiston area produced a structural basin which drained via a canyon that was cut parallel to and a few miles to the northeast of the present Snake River canyon northwest of Clarkston, Washington. This canyon was cut into the Priest Rapids Member by the ancestral Clearwater and Salmon Rivers. The Wilbur Creek and Asotin Basalts filled this canyon, and a new canyon, the ancestral Snake River canyon, was cut to the southwest.

Downwarping and faulting continued, and the Clearwater and Salmon Rivers cut canyons to the approximate depth of the present Snake River canyon in the Lewiston basin by Pomona time (12 million years ago). The Clearwater River was in the same general position as at present. Lupher and Warren (1942) suggested that a larger stream had cut the wide canyon of lower Tammany Creek, possibly the Clearwater River. There is no gravel deposit or topographic evidence to support a Clearwater drainage into the Tammany valley. We propose that the ancestral Salmon River occupied the wide canyon of lower Tammany Creek. A gravel deposit approximately 2 miles (3.2 kilometers) southeast of Waha, Idaho, in a road cut (NE¼SE¼NW¼, sec. 15, T. 33 N., R. 4 W.) supports our proposal. This gravel occurs at an elevation of 3,800 feet (1,158 meters) and contains pebbles and small cobbles of typical modern Salmon River drainage. It is uncertain whether this gravel is an interbed or a remnant of an abandoned stream channel (V. E. Camp, personal communication, 1979). If the Salmon River occupied Tammany Creek, some unrecognized event diverted the lower Salmon River to its present course. Additional study of the gravel and Waha area is needed to resolve this issue.

Outpouring of the Pomona flow (12.0 million years ago) filled the ancestral Salmon River drainage in the vicinity of Clarkston and a new canyon was incised nearly to the depth of the present Snake River canyon, along the southwestern side of Clarkston (under the present day Clarkston Heights area). The Elephant Mountain flow should have partly filled this canyon and perhaps was the cause of the aggradation that formed the North Lewiston Gravel.

Aggradation of the ancestral Salmon River along the southwestern side of Clarkston formed the Clarkston Heights Gravel after the canyon was cut. We suggest that this occurred between 6.0 and 2.0 million years ago at the same time the Clearwater Gravel was deposited on the Lower Monumental Flow in the lower Clearwater River valley.

The ancestral Salmon River was then diverted north at Swallow Rock, opposite the mouth of Tammany Creek, probably cutting its initial canyon to the northwest along the east side of the Pomona flow, or what is today the southwestern edge of Clarkston (Waggoner, 1981). It then eroded to the northeast to the present junction of the Snake and Clearwater Rivers. The Snake River may have been diverted to the north during this time (Waggoner, 1981). We interpret the Clarkston Gravel as a point bar. Perhaps it was deposited by a large-scale flood of unknown causes, possibly glacial, after erosion of a wide flood plain by the ancestral Salmon or Snake River in the Clarkston area. With a glance at the map (Figure 2), one should observe that the Clarkston Gravel clearly truncates the Clearwater Gravel, and thus must be younger.

Approximately 14,000 to 15,000 years ago (Scott and others, 1982 this volume) Lake Bonneville overflowed through Red Rock Pass south of Pocatello, Idaho, to create the Bonneville Flood.
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(Malde, 1968) which proceeded down the Snake River. This flood produced a flow of 10 million cubic feet per second in the vicinity of Brownlee Dam and was at least 410 feet (125 meters) deep (Stearns, 1962). Below Oxbow Dam, numerous expansion bars, point bars, and back-edy deposits were formed by the Bonneville Flood.

The Bonneville gravel is overlain by the Touchet Beds deposited from the Missoula Floods. The Missoula Floods occurred between 14,000 to 15,000 and 12,000 years ago. The Touchet Beds are here recognized in the lower Clearwater, Salmon, and Grande Ronde River valleys and record at least seventeen floods.

Modern fluvial processes are eroding parts of these earlier gravel sequences and depositing gravels along the drainages at present stream level. Within the Holocene colluvium local deposits of the Mazama ash (6,600 years ago) may be found.

CONCLUSIONS

From cobble counts, sedimentologic analysis of matrix materials, stratigraphic relations, and a comparison to modern gravels in the Snake, Salmon, and Clearwater Rivers, we draw several conclusions:

1. Six distinct gravel units are recognized in the Lewiston basin area.
2. Gravels derived from the Clearwater River lack the abundant red and green volcaniclastic clasts present in gravels from the Salmon and Snake River drainages.
3. Gravels derived from the Snake River have lower percentages of the abundant quartzites and medium- and high-grade metamorphic clasts common in materials from the Clearwater and Salmon Rivers.
4. The Clarkston Gravel as defined by Lupher (1945) is restricted to a Salmon River or possibly combined Salmon-Snake River derived gravel that is younger than the Clearwater Gravel and the Clarkston Heights Gravel.
5. The Clarkston Heights Gravel is derived from the Salmon River and preceded the northward diversion of the Snake River.
6. The Clarkston Heights Gravel and Clearwater Gravel are believed to be coeval.
7. Some gravels in the Ringold Formation of the Pasco Basin are probably coeval with the Clearwater Gravel and Clarkston Heights Gravel.
8. Bonneville Flood gravel is probably the most widespread deposit in the Snake River canyon and was not recognized by the first researchers in the Lewiston basin.
9. At least seventeen Missoula Floods are recognized to have inundated the Lewiston basin.
10. Touchet Beds are reported for the first time in the lower Salmon River valley and lower parts of the Grande Ronde River valley.
11. Holocene gravels as well as the older gravels require additional provenance studies to provide answers to unresolved problems of the gravel deposits in the Lewiston basin.

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