Late Pleistocene Glacial Lakes of Foster Creek Watershed, Washington

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Abstract:

Ice age floods scoured, and the Okanogan Lobe of the Cordilleran Icesheet covered, the Foster Creek Watershed of northcentral Washington, in the late Pleistocene. Glacial lakes formed when ice dammed meltwaters from the receding Cordilleran Icesheet filled the Foster Creek Watershed. I mapped the glacial lake sediments along East Foster Creek to understand: 1) the extent of the glacial lake sediments; and 2) how the glacial lake sediments shaped the geomorphology, soils, and land use in the Foster Creek Watershed. I mapped the glacial lake extents using airphoto and topographic map interpretation, and field surveying using a Geodetic Total Station. The lake extents were mapped by the lacustrine sediments upper extents and five glacial lake elevations were found within the Foster Creek Watershed with elevations of 2124' (upper Foster Creek), 1920'-1940' (mid East Foster Creek), 2100'(Upper Middle Foster Creek), 1760' (lower Middle and main channel of West foster Creek, and 2220'(upper West Foster Creek). Indicating localized ice dams from the receding Okanogan Lobe impounding the meltwaters, forming glacial lakes. The research is significant in understanding the glacial history, arroyo incision, soil erosion, and badland topography in the watershed.

Introduction:

As ice from the late Pleistocene Okanogan Lobe of the Cordilleran Icesheet (figures A-E) blocked the drainages once used by the Missoula Floods, lakes formed behind the ice dam, filling the Foster Creek Watershed of northcentral Washington with glacial meltwater. The continued melting of the receding Cordilleran Icesheet caused the meltwater in East, West, and Middle Foster Creeks to swell, forming glacial lakes (figures F-I). Little is known about the glacial lakes of the Foster Creek Watershed. The goal of this research was to begin to understand the extent of the glacial lakes in this watershed. I mapped the glacial lake sediments along East, West, and Middle Foster Creeks to understand: 1) the extent of the glacial lake sediments; and 2) how the glacial lake sediments shaped the geomorphology, soils, and land use in the Foster Creek Watershed. This research is significant in developing a better understanding of the glacial history, arroyo incision, soil erosion, and badland topography of the Foster Creek Watershed in northcentral Washington.

Study Area Description:

The study area is located in the Foster Creek Watershed in northcentral Washington. The watershed is located on the Waterville Plateau, which experienced the Missoula Floods and late Pleistocene glaciation from the Okanogan Lobe of the Cordilleran Icesheet, and more recently, arroyo incision and badland topography formation. The watershed comprises an area of approximately 100,000 acres with poorly defined boundaries (figure A) (Thompson and Ressler, 1988). The Foster Creek channels come together, and then flow into the Columbia River just below the Chief Joseph Dam. The channels of the watershed are cut through Columbia River Basalt and have mass wasting along steep slopes caused by interbed failure. The Foster Creek Watershed is in a semi-arid, shrub-steppe climate with nine to twelve inches of precipitation annually, making dry-land wheat farming the main economic activity. The vegetation of the study area is made up of shrub-steppe vegetation (Daubenmire, 1988). The watershed is unusual because of the lacustrine sediments.

Literature Review:

There has been little past research, and therefore literature, that deals directly with late Pleistocene glacial lakes in the Foster Creek Watershed. Garrey (1902) wrote of glaciation in eastern Washington, giving insight to the processes that have acted upon the watershed. Garrey's early work is filled with details of general glaciation, but fails to investigate glacial lakes caused by the late Pleistocene glaciation. Pardee (1918) was working on geology and mineral deposits on the Colville Indian Reservation when he made important notations of the Nespelem Silt, glaciation, geology, and mineral deposits that are common in the study area. Pardee (1918) notes that there are "unconsolidated lake and stream sediments of glacial origin," which spawned the name Nespelem Silt. The Nespelem Silt described by Pardee (1918) was white-buff in color. Bretz (1923) was the first to recognize and record his findings of coulees and gravel bars across northcentral Washington. Bretz (1923) did further field studies and concluded that meltwater from the Grand Coulee flowed down the Foster Coulee. The early work by Bretz (1923) opened up the debate in the geologic community of the "Spokane Floods," later called the Missoula Floods. Bretz (1923) got the geologic community thinking about the creation of the channeled scablands, and the unusual topography exhibited in eastern Washington.

Waters (1933) did field work around the Chelan area on Coulees and glacial features. Special attention was paid to the "great terrace" and the silt laid upon the surface. Waters (1933) explains that the receding Okanogan Lobe caused enormous floods, proposing that the floods caused ice dams to form by rafted ice conglomerated in drainage openings (Waters 1933). Waters' (1933) work in the Alta Lake region indicates that glacial lakes formed as the Okanogan Lobe receded.

Flint (1935) did not believe the Bretz (1923) flood theory; therefore he conducted his own research on the Quaternary stratigraphy, which supports the existence of glacial lakes in Eastern Washington. Flint (1935) made direct reference to the Nespelem Silt being deposited in lakes behind ice or debris dams. Flint (1935) described these silts found in the northcentral Washington appeared as laminated or varved, and found them to be hundreds of feet thick in places. Flint went further and explained that the varved bedding was "fresh," meaning that the varved bedding had not been compressed under the weight of 1500' of glacial ice; therefore concluding that the sediments had been emplaced after the Cordilleran Icesheet covered the Waterville Plateau. The notations by Flint (1935) correlated with the hypothesis that the lacustrine sediments were deposited while the icesheet receded northward. Flint (1935) gained the information pertaining to the Nespelem Silt via Pardee's (1918) work. Flint (1935a) wrote of "white silt" found in the Okanagan Valley, British Columbia, consisting of a white to pale buff color. Flint (1935a) explained that the "white silt" was found in stratified parallel laminations. Flint (1935a) notes that the "white silt" deposits appear to be of Pleistocene age. The "white silt" described by Flint (1935a) was thought to be of glacial origin and composed of lacustrine varved sediment. Flint (1935a) went further to investigate the causes of the "white silt," concluding that the silts were deposited when ice dammed the drainage outlet creating a glacially fed lake. This follows the hypothesis that the glacial lakes in the watershed were the result of localized ice dams.

Richmond and others (1965) looked at the Quaternary glacial history of the Columbia Plateau, with research directed at the Cordilleran Icesheet. Richmond and others (1965) provided useful information and mapped the extent of the Cordilleran Icesheet, and more importantly, the Okanogan Lobe. Richmond and others (1965) indicated that the Okanogan Lobe advanced and impounded glacial Lake Columbia. The information gathered by Richmond and others (1965) was useful in examining the advance of the Okanogan Lobe as well as the re-advance, which caused further lacustrine sediment deposition (Richmond and others 1965).

Like the previous research by Garrey (1902), Pardee (1918), Bretz (1923), Waters (1933), Flint (1935) (1935a), and Richmond and others (1965), Hanson (1970) was interested in the scabland features created by the Missoula Floods. Research done by Hanson (1970) on the Foster Coulee examined how the Coulee was shaped by the Missoula Floods, and subsequently partially covered by glacial debris.

Flint (1971) gave general information about glacial lake sediments such as the types, formation, and location within glacial lake, which determined the type of lacustrine formation. Flint (1971) explained patterns of the formation and the implications that can be made from types of the stratified sedimentation. Flint (1971) offers a generalized insight about glacial lake sediment, but nothing specific to the study area.

The Douglas County Soil Survey, put together by the Soil Conservation Service (1981), listed the soils found in the Foster Creek Watershed and examined their use and components. The soil survey explains the soils formed by the glacio-lacustrine parent material, but did not look into the origination of these sediments.

Hankanson and Jansson (1983) discuss the sedimentology of lakes and made specific references to glacially fed lakes. Hankanson and Jansson (1983) provided detailed descriptions of lake sediments and the role that turbidity played in the formation.

Waitt (1983) acknowledged that the varved lacustrine sediments were observed between areas of Missoula Flood deposition in eastern Washington. Waitt never noted varved lacustrine sediments as far west as the Foster Creek Watershed, but notes their formation in northeastern Washington. Waitt with Thorson (1983) looked at the landforms due to glaciation caused by the Cordilleran Icesheet and the Missoula Floods. Waitt and Thorson (1983) looked closely at the Okanogan lobe and the Waterville Plateau, as well as ice dams caused by the Okanogan Lobe. However, the research done by Waitt and Thorson failed to mention ice dams the affecting Foster Creek Watershed.

The research was helpful in understanding the overall picture of the environment present in the late Pleistocene, when ice damming occurred on the Waterville Plateau.

Atwater (1986) wrote a detailed description of glacial lake deposits in the Sanpoil River Valley, located northeast of the Foster Creek Watershed. Atwater (1986) investigated the causes of ice dams the formation of glacial Lake Columbia, and the resulting varved lacustrine deposits. Atwater (1986) is very instrumental in understanding the watershed's glacial lake past. The field research accomplished by Atwater (1986) examined glacial lakes of northeastern Washington, and investigated the factors and processes, which were acting upon northcentral Washington during the late Pleistocene. The information gathered by Atwater (1986) has many similarities to the glacial lakes found in the Foster Creek Watershed, such as ice dams, varved lacustrine sediments, and the age of deposition.

Thompson and Ressler (1988) researched soil erosion, water quality, and habitat improvement in East Foster Creek. The study done by Thompson and Ressler (1988) was important because it dealt with soil erosion in the watershed. Thompson and Ressler (1988) aided explained the erosion problems present in East Foster Creek, which were later used by Munson Engineers (1989). This study was directed at hydrology and sedimentology in East Foster Creek, but also gave general conditions present in the sub-watershed. Munson Engineers (1989) provided useful information about the East Foster Creek sub-watershed, and the soil erosion problems associated with the lacustrine sediments.

The mapping and delineation of glacial lakes in northeastern Lower Michigan, done by Schaetzl and others (2000) brought a new element of mapping into view using

Geographical Information System (GIS). The paleolakes mapped, and techniques used, were pertinent in understanding the formation of the lakes, and the soils found presently, which indicated glacial formation.

Methodology:

Airphoto and topographic map interpretation were used as the primary methodologies while mapping the glacial lake extents in the watershed, in winter and spring quarters, 2001. Surveying was used to verify the mapped elevations along, with field visits to decipher the upper extent of the lacustrine sediments.

The 1965 black and white USDA airphotos were used in the laboratory research. The 1965 airphotos were helpful in giving an overview of the watershed, and aided in locating lacustrine sediments, as well as the suspected extents of the glacial lakes. In the airphotos, sediments appeared bright white in color, and showed high reflectivity. The upper extent of lake sediments were established by the upper extent of the sediments seen on the airphotos, and are within a similar elevation to the rest of the upper extents mapped. In the airphotos, lacustrine sediments appeared as bright white in color and showed high reflectivity. I first viewed the lacustrine sediments on airphotos using a pocket stereoscope, which provided an aid for determining glacial lake extents. The lake extents were recognized on the airphotos, which were then manually transferred to the USGS topographic maps. After the extents were mapped through airphoto and topographic map interpretation, they were then field checked, first by myself, and then surveyed using Geodetic Total Station by Dr. Karl Lillquist and myself. The Geodetic Total Station allowed for the elevation of the lacustrine sediments to be precisely determined. First the USGS benchmarks were located, then the elevations, were used to determine the highest elevation of lacustrine sediments found in East, West, and Middle Foster Creeks. Field checking of the compiled data was essential to the study for site verification of the mapped glacial lake extents. After the final field check, the glacial lake elevations were mapped accordingly, and the area within the glacial lakes were colored for quick differentiation from the surrounding areas. The glacial lakes were colored using Corel Draw, to separate the lakes by elevation, for quick referencing.

Results & Discussion:

Glacial Lake Extents:

The late Pleistocene glacial lakes of the Foster Creek Watershed probably existed from around 13,000 through 11,200 years ago. The research by Waitt and Thorsen (1983) and Atwater (1986) on the ice dams in the northcentral Washington forms part of the basis to the ice dam argument. The presence of the Okanogan Lobe on the Waterville Plateau and ice dammed lakes in the Sanpoil Arm and Lake Columbia gives backing to ice dam hypothesis.

As the Okanogan Lobe receded northward, it blocked the watershed's drainage outlet, causing meltwater to accumulate into glacial lakes. Five glacial lakes were observed and mapped within the watershed according to the upper extents of the lacustrine sediments. The terminology that better represents the lacustrine sediments, because rhythmites do not indicate that the lacustrine sediments were deposited seasonally as does varving (Bramlette 1946). Since the season of deposition is unknown rhythmites should be the language used to convey that the sediments are thinly bedded.

Upper East Foster Creek:

The upper lake extents in Foster Coulee and upper East Foster Creek, which cover the area east of Leahy, and all the way to the mouth of Deep Creek, are 2124' in elevation (figures F, G). The upper lake occupies the Foster Coulee and drainages within the mapped extents. The elevation of the upper lake was surveyed and field checked for exact verification.

The edge of the ice dam in all the lakes would be well back from the layered lacustrine sediments observed because the turbidity of the meltwater streams and ice calving off the Okanogan Lobe would have caused a lack of rhythmites. The character of the sediments near the receding lobe would have been more mixed up and lacked rhythmite formation and possibly would have looked as if it was more of dumped in place than deposited

Mid East Foster Creek:

The lower lake in mid East Foster Creek, elevation was between 1920'-1940' (figures F, H). The lake in mid East Foster Creek encompassed the area of the Chalk Hills, and extended further west to within approximately five miles of the main channel. The fluvial erosion that have plagued the lacustrine sediments of the watershed have left the Chalk Hills relatively untouched as remnants of the lacustrine sediments that once filled the Ruben Blue Springs drainage. Judging by the severe erosion of sediments and the remnant nature of the Chalk Hills further erosion could cause the erosion the remnants themselves.

Upper Middle Foster Creek:

The upper lake in Middle Foster Creek occupied the area of Buckingham Flats and had an elevation of 2100' (figures F, G). The upper lake was dammed in lower Middle Foster Creek and filled the majority of Middle Foster Creek with lacustrine sediments.

Upper West Foster Creek:

The upper lake in West foster Creek had a higher elevation than all of the other lakes within the watershed and had elevation of about 2220' (figures F, I). The least amount of information was gathered pertaining to the upper lake because the majority of the property is privately owned. The only evidence of glacial lake sediments observed in upper West Foster Creek, were found in small pocket depressions near road cuts. Erosion of sediments by annual drainages and thicker vegetation could account for the lack of sediments found in upper West Foster Creek.

Lower West and Middle Foster Creeks:

The lake occupied the main channel of West and Middle Foster Creeks had an elevation of 1760', and encompassed parts of lower Middle Foster Creek around Sharyer Springs (figures F, I). The lower lake in the main channel had the lowest glacial lake elevation and possibly was the last lacustrine sediments deposited, in the watershed before the ice dam receded.

Impacts of Lacustrine Sediment on the Watershed:

The lacustrine sediments that are located in the drainage bottoms or on steep slopes have been eroded for over 11,200 years. The erosion of the lacustrine sediments by water since their deposition has caused the arroyo incision and badland topography to form in portions of the watershed. Because of the vast erosion processes acting upon the watershed, nearly half the cropland has been put in the Conservation Reserve Program (Thompson and Ressler, 1988). The severe erosion of the sediments makes some of the glacial lake sediments undeterminable from the airphotos, therefore requiring field research. The land use activities of dry-land wheat and grazing aided in the rapid erosion of the lacustrine sediments. The tillage of the soils and bare nature before planting allows for water and wind erosion of the lacustrine sediments.

The erosion of the lacustrine sediments by piping had significant effects upon the watershed. Piping initiates where water erosion begins under the surface and slowly carves out passageways, which widen (Bloom, 1998). Results of piping are often in rill erosion that forms atop the surface when the passageways are collapsed due to the soft sediment. The evidence of piping within the watershed can be seen by the small holes in the Chalk Hills indicating that piping has caused headward erosion of sediments. Piping began the erosional process that led to rill, then gully erosion and ultimately into, arroyo incision and the formation of badland topography.

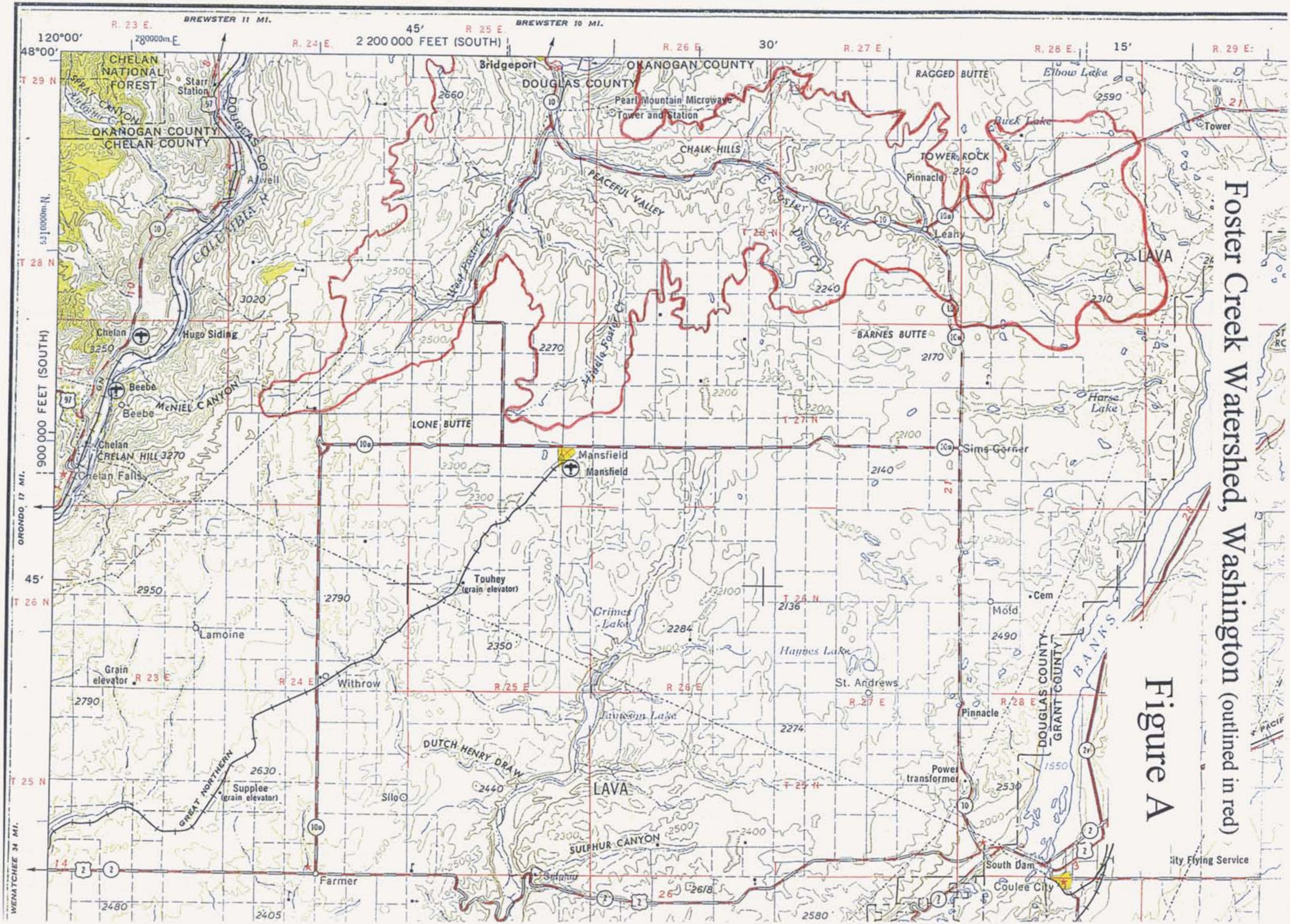
Erosion begins with piping and then grows into arroyo incision and lastly into badland topography. The arroyo incision and badland topography in the watershed are due to the fine texture of the sediments, making them more vulnerable to water erosion (Thompson and Ressler, 1988). The headward erosion of the sediments started from nick points, and then eroded further headward due to flash flooding. As arroyo incision grows in scale, and many gullies and rills form, the area will acquire a badland topography appearance. Arroyo incision and badland topography are a major aspect that needs further research attempts to develop solutions to the problems associated with severe erosion problems.

Conclusion:

Five glacial lakes extents were mapped according to the upper extent of lacustrine sediments in the watershed. After the extents were mapped the research aimed at erosion of the lacustrine sediments began. The varying elevation of the glacial lakes was accredited to a receding Okanogan Lobe, causing lake formation in three separate glacial related events.

Understanding the past before attempting to understand the present was a main focus of this research. I had to understand how the Missoula Floods shaped the landscape, and how the Cordilleran Icesheet covered the watershed, impounding the late Pleistocene glacial lakes of the Foster Creek Watershed. Understanding the glacial and human history of the watershed was essential to view the airphotos. Through field and lab mapping I found that the extents of the late Pleistocene glacial lakes were variable because of localized ice damming, due to a receding Okanogan Lobe. This research on lake elevations was fundamental in gaining an understanding of how the glacial lakes affected the glacial history, geomorphology, soils, arroyo incision, badland topography, and land use of the entire Foster Creek Watershed.

WESTERN UNITED STATES 1:250,000



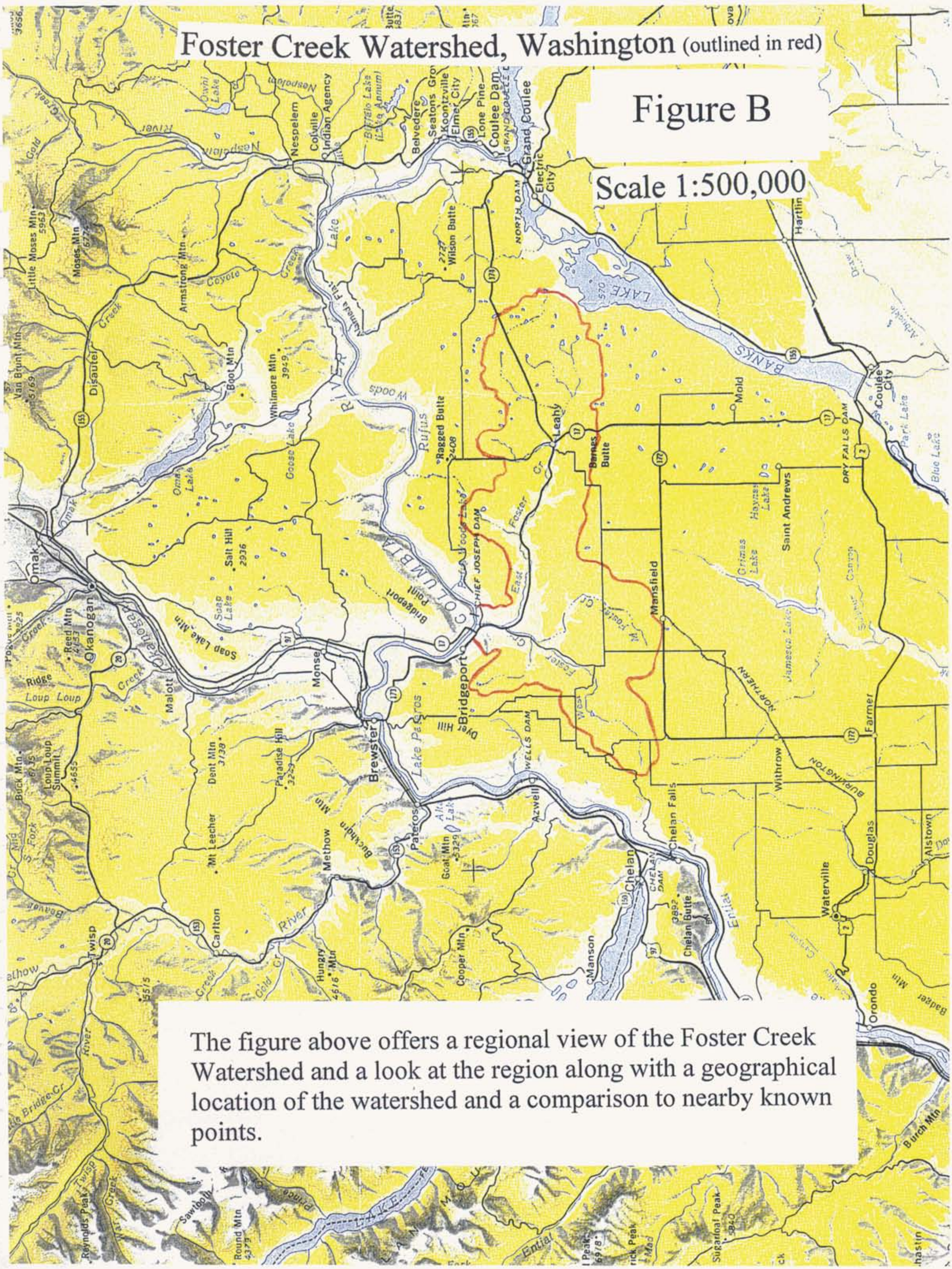
Foster Creek Watershed, Washington (outlined in red)

Figure A

Foster Creek Watershed, Washington (outlined in red)

Figure B

Scale 1:500,000



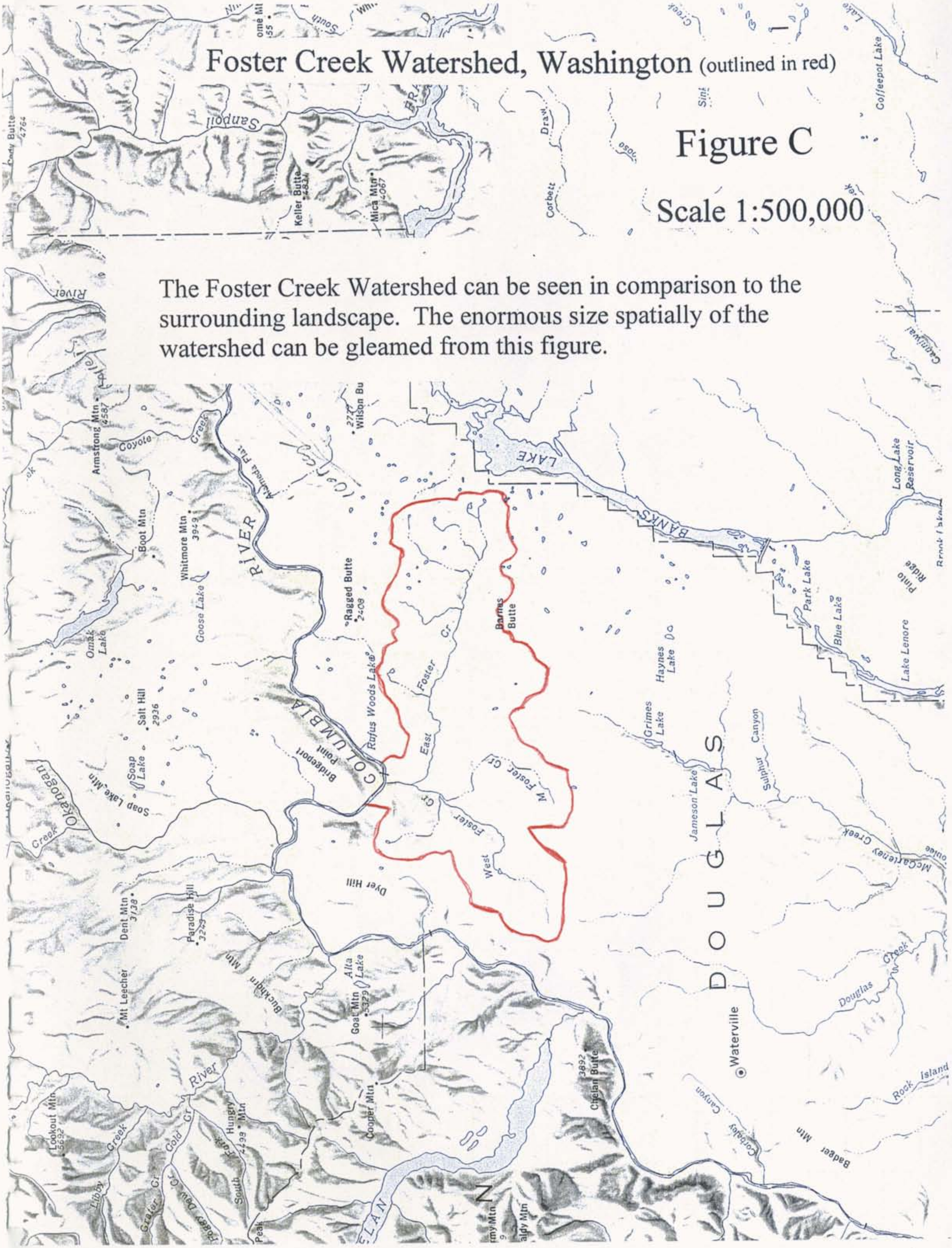
The figure above offers a regional view of the Foster Creek Watershed and a look at the region along with a geographical location of the watershed and a comparison to nearby known points.

Foster Creek Watershed, Washington (outlined in red)

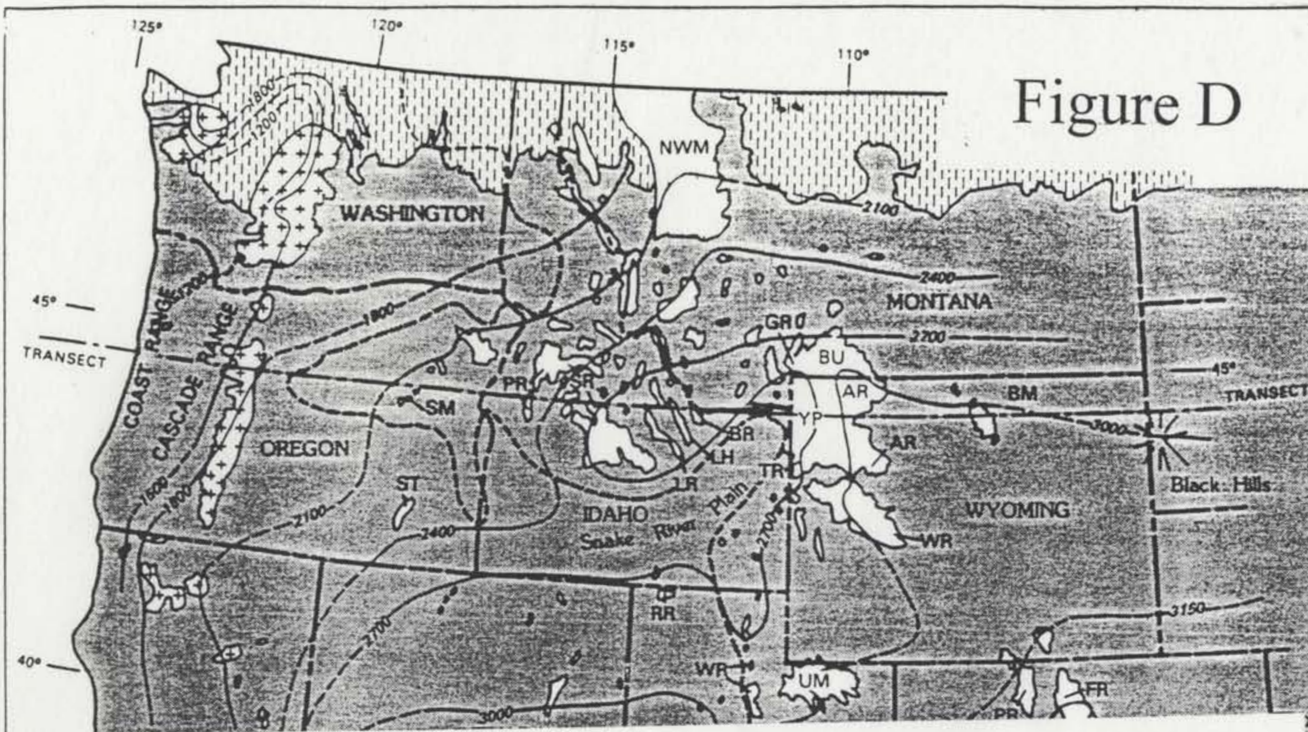
Figure C

Scale 1:500,000

The Foster Creek Watershed can be seen in comparison to the surrounding landscape. The enormous size spatially of the watershed can be gleamed from this figure.



Furthest Extent South of the Cordilleran Icesheet



The figure shows the southern extent of the Cordilleran Icesheet in eastern Washington. This aids in the understanding of the processes and factors that have acted in the past upon the Foster Creek Watershed.

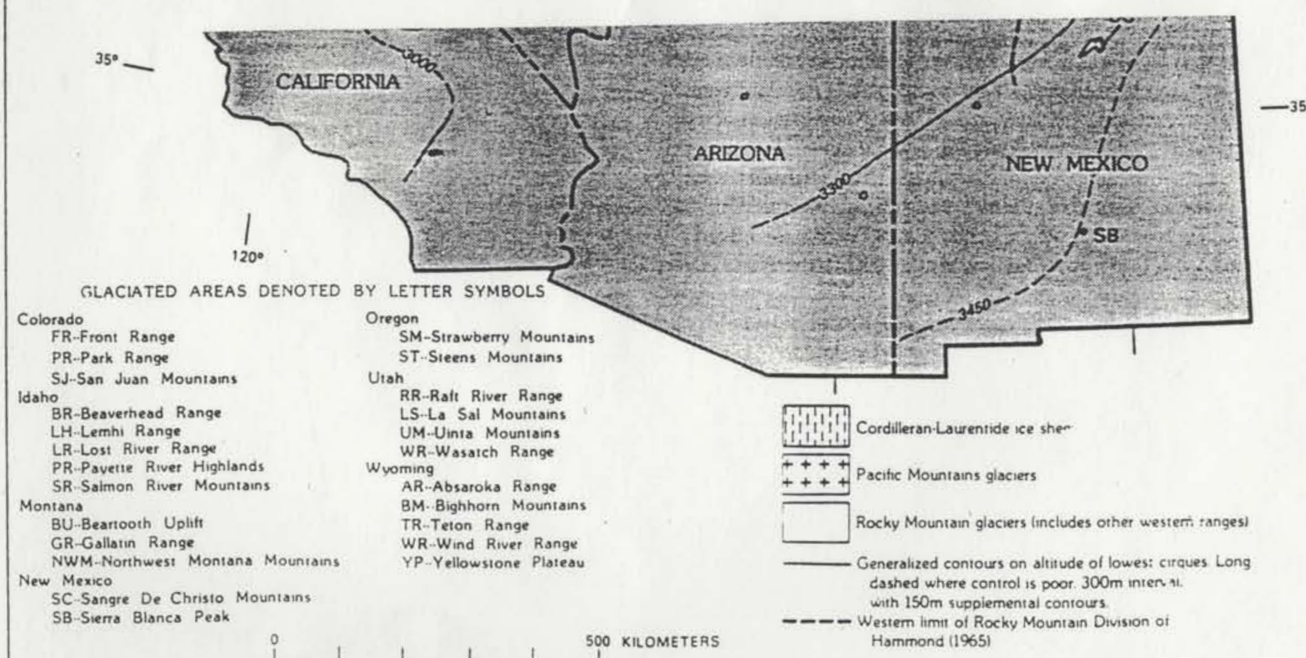


Figure 4-2. Map showing extent of Late Wisconsin glaciers in the Rocky Mountains and other areas of the western United States. For Sierra Nevada and Cascade Range contours on lowest cirque floors are from Flint (1971: Figure 18-4), and Porter (1964a). For Rocky Mountains and adjacent areas, contours are based on about 100 altitudes of lowest cirques as defined by altitude of break in slope between cirque floor and headwall. (Map was compiled and modified from Colman and Pierce, 1979; Montagne, 1972; Flint, 1971; and Hollin and Schilling, 1981.)

The Okanogan Lobe's Deposition on the Waterville Plateau

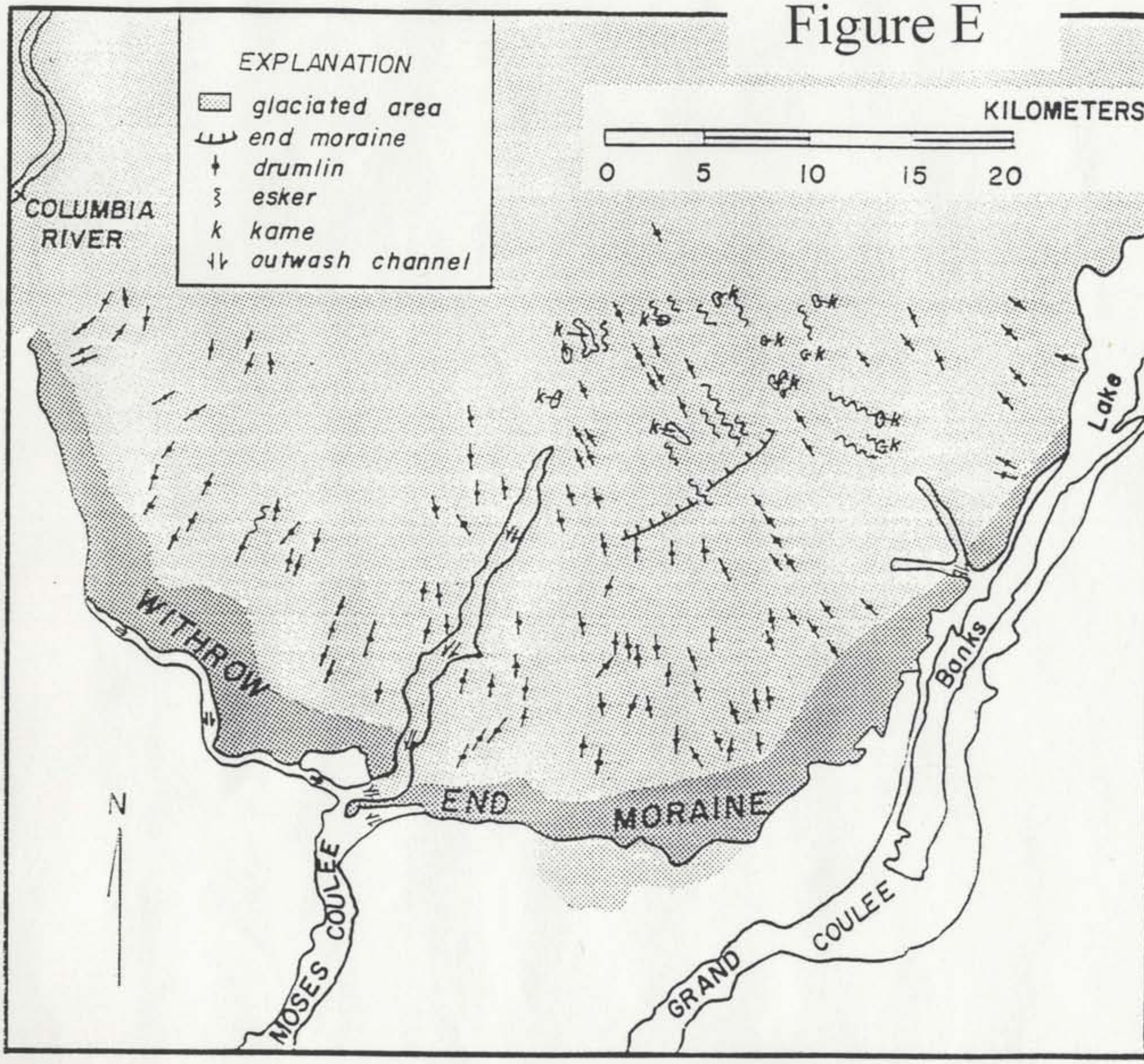
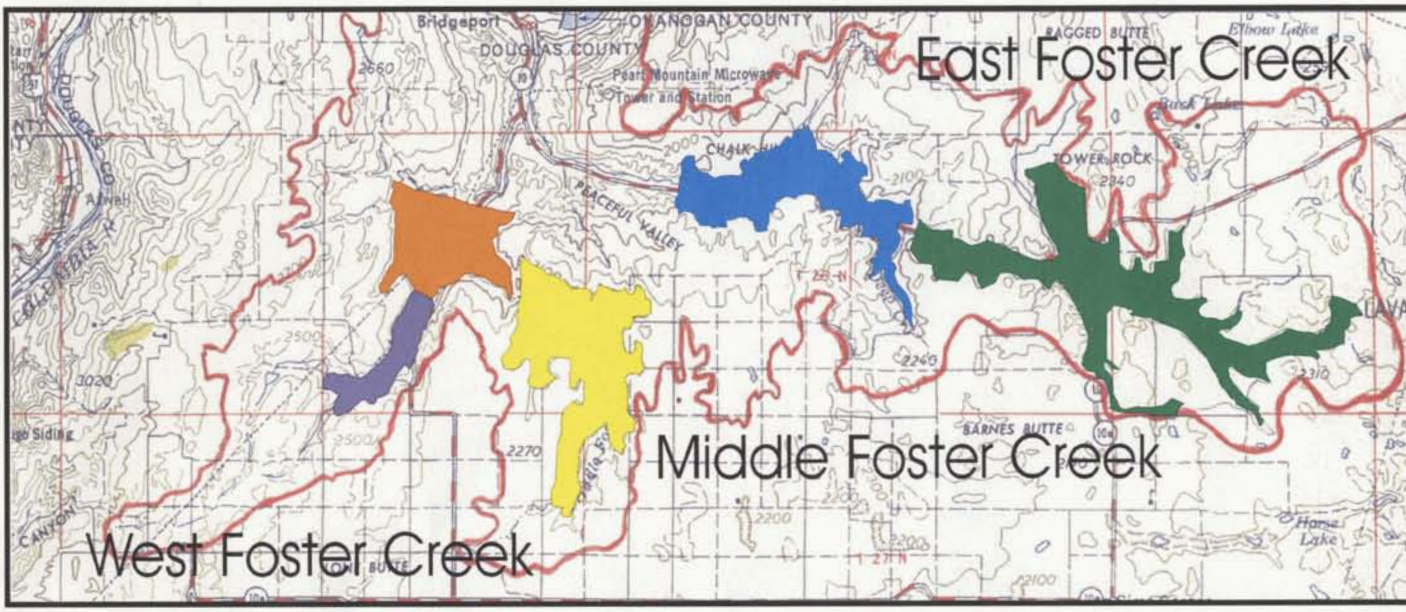


FIGURE 7 OKANOGAN LOBE OF THE CORDILLERAN ICE SHEET. COMPILED BY LUCY L. FOLEY.

The figure above maps the glacial deposition on the Waterville Plateau caused by the Okanogan Lobe of the Cordilleran Icesheet. The Foster Creek Watershed near the top of this map located under the scale bar.

Figure F

Glacial Lakes of the Foster Creek Watershed

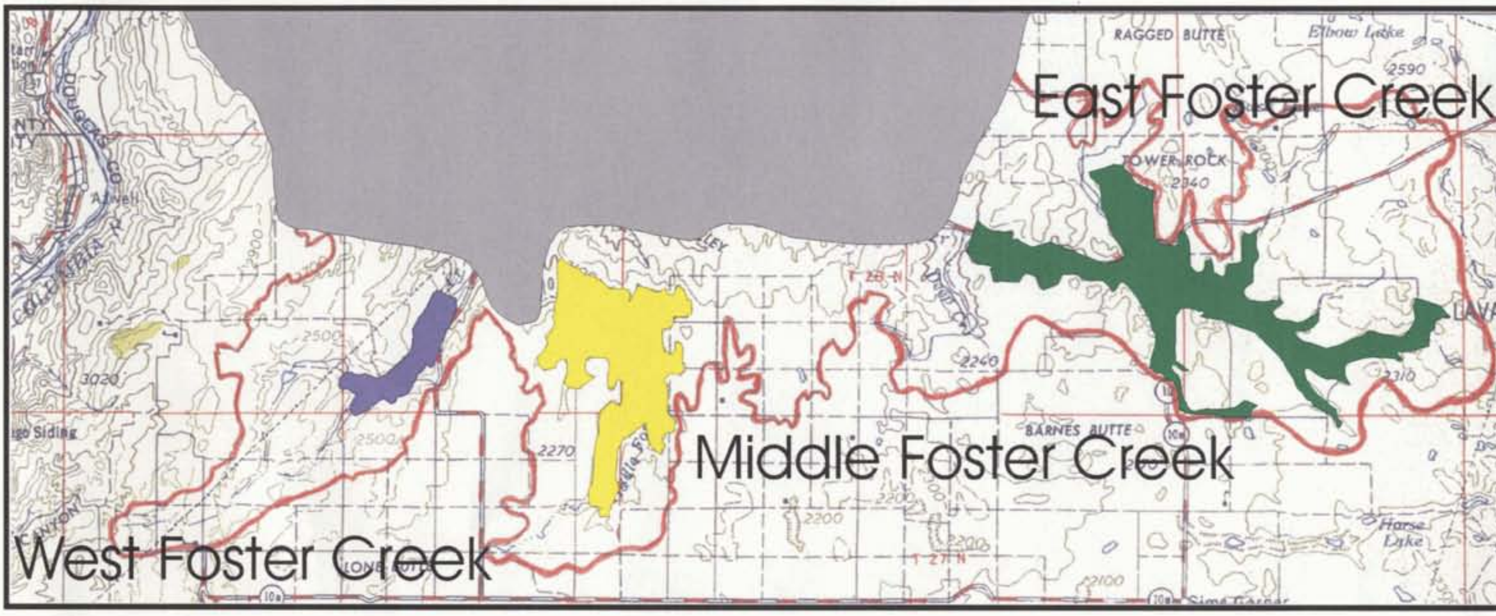


Legend

- Outline of the Foster Creek Watershed (red)
- Upper East Foster Creek (elev. 2124') (green)
- Upper Middle Foster Creek (elev. ~2100') (yellow)
- Upper West Foster Creek (elev. ~ 2220') (purple)
- Lower West and Middle Foster Creek (elev. ~1760') (orange)
- Mid East Foster Creek (elev. ~1920'-1940') (blue)

Figure G

Ice Dam Causing the Formation of the Upper Glacial Lakes

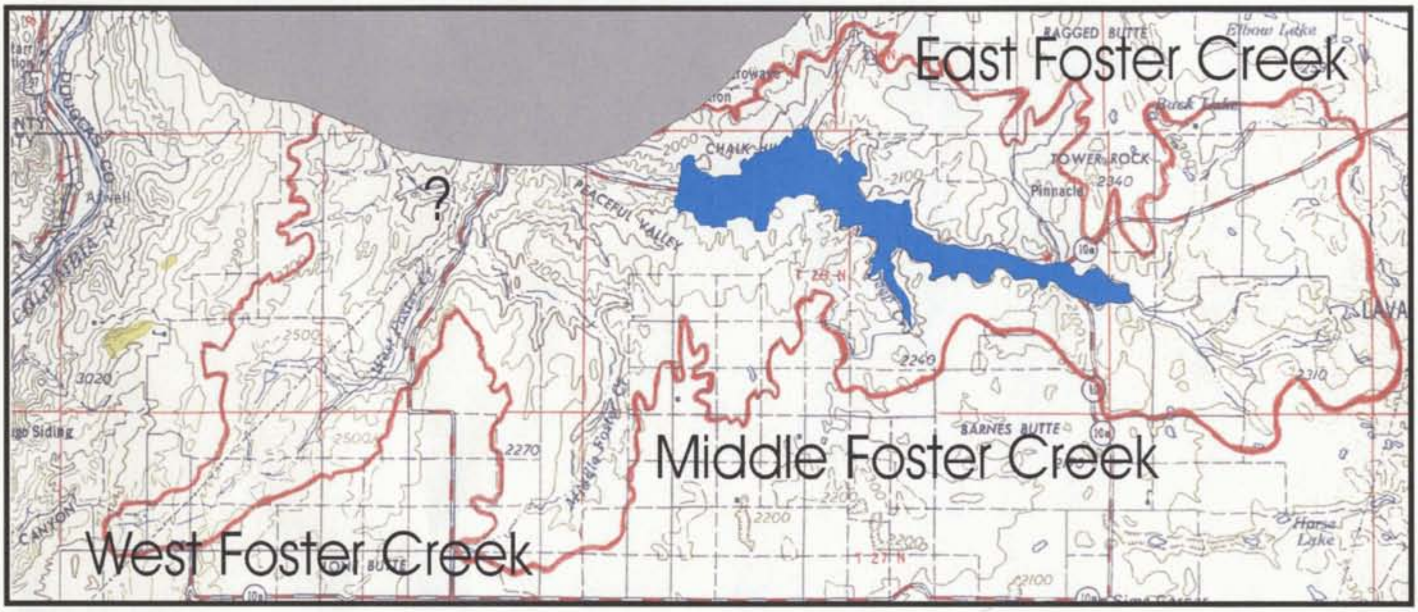


Legend

- Outline of the Foster Creek Watershed
- Upper East Foster Creek lake (elev. 2124')
- Upper Middle Foster Creek (elev. ~2100')
- Upper West Foster Creek (elev. ~ 2220')
- Ice Dam (created the upper elev. Lakes)

Figure H

Ice Dam Causing the Formation of the mid East Foster Creek Glacial Lake

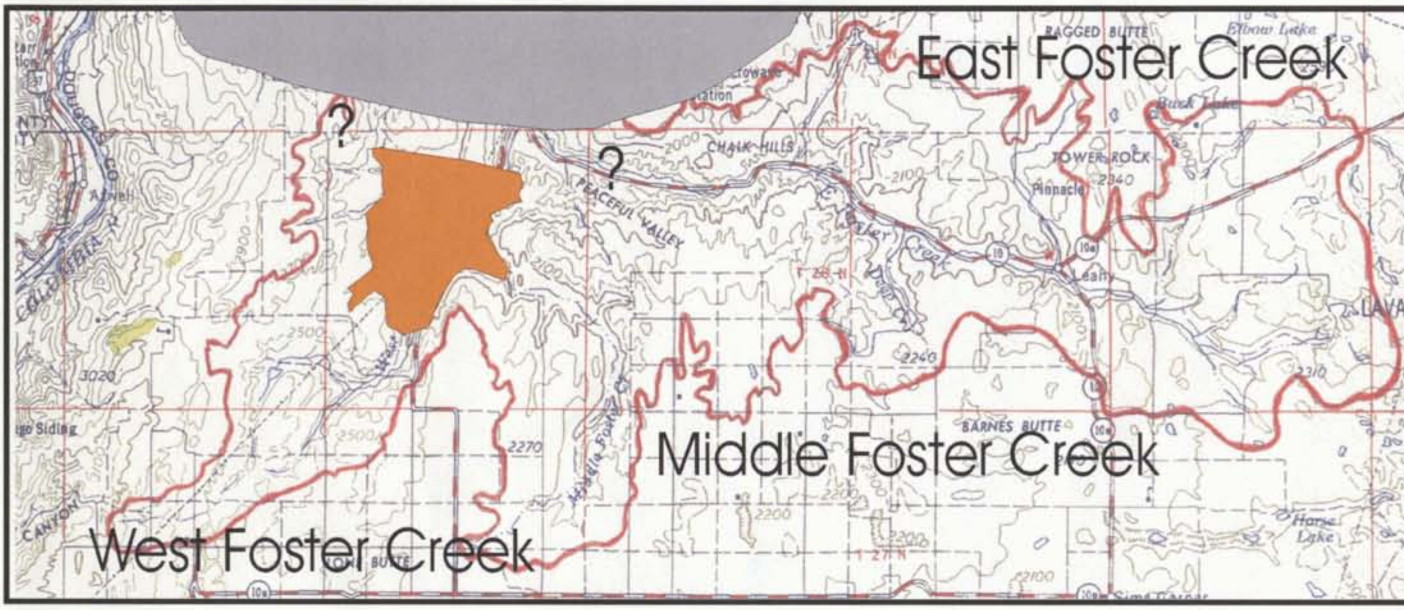


Legend

- Outline of the Foster Creek Watershed
- Mid East Foster Creek elev. ~1920-1940'
- Ice Dam (created the mid elev. Lake)

Figure I

Formation of Lower West and Middle Foster Creek Glacial Lake



Legend

(red)	Outline of the Foster Creek Watershed
(orange)	Lower West and Middle Foster Creek elev. ~1760'
(grey)	Ice Dam (created the low elev. Lake)

Future Research:

Based on my research I suggest the following further research in the Foster Creek Watershed.

- Digitizing the mapped glacial lake extents to calculate the lake volumes using GIS
- Research directed at the location of the ice dams
- Research directed at arroyo incision and the formation of the badland topography
- Dating lacustrine deposits using organic layers and tephra to determine age of the glacial lakes and Okanogan Lobe's recession off the Waterville Plateau.

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