2. DESCRIPTION OF GEOLOGY

SECTION 2
DESCRIPTION OF GEOLOGY

2.1 PHYSIOGRAPHY

The Coeur d'Alene planning area is located in the Northern Rocky Mountain Physiographic Province. The western edge of this province is further divided into the Tri-state Upland Section in and around Lewiston and Grangeville, Idaho. Farther south the Seven Devils Section is east of the Snake River and west of the Salmon River and extends from Riggins south past Cascade. The physiography of the region is shown in **Figure 2-1.**

The Northern Rocky Mountain Physiographic Province within northern and central Idaho consists of a rather ill-defined system of northerly trending mountains and broad upland plains that is bordered by the Snake River on the west and the Continental Divide on the east. This complex of mountains includes the Bitterroot, Coeur d'Alene, St. Joe, Cabinets, Purcell, Selkirk, and Seven Devils Mountains. Mountain peaks in the central and northern panhandle of Idaho are generally at altitudes of 7,000 feet or less, with deeply incised rivers and rugged topography that has been accentuated by glaciation. Northern Idaho is in the drainage basin of the Columbia River, with most of it drained by the Snake, Salmon, Clearwater, St. Joe, Coeur d'Alene, Pend Oreille, and Kootenai Rivers.

The broad upland plains form the western slope of the Northern Rocky Mountain Physiographic Province and include the Tri-state Upland Section, which extends from Grangeville in the southeast to Coeur d'Alene in the north. These broad uplands sections are generally low rolling topography at an altitude of about 3,000 to 4,000 feet, with locally higher hills extending above the plain. This subdued erosional feature is caused by the relatively flat Columbia River basalt flows that predominate this area. The elevation at Lewiston where the Snake River flows out of the state is around 700 feet and represents one of the lower altitudes in the state.

The rugged Seven Devils Physiographic Section is in the southern part of the planning area, extending from the Little Salmon River around Riggins, Idaho westward to the Snake River along the Oregon border. Hells Canyon is a unique physiographic feature that represents the deepest gorge in North America, with topographic relief of over 7,000 feet from the peaks in the Seven Devils Range to the bottom of the canyon. This is related to the resistant older volcanic terrain that was accreted to the North American continent and the extensive downcutting by the Snake River as the Rocky Mountains rose during the Plio-Pleistocene Epoch.

In the northern panhandle of Idaho the Purcell Trench represents a long narrow valley surrounded by the rugged Selkirk Mountains on the west and the Purcell and Cabinet Mountains on the east. The floor of the valley north of Sandpoint is well-defined and relatively flat, whereas further south toward Coeur d'Alene it becomes more diffuse and irregular in shape and relief. This physiographic difference is due to the nature of the geological forces that shaped the valley—to the north it is an erosional feature where glaciers emanating in Canada scoured out the valley, whereas to the south floodwaters from Lake Missoula deposited large amounts of fluvio-glacial material, forming the hummocky and irregular Rathdrum Prairie.

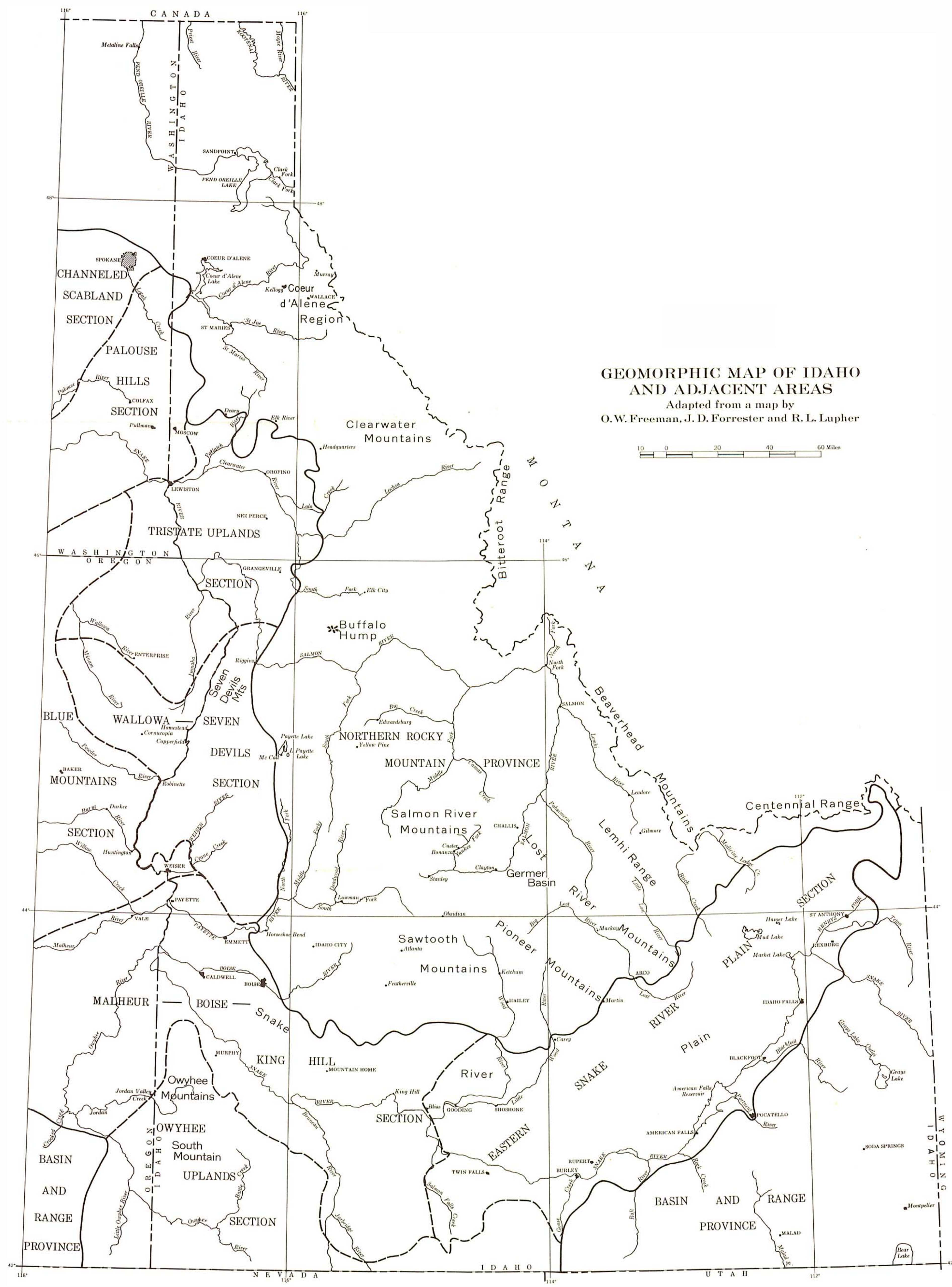
The distinct physiographic character of the planning area is a direct reflection of the geologic differences in rock types, structure, and chemical and physical weathering of the underlying rocks.

2.2 General Stratigraphy

The layered sedimentary rocks of the planning area represent many geologic ages, ranging from Precambrian to Recent. The distribution and character of these rocks are reflected in the variable topography of the region and significantly influence human activity and the environment. These layered rocks, along with the igneous and metamorphic rocks, exert a strong spatial influence on the nature and location of the mineral resources of all types throughout the region. The distribution of the rock units that underlie the state is shown in a generalized geologic map of Idaho (**Figure 2-2**) (US Geological Survey 1964). A detailed geologic map of the planning area is presented in **Figure 2-3** and shows the distribution of lithologic units rather than time stratigraphic units. The stratigraphic names commonly used in various parts of the planning area are outlined in **Figure 2-4** (US Geological Survey 1964).

2.2.1 Precambrian Era

The oldest rocks in the planning area are of Precambrian age and consist of an older highly metamorphosed unnamed sequence and a younger Belt Super Group. The older gneissic rocks, consisting of mica schist and gneiss, are found on the west side of Boundary, Bonner, and Kootenai counties, where



Source: Ross, PR and Forrester, JD 1958

Physiographic Provinces of Idaho

U.S. Department of the Interior
Bureau of Land Management

Figure 2-1

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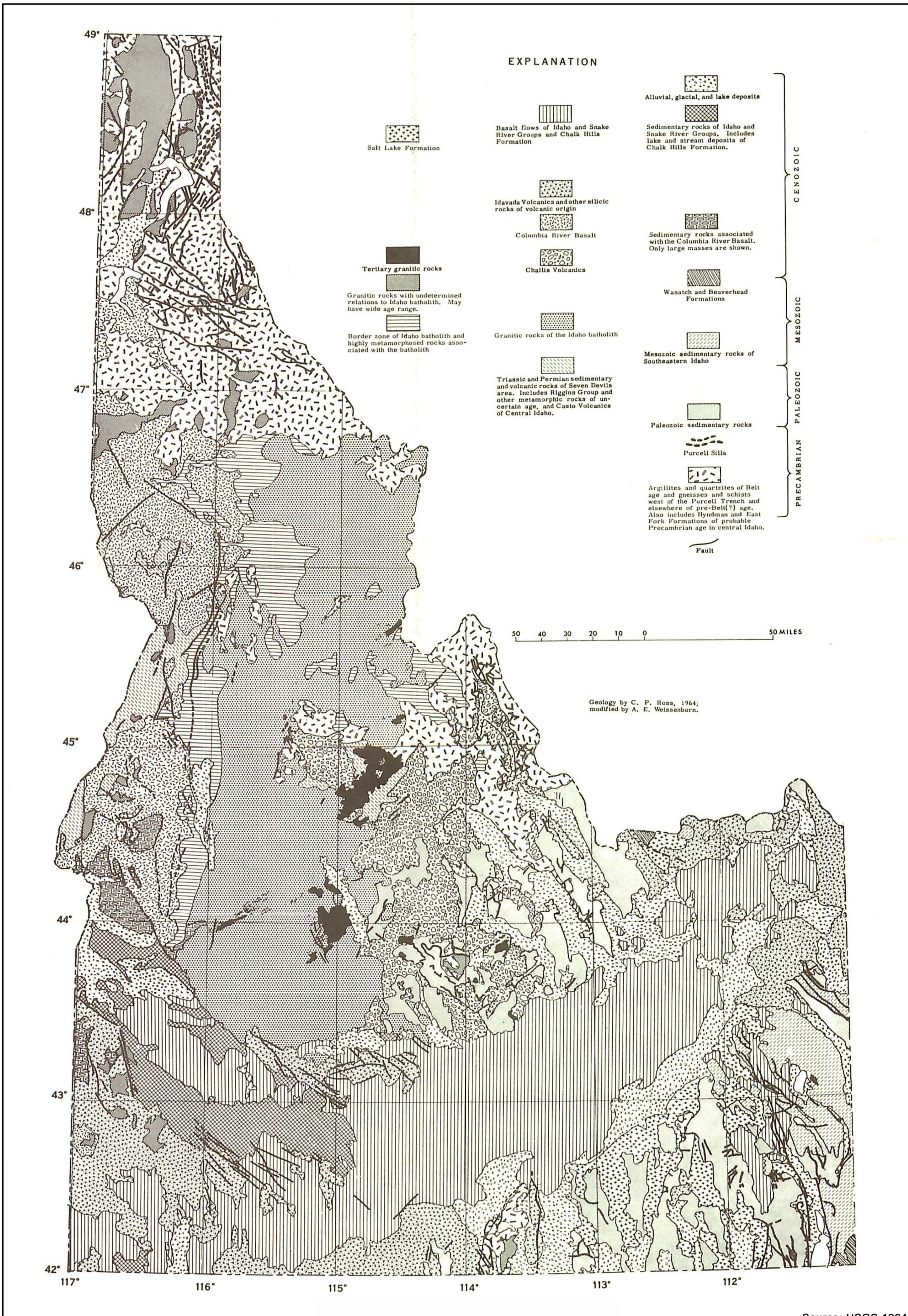

Generalized Geologic Map of Idaho

U.S. Department of the Interior
Bureau of Land Management

Figure 2-2

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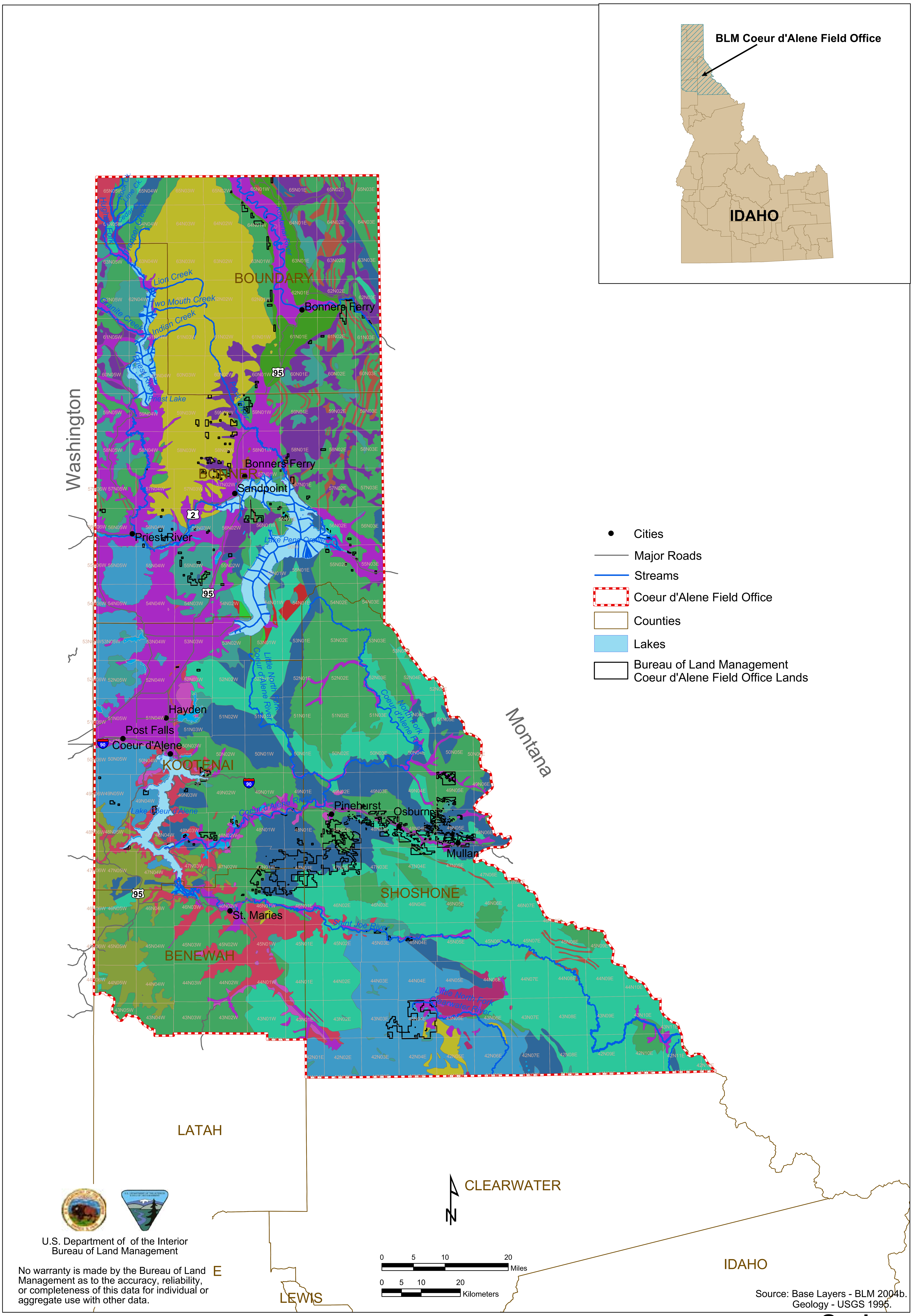

Geology

Coeur d'Alene Field Office, Idaho

Lithology

- alluvium
- argillite and slate
- calc-alkaline intrusive
- carbonate
- glacial drift
- granite
- granitic gneiss
- interlayered meta-sedimentary
- lake sediment and playa
- loess
- mafic intrusive
- mafic schist and greenstone
- mafic volcanic flow
- meta-conglomerate
- meta-sedimentary phyllite and schist
- meta-siltstone
- metamorphosed carbonate and shale
- sandstone
- shale and mudstone

Figure 2-3

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Figure 2-4 Correlation of Stratigraphic Names Commonly Used in North and Central Regions of Idaho

ERA	Period	*Epoch*	Pend Orielle and Purcell Trench	Coeur D' Alene	Orofino/Elk City/ Marshall Mountain	Riggins and Seven Devils
CENZOIC	**Quaternary**	*Holocene*	Alluvium	Allluvium	Alluvium	Alluvium
		Pleistocene	Glacial Deposits	Glacial Deposits	not present	not present
	Tertiary	*Miocene*	Columbia River Basalt/ Latah Formation.	not present	Colulmbia River Basalt	Columbia River Basalt/ Latah Formation
MESOZOIC	**Triassic - Permian**		not present	not present	not present	Lucile Slate/Hurwal Fm
			not present	not present	not present	Martin Bridge Limestone
			not present	not present	not present	Seven Devils Volcanics
PALEOZOIC	**Cambrian**		Lakeview limestone/ Rennie shale/ Gold Creek Quartz	not present	not present	not present
PRE-CAMBRIAN	**Proterozoic**		**Belt Super Group:**	**Belt Super Group:**	**Belt Super Group:**	**not present**
			Libby Fm	not present	Metamorphic gneiss, schist and quartzite located in roof pendents and border phases of the Idaho Batholith may be equivalent to the Belt Super Group rocks	
			Striped Peak Fm	Striped Peak Fm		
			Wallace Fm	Wallace Fm		
			St. Regis Fm	St. Regis Fm		
			Revett Fm	Revett Fm		
			Burke Fm	Burke Fm		
			Prichard Fm	Prichard Fm		

Source: U.S. Geological Survey 1964

Compiled by R.R. Reid and A.E. Weissenborn from various sources they are thought to be a part of metamorphic core complex. Other highly metamorphosed gneisses are present in the Clearwater and Elk City area, where they represent Proterozoic/Paleozoic meta-sediments and meta-igneous rocks along the margins and as roof pendants of the Idaho Batholith. Other highly metamorphosed rocks occur along a narrow corridor north and south of Riggins, where they form the Western Idaho Suture Zone, which represents the boundary between oceanic terrain of Paleozoic/Mesozoic age to the west in the Seven Devils region and the continental terrain of Precambrian to Mesozoic age in central Idaho.

Precambrian rocks correlated with the Belt Super Group of Proterozoic age are extensively exposed north of the North Fork of the Clearwater River, extending to the Canadian border along the east side of the Idaho panhandle. The series consists of a thick sequence of argillite, quartzite, and calcareous rocks that has been subjected to widespread low-grade regional metamorphism. Thickness of the Belt Super Group is estimated to be over 50,000 feet, but complex structural features, including low angle thrust faults active during the Cretaceous Period, have complicated the section. The rocks of the Belt Super Group are recrystallized to varying degrees but in general retain the appearance of sedimentary rocks. The Belt Super Group ranges in age from about a 1500 to 1100 million years, based on radiometric dates (Obradovich 1983).

The Belt Super Group rocks are extremely important for mineral resource potential within the planning area. The extensive lead/zinc/silver deposits of the Silver Valley are developed in quartzite units of the Revett and St. Regis formations. The gold-bearing quartz veins of the Murray Mining District are found in argillites and quartzite units of the Pritchard Formation. The strata-bound silver/copper deposits of the Spar Lake and Rock Creek deposits just across the border in northeastern Montana are formed in the Revett quartzite of the Belt Super Group. Decorative building stone has been identified and developed within various quartzite units, particularly where iron staining and lichen cover the white quartzite. Garnets weathered out of the upper Belt Super Group provide the source for the alluvial garnet deposits along Emerald Creek District in Latah County.

2.2.2 Paleozoic Era

Stratified rocks of Paleozoic age are almost nonexistent in the planning area, although they are extremely prevalent elsewhere in the eastern and central part of the state. Southeast of Lake Pend Oreille in Bonner County is a small area underlain by quartzite, shale, and limestone of Cambrian age that is the only known occurrence of rocks of this age in the planning area (US Geological Survey 1964). Rocks of Paleozoic age may have once covered the area but have since been eroded away, or may be a part of the metamorphic rocks of unknown age located around the margins and within the Idaho Batholith in central Idaho.

These rocks are of limited importance for mineral resource development because they are not found in the planning area, although limestone has been mined from these rocks in the past.

2.2.3 Mesozoic Era

In western Idaho, rocks of Mesozoic age include the Wallowa-Seven Devils terrain that consist of (1) intermediate to gabbroic plutonic rock with low metamorphic grade and Permian to Triassic in age; (2) basaltic to andesitic volcanic and volcaniclastic rocks of Triassic to Jurassic age; and (3) overlying Late Triassic to Early Jurassic carbonate rocks of the Martin Bridge Formation and fine-grained clastics of the Hurwal formation. The Wallowa-Seven Devils terrain is exposed throughout Hells Canyon and the Seven Devils Mountains west of Riggins, from Oxbow Dam northward to the junction of the Salmon and Snake Rivers. The Martin Bridge Limestone is exposed along the Snake River north of the Salmon River/Snake River junction and near Riggins. The Wallowa-Seven Devils terrain represents meta-volcanic and meta-sedimentary rocks derived from a volcanic island arc assemblage that was accreted to the western edge of North America in the Early Cretaceous Period around 118 million year ago (Maley 1987). The Western Idaho Suture Zone, represented by strongly sheared metamorphic schist and gneiss, extends in a northerly direction through Idaho County and northward along the Clearwater River. It represents the faulted boundary zone between the oceanic terrain to the west and continental terrains to the east.

The mineral resource importance of the Wallowa-Seven Devils terrain centers on the volcanogenic copper-zinc-gold deposits found within the Hells Canyon region. Quartz-gold lodes occur intermittently along the Western Idaho Suture Zone. Limestone of the Martin Bridge Formation may be important as a source rock in developing commercial limestone facilities.

2.2.4 Cenezoic Era

The Cenozoic Era began about 65 million years ago and includes two distinctly different geologic episodes that sculptured the modern landscape within the planning area. These two episodes include the Tertiary Period, with a widespread outpouring of the Columbia River Basalts, and the Quaternary Period, producing glacial landscapes and depositing extensive sand/gravel material. Uplift and erosion during this period accentuated the rugged landscape of Northern Idaho and downcut the Snake River, which formed Hells Canyon.

2.2.4.1 Tertiary System

A large part of west-central and northwestern Idaho is covered by volcanic flows of the Columbia River Basalt of Miocene and Pliocene Age (17 to 6 million years). These volcanic flows and interbedded volcaniclastic sediments are several thousand feet thick and cover much of the underlying rock units in the planning area. Intercalated within the volcanics and in places adjacent to them are freshwater fluvial and lacustrine sediments that produced clay stone, rich fossil localities, and small discontinuous coal lenses. The Columbia River Basalts were erupted from a series of northerly trending fissure zones along the Oregon-Idaho border and form much of the flat upland terrain, such as the Camas Prairie and the Palouse country around Moscow, Idaho.

The Columbia River Basalts are an important source of construction stone, crushed aggregate, and decorative stone for landscaping, particularly around the population centers of Coeur d'Alene and Spokane. Deposits of various types of clay are found in the sedimentary units as by-products of the deep weathering that occurred during the Tertiary Period (US Geological Survey 1964). The Clarkia fossil beds represent a unique world-class fossil locality that yields extremely delicate and well-preserved specimens.

2.2.4.2 Quaternary System

The youngest rocks within the region are the Quaternary System, which includes the Pleistocene Epoch beginning about 2 million years ago and the Holocene Epoch about 10,000 years ago. The Pleistocene Epoch ushered in prominent glacial development that is evident in the northern Idaho panhandle as catastrophic flood deposits. The most prominent event is the Spokane Flood from ancient Lake Missoula that flowed southwestward from Pend Oreille, across the Rathdrum Prairie, and into the scablands of Eastern Washington. In northern Idaho the Purcell Trench and Rathdrum Prairie are filled with thick sand and gravel debris derived from the Lake Missoula floodwaters. Lakes of northern Idaho, such as Pend Oreille and Coeur d'Alene, are deep lakes formed by glacial scouring and deposition of reworked glacial material forming natural dams. The Spokane aquifer that provides the water source for much of the city of Spokane forms in the extensive sand/gravel fill that underlies the Rathdrum Prairie. Elsewhere water from Missoula Flood backed up along the lower Clearwater and Snake Rivers, depositing thick sections of light-colored clay for several miles upstream from the junction of these two rivers.

More recent Holocene material is formed as alluvium along the major streams and rivers that cut through the region. Much of this is reworked material deposited during the earlier Pleistocene Epoch, when rainfall and water flows were much higher than they are today. Evidence of the major Bonneville flood that occurred about 15,000 years ago along the Snake River is found in the scoured bedrock and eroded high terraces along the Snake River. Local physical and chemical weathering has concentrated heavy minerals and formed placer deposits in the alluvial material.

These younger deposits are important for mineral resources evaluation by forming the material for the important sand and gravel construction industry in northern Idaho, the commercial and recreation garnet development along Emerald Creek, and various placer deposits of gold and heavy minerals throughout the rest of the region. In addition, the very important Spokane aquifer underlying the Rathdrum Prairie in northwest Idaho is a critical water source for northern Idaho and eastern Washington.

During and following the ice age, the streams and rivers of Idaho carried a larger volume of water than they do now, enabling them to carry more sediment. The natural, enhanced river flow and the periodic floods scoured out many of the larger river canyons and increased the downcutting and erosion of the rivers and mountains, leaving the landscape that is present today. Extensive windblown loess deposits from residual fine-grained glacial material formed thick deposits in the Palouse country and on the flat prairies, which has created excellent soils for agricultural production in the region.

2.3 INTRUSIVE/EXTRUSIVE ROCKS

2.3.1 Proterozoic Age Intrusives

The Purcell Sills are sheet-like bodies of dark gabbro and diorite that intrude the Prichard and Aldridge Formations of the lower Belt Super Group in Boundary County, Idaho. Generally concordant relationships occur with the intruded meta-sediments; however, local small-scale discordance is evident. The multiple sills range from less than 3 feet to over 2,000 feet thick, and the intrusive zone can be traced over 50 miles in length in the northeast Idaho panhandle. Sills greater than 300 feet thick display a differentiated mineralogical and chemical pattern, with elevated concentrations of Zirconium, Hafnium, and Thorium that produce zircon and rare thorite. A mid-Proterozoic radiometric age of 1320 m. y. has been obtained from the Crossport sill in Boundary County (Bishop 1973).

These sills are important as potential sources for thorium, which is used in the conversion to uranium as a future energy source. Other rare earth elements and cobalt/nickel may be concentrated in the Purcell sills.

2.3.2 Mesozoic Age Intrusives

The Idaho Batholith is a composite mass of granitic plutons that are exposed over an area nearly 250 miles long and 80 to 100 miles wide in central Idaho. It has an irregular shape and consists of two lobes. The northern Bitterroot lobe extends from central Idaho into Montana, and the southern Atlanta lobe occupies most of central Idaho. The composition of the Idaho Batholith is highly variable and ranges from quartz monzonite to diorite, although it is dominantly granitic. In both lobes the western side is generally more mafic, and the east side is generally more granitic. Margins of the various intrusive phases are concordant with the surrounding wall rock and are generally sheared with gneissic texture. Pegmatite and aplite dikes with compositions similar to the enclosed intrusive were formed late in the plutonic phase and often follow zones of structural weakness. The dominant period of emplacement was about 75 to 100 million years ago (Maley 1987) during the Early to Middle Cretaceous Period, as represented by a number of distinctive plutonic phases. Other smaller intrusive masses, such as the Kaniksu Batholith in the northern Idaho panhandle, are of similar age and composition and represent outliers of the main Idaho Batholith.

The Idaho Batholith is the primary source for most of the metal deposits developed in central Idaho, including the quartz-gold lodes of the Murray or Elk City Districts, and numerous smaller mining districts and mineral prospects in the region. Geothermal hot springs may be related to residual heat developed by the Idaho Batholith and possibly the Tertiary plutons, which raise the temperature of the water and circulate it to the surface through major fault zone conduits.

2.3.3 Tertiary Age Intrusives

Tertiary age plutons that intrude the Idaho Batholith have a different composition and appearance than the main batholith. These are roughly aligned north-south along the east-central part of the batholith and account for an estimated twenty percent of the exposed batholith. More than forty plutons of Tertiary Age have been identified in and near the Idaho Batholith; these plutons range from small dikes to moderate-sized plutons. An Eocene age of 42 to 50 million years (Maley 1987) is assigned to many of these intrusives, and some of these are considered the source of the Challis Volcanics in south-central Idaho. Characteristics of the Tertiary plutons include a pink coloration due to abundant potassium feldspar, narrow composition range of quartz monzonite to granite, miarolitic (gas) cavities, euhedral smoky quartz and feldspar in the cavities, and more than twice the uranium and thorium concentration as in the Mesozoic Batholith (Maley 1987). There is also a lack of foliation or gneissic borders along the boundary of the plutons, indicating a relatively shallow depth of emplacement, as compared to the main Idaho Batholith. In some areas the Tertiary plutons have caused an extensive convective hot water system that has created hydrothermal alteration in the surrounding wall rock and has deposited various metals.

Mineral deposits related to the Tertiary plutons, based on a spatial association, include gold, silver, lead, zinc, molybdenum, copper, tungsten, fluorine, barite, stibnite, beryllium, and uranium. In addition many black sand deposits containing gold, garnet, monazite, niobium, tantalum, and uranium may be originally derived from the Tertiary plutons (Savage 1961).

2.3.4 Tertiary Volcanics

The Columbia River Basalt Group of Tertiary age represents an extensive volcanic outpouring that covers an area of approximately 80,000 square miles in Oregon, Washington, and western Idaho. This is the largest volcanic event in North America and represents one of the few large plateau basalt eruptions in the world. In Idaho the basalts form three distinct embayments that flowed from the source area to the west: (1) the St. Maries embayment in and around Coeur d'Alene Lake; (2) the Clearwater embayment, a larger mass between Grangeville and Moscow, Idaho; and (3) the Weiser embayment, extending from Riggins southward to the Snake River Plain near Sweet, Idaho. Columbia River Basalts were erupted from a series of north-northwest trending fissure dikes in eastern Oregon, southeast Washington, and western Idaho. A wide variety of volcanic material was erupted, including massive basalt flows, tuffaceous units, pyroclastic material, and volcanic breccias that filled and enveloped the underlying bedrock. Extensive columnar basalt forms as cooling joints in the more massive flows, forming a distinctive six-sided column that creates attractive decorative stone.

Many of the flows along the eastern Clearwater embayment impounded streams and rivers forming local lacustrine deposits (Latah Formation) of clay and sand with a rich variety of fossils, such as the world famous Clarkia fossil beds (Smiley 1989). In some instances thin discontinuous coal seams were formed within swamps that developed as intervolcanic features. Most of individual flows are about 100 feet thick, but other massive units may be up to several hundred feet thick and flowed hundreds of miles due to the large volume of the basaltic magma. The Camas Prairie near Grangeville reflects a broad plateau surface developed on the flat volcanic surface of the Columbia River Basalts with local protrusions of underlying bedrock. Local source vents or fissure zones, paleotopography, volume of material in the flows, and deformation before and during the eruptive event control distribution of the basalt throughout the region. The Eastern plateau has been uplifted over 6,000 feet allowing for deep erosion by the Snake, Salmon, and Clearwater Rivers, which exposes a nearly complete volcanic section. Horizontal layering is evident in most areas except where modified by local structural elements as can be seen along the Snake, Clearwater, and Salmon Rivers, where the basalt volcanic layers overlie the underlying bedrock.

Landslides, slumps, and massive earth movements are influenced directly by the presence of flat-lying basalt flows overlying relatively impermeable rock units, such as the metavolcanics of the Wallowa-Seven Devils terrain. This feature creates a water-saturated surface that is prone to mass earth movements, particularly in steep topographic terrain along major river systems. Individual flows can be identified on a variety of petrologic, chemical, trace element, stratigraphic and magnetic polarity criteria. Radiometric age dates indicate that the eruptions occurred from 17 to 6 million years ago (Maley 1987).

The Columbia River Basalts are important to consider from a variety of viewpoints in management of the BLM lands within the region. This includes the presence of industrial mineral material, such as decorative stone for landscaping and crushed aggregate for surfacing local roads. Local clay deposits are developed within lacustrine units that occurred upstream from the basalt flows. Landslides are another consideration in overall land management, particularly where the basalt volcanics occur in combination with other geological factors that contribute to mass earth movements.

2.4 STRUCTURAL GEOLOGY

The west central and northern Idaho area is one of extreme structural complexity and has structural features ranging in age from Precambrian to nearly Recent. This includes fold and fault trends that are important in the development of mineral deposits associated with a variety of host rocks.

The Precambrian Belt Series formed in a broad basin or down-warp in northern Idaho, where several thousand feet of quartzite and argillite were deposited. Quartzites are the preferred host for the extensive lead-zinc-silver deposits of the Coeur d'Alene Mining District. The faults and fissures along the west-northwest trending Lewis and Clark shear zone are of equal importance in concentrating the mineralization. The Lewis and Clark shear zone is composed of separate discontinuous faults that collectively form a major intracratonic plate boundary in the northwestern United States. It extends for over 500 miles in length from central Montana to eastern Washington. Movement along this zone has created a number of important subsidiary fault zones in northern Idaho, including the Thompson Pass, Placer Creek, and Osborn faults. The Osborn Fault extends through the center of the Silver Valley and is important in creating subsidiary faults and fractures, controlling mineral deposits. It exhibits right lateral displacement of several miles based on offset of correlative structures. Faulting has been continuously active from the Precambrian thorough the Cretaceous Periods. Subsidiary faults and fractures between major fault zones preferentially concentrate the lead-zinc-silver in quartzite units within steeply pitching vertical extension zones. Deformation of the Belt meta-sediments is most intense in and near this zone, with the result that major mineralization is concentrated in the most highly folded zones. Understanding structural geology is of prime importance in evaluating the mineral deposits of the Silver Valley (Bennett et al 1989).

Another important structural feature is the Western Idaho Suture Zone, which extends northerly for over 150 miles, from New Meadows, Idaho to Orofino, Idaho (Hyndman 1989). It follows the Little Salmon River and ultimately curves along the Clearwater River, where it turns westward toward Lewiston and is covered by Columbia River Basalt. This is a narrow zone up to a few miles wide characterized by intense deformation and gneiss and schist, with local masses of serpentinite, indicative of a deep-seeded mantle origin. It represents the accreted boundary of the oceanic terrain to the west from the North American continental terrain to the east that was tectonically emplaced about 80 to 100 million years ago during the late Cretaceous Period (Hyndman 1989).

Local lode gold mineralization is associated with this zone, and some of the major rivers, such as the Little Salmon River and the Clearwater River, which contain placer gold and other heavy metal commodities, are located along this suture zone. Landslides occur along the steep slopes of the rivers and streams incised along the Western Idaho Shear Zone.

2.5 GEOLOGICAL HISTORY

The geological history of central and northern Idaho is complex and spans a long period from the Precambrian to the Recent. The dominant feature throughout most of the region is the Idaho Batholith, but other geological events have strongly shaped the terrain and provided the source for a multitude of mineral resources.

2.5.1 Proterozoic Era

The initial geological history is recorded in the thick sequence of meta-sediments of the Belt Super Group, which occupied a vast basin in northern Idaho and Western Montana as an extension of the sea to the west. Sedimentary rocks of the Belt Super Group formations range from about 850 to 1,450 million years (Maley 1987). Quartzite, argillite, and upper carbonate units dominated the basin sedimentation, indicating deposition in a relatively shallow environment that was continually subsiding at about the same rate as the sedimentation. Thickness of the sedimentary package is over 50,000 feet, however later thrusting during the Cretaceous Period complicates the picture. The Purcell Sills represent a period of significant intrusive activity that occurred about 1,300 million years ago, when gabbroic bodies invaded the Belt Basin sediments. The sedimentary section has been expanded several thousand feet by the intrusion, filling in along the bedding planes and lifting the overlying units. Middle Cambrian quartzites disconformably overlie the Belt rocks, indicating a significant period of erosion following deposition of the Belt sediments.

Possible pre-Belt age rocks of high metamorphic grade are exposed in the Elk City area. An age date of 1,500 million years was obtained on augen gneiss in this sequence (Reid et al 1970). The augen gneiss may represent an older Precambrian age plutonic complex that occupies the same site as the Cretaceous Idaho Batholith. West of Elk City and east along the Salmon River are exposures of probable pre-Belt age metamorphic rocks, but the association or age of these units is not firmly established.

2.5.2 Paleozoic Era

During the Paleozoic Era most of the area of central and northern Idaho is thought to have been a land mass, or structurally positive area, that stood above the seas and deposited sediments in the basins to the east and west.

Only one small exposure of Cambrian rocks with similarities to the units in northeast Washington has been positively identified in northern Idaho. Elsewhere in central Idaho, schist and gneiss preserved within the Idaho Batholith may represent the metamorphic equivalents of the Paleozoic and Proterozoic strata. However, positive identification is not possible due to the intensity of the metamorphic process that occurred at a much later time during emplacement of the Idaho Batholith and related Laramide Orogeny of late Cretaceous age. Therefore, the Paleozoic history of central Idaho remains unresolved until better correlation and age dating of the units can be completed.

2.5.3 Mesozoic Era

The Mesozoic Era was characterized by intense crustal deformation, accretion of exotic terrains, and the intrusion of the Idaho Batholith during the late Cretaceous Period. Most of the pre-Cretaceous rocks west of the Idaho Batholith represent a complex mixture of oceanic or island arc assemblages, termed the Wallowa-Seven Devils terrain, which were formed elsewhere and accreted to the North American continent between Late-Triassic and mid-Cretaceous time (Vallier 1967, 1977; Brooks and Vallier, 1978). The dismembered oceanic/island arc terrain has undergone intense deformation, creating a tectonic mélange of rock that ranges in age from lower Permian to Middle Triassic. The Western Idaho suture zone forms an abrupt near-vertical junction between the oceanic terrain to the west and the North American continental terrain to the east. According to Lund (1984) the suture was created by right lateral movement during the mid-Cretaceous that sliced off the western edge of the North American continent and carried in the exotic oceanic terrain, leaving it docked along the edge of the continent. Geological evidence indicates that the subduction zone related to the Laramide Orogeny was located slightly westward of the suture zone along the Idaho/Oregon border.

The strata-bound volcanogenic massive sulfide deposits in Western Idaho were formed at the same time as the enclosing meta-volcanics of the Wallowa-Seven Devils terrain. The relationship or ages of the other mineral deposits, such as lode gold or disseminated copper deposits, in this terrain is less evident and may be related to later intrusions of the Idaho Batholith or Tertiary Age plutons.

Intrusion of the Idaho Batholith during the middle to late Cretaceous Period represents a dominant episode in the geological history of central Idaho. Emplacement of the southern Atlanta lobe at 75 to 100 million years ago was slightly older than the northern Bitterroot lobe at 70 to 80 million years ago (Armstrong 1977). The batholith is a composite of a number of intrusive phases with slightly different composition, age, and metal association. According to Hyndman (1985), the more mafic tonalites on the west side of the intrusion were derived from oceanic rocks near the subduction zone, based on low Sr isotope ratios, low silica and potassium concentrations, high iron and magnesium, and up to 30 percent mafic minerals. The granodiorite and granite of the eastern side were derived from melting of the Belt Super Group or pre-Belt continental crust based on the high Sr isotope ratios, high silica and potash, abundant muscovite-orthoclase-quartz minerals, and zircons dated at 1700 to 1800 million years.

The western margin and interior of the Atlanta lobe contains large areas of meta- sedimentary and meta-volcanic rocks of unknown age, including those of the Elk City, Marshal Mountain, and Buffalo Hump Mining Districts. These include augen gneiss, amphibolite, quartzite, and gneiss/schist of variable composition. Estimated age of these high-grade metamorphic rocks ranges from Precambrian to Paleozoic, with evidence of a pre-Belt association in the augen gneiss that is dated at 1500 million years (Maley 1987). These rocks developed just above the zone of plutonic intrusion are high-grade gneisses and migmatites formed at depths of several miles, which has destroyed their original character or association. Therefore, the age of these units is conjectural.

Younger plutonic phases of early to mid-Tertiary age intrude the Idaho Batholith and surrounding metamorphic units. Composition of the intrusions is generally more felsic than the Idaho Batholith, ranging from quartz monzonite to granite. Radiometric ages of the intrusions are 42 to 46 million years, which is substantiated by some of the intrusions that cut the Challis Volcanics dated 40 to 50 million years.

Deformation in the mid- to late Cretaceous Period created folding and faulting in the sediments and volcanics of north and central Idaho. It is less evident within the relatively homogenous Idaho Batholith, although major drainage patterns, such as the St. Joe, Coeur d'Alene, and the Clark Fork Rivers, reflect the presence of underlying fault zones. In northern Idaho, the Belt Super Group has been warped into a series of broad folds that trend northwest and are cut by a series of low-angle thrust faults. Repetition of major units and stacked thrust faults are a result of this intense deformation, which has foreshortened the Belt Basin by a significant amount. North- or northwest-trending faults of similar age cut through the Idaho Batholith and the resistant Belt Basin meta-sediments. The significant Cretaceous structural feature in Northern Idaho is the prominent northwest-trending Lewis and Clark Line. It is probable that this and other similar fault zones represent old structural breaks of continental proportion that have had intermittent movement from the Precambrian to the Present time.

2.5.4 Tertiary Period

Outpouring of the Columbia River Basalts occurred in the Miocene Epoch from 6 million to 17 million years ago; however, most of this was erupted over 3.5 million years, from 13.5 to 17 million years ago. The individual volcanics filled valleys and depressions and covered several thousand square miles in a relatively short period of time due to the low viscosity of the basalt magma. Small short-lived lakes and swamps formed at the upstream end of the volcanic flows, where streams and rivers were dammed up with accumulation of organic debris, creating rich fossil beds and local lenticular coal seams. Intra-volcanic weathering of basalt and clay-stone of the Latah Formation produced residual and transported soil horizons that were converted to significant clay deposits. This intense deep-weathering cycle is called the Excelsior weathering period and is only recognized at one interval in the Columbia Basalt flow sequence. Other minor weathering cycles are present but are not as intense or as widespread as the Excelsior period.

2.5.5 Quaternary Period

Glaciation began about 2 million years ago in North America at the beginning of the Pleistocene Epoch. However, it was not until about 100,000 years ago that glaciers formed in southern Canada and began moving southward along the main drainages, such as the Kootenai River. Central and northern Idaho was subjected to alpine glaciation that created the rugged landscape during Pleistocene time. Northern Idaho was first covered by continental glaciation that covered the highest peaks to depths of a few thousand feet, followed by alpine glaciation that scoured out the river valleys. The continental ice sheets advanced and retreated several times as far south as the north end of Coeur d'Alene Lake. During the melting phases, thick deposits of sand and gravel were deposited at the downstream end of the glaciers as terminal moraines and outwash plains, creating Rathdrum Prairie and the Purcell Trench.

During this period an ice lobe blocked the Clark Fork River near the Idaho-Montana border to create the ancient Lake Missoula. The ice dam melted, producing catastrophic floods (Spokane Flood) that moved across Northern Idaho and the channeled scablands of eastern Washington. This process was repeated several times during the past 100,000 years, forming multiple flood deposits throughout the region (Maley 1987). Major lakes of northern Idaho, including the Pend Oreille, Coeur d'Alene, and other smaller ones, were created by the Pleistocene glacial activity that scoured out the basins, created the natural dams, and provided significant volumes of melt-water.

Recent alluvium is deposited along the streams and rivers of the region from weathered and reworked material produced since the latest Ice Age, which peaked about 20,000 years ago. During the current inter-glacial period, the runoff is much lower than during the last glacial event, creating rivers and streams that are undersized compared to the erosional features that they occupy.