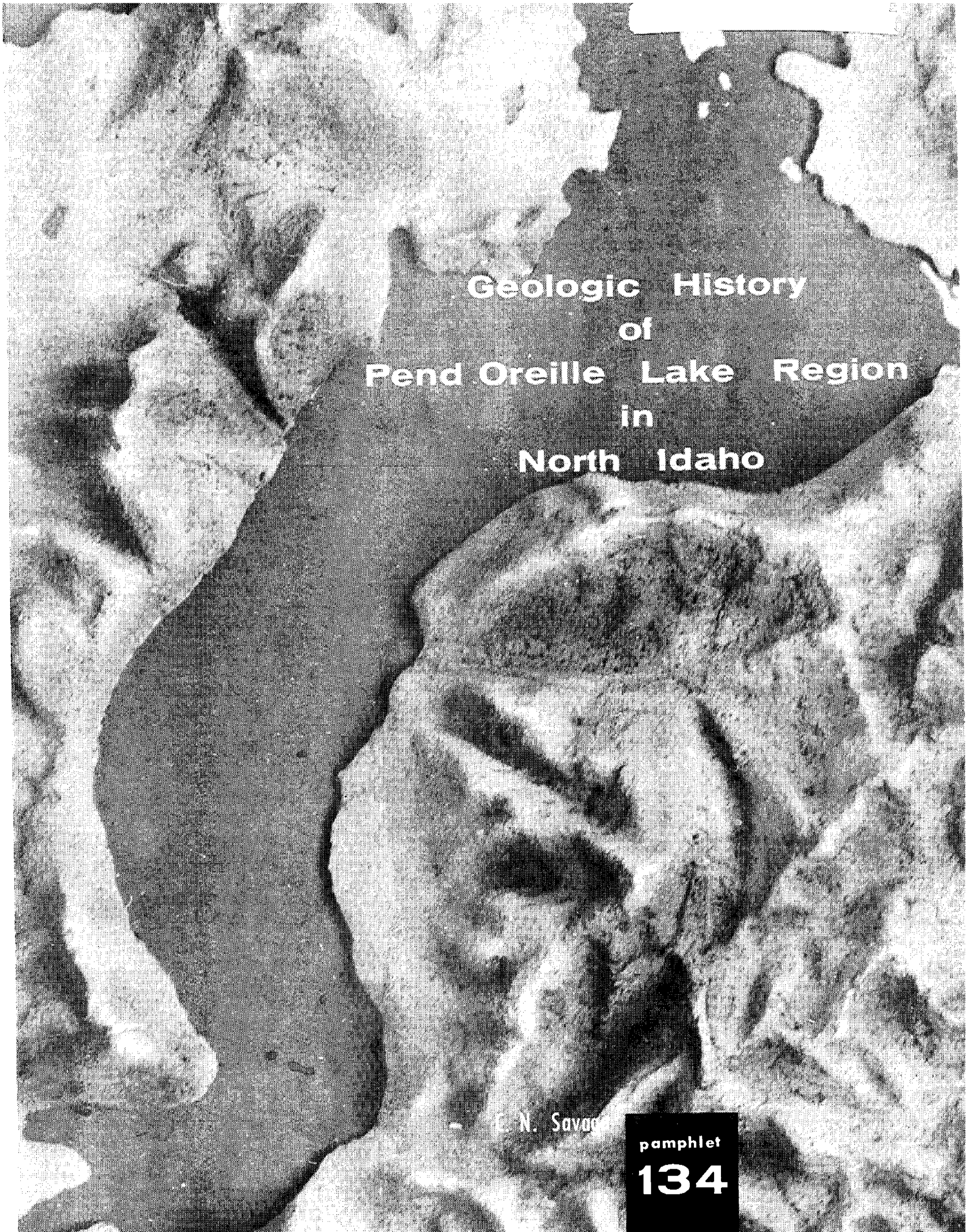
IDAHO BUREAU OF MINES AND GEOLOGY . . . R. R. REID, Director STATE OF IDAHO . . . ROBERT E. SMYLIE, Governor



Geologic History of Pend Oreille Lake Region in North Idaho

C. N. Savage

pamphlet 134

Idaho Bureau of Mines and Geology
Moscow, Idaho
July, 1965

Pamphlet 134 July, 1965

GEOLOGIC HISTORY OF PEND OREILLE LAKE REGION IN NORTH IDAHO

by

C. N. SAVAGE

IDAHO BUREAU OF MINES AND GEOLOGY

Moscow, Idaho

CONTENTS

TABLES

ILLUSTRATIONS *

*Cover from a photograph of a relief model by John Trumpeter, University of Idaho.

GEOLOGIC HISTORY OF PEND OREILLE LAKE REGION IN NORTH IDAHO

by

C. N. Savage

INTRODUCTION

Most people have a basic interest in natural history, that is, the nature of plant and animal life, and the origin of our physical environment. This physical environment includes a fascinating world of rocks, fossils, minerals, and landscape features that have evolved throughout geologic time. The record of these things is the record of the rocks and earth history, including both physical and biological events.

The purpose of this report is to present a somewhat simplified resume of the geologic history of northern Idaho in the vicinity of Pend Oreille Lake; a region visited annually by many hundreds of people seeking rest and recreation (Fig. 1). The following paragraphs were prepared principally for persons who have little training in the geological sciences, and technical terminology has been kept to a minimum; however, some technical terms have been used and explained in the text. It is hoped that this brief geological history will be of interest to all who enjoy outdoor life and natural history when they visit the Pend Oreille Region.

IDAHO AND ITS GENERAL GEOLOGIC SETTING

The landscape in Idaho is composed of major and minor landforms such as mountains, plateaus, plains, mesas, buttes, canyons, etc., all developed from very ancient to very recent rocks and rock materials (Fig. 2). Some of these rocks are soft and some are hard, and some have been deformed by folding or breaking (faulting). Because the rocks are soft, hard, massive, or layered, and because their attitudes may be horizontal, tilted or intensely folded, a broad range of resistance is encountered by the weathering and erosional processes.

Enormous spans of geologic time are available for landscape development. In fact, the rocks and structural foundations of Idaho originated more than two billion years ago; an unimaginable amount of time for man to comprehend. However, the actual sculpturing of the present landform features has taken place in a relatively short time (geologically speaking); that is, about 70 to 75 million years. Even so, this span of time is still more than 10,000 times the length of history as recorded by man.

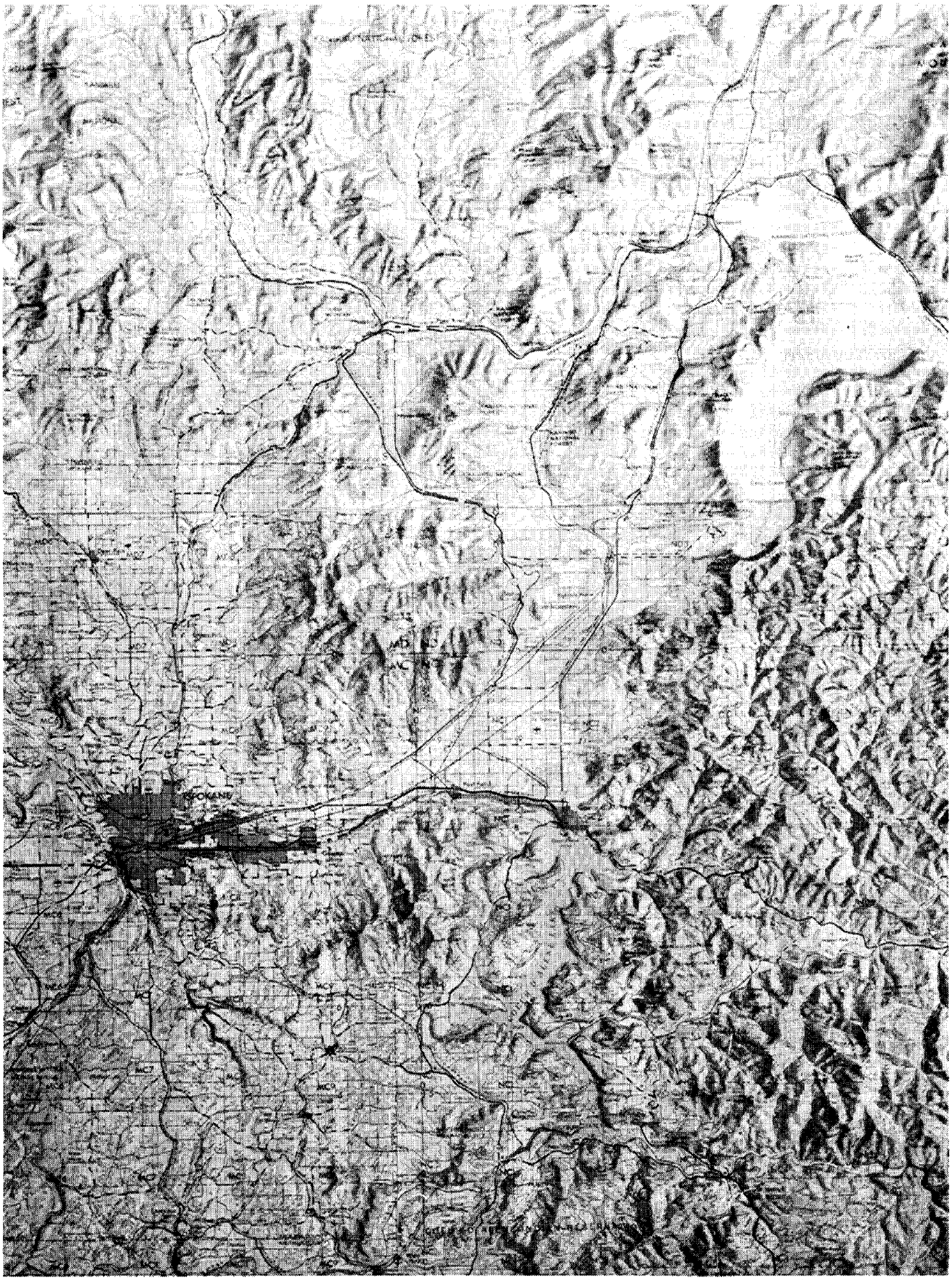


Figure 1. Relief map of the Pend Oreille Region

Geologic time is measured in terms of eras, subdivided into successively smaller units called periods, epochs, ages and subages; rocks representing these time units are referred to as rock systems, series, stages, and substages, respectively. Table 1 is a simplified general geologic time table.

Early Precambrian history in Idaho is indistinct and difficult to reconstruct; however, it may be safely stated that more than one shallow, marine sea slowly expanded from deeper outlying oceans, submerged the surface of the land, and flooded large areas with salt water. Just as slowly the floods receded leaving a variety of accumulated sedimentary rock materials behind. These layered strata consisted of mineral and rock particles derived from the weathering and erosion of elevated lands or source areas. Such layers or beds included clay, silt, sand, and gravel, and also included limy precipitates resulting from marine processes. In time these sedimentary materials were greatly consolidated and cemented by pressure and chemical changes, until they became firm sedimentary rocks (Fig. 3). Such rocks are called shale, siltstone, limestone, sandstone, and conglomerate and they are formed from clay, silt, lime, silica sand, and gravel, respectively.

In some areas, because of increased heat and pressure, and deep crustal activity, hot, liquid rock (called magma) moved from lower regions of the crust into overlying cold, solidified country rock. These liquid invasions commonly cooled before reaching the surface and remained in the crust as large rock masses called batholiths, and smaller intrusive bodies called stocks and dikes (Fig. 4). Hot magma that succeeded in reaching the surface came forth as lava flows and hot to cold fragmental particles called pyroclastics (ash, cinders, and blocky fragments). These once molten rocks are all called igneous rocks (Fig. 2).

In some localities, following an invasion of igneous rocks, late stage liquids and gases produced valuable minerals that were precipitated in openings or replaced adjacent rocks and minerals. Locally these mineral concentrations have included valuable gold, silver, lead, copper, zinc, iron and tungsten ores. Idaho's world-famous Coeur d'Alene lead, zinc, and silver deposits, just south of the Pend Oreille region are an example of such mineralized belts. Minerals of potential value also occur in the Pend Oreille region itself.

As a result of repeated changes in environment, principally variations in heat and pressure within the earth's crust, many of the older rocks in Idaho were altered. Alteration and the addition of new minerals commonly produced hard crystallines or metamorphic rocks. The metamorphic rocks included those called argillite, siltite, quartzite, marble, schist, and gneiss (Figs. 5 and 6).

During the Paleozoic and Mesozoic Eras (Table 1), again seas repeatedly encroached on, and retreated from many of the land areas of Idaho. Locally, some of

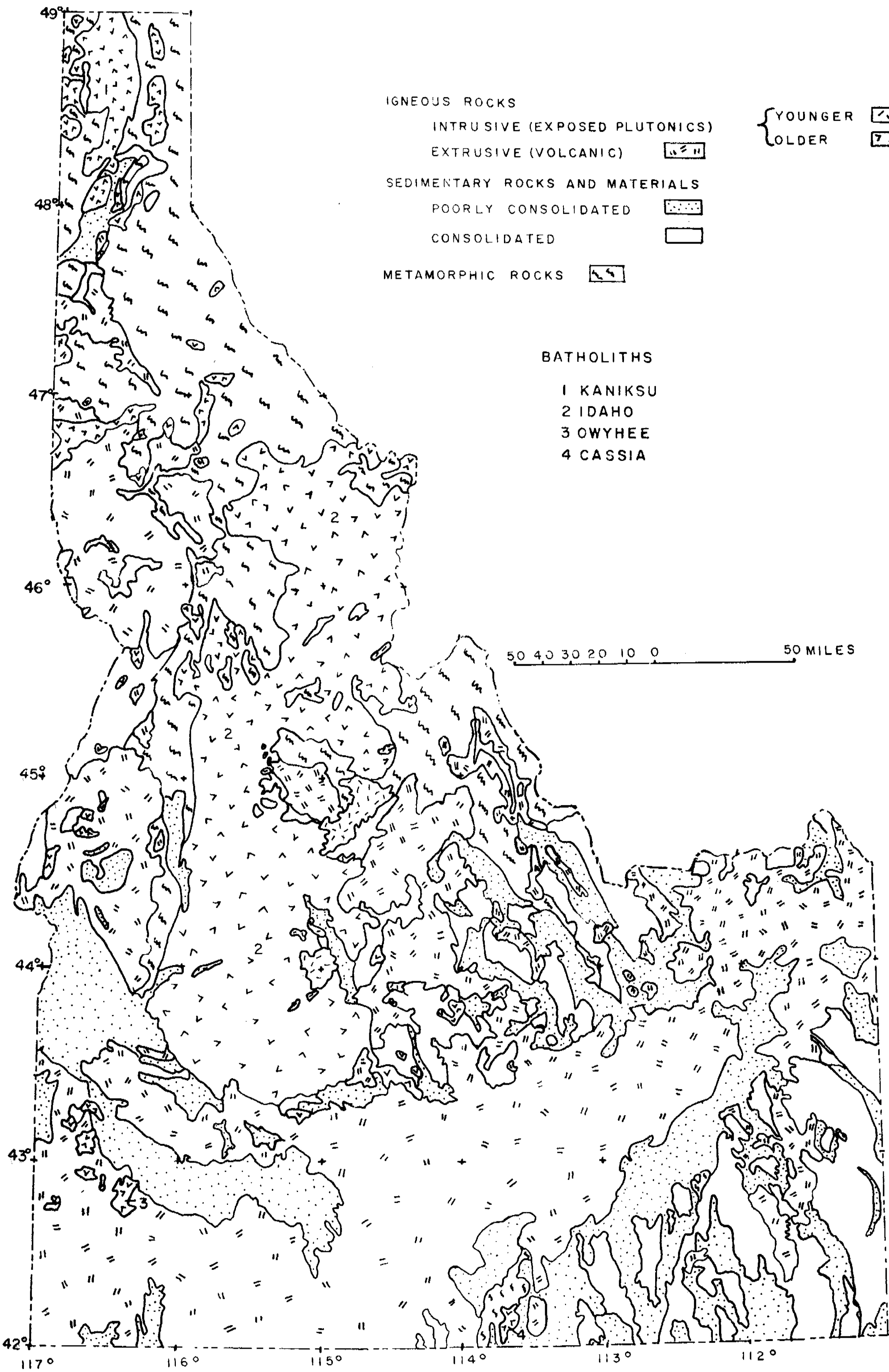


FIGURE 2. GENERAL DISTRIBUTION OF ROCK TYPES STATE OF IDAHO (PACIFIC NORTHWEST)

TABLE 1. Geologic time table

(*Time in millions of years duration)

ERA	PERIOD	EPOCH	
		Recent Pleistocene	"Quaternary"
CENOZOIC (63 plus m.y.*)	Neogene	Pliocene Miocene	"Tertiary"
	Paleogene	Oligocene Eocene Paleocene	
MESOZOIC (167 m.y.)	Cretaceous Jurassic Triassic		
PALEOZOIC (370 m.y.)	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian		
PROTEROZOIC ARCHEOZOIC	Precambrian (3.5 to 4 billion years duration)		

Fig. 3. Layered or bedded sedimentary rocks (Wallace Formation) with an algal reef structure, east of Clark Fork.

Fig. 4. Fine-grained granitic rock (aplite) in a dike cutting through coarse-grained granitic rock (granodiorite) of the Kaniksu batholith northwest of Trestle Creek, Bonner County.

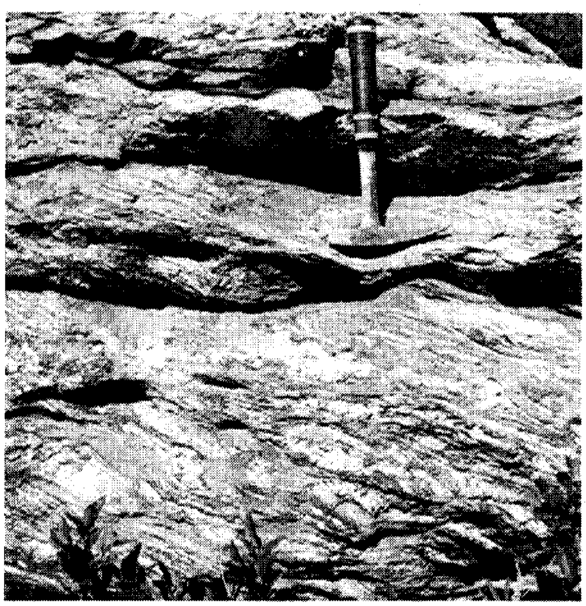


Fig. 5. Banded metamorphic rock (gneiss) on Sundance Mountain west of Sandpoint.

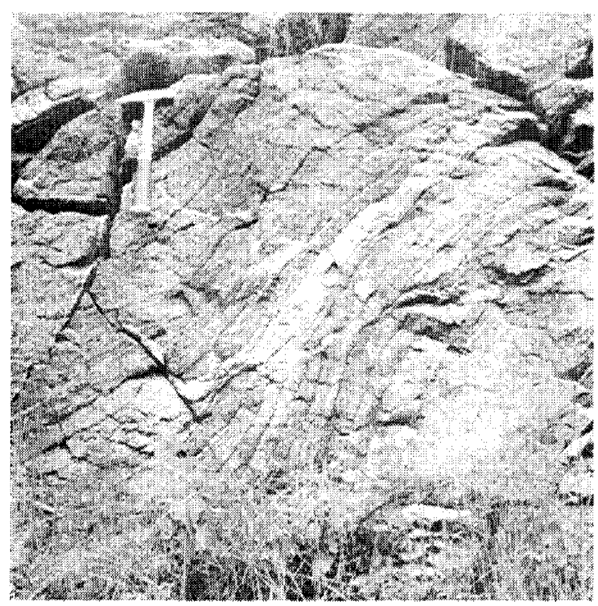


Fig. 6. Highly contorted gneiss west of Sandpoint.

the earlier older Precambrian rocks were uplifted, weathered, and eroded. The erosional products formed conglomerates, sandstone, shales, and limestones which now represent the Paleozoic and Mesozoic Eras of geologic time. As crustal disturbances and upheavals became more frequent, volcanism occurred in western Idaho in the Seven Devils region and in the region to the north near Orofino. This took place in the latter part of the Paleozoic Era (Permian Period). In Middle and Late Mesozoic time the earth's crust beneath Idaho was injected by great masses of magma which did not rise to the surface, but cooled at depth to form granitic rock types; for example, batholiths, stocks, and dikes. Igneous rocks of this kind were emplaced in both south and north Idaho, while the entire central portion of the state was injected successively by igneous rocks; a mass that collectively is called the Idaho batholith (Fig. 2).

Several years ago the ages of these batholithic rocks were investigated by the lead-alpha radioactive isotope method of rock dating, and the results suggested that the batholith rocks averaged about 106 million years in age. However, the actual range in ages suggests that as a whole the batholiths originated over a span of time ranging from the Cretaceous to the Cenozoic (Table 1). In North Idaho granitic rocks of batholithic type are called the Kaniksu batholith (Fig. 4). These and the rocks of the Idaho batholith have been exposed at the surface as a result of late crustal uplift and erosion on a grand scale.

The Cenozoic, or most recent geologic era, is associated with increasing crustal uplift, folding, and faulting (breaking) of the rock systems of earlier ages. In fact, during the transition from Mesozoic to Cenozoic time, regional folding and thrust faulting deformed Precambrian, Paleozoic and Cenozoic rocks in many parts of Idaho. Streams and river drainage patterns have shifted and changed continually. Geological evidence based on a study of Idaho's rocks and topography suggests that principal early drainage of the state was from north-central areas toward the north, and from south-central areas toward the south.

As the central part of the state lying over the Idaho batholith was elevated slowly, master streams developed, and eventually these drainage systems succeeded in deroofing and exposing large areas of the older batholith rocks, including those of central and northern Idaho. These commonly resistant rocks, among others, became the cores of some of the most rugged mountains of the Gem State. Examples are the Sawtooth and Salmon River Mountains of central Idaho. To the east in Idaho and Montana stand the peaks of the Bitterroot Range, locally formed because of the resistance of underlying batholith rocks. In other areas of Idaho resistant metamorphic rocks of Precambrian age have been sculptured into uplands such as the Beaverhead and Clearwater mountains.

In panhandle Idaho to the north, the beautiful Coeur d'Alene and Cabinet ranges are composed of Precambrian, slightly metamorphosed or altered rocks, called the Belt Series (Figs. 7 and 8). In northwest Idaho the spectacular Selkirk

Fig. 7. Packsaddle Mountain, Coeur d'Alene Range southeast of Pend Oreille Lake.

Fig. 8. East from Trestle Creek towards the highest mountains in Bonner County (7,000 ft elevation) in the Cabinet Range northeast of Clark Fork.

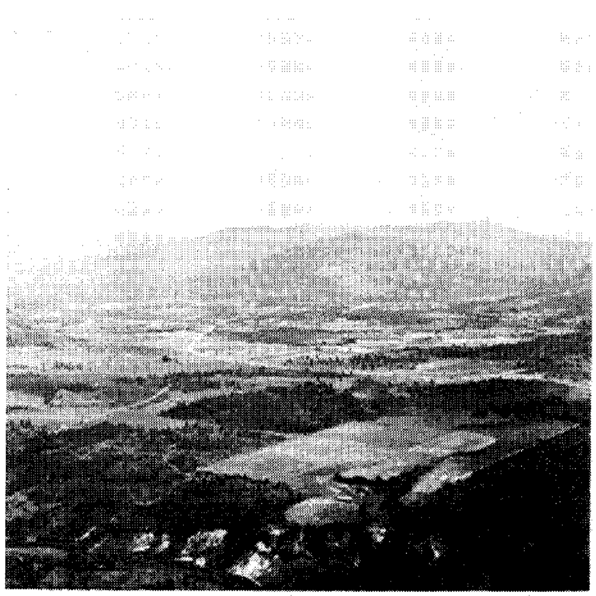


Fig. 9. Southern end of the Selkirk Range across Priest River valley.

Fig. 10. Upper Priest Lake with part of the Selkirk Range in the background.

Range is held up by the granitic rocks of the Kaniksu batholith (possibly related to the central Idaho batholith) (Figs. 9 and 10). In western Idaho one may observe the resistant metamorphic and volcanic rocks of the Seven Devils Mountains rising more than a mile above the deep and rugged reaches of Hells Canyon on the Snake River.

Southern Idaho is characterized by the huge Snake River Plain, an arcuate down-warped and downfaulted crustal segment with low relief that sweeps across the entire state from east to west. In southeastern Idaho this great plain breaks across a north-west-southeast trending mountainous region composed of folded and faulted Paleozoic and Mesozoic sedimentary rocks, including conglomerates, sandstones, limestones, and shales. Many of these rocks were deposited as sediments on the floors of the above described, long vanished seaways (Fig. 2).

Since late in the Paleozoic Era and through the younger Mesozoic and Cenozoic Eras, volcanic eruptions have been responsible for modifying much of Idaho's land-scape. In the Late Cenozoic volcanism waxed and waned intermittently in north, west, central and southern Idaho over a span of about 70 million years. Successive flows of lava have poured out of fissures and cracks or from central vents to build a most im-pressive shield-like surface called the Columbia Intermontane Plateau in eastern Washington and Oregon and in western Idaho.

The most recent volcanism in Idaho occurred along the Snake River Plain. For example, in the Craters of the Moon area of southeastern Idaho volcanism has oc-curred within the time of man. Probably American Indians witnessed some of the most recent volcanic eruptions in this area. There is no reason to believe that such vol-canism is over. Volcanism in the Pacific Northwest could occur again in the future, for this area lies relatively close to the active or live circum-Pacific "Ring of Fire." For example, several very recent earthquakes attest to the active nature of the crust in this belt. In summary, geological events of the Late Cenozoic Era, have included earthquakes, faulting, volcanism, uplift, and erosion which has continued through the Pleistocene Epoch (Table 2) into the Recent.

Many stream systems have been temporarily dammed or their direction of flow has been altered by geological events of the Cenozoic. During the Paleogene and Neogene periods, local piedmont basins developed over pre-existing less-resistant rocks. These basins and elongate valleys were undoubtedly the result of crustal tension and faulting, as well as erosion along belts of softer rock. The drainage of such basins commonly was dammed by repeated local lava flows, faulting, glacial ice or glaciofluvial deposits, and landslides. Such dams resulted in ponding of water to form temporary lakes which in turn trapped volcanic ash from the atmosphere and alluvial debris from the streams. These lake sediments in North Idaho are referred to as the Latah sedimentary members of the "Tertiary" Columbia River Group of lava flows. In other parts of Idaho similar lake beds have been called the Idaho-Payette

Formations (south and southwest) and the Salt Lake Formation (southeast).

Glaciation in central and north Idaho occurred in Early and Late Pleistocene time (Figs. 11, 12, 13 and 14). There is abundant evidence of earlier continental ice sheets and a late glacial episode which seems to have been limited to small valley and cirque-type glaciers. Such late mountain and valley glaciers formed in central and northern Idaho mountains. The subdivisions of geologic time representing the Pleistocene ice age in Idaho are as follows (Table 2):

TABLE 2. Subdivisions of Pleistocene time

Late Wisconsin Age (Stage)
  Temple Lake glaciation (Subage)
    Largely alpine glaciers in the highest mountains
  Pinedale glaciation
    Continental glaciation, for example, Priest River, Laclede, Cocolalla, Pend Oreille, and Clark Fork sublobes of glacial ice (Fig. 15)

Early Wisconsin Age
  Bull Lake glaciation
    Spokane glaciation, associted with the Spangle and Rathdrum lobes of continental glacial ice (Fig. 15).

Pre-Wisconsin glaciation
  Buffalo and earlier phases
    (Not yet definitely recognized in area)

By the Pleistocene Epoch topographic relief in Idaho was probably about as it is today. Evidence of the above mentioned relatively recent mountain glaciation extends downward to elevations of 5,500 and even 5,000 ft above sea level in many places; in a few localities indistinct traces of glacial ice action may be recognized as low as 4,000 ft elevation.

In North Idaho a continental ice mass moved toward the south from lobate centers of the Canadian ice fields. Maximum expansion of the ice was about as far south as the north end of Coeur d'Alene Lake. From time to time all of the Pend Oreille Lake region was covered with considerable thicknesses of glacial ice. Geological evidence indicates that these glacial episodes were repeated more than once, for example, as ice nourishment fluctuated with climatic changes in the source areas to the north.

Some of the latest Cenozoic geologic history in Idaho, characterized by major drainage derangements and innumerable changes in stream flow (or regimen), have resulted from those changing climates; that is, with the changing glacial and interglacial phases of the Pleistocene. Such drainage changes are everywhere apparent, but

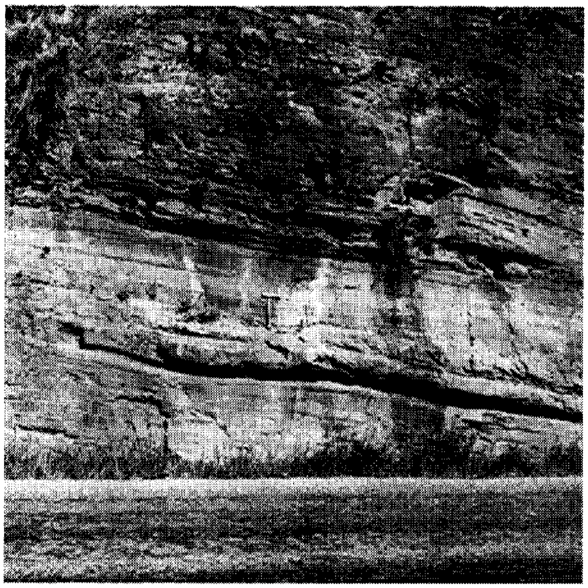


Fig. 11. Grooves and striations eroded by rock debris held in glacial ice as it moved past a rock wall east of Clark Fork.

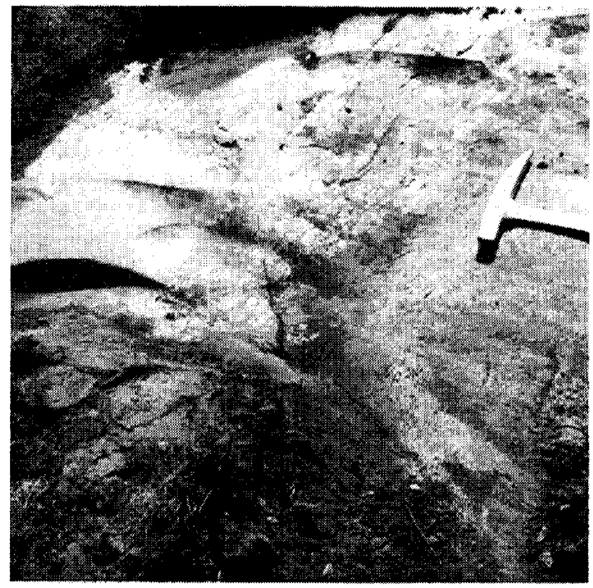


Fig. 12. Grooves, fluting, and glacial pavement produced by erosion as glacial ice swept over the bedrock northeast of Priest River.

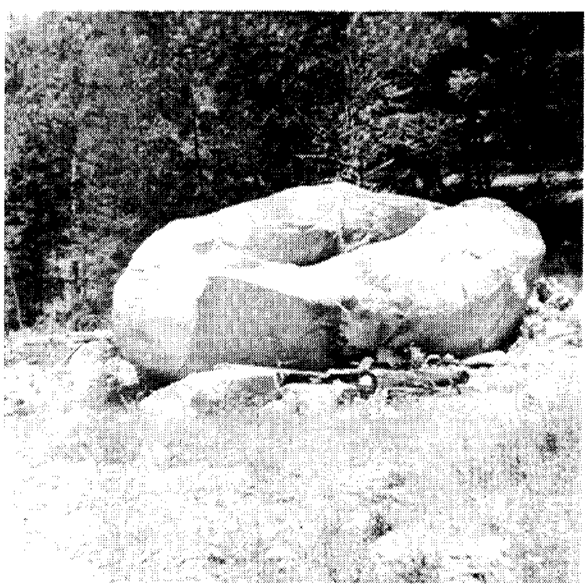


Fig. 13. Granodiorite boulder or erratic transported by glacial ice from the Selkirk Mountains south to a point just north of Laclede.

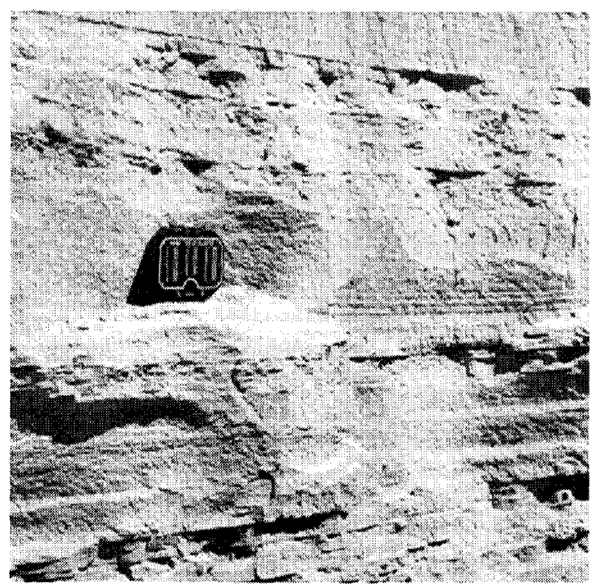


Fig. 14. Fine laminated (layered) sand and silt of glacial meltwater origin, east side of Priest River valley.

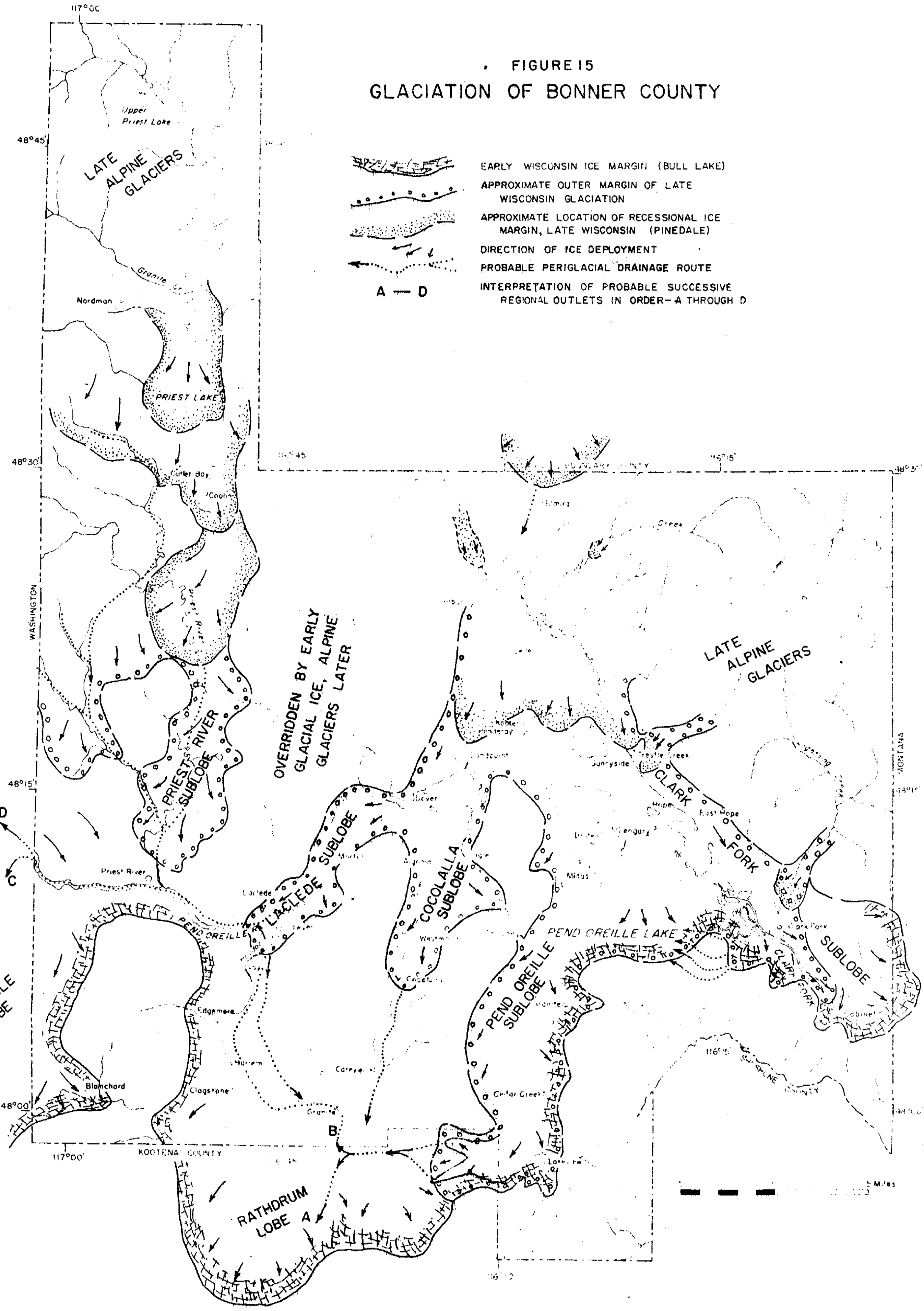
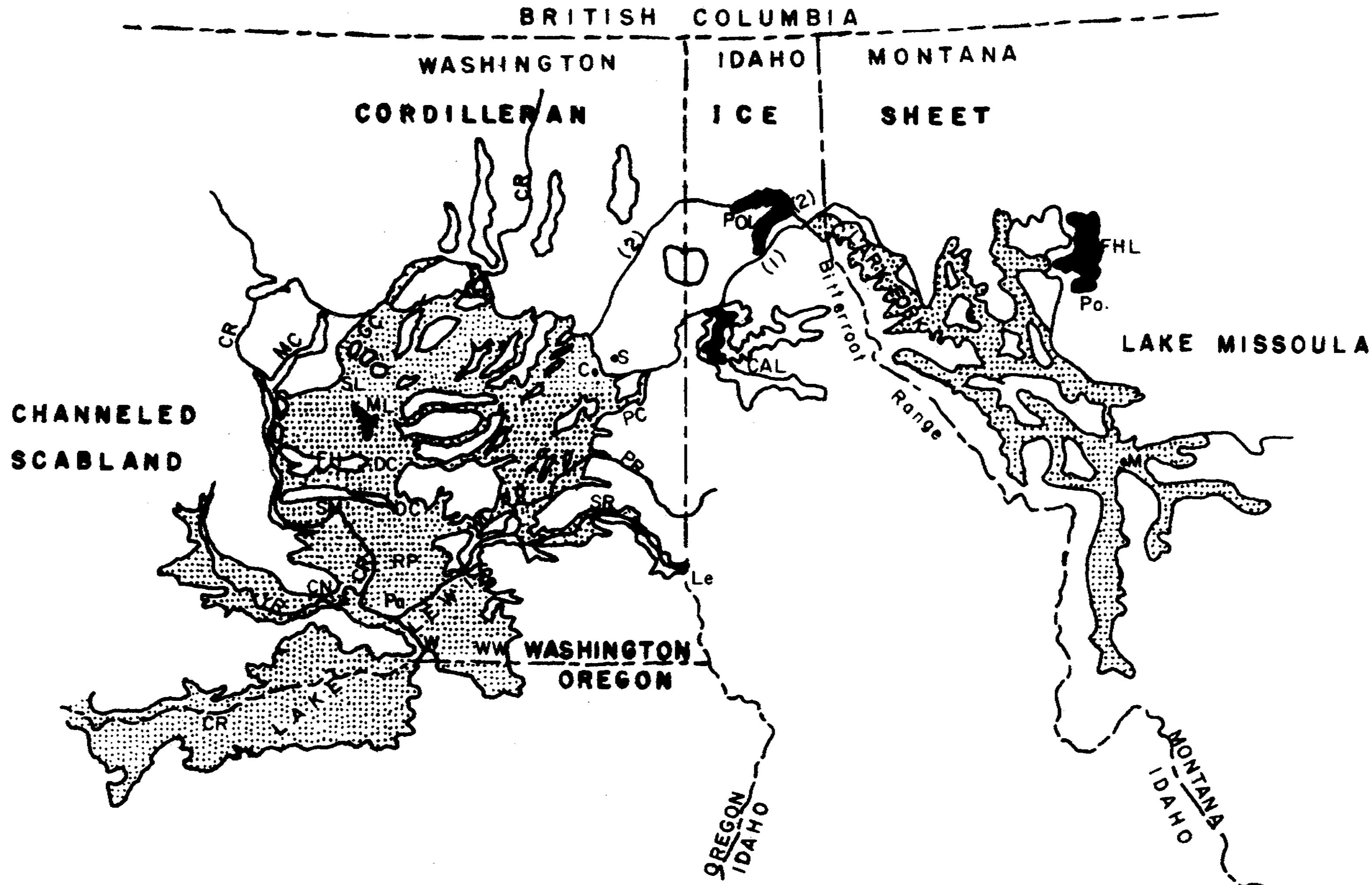


FIGURE 15

GLACIATION OF BONNER COUNTY



C	Cheney	GC	Grand Coulee	PC	Pine Creek	SR	Snake River
CAL	Coeur d'Alene Lake	Le	Lewiston	Po	Polson	W	Wallula
CN	Chandler Narrows	M	Missoula	POL	Pend Oreille Lake	WC	Washtucna Coulee
CR	Columbia River	MC	Moses Coulee	PR	Palouse River	WW	Walla Walla
DC	Drumheller Channels	ML	Moses Lake	RP	Ringold Plain	YR	Yakima River
FM	Frenchman Hills	OC	Othello Channels	S	Spokane	(1)	Bretz' drainage spillway
FHL	Flathead Lake	Pa	Pasco	SL	Soap Lake	(2)	Alternate proposed drainage of Glacial Lake Missoula (Savage)

Fig. 16. Map of Glacial Lake Missoula and Channeled Scabland Area (Adapted from Bretz, Smith and Neff, 1956)

because of their complexity, it is difficult to reconstruct their exact history. Most impressive are some drainage changes brought about through the effects of <u>both</u> earlier lava flows and later glaciation.

In North Idaho large quantities of meltwater runoff, derived from melting glacial ice, have transported abundant rock debris and locally spread it out over the landscape. The breaking of dams of such glacial debris, or ice retreat by melting and erosion of ice dams and lobes, have resulted in major floods and times of rapid erosion of the landscape. For example, the impressive scablands of eastern Washington southwest of Spokane were formed by the erosive action of meltwater from glacial Lake Missoula located in Montana (Fig. 16). Here great dry stream channels and waterfalls mark the courses of former streams.

Increased atmospheric moisture accompanying the Pleistocene glacial phases produced lakes in some closed drainage basins. For example, Pluvial Lake Bonneville occupied Great Salt Lake basin in northern Utah in late glacial times. The growth and subsequent spillover of this body of water carried floods over Red Rock Pass in southern Idaho and into the Snake River drainage system. The effects of these floods may be observed all along the Snake River Plain, providing a scabland-like terrain similar to that in eastern Washington.

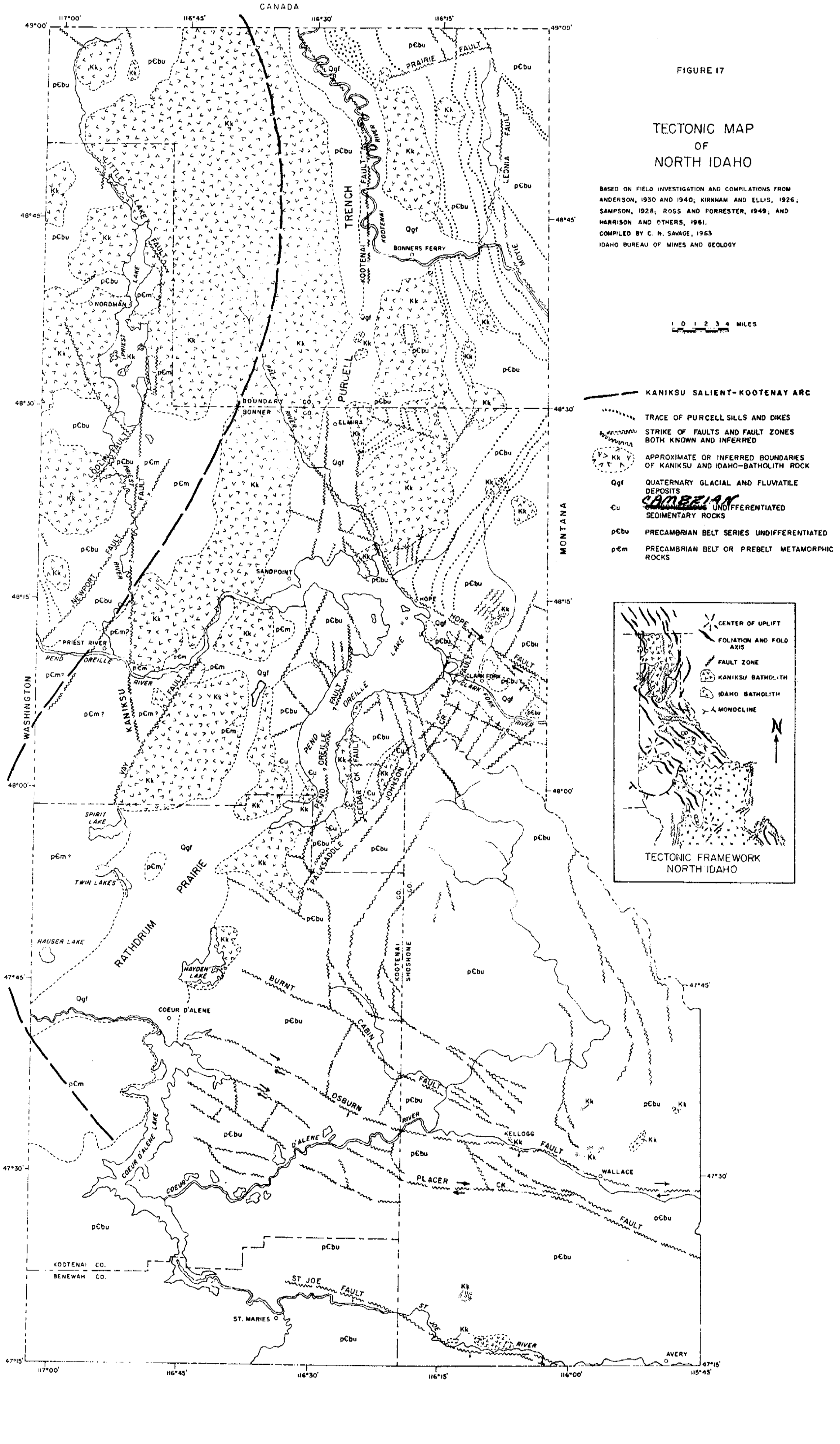


FIGURE 17
TECTONIC MAP
OF
NORTH IDAHO
BASED ON FIELD INVESTIGATION AND COMPILATIONS FROM ANDERSON, 1930 AND 1940; KIRKHAM AND ELLIS, 1926; SAMPSON, 1928; ROSS AND FORRESTER, 1949; AND HARRISON AND OTHERS, 1961.
COMPILED BY C. N. SAVAGE, 1963
IDAHO BUREAU OF MINES AND GEOLOGY
1 0 1 2 3 4 MILES
KANIKSU SALIENT-KOOTENAY ARC
TRACE OF PURCELL SILLS AND DIKES
STRIKE OF FAULTS AND FAULT ZONES BOTH KNOWN AND INFERRED
APPROXIMATE OR INFERRED BOUNDARIES OF KANIKSU AND IDAHO-BATHOLITH ROCK
Qgf QUATERNARY GLACIAL AND FLUVIATILE DEPOSITS
Cu CAMBRIAN UNDIFFERENTIATED SEDIMENTARY ROCKS
pCbu PRECAMBRIAN BELT SERIES UNDIFFERENTIATED
pCm PRECAMBRIAN BELT OR PREBELT METAMORPHIC ROCKS
CENTER OF UPLIFT
FOLIATION AND FOLD AXIS
FAULT ZONE
KANIKSU BATHOLITH
IDAHO BATHOLITH
MONOCLINE
N
TECTONIC FRAMEWORK
NORTH IDAHO
CANADA
WASHINGTON
MONTANA
49°00'
48°45'
48°30'
48°15'
48°00'
47°45'
47°30'
47°15'
117°00'
116°45'
116°30'
116°15'
116°00'
115°45'
BONNERS FERRY
SANDPOINT
NORDMAN
PRIEST RIVER
HOPE
CLARK FORK
ELMIRA
COEUR D'ALENE
KELLOGG
WALLACE
ST. MARIES
AVERY
PURCELL TRENCH
KOOTENAI FAULT
PRAIRIE FAULT
LEONIA FAULT
MOYIE
PRIEST LAKE
LITTLE LAKE FAULT
NEWPORT FAULT
KANIKSU
PEND OREILLE LAKE
HOPE FAULT
CEDAR CK FAULT
JOHNSON
PACKSADDLE
RATHDRUM PRAIRIE
SPIRIT LAKE
TWIN LAKES
HAUSER LAKE
HAYDEN LAKE
BURNT CABIN FAULT
OSBURN FAULT
PLACER CK FAULT
ST JOE FAULT
ST JOE RIVER
COEUR D'ALENE RIVER
COEUR D'ALENE LAKE
BOUNDARY CO.
BONNER CO.
KOOTENAI CO.
SHOSHONE CO.
BENEWAH CO.

GEOLOGIC HISTORY OF PEND OREILLE LAKE REGION

INTRODUCTION

More than 550 square miles of the Pend Oreille region in North Idaho are underlain by igneous, sedimentary and metamorphic rocks, ranging in geologic age from the Precambrian to the Recent (Fig. 17). Some of the oldest of these rocks are "pre-Beltian" rocks cropping out south, east and northeast of the village of Priest River (Table 3) Figs. 5 and 6). The largest exposures of bedrock in the region are (1) slightly metamorphosed or altered sedimentary rocks (Fig. 3), (2) granitic rocks of the Kaniksu batholith (Fig. 4), and (3) more recent clay, sand, and gravel of glacial and stream origin called "drift" and "alluvium", respectively (Table 3) (Fig. 14).

PRE-BELTIAN TIME

Some of the oldest Precambrian rocks in the Pend Oreille Lake region are the folded, faulted, and contorted schists and crystalline gneisses of west-central and southwestern Bonner County. These were once sedimentary (and possibly igneous) rocks. Changes in environment (heat and pressure changes) through long years of burial deep in the earth's crust altered the rocks to their present metamorphosed condition (Table 3).

BELTIAN TIME

Later Precambrian rocks are composed of layered or bedded, slightly metamorphosed sedimentary rocks called the Belt Series (Table 3). These were altered from clays, silts, sands, and limes to shales, siltstones, sandstones, and limestones, respectively, by compaction and natural cementation. Still later they were altered by mild pressure and temperature changes to produce argillites, siltites, quartzites, and dolomites, the metamorphosed equivalents of the above sedimentary materials. Such rocks are represented over much of the Pend Oreille Lake region, but some of the best exposures may be found along the main highway to Cabinet Gorge Dam (Fig. 3). In general, the Belt Series are metasedimentary rocks that have been buckled into broad open folded structures, that is, they are no longer horizontally bedded rocks as they were when deposited as marine sediments. They have also been faulted and injected by a number of kinds of igneous rocks. In the Clark Fork area the Belt rocks constitute deposits that were 38,000 ft thick, and perhaps even thicker at the time of their deposition.

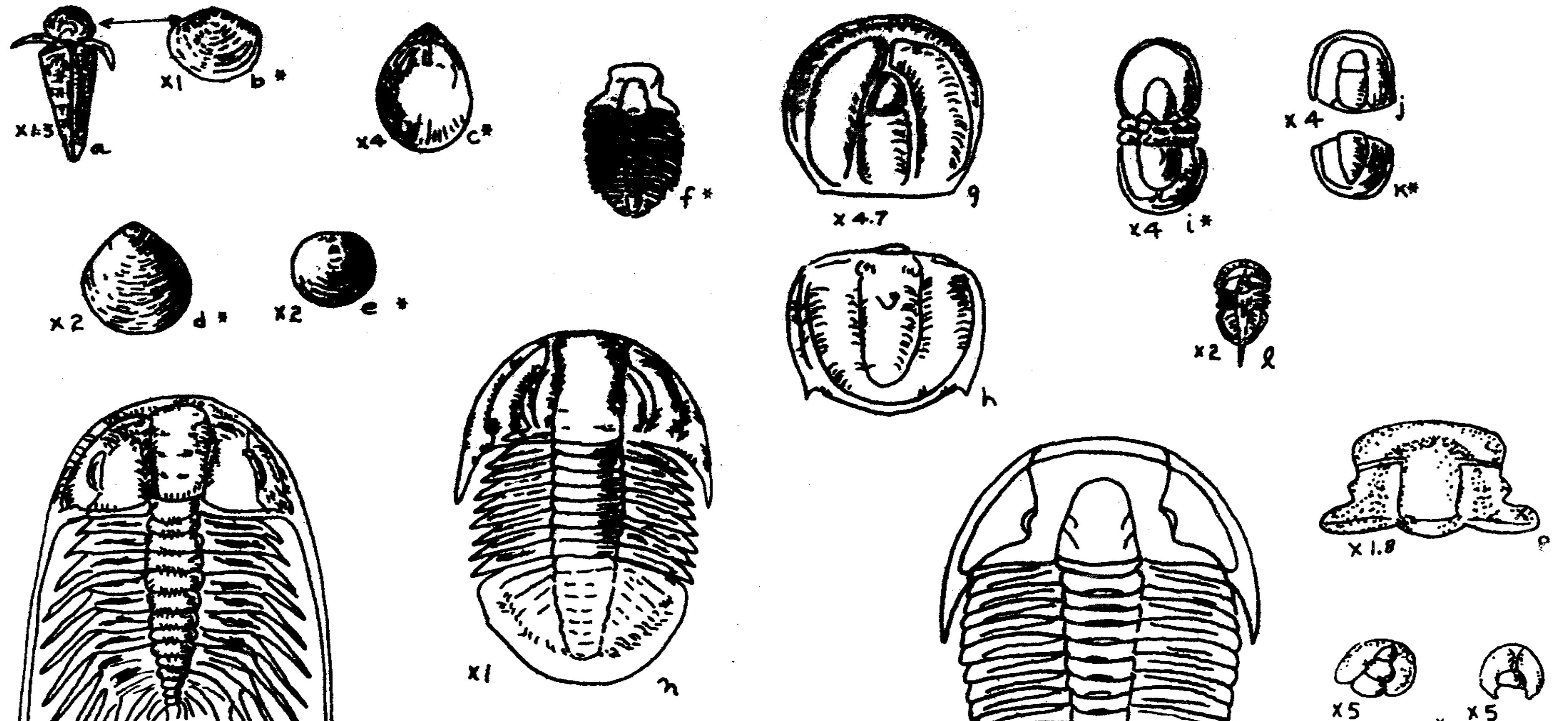
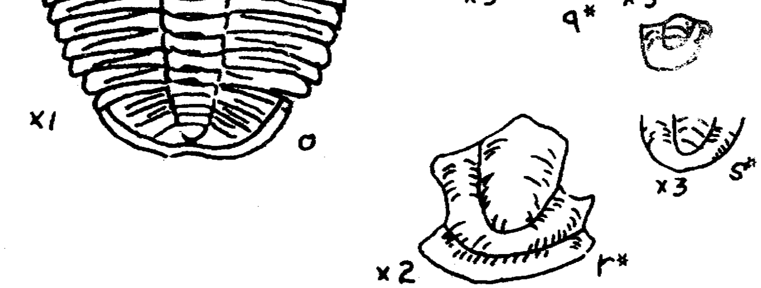
It is difficult to identify the different formations comprising the Belt Series (Table 3), particularly for someone who is untrained in such techniques. However, differences between the rock formations are detectable to geologists who recognize distinct units locally. The Belt rocks were deposited in relatively shallow marine waters, probably part of a long

TABLE 3

Rock units and associated materials, Pend Oreille Region

(Oldest units on bottom, youngest on top)

ERAS	PERIODS		
CENOZOIC			Recent glacial, lake, and stream deposits of clay, silt, sand, and gravel. Widely distributed over the region. Began approximately 1.5 million years ago.
CENOZOIC	Paleogene-Neogene	Many types of igneous intrusive rocks, ranging from granitic to basaltic; stocks, dikes, and sills	Columbia River Basalt (Igneous rocks) Began about 25 million years ago. Black lava flows. May be viewed in Hoodoo Valley west of Kelso Lake.
			Extensive erosion, no record of rock formation preserved during this time. Began about 63 million years ago.
MESOZOIC	Cretaceous		Kaniksu batholith (Igneous rocks) Largely granitic rocks widely distributed. Examples west of Pend Oreille Lake, Cocolalla Lake, and Sandpoint along highways. About 116 millon years ago.
			Sandpoint Conglomerate (Sedimentary rocks) Exposed in quarries and roadside cuts northeast of Sandpoint. May be older than Cretaceous.
PALEOZOIC	Cambrian		Lakeview Limestone (Sedimentary rocks) Often seen in old quarries in Bayview and along east shore of Pend Oreille Lake near town of Lakeview.
			Rennie Shale (Sedimentary rocks) Commonly covered with soil and vegetation, but exposed in the bed of Gold Creek about one mile south of Lakeview.
			Gold Creek Quartzite (Metamorphic rocks) Also exposed along Gold Creek beneath the Rennie Shale and along the West Gold Creek road to Lakeview. Began accumulating about 568 million years ago.
PRECAMBRIAN			Belt Series (mildly metamorphosed, sedimentary rocks, including so-called argillites, siltites, quartzites, and dolomites) Libby Formation Striped Peak Formation Wallace Formation St. Regis Formation Revett Formation Burke Formation Prichard Formation These rock formations are widely distributed, but the best exposures are along the highway from Sandpoint to Cabinet Gorge Dam, and in the area of David Thompson Game Preserve southeast of Hope, Idaho. These rocks began accumulating about 1.6 billion years ago.
			Pre-Belt (Strongly metamorphosed rocks called gneisses and schists) May be observed along the highway and railroad cuts along Priest River to Sandpoint highway. These rocks are about 2 billion or more years old.


a. Hyolithes (gastropoda?)
b. Operculum of Hyolithes
c. Lingulella (branchiopoda)
d. Leptobolus (branchiopoda)
e. Acrothele (branchiopoda)
f. Elrathina (trilobita)
g. Agnostus (cephalon-head)
h. Agnostus (pygidium-tail)
i. Hypagnostus (trilobita)
j. Peronopsis (cephalon)
k. Peronopsis (pygidium)
l. Pagetia (trilobita)
m. Oryctocephalus (trilobita)
n. Glossopleura (trilobita)
o. Elrathia (trilobita)
p. Utia (part of cephalon)
q. Agnostida (?) (cephalons and pygidium)
r. Fragment of trilobita
s. Pygidium of trilobita

FIGURE 18. FOSSILS OF MIDDLE CAMBRIAN AGE (Note:* Some of these may be found in the Pend Oreille Region)

narrow seaway stretching from the Arctic to at least as far south as Arizona.

Interesting fossil algae or former marine plant life may be found in the Beltian rocks. These consist of bands of light and dark colored mineral matter arranged in swirling, moss-like patterns. The masses of fossilized algae are nearly spherical or ellipsoidal structures ranging from the size of a football to a large reef-like structure (Fig. 3). All the algal forms are collectively called stromatolites or when forming massive rock they are called stromatoliths. The genus name for many of the forms in this area is Collenia. Collenia lived in protected intertidal flats of the ancient Precambrian Beltian sea. Examples of these fossils may be found in a quarry along the highway just west of Cabinet Gorge Dam and in other less accessible places.

Other features that reveal the geologic history of the Belt rock series are cross-laminated structures caused by sediment-laden streams or currents entering the sea, and ripple-marked bedded surfaces formed by the same agencies. In some places mud cracks, mud chip breccia, and the imprint of salt crystals may be found; these all attest to an environment of relatively shallow water, and the fact that at times the sea floor was elevated and exposed to surface drying by the atmosphere.

Dark-colored, iron- and manganese-rich igneous rocks were intruded into the Belt Series at an early date. These intrusions are now exposed as flat tabular masses paralleling the bedding (sills) or cutting across the layers (dikes). Volcanism may have been associated with this Precambrian igneous phase.

Radioactive isotope dating has revealed that the Belt rocks accumulated from about 1.4 to 1.6 billion years ago. Therefore they are approximately equivalent to age-dated rocks in the Grenville area of eastern Canada and the Grand Canyon Series in the bottom of the Grand Canyon of Arizona.

After many thousands of years the Belt sedimentary rocks were tilted, gently folded, faulted and uplifted; they were thus elevated by an estimated 20,000 ft from their original location in the earth's crust. During this event and thereafter, geologic processes extensively weathered and eroded the rocks.

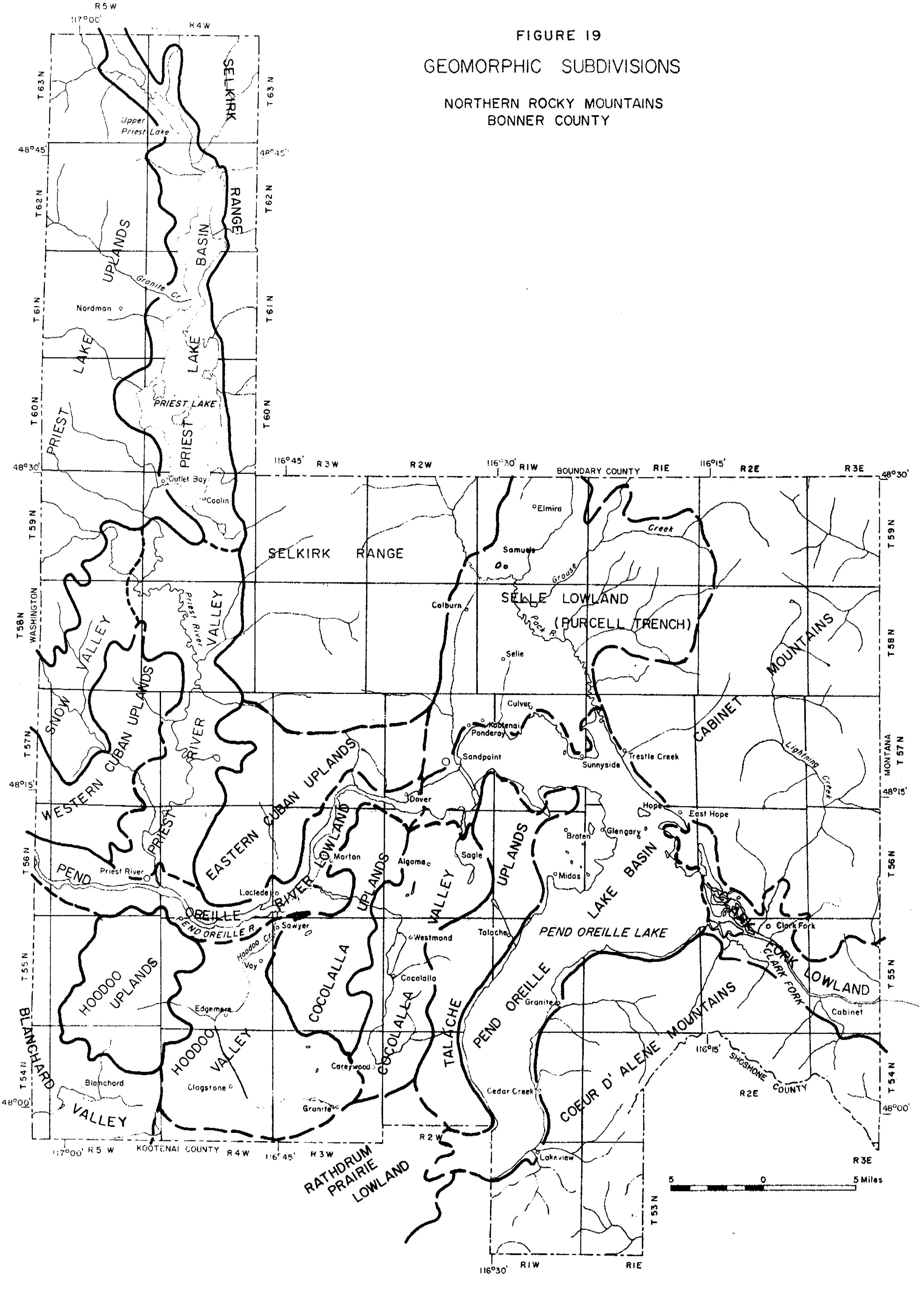
PALEOZOIC TIME

With the coming of another great era of geologic time, the reduced and eroded uplands of exposed Belt rocks were again depressed and submerged by a clear, mild, seaway in which marine sediments again accumulated. Rock strata representing this phase consist of altered or metamorphosed sandstone, shale, and limestone (Table 3), called the Gold Creek Quartzite, Rennie Shale, and Lakeview Limestone. These rocks may be observed in the regions adjacent to the southern end of Pend Oreille Lake, for example, some on the west and some on the southeast sides of the lake. Along the lower reaches of Gold Creek marine fossils of Cambrian age may be found in early

FIGURE 19

GEOMORPHIC SUBDIVISIONS

NORTHERN ROCKY MOUNTAINS
BONNER COUNTY



Paleozoic rocks (Fig. 18). These fossils for the most part are small forms and probably represent life that dwelt in a relatively unfavorable environment. The rocks are some of the first Cambrian strata to be discovered west of the Rocky Mountains.

The geologic history of the Paleozoic is difficult to interpret because it involved repeated uplift and erosion of the crust. Much of the rock record was probably eroded away. However, somewhat late in this era, cobbly gravels accumulated along the base of broken or upfaulted crustal blocks. These sands and gravels are now represented by the Sandpoint Conglomerate (Table 3). Remnants of such deposits may be observed in quarries and roadcuts north and northeast of Sandpoint. The rock is resistant and tends to stand out as knolls, hills and cliffs. The partially rounded to angular boulders and cobbles in this conglomerate make the formation easy to identify.

MESOZOIC TIME

The Mesozoic Era was a time of general crustal disturbance associated with the formation of early folded and faulted structures in the Northern Rocky Mountain Region. This widespread disturbance or diastrophism has been called the Laramide Revolution.

Perhaps the most important event of the Laramide diastrophism in northern Idaho was the emplacement of the Kaniksu batholith and associated igneous rock intrusions. Subsequent erosion has exposed these rocks over at least 400 square miles of Bonner County (Fig. 17). Examples may be found exposed around the southeast end of Pend Oreille Lake and in the area to the west of the lake. Many of the higher mountain peaks west of Pend Oreille Lake, and west of Sandpoint are composed of granitic-type Kaniksu batholith rocks. Judging from radioactive isotope dating of similar rocks in other areas, the rocks of the Kaniksu batholith probably range from 94 to 116 million years old. In other words the intrusion of these rocks into the crust of the region occurred over a rather long span of time instead of all at once.

Many of the minerals found in North Idaho are thought to have been formed as the result of late activity associated with the Kaniksu batholith. Late solutions and gases charged with mineralizing chemicals moved up through the crust at this time. When a suitable environment was encountered, that is, when physical conditions were suitable, minerals were emplaced.

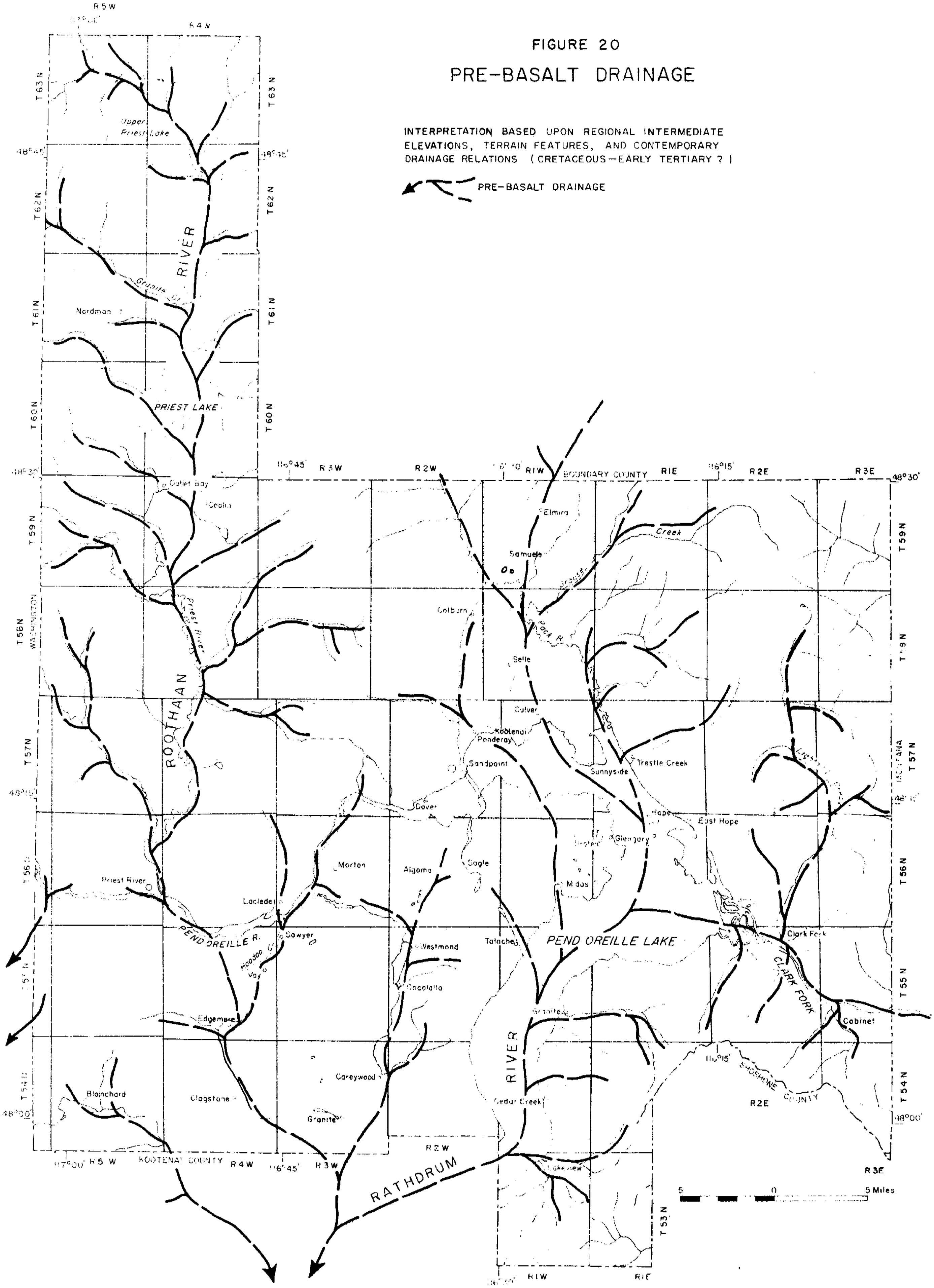
CENOZOIC TIME

Because Cenozoic time is more recent, geologists generally are able to assemble more data to use for interpretation of the geologic history of this era. All surface features were evolved by the many geologic processes during the Cenozoic Era. Near the beginning of the era, Bonner County and the Pend Oreille Lake region were probably a

FIGURE 20
PRE-BASALT DRAINAGE

INTERPRETATION BASED UPON REGIONAL INTERMEDIATE ELEVATIONS, TERRAIN FEATURES, AND CONTEMPORARY DRAINAGE RELATIONS (CRETACEOUS—EARLY TERTIARY ?)

PRE-BASALT DRAINAGE



gently undulating broad erosional landscape with a well-developed system of stream drainage. Absence of recognizable sedimentary materials that can be related to Jurassic and Cretaceous ages (Table 1) suggest that during the earlier Mesozoic Era the region was undergoing slow erosion, and the debris from this process was being carried outside the boundaries of the area. With crustal uplift during the Laramide Revolution greater relief developed as rivers and streams incised to greater depths. Continued intermittent uplift and erosion eventually resulted in the exposure of deeper seated Mesozoic, Paleozoic, and Precambrian rocks essentially as they are now. Eventually, low mountain ranges and then more rugged mountainous uplands were eroded out of these rocks (Figs. 1 and 19).

By Miocene time (Table 1) North Idaho was a region of considerable relief drained by large master streams and their tributaries. However, continued breaking or faulting of the earth's crust, the eruption of material from volcanoes and volcanic fissures, and the invasion of the area by great rivers of moving glacial ice in the Pleistocene Epoch all produced their mark on the landscape. Changes in the evolving drainage pattern became the rule instead of the exception. An ancestor of the Clark Fork River in eastern Bonner County sought out more easily eroded rocks in the broken and disturbed belt called the Hope fault. A major stream paralleled this valley. The broad north-south trending Selle lowland or Purcell trench separated the Cabinet and Coeur d'Alene mountains on the east from the mighty Selkirk Range to the west (Fig. 19). Undoubtedly both downfaulting of crustal segments and early deep stream erosion contributed to the development of this Selle lowland east of Sandpoint. Similar processes were probably responsible for development of the early basin in which Pend Oreille Lake is now located (Fig. 1). Later both of these valleys were modified by glacial ice during the ice age.

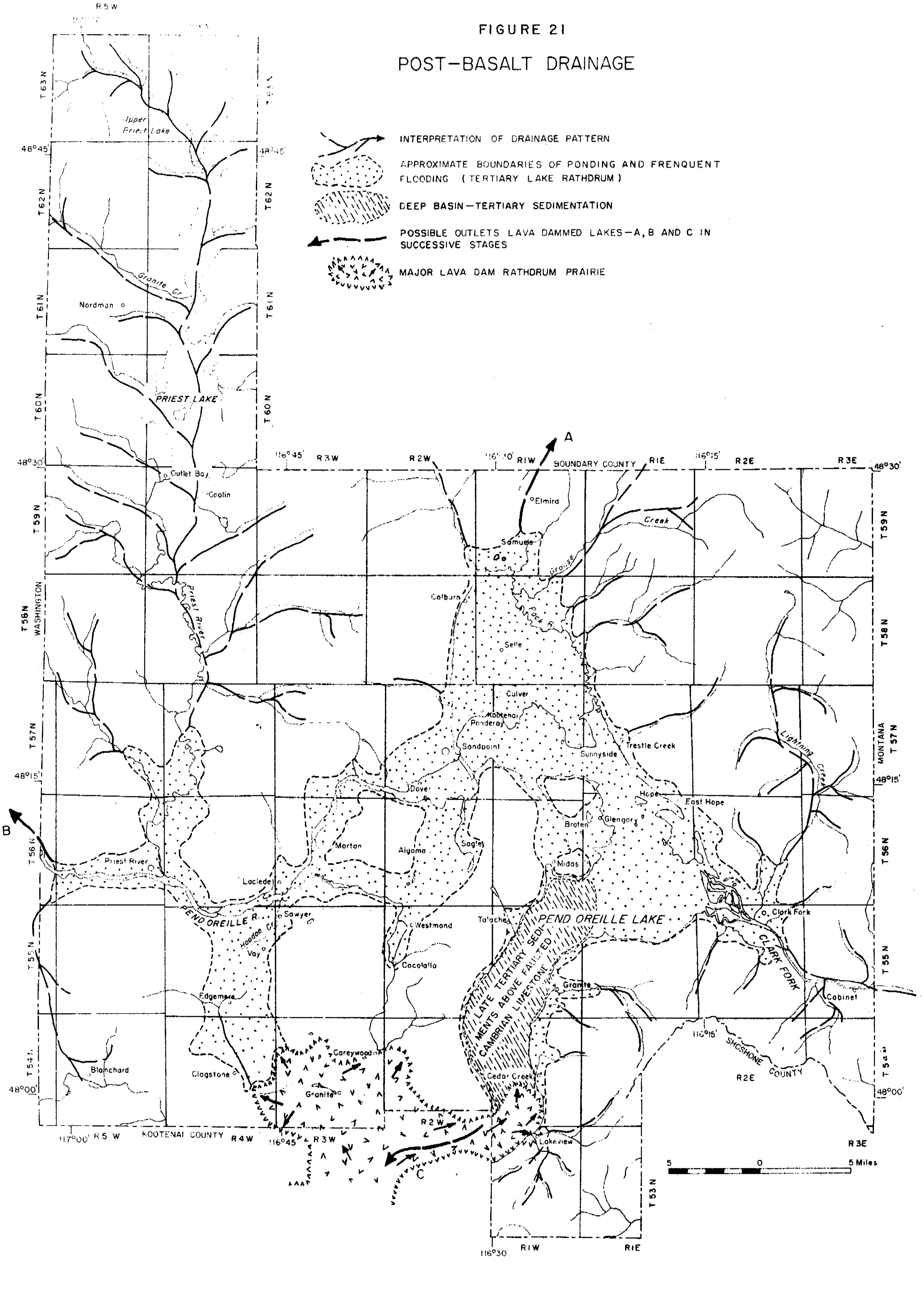
Just before the Miocene Epoch, the drainage pattern in the Pend Oreille region is thought to have looked like that shown in Figure 20. For convenience, the streams as interpreted here have been given names. The map is based upon geologic evidence suggesting the location of old stream patterns, for example, the principal stream was the Rathdrum River flowing southward toward the Spokane area. This river apparently paralleled the present axis of Pend Oreille Lake and began the development of the deeply eroded basin now occupied by the lake. The present valley of the Clark Fork is also believed to be parallel to the axis of the ancient Rathdrum River.

A northern tributary of the main Rathdrum River flowed south along the Selle lowland. It is not clear whether this was an extension of a major stream coming from the Kootenai-Purcell trench (lowland) in British Columbia, or whether it was a shorter stream entirely within the confines of present Bonner County. Probably the latter was the case. Glacial ice flowing southward from continental glacial ice fields to the north later modified and altered these early drainage systems and undoubtedly obscured many of their features.

Roothaan River on the west probably paralleled the present Priest River valley in western Bonner County (Fig. 20). It flowed southeast near the town of Priest River

FIGURE 21

POST-BASALT DRAINAGE



and along the axis of present Hoodoo Valley, joining Rathdrum River south of Granite. At least 470 ft of stream-deposited alluvium and glacial debris subsequently filled the old Roothaan River valley in the Hoodoo Creek area. The great depth of this valley is attested to by water well drilling records.

Just west of Newport, Washington another major river is believed to have flowed south toward the Spokane area. This southward-trending old valley in this area may be recognized topographically. East of Spokane the Rathdrum River system was probably joined by another major river system carrying drainage from the Coeur d'Alene-St. Joe regions (south of Pend Oreille region) toward the west.

As a result of lava extrusion, the well-developed Rathdrum River was effectively dammed during Miocene time (Fig. 21). For example, locally, erosional remnants of some of the Columbia River basalt flows of about Miocene age occur in Hoodoo Valley west of Pend Oreille Lake. As result of lava damming, a large lake backed up into the Spokane basin and into low areas northeast of Spokane all the way to the Pend Oreille region. Rathdrum River valley and the valleys of its tributaries, probably including all areas below 2,500 to 2,600 ft in elevation, were covered by lake waters (Fig. 21). For convenience this has been called Tertiary Lake Rathdrum. Late flows of lava in the vicinity of the town of Granite effectively dammed off any possible northern outlets of this Tertiary lake.

Sedimentary material, carried into the lake by tributary streams, accumulated in the flooded areas. These sediments consisted of volcanic ash, clay, silt and sand. Much of this material is now buried beneath later glacially deposited debris; however, representative, richly fossiliferous, old Tertiary lake beds are well displayed in the vicinity of Spokane. Similar lake beds may be found in the Coeur d'Alene region and probably also occur beneath younger sediments in the basin of Pend Oreille Lake (Fig. 21). The sediments are called the Latah members of the Columbia River Group of basalt lava flows. Fossils in these beds consist principally of leaves. Representing the vegetation of Miocene time they include leaves from laurels, ginkgos, pines, sequoias, ferns, scouring rushes, willows, aspens, beeches, chestnuts, oaks, plums, maples, and magnolias among other types. These kinds of flora suggest that the climate in the Miocene and Pliocene epochs was more mild and moist in the Pend Oreille region than it is today.

During the most effective stage of water ponding, Tertiary Lake Rathdrum may have drained north into the region now occupied by Kootenai Valley or alternatively, north by way of Pend Oreille Valley (Fig. 21, at A or B). Eventually, drainage to the south across the Rathdrum area probably was restored as the basalt flows were subjected to extensive stream erosion. Much of the lava was probably eroded away until the drainage pattern again resembled the pattern established before the volcanic flows were extruded.

In Pleistocene time (Table 2) the general southwest drainage pattern was disrupted once again. This occurred when great lobes of glacial ice moved slowly down from northern ice fields in Canada. Repeated invasions of the Pend Oreille region took place as ice flows waxed and waned with climatic variations (Fig. 15). Deposition of clay, silt, sand, and gravel both by the debris laden ice and meltwater streams issuing from the ice was commonplace. During melting phases glacial deposits of sand and gravel accumulated to great thicknesses south of the ice margins. Rathdrum Prairie west of Pend Oreille Lake is a remarkable example of such a glacial plain (Fig. 1).

The grinding and scouring action of the rock laden ice sheet also left scratches, grooves, and polished surfaces on the bedrock over which the ice moved (Fig. 12). Evidence of the passage of an ice lobe is preserved on the wall of a road cut east of Clark Fork (Fig. 11). Glacially eroded grooves and striated surfaces occur on the bedrock above the cliffs at the Denton curves east of Hope, and in the mountains west of Sandpoint.

During maximum glaciation the glacial ice was apparently thick enough to pass right over the tops of the Selkirk and Cabinet ranges at elevations of 6,000 ft or more (Figs. 1, 8 and 9). This would require a mobile ice mass with a minimum thickness of 4,500 to 5,000 ft in the vicinity of Sandpoint. Evidences of continental glaciation on the flanks of the Coeur d'Alene Mountains are found as high as 3,500 ft, but the latest ice margins probably ended near Coeur d'Alene Lake. Ice over the south end of Pend Oreille Lake at times during maximum glaciation must have been 2,000 ft or more thick.

Arriving early in the Spokane area, the slowly advancing Spangle ice lobe on the west (Fig. 15), dammed a large northwest-flowing ancestor of Latah Creek. Moving more slowly and arriving later, the Rathdrum ice lobe (Fig. 15) flowed south and formed a dam across an ancestor of the Clark Fork River near the town of Clark Fork.

In the Spokane area, the earlier ice flow formed an ice dam producing a lake called Glacial Lake Spokane (including "Lake Lewis") (Fig. 16). This body of water, like earlier Tertiary Lake Rathdrum, backed up into lowlands to about 2,600 ft elevation. Portions of Pend Oreille, Priest, Clark Fork and St. Joe river valleys would have been flooded by the ponded water. Sedimentary materials, such as thinly bedded clay and silt deposits are evidence of this flooding, and are exposed where areas were covered by this lake.

Later the ice lobe to the east formed another effective dam near the Idaho-Montana boundary producing a second great lake (mentioned above) called Glacial Lake Missoula (Fig. 16). Several levels of this lake are preserved as traces of ancient shore lines along the large valley which extends northwest from Missoula to the Idaho boundary.

From time to time, the above-described ice dams were destroyed by melting and lack of nourishment, or by erosion; when such dams were removed, great floods of water spilled out of the lakes and poured over northeastern Washington. These floods produced ancient stream channels or coulees, and dry waterfalls characteristic of the eroded scabland terrain, as noted earlier (Fig. 16).

During the Pleistocene, glacially transported rock debris called moraine, effectively dammed several streams which flowed east and west into the Rathdrum area. These glacial-debris-dammed streams formed several modern lakes including Hayden, Spirit and Twin lakes lying along the boundaries of modern Rathdrum Prairie lowland (Fig. 1).

Pend Oreille Lake was also formed during the Pleistocene Epoch. Pend Oreille glacial sublobe (Fig. 15) was partly responsible for deepening the lake basin that formerly was part of Tertiary Rathdrum River valley (Fig. 20). Actually the deepening of this basin, to approximately 900 ft elevation, was the result of several events, probably in the following order:

(1) early intricate faulting and shattering of the bedrock;
(2) probable presence of soluble, easily eroded Cambrian limestone along the axis of the basin;
(3) presence of the deeply eroded Tertiary Rathdrum River valley;
(4) presence of soft, easily eroded fill consisting of Miocene and Pliocene lake sediments;
(5) erosion by two or more glacial ice lobes, during the latter part of the Wisconsin ice age; and
(6) damming of the south end of the lake basin by glacial debris.

As the main Late Pleistocene ice margin melted backward or receded toward the ice source in the north, various meltwater drainage outlets developed. One of the first outlets for the water ponded in front of the ice in the Pend Oreille region was probably south across Rathdrum Prairie (Fig. 15A). Later, lower outlets were developed as they were exposed by the retreating ice margin (Fig. 15B, C, and D).

Late Wisconsin glacial ice lobes or long valley glaciers to the east, extended south to the valley of the ancestral Clark Fork River. These late Wisconsin valley glaciers probably produced some of the late dams that ponded water in the basin occupied by Glacial Lake Missoula. Disruption of these ice dams permitted major spillovers, or floods from Glacial Lake Missoula. This water passed through the northern part of Pend Oreille Lake, then down Pend Oreille River valley and south by way of the Little Spokane River valley (Fig. 15C) to the Spokane River valley, and finally flowed into the scabland area west of Spokane. In 1962 the first radiocarbon dating of this scabland flooding was derived from carbonaceous material at the Wanapum dam site. A maximum limiting date for the latest flooding in the Wisconsin Age was approximately 32,000 years ago.

In latest Wisconsin time, wherever the uplands extend up to 5,000 ft or more, alpine glaciers were effective in sculpturing the peaks of the Cabinet and Selkirk ranges. Much of the scenic beauty of these areas today may be attributed to this late glacial erosion.

After the Wisconsin ice age, the terrain about Pend Oreille Lake evolved into the present scene; one of greatly contrasting relief developed over an originally mature mountainous landscape. This landscape was modified by complex outpourings of volcanic flows, encroachment of glacial ice, and complex drainage and erosion patterns (Fig. 1).

Post-glacial sand flats, capped by sand dunes, developed over sandy glacial outwash deposits around Elmira, north of Sandpoint, and an estuarine delta was built by the Clark Fork River where it joined Pend Oreille Lake on the east. This delta is still growing larger at the expense of the northeast end of the lake.

On the east side of Bonner County, Clark Fork River eroded Cabinet Gorge in the resistant argillites of the Libby Formation, part of the Belt Series. Here the river was probably superposed across the bedrock as it eroded down through layers of sediment deposited in Glacial Lake Missoula.

ECONOMIC MINERAL DEPOSITS IN THE PEND OREILLE REGION

Of past and future potential value in the Pend Oreille region are abundant sand and gravel, dimension stone, limestone, silica, and peat, as well as minerals containing gold, silver, lead, zinc, and copper (Fig. 22). On record, Bonner County has produced minerals worth more than 13.5 million dollars (1965 prices). Unrecorded production, added to this total, might easily more than double this figure.

Old quarries, mines, and mining prospect holes are common in parts of this region. In fact, one should exercise the greatest caution when exploring any area off the highway in some sections, because of the danger of falling into old shafts, ore chutes or pits.

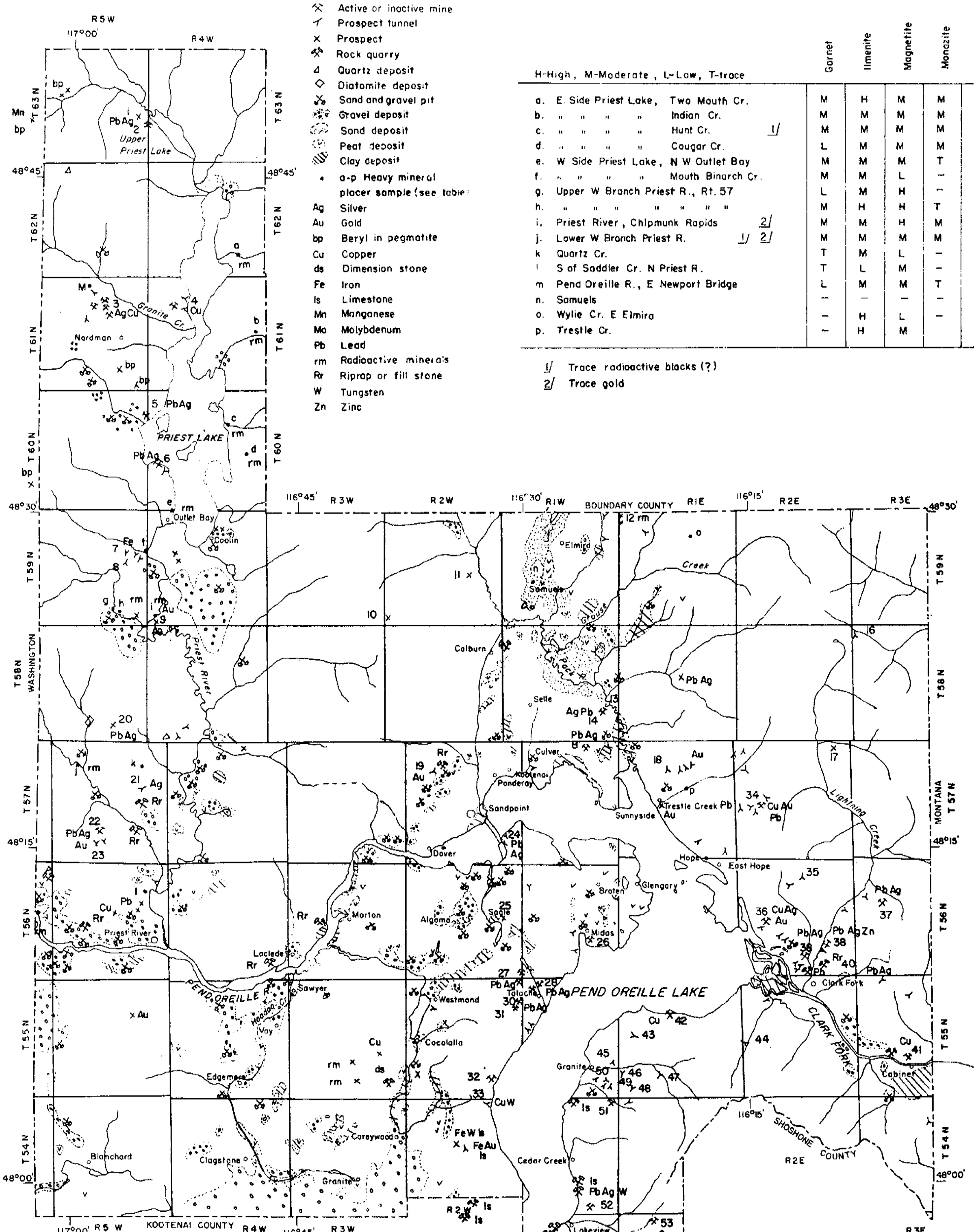
The Cambrian limestones adjacent to the south end of Pend Oreille Lake and near Lakeview, attain a thickness of over 200 ft. In the early 1900's Washington Brick and Lime Company was located adjacent to some of these limestone deposits at Bayview near the south end of Pend Oreille Lake. Here lime kilns prepared lime for shipment across the lake to a railhead at Hope. Portions of the kilns and the gaping quarries may still be observed at the north edge of Bayview. Furthermore, large quarries along the lake front south of Lakeview, once supplied rock for the manufacture of cement at the International Portland Cement Company's plant near Spokane, Washington.

Commercial silica rock has been exploited from a quarry on Freeman Lake in Idaho northeast of Newport, Washington, and granitic rock has been quarried for building stone from a quarry west of Pend Oreille Lake.

Clay deposits near Sandpoint and east of Clark Fork have been used for making brick and pottery. As late as 1963, a small pottery industry was being developed in the town of Clark Fork (Fig. 23). The industry used clay obtained west of Cabinet Gorge Dam to make a great variety of ceramic pieces, including dishes, vases, and figurines.

Water is one of the most abundant and widespread natural mineral resources in the Pend Oreille Region. With proper development all settlements may be assured of a good supply of high quality water. Lakes and streams are numerous and provide ample water resources for recreational use.

Bonner County lies between the fabulous Coeur d'Alene mineralized region on the southeast, and the Metaline-British Columbia mineralized belts on the northwest. It is a region of widespread showing of metallic mineralization that is associated with metasedimentary and igneous rocks. During the 41 year period, 1916 to 1956, Bonner County produced gold, silver, copper and zinc valued at 5.6 million dollars. In terms of present prices (1965), the value of the metals would be about two times this figure.



SYMBOLS

- Active or inactive mine
- Prospect tunnel
- Prospect
- Rock quarry
- Quartz deposit
- Diatomite deposit
- Sand and gravel pit
- Gravel deposit
- Sand deposit
- Peat deposit
- Clay deposit
- a-p Heavy mineral placer sample (see table)
- Ag Silver
- Au Gold
- bp Beryl in pegmatite
- Cu Copper
- ds Dimension stone
- Fe Iron
- ls Limestone
- Mn Manganese
- Mo Molybdenum
- Pb Lead
- rm Radioactive minerals
- Rr Riprap or fill stone
- W Tungsten
- Zn Zinc

PLACER SAND SAMPLES

H-High, M-Moderate, L-Low, T-trace	Garnet	Ilmenite	Magnetite	Monazite	Olivine	Quartz	Sphene	Zircon
a. E. Side Priest Lake, Two Mouth Cr.	M	H	M	M	–	M	M	L
b. " " " " Indian Cr.	M	M	M	M	–	M	T	L
c. " " " " Hunt Cr. 1/	M	M	M	M	–	M	L	L
d. " " " " Cougar Cr.	L	M	M	M	–	H	L	M
e. W Side Priest Lake, N W Outlet Bay	M	M	M	T	–	M	M	L
f. " " " " Mouth Binarch Cr.	M	M	L	–	–	M	M	L
g. Upper W Branch Priest R., Rt. 57	L	M	H	–	–	H	L	M
h. " " " " " " "	M	H	H	T	–	M	L	L
i. Priest River, Chipmunk Rapids 2/	M	M	H	M	–	H	L	M
j. Lower W Branch Priest R. 1/ 2/	M	M	M	M	T	L	L	L
k. Quartz Cr.	T	M	L	–	–	L	L	M
l. S of Saddler Cr. N Priest R.	T	L	M	–	–	H	L	M
m. Pend Oreille R., E Newport Bridge	L	M	M	T	–	H	M	L
n. Samuels	–	–	–	–	–	H	–	–
o. Wylie Cr. E Elmira	–	H	L	–	M	L	H	T
p. Trestle Cr.	–	H	M		M	L	M	L

1/ Trace radioactive blacks (?)
2/ Trace gold

MINES AND PROSPECTS

1. Plowboy
2. Mountain Chief
3. Nickleplate
4. Virginia Lakeshore
5. Milwaukee
6. Woodrat
7. Binarch Cr. Group
8. Nevada
9. Big Step
10. Lost Cave
11. French Cr.
12 Hottentot
13 Reynolds
14 Howard Davis
15 Larkin
16 Dougherty
17. Lightning Peak
18. Marguerite
19. Hunt
22. Luckey Lead
21. Nancy K
22. Farmer Jones
23. Camp Bird
24. Hayes
25. Santiago
26. Gold Coin
27. Iron Mask
28. Talache
29. Brown Bear
30. Blacktail
31. Blue Bird
32. American Eagle
33 Glowing Rock
34 Auxer
35. Delorah
36. Alamo
37. Regal
38. Hope
39. Whitedelph
40. Lawrence
41. Carpie
42. Green Monarch
43. Shafer
44. Bumble Bee
45. Phil Sheridan
46. Whalen
47. Fleming
48. Jolly Rodger
49. Minerva
50. Weisenberger
51. Falls Cr.
52. Vulcan
53. Dixie Queen
53. Hidden Treasure
54. Silver Leaf
55. Perry
56. Conjecture
57. Keep Cool
58. Idaho Lakeview
59. Long Hand
60. Bellville
61. New Rainbow
62. Weber

FIGURE 22 ECONOMIC GEOLOGY OF BONNER COUNTY NORTH IDAHO

Mineral production has come chiefly from the Clark Fork, Lakeview and Pend Oreille districts (Fig. 24). At the present time, some mineral development work is in progress, but only two or three small producers are selling ore. One of the producers is the Weber silver mine (open pit mine) just southeast of Pend Oreille Lake (Fig. 25). Other small operations are located near Talache on the west side of the lake. Once a major producing area, the Clark Fork district is essentially closed down.

This region is principally a silver province, but ores of lead, zinc and copper add value to any commercial ores that are produced. Iron and tungsten also occur in local mineralized zones, and gold has been recovered from prospects and mines scattered widely over the region. It is highly probable that some day one or more profitable silver mines will again be producing in Bonner County.

Interesting minerals may be found on some of the old mine dumps in the Pend Oreille region; examples are quartz, magnetite, specularite, pyrite, chalcopyrite, tetrahedrite, and galena. One of the more accessible places to look for such minerals is in the Talache area, but one should beware of entering old mine tunnels or falling into old hidden shafts. Old mine dumps in the Clark Fork and Lakeview areas also yield interesting mineral specimens. Figure 22 shows the approximate locations of some of the economic mineral deposits of Bonner County. Among the mines in this district which have produced commercial ore are the Alamo, Auxer, Carpie, Copper Giant, Clarinda, Hope, Lawrence, Whitedelph, Conjecture, Keep Cool, Weber and Talache.

Fig. 23. Drying pottery shelf at the Clark Fork Pottery.

Fig. 24. Headframe of new exploratory shaft Conjecture mine southeast of Pend Oreille Lake.

Fig. 25. Drilling to blast at the Weber open pit silver mine, southeast of Pend Oreille Lake.

SELECTED REFERENCES

Bretz, J. H., Smith, H. T. V., and Neff, G. E., 1958, Channeled scabland of Washington, new data and interpretations: Geol. Soc. America Bull., v. 67, p. 957-1049.

Mineral and water resources of Idaho, 1964, Idaho Bur. Mines and Geology Spec. Rept. no. 1, 335 p. ($1.00).

Pardee, J. T., and Bryan, Kirk, 1926, Geology of the Latah Formation in relation to the lava of the Columbia Plateau near Spokane, Washington: U.S. Geol. Survey Prof. Paper 140-A, 81 p.

Resser, C. E., 1938, Middle Cambrian fossils from Pend Oreille Lake, Idaho: Smithsonian Misc. Collections, v. 97, no. 3, p. 1-11.

Ross, C. P., and Forrester, J. D., 1958, Outline of the geology of Idaho: Idaho Bur. Mines and Geology Bull. 15, 74 p. ($1.50).

Savage, C. N., 1965, Geology and mineral resources of Bonner County: (in preparation), Idaho Bur. Mines and Geology.