2006 Idaho Earth Science Teachers
Summer Field Workshop

Geology and Natural Hazards of the
Lake Pend Oreille-Clark Fork Area

July 9-14, 2006

Detail from Geologic Map of the Hope Quadrangle, Bonner County, Idaho by Russell F. Burmester, Roy M. Breckenridge, Reed S. Lewis, and Mark D. McFadden (2004)

Idaho Geological Survey
University of Idaho
Moscow, Idaho
FIELD TRIP GUIDE

START - PAVILION, SAM OWEN CAMPGROUND. Take Peninsula Road to State Highway 200. Turn north (left) on Highway 200. Proceed 3.7 miles to highway overlook on west (left) side of highway.

STOP 1 - LAKE PEND OREILLE - HIGHWAY SIGN OVERLOOK

Lake Pend Oreille, the largest lake in Idaho, is located about 50 miles south of the British Columbia border in the Purcell Trench. The lake level is 2062 feet above sea level, with the surrounding terrain as high as 6000 feet. The maximum depth of the lake is an impressive 1150 feet, the deepest lake, by far, in the region. The location of the lake is probably related to an old river valley controlled by faults. Lake Pend Oreille was carved repeatedly by a lobe of Pleistocene ice, scoured by ice age floods and filled with glacial outwash and flood deposits.

Lake Pend Oreille in northern Idaho is a fascinating geomorphic feature. This lake lies in a basin formed by Cordilleran glaciation immediately below the site of the ice dams that repeatedly formed Pleistocene Lake Missoula. The Cordilleran ice sheet extended farthest along major south-trending valleys and lowlands, forming several composite lobes segregated by highlands and mountain, leaving behind distinctive landforms, weathering, and soils in these valleys. This view provides a vista of the intersection of the Clark Fork valley and the Purcell Trench as well as the area of the Clark Fork ice dam and Lake Pend Oreille trough. The Purcell Trench, a major topographic depression in British Columbia and northern Idaho, is incised into the margin of a metamorphic and granitic complex, formed during Mesozoic convergent tectonics, but later subjected to Eocene extension. The trench is bounded on the west by the Selkirk Range and on the east by the Cabinet Mountains. The Purcell Trench has been the site of several drainage reversals. Prior to Miocene time (~22 myr), an ancestral river flowed within the Purcell Trench from the Canadian border south to the Coeur d'Alene area in a meandering pattern following the least resistant rock exposures and fault zones. This pattern is still apparent in the present day meandering shape of Lake Pend Oreille. During Miocene time, Columbia River basalts invaded the southern part of the trench and formed a lava-dammed lake with water levels up to 800 m above sea level. The basalt dam eventually was eroded, restoring southward drainage.
During the Pleistocene, Cordilleran ice advancing into Lake Pend Oreille repeatedly blocked the Clark Fork drainage and formed glacial Lake Missoula. The terminus of the glacial advance extended to the southern end of the lake and upon each failure of the ice dam, much of the catastrophic flood discharge was directed through the lake basin and into the Rathdrum Prairie. The Cordilleran late Wisconsin ice was north of the Canadian border as late as 17,500 $^{14}$C yr BP and the maximum in the Purcell Trench was reached about 15,000 $^{14}$C yr BP. Glacial lobes of moved south from Canada again blocking the south end of the trench and impounding Lake Pend Oreille basin, this time with glacial debris. In eastern Washington, Wisconsin glacial lobes dammed the Columbia River and its tributary drainages forming Pleistocene Lake Columbia with a water level up to 2400 feet above sea level. Lake Columbia covered the Rathdrum Prairie and created proglacial waters in front of the ice sheets advancing down the Purcell Trench. The present outlet of Lake Pend Oreille is at the northwest arm of the lake issuing into the Pend Oreille River, which then flows, to Washington and north into British Columbia. No modern surface drainage of the northern Rathdrum Prairie exists; all water flow is in the subsurface.

One of the most intriguing questions about the catastrophic flooding is how the ice dam failed. Various mechanisms for glacial outburst floods have been proposed: Ice erosion by overflow water, subglacial failure by flotation, deformation of ice by water pressure, and erosion of
subglacial tunnels by flowing water. One popular model suggests a self-dumping phenomenon. In this mechanism, floodwaters are released when the lake level reaches nine-tenths the height of the ice. At this depth the increasing hydrostatic pressure makes several things happen: The ice becomes buoyant, subglacial tunnels form and enlarge, and drainage occurs until hydrostatic pressure is decreased and the ice again seals the lake. Sub-glacial tunneling and progressive enlargement due to thermal erosion progressing to collapse has been proposed as well as the catastrophic failure due to water pressure. All of these mechanisms are dependent on the configuration of the ice dam and structure of the ice. The self-emptying model is used to explain the numerous cycles in the rhythmite deposits and to interpret each cycle as a separate flood. Even so, geologists argue that only the total collapse of the ice dam can explain the largest of the catastrophic floods.

After the latest flood, a glacier again reoccupied the Pend Oreille basin but this advance did not result in catastrophic lake drainage. Terminal deposits of till at the southern end of Lake Pend Oreille are undisturbed. Proglacial deltas and kame terraces in the Clark Fork valley left by this advance are intact and therefore post-date the catastrophic Missoula Floods. Furthermore, giant current ripples, expansion bars and other flood deposits in the lower Clark Fork valley are mantled by lacustrine silts indicating that the last glacial Lake Missoula did not drain catastrophically. Evidence from radiocarbon dating shows that glacial Lake Missoula existed only between about 17,200 and 11,000 14C years ago. The Purcell Trench was free of Cordilleran ice by the time of two closely spaced Glacier Peak eruptions about 11,200 14C years ago (13,100 cal yr ago). Latest glacial alpine moraines formed by valley glaciers in the Selkirk and Cabinet Ranges occupy the tributary valleys of the Purcell Trench. These deposits must post-date retreat of the Cordilleran ice lobe and are evidence for a late Wisconsin alpine glacial advance. A radiocarbon date of 9,510 ± 110 14C yr BP from a peat bog within the glacial limit on the west slope of the Selkirk Mountains may provide a limiting date on the last alpine ice.

Little is known about Lake Pend Oreille basin because the lake bottom has never been cored. The great depth of the lake and the thickness of the lake bottom sediment make it is unlikely that such a core will be obtained in the foreseeable future. However, we have been fortunate to obtain data from United States Navy seismic reflection surveys performed on the lake. Although these surveys were performed primarily for geotechnical studies of the lake-bottom surface, the data show distinct sub-bottom reflections. United States Navy seismic reflection surveys performed on the lake show that the bedrock lake basin has been glacially overdeepened to a depth more than 500 feet below present-day sea level. The seismic sections show a record of subglacial erosion, Missoula Flood deposition, and a post-flood glacial readvance. Seismic studies of the bedrock morphology and sedimentary facies of inland linear valleys, such as the Okanogan and Kalamalka valleys in British Columbia, have revealed bedrock erosion to depths well below sea level and subsequent rapid infilling by sediment. These valleys, which are similar to Lake Pend Oreille basin, contain substantial sediment thicknesses and owe their locations to structural lineaments and their morphology to large-scale glacial erosion beneath Cordilleran ice sheets. These are all elongate, deep valleys, controlled by pre-existing fluvial channels, and preferentially carved along pre-existing structural features at the southern margins of the Cordilleran ice scour.
Seismic record section across Lake Pend Oreille basin obtained in 1966. Roman numerals refer to seismic stratigraphic units. I = Holocene sediments; II = post-Missoula flood glacial deposits; III = glacial deposits; IV = bedrock. Horizontal scale approximately 5 kilometers (From Breckenridge and others, 1996).

STOP 2 - PRICHARD FORMATION. Continue north 2 miles to Trestle Creek Recreational area for bathroom stop. Return to Highway 200 and travel 2.1 miles south to road junctions west of Hope, Idaho. Turn left into pullout area along highway. View Pritchard Formation of the Precambrian Belt Supergroup. Discuss sedimentary environment (deep water). Identify lithologies (siltite and quartzite). Note characteristic rusty color indicative of weathering of disseminated sulfides. Discuss Purcell sills, emplacement and relationship to basin tectonics.
STOP 3 - REVETT AND ST. REGIS FORMATIONS. Return to the junction of Peninsula Road and Highway 200 by driving 3.5 miles south on Highway 200. Turn northeast (left) on paved road leading to rusty iron bridge over railroad tracks. Cross tracks, then turn southeast on old Highway 200. Continue 2.6 miles on this paved road, then park carefully on west (right) side of road on grassy pulloff. **DANGER:** This road has limited view distances and pedestrians along the side of the road must be alert for approaching cars.

Walk about 0.3 miles (~1800 feet) south along the road. View outcrops of Revett Formation grading upward to the St. Regis Formation. Note dip of units steeply to the southeast. Lithologies are interbedded quartzite, siltite and argillite, becoming more argillite-rich up section as we move from Revett into St. Regis. Sedimentary structures include ripples, dessication cracks, mud chips, load structures, and graded beds (quartzite fining to argillite). Discuss sedimentary environmental model of unconfined sheet flows over low relief surface, and shallow water and periodic drying up of basin. Show how to determine “way up” using sedimentary structures.

Geology in vicinity of Stops 1 and 2 (Lewis and others, 2006). Ypab = Prichard Formation, members a, b; Ypc = Prichard Formation, member c; Ymi = mafic intrusive rock; Tpd = Tertiary dacite dike; Qgt = glacial till; Qad = alluvium and deltaic deposits; Qal = alluvium.
Walk up to first appearance of green and brown carbonate-bearing siltite and quartzite of the lower Wallace Formation (western facies of the Helena Formation).

Pick up passengers on wide pull-off near end of walk.

**STOP 4 - CLOUDSLEDGE.** From the end of Stop 2, drive ~0.3 miles (~1700 feet) south on old Highway 200 to gated road on east (left) side of highway. Turn east (left) onto the gravel road and proceed uphill and north ~0.4 miles to Cloudsledge, home of the Stearns family. Continue past the historic home on a smaller gravel road about 300 feet to a large clearing. Park and walk short distance to spectacular view of Lake Pend Oreille. The St. Regis Formation here has been glacially eroded to form striated pavements with erratic boulders of granodiorite. Good views of Belt sedimentary structures on flagstones around house. Discuss evidence for limit of ice sheet glaciation, breakup of the ice dam.
Harold T. Stearns was a geologist and hydrologist well known for his pioneering studies of volcanic rocks and groundwater in Hawaii and Idaho. Stearns was an amazingly versatile and productive geologist who authored over 117 publications. Among his Idaho classics are *Geology of Craters of the Moon National Monument* (1924, revised 1963), and *Evidence of Lake Bonneville flood along Snake River below King Hill, Idaho* (1962). Stearns was born in Connecticut and received his B.S. degree from Wesleyan University in 1921 and his Ph.D. in geology from George Washington University in 1926. He began his career with the United States Geological Survey in 1923 and was the author of numerous reports to the General Land Office on irrigation projects in Idaho. He also explored the Craters of the Moon region and was the author of the report to the National Park Service recommending the area be set aside as a national monument, which it was in 1924. From 1924 to 1925 he traveled around the world visiting the volcanoes of Hawaii, Japan, the Philippine Islands, Java, Sumatra, Africa, and Italy. During WWII, he was the geologist in charge of Hawaiian ground water investigations from 1943 to 1946, and also explored numerous other Pacific Islands for groundwater in support of the war effort. Following his retirement from the U.S.G.S. after the war, he had an important second career as a consulting geologist specializing in dam sites. Stearn’s wife, Claudia, was also a very interesting person. Trained in art at Berkeley, her acquaintances included Gertrude Stein. She shared many of Harold’s adventures on Pacific Islands, including witnessing the attack on Pearl Harbor in 1941 by the Japanese. Claudia and Harold obtained the Cloudsledge property, then a cut-over, abandoned homestead, in 1946. After Harold’s death, Claudia lived at Cloudsledge for many years until her death at age 100.

**STOP 5 - MIDDLE BELT CARBONATE, THE WALLACE FORMATION AT THE DUMPSTERS.** Retrace route back to Old Highway 200. Turn south (left) onto the Old Highway
and proceed 0.6 miles to junction with Highway 200. Park in the large turnout next to trash dumpsters. Discuss occurrence of carbonate and stromatolites in the black argillite of the Wallace Formation. Also, hummocky cross-stratification, molar tooth structure, and bird’s foot cracks showing evidence for storm deposits in deeper water than in St. Regis or Revett Formation.

East-dipping strata exposed here are carbonate-bearing (dolomitic) siltites in the middle part of the Belt Supergroup (Wallace Formation). The dolomitic rocks weather orange-brown. Thin black argillite “caps” are the result of clay-sized particles that settled out of the water column following each storm-related silt and sand depositional event. From here northwest (down section) along the old highway is the “classic” Belt Supergroup section for this region. Algal mats (stromatolites) are present in the exposures to the southeast along the new highway.

STOP 6 - LUNCH. Join Highway 200 and proceed south 3.7 miles to the city park of Clark Fork. Grass, shade trees, picnic table and one porta-potty are available. Alternatively, stop at convenience stores in Clark Fork for restrooms, cold drinks, etc. but no place to sit.
STOP 7 - CASTE ROCK. Rejoin Highway 200 in the center of Clark Fork. Turn south (right) onto road E74 4.3 miles to Castle Rock, an ice-smoothed hill. Discuss erosion by ice, roche moutonée and chatter marks, etc. Examine glacial polish and striae preserved beneath talus that has since been removed. Note amount weathering above the former talus limit. The bedrock unit here is Mt. Shields Formation. Note mm-scale laminae in argillite with lots of mica visible. Note numerous erosional channels.
STOP 8. OUTWASH DELTA, DRY CREEK GRAVEL PIT. Continue east on road E74 2.7 miles to junction with road 208. Turn south (right) onto this gravel road and proceed about 1 mile to large gravel pit. Park in upper portion of the pit.

This site exposes a section deposited at the mouth of Dry Creek with the Clark Fork valley. The pit is at an elevation of 2680 feet, over 400 feet above the present floor of the valley. The foresets are tens of feet high and dip up river to the east. The clasts are poorly rounded, and some cobbles are striated. Although most of the clasts are of Precambrian Belt metasediments derived locally, some are from granite and diorite (Purcell sills) from rocks exposed in the Purcell Trench. The granules are cemented, and the pit walls must be ripped before the aggregate can be excavated. This gravel probably was deposited into Lake Missoula in the form of a pro-glacial
delta. It is not to be confused with the so-called gulch fills or eddy bars of Pardee that formed in the side-valleys during Missoula Floods. Most of the drainages on the south side of the Clark Fork valley from Lake Pend Oreille upstream to nearly Thompson Falls contain these features. Thus glacial ice advanced upstream much farther than had been previously recognized.
Because the proglacial deltas and kame terraces in the Clark Fork valley left by this advance are intact they must post-date the major catastrophic Missoula Floods. Furthermore, giant current ripples, expansion bars and other flood deposits in the lower Clark Fork valley are mantled by lacustrine silts indicating that the last glacial Lake Missoula did not drain catastrophically.

**STOP 9 - SEDIMENTARY STRUCTURES IN MT. SHIELDS FORMATION.** Continue on road 208 west 2.2 miles to roadcut. **DANGER:** Limited view distances along road. View and optionally collect salt-casts, boxwork structure, ooids, stromatolites, and dendritic structures composed of Mn-oxides.
This stromatolite once grew in a shallow carbonate platform in water depths of a few meters, about 1350 million years ago. It was part of an extensive subtidal and intertidal reef and mudflat complex that, despite the absence of plants and animals, bore striking resemblance to modern coastal environments (Image form NASA)
STOP 10 (Optional) – CABINET DAM. Retrace route on road 208 to junction with road E74. Turn east (right) on road E74 and proceed ~6 miles to junction with Highway 200. Turn west (left) on Highway 200. Drive past turnoff for Cabinet Gorge Dam, a true arch dam 208 ft high and 600 ft long built in 1951-52. Operation of the dam creates problems for fish. During spring runoff, huge volumes of water plunge over the dam’s spillway and traps nitrogen and oxygen from the air in the deep spilling basin below. The gases can cause a potentially fatal bubble disease in the blood vessels of fish, which is akin to a diver experiencing the bends.

Cabinet Gorge Dam (photo Association of Washington Business).

Continue northwest on Highway 200, past Clark Fork, and return to Sam Owen Campground.

Return to Highway 200 and Peninsula Road to Sam Owen Campground.
Staff Biographies

Roy Breckenridge

Roy is the Idaho State Geologist. He came to IGS from the Wyoming Geological Survey in 1978. Roy’s PhD and M.S. are in geology from the University of Wyoming. His areas of expertise are geomorphology, Quaternary geology, and field mapping. Roy enjoys all disciplines of geology and has worked in many diverse geologic terranes. He is currently working on the glacial geology of northern Idaho and the Long Valley area near McCall.

Jim Cash

Jim is a teacher with the Moscow School District. He has taught earth science at Moscow High School since 1982. Jim has presented research on earth science teaching at both state and national conferences. He was actively involved in creating curriculums and course assessments for the teaching of earth science in Idaho. Jim also worked with Idaho State University and the Idaho Geological Survey to develop the geology portion of the Idaho Digital Atlas.

Mark McFaddan

Mark is a geology instructor with North Idaho College in Coeur d’Alene. He also teaches upper division geology courses for the University of Idaho at Coeur d’Alene and supervises undergraduate UI Environmental Science students. Mark has a Ph.D in geology from the University of Idaho and has been mapping Precambrian Belt Supergroup rocks in northern Idaho for 16 years during the summer months for the Idaho Geological Survey. His current focus is mapping the diverse geology and structure of the Sandpoint area of northern Idaho.

Bill Phillips

Bill is an assistant research geologist with the Idaho Geological Survey. A Pocatello native, Bill joined the IGS in 2004 after many years living away from Idaho. He has taught university courses in geomorphology, field methods, hydrology, and introductory geology, most recently at the University of Edinburgh and Colorado College. For a decade, Bill worked at the Washington Division of Geology and Earth Resources in Olympia where he conducted geological mapping projects in the Cascades. Bill has a Ph.D in geology from the University of Arizona. His current research focuses on dating glacial deposits, faults, and lava flows with cosmogenic nuclides, and the geology of the Idaho Falls-Blackfoot area in southeastern Idaho.

Stephen Weiser

Until his retirement in May, 2006, Stephen was employed by the Idaho Bureau of Homeland Security in Boise. His job focused on the reduction of losses from floods, wildland/urban fires, landslides, and earthquakes. In addition, he assisted state and local governments to take advantage of funding opportunities. Education was also a big part of his job. Over the years, Stephen has been instrumental in helping IGS obtain BHS funding for the Earth Science Teachers workshop, and has taught at many previous workshops. He has an M.A. in English from the University of Oregon, and a B.A. in German, also from Oregon.