WHISKEYTOWN NATIONAL RECREATION AREA
GEOLOGIC RESOURCES MANAGEMENT ISSUES
SCOPING SUMMARY

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Executive Summary

A Geologic Resources Evaluation scoping meeting for Whiskeytown National Recreation Area was held in Ashland, Oregon, March 2, 2004. The scoping meeting participants identified the following geologic resources management issues.

1. Restoration of roads from logging and mining activities is needed to stabilize slopes and prevent further erosion and sedimentation.

2. Mine drainage from abandoned gold and copper mines introducing heavy metals into the environment.

3. Mercury contamination from past placer mining has introduced free mercury into streams and drainages raising concentration above background levels.

Introduction

The National Park Service held a Geologic Resources Evaluation scoping meeting for Whiskeytown National Recreation Area on the campus of Southern Oregon University on Tuesday, March 2, 2004. The purpose of the meeting was to discuss the status of geologic mapping in the NRA, the associated bibliography, and the geologic issues in the park. The products to be derived from the scoping meeting are: (1) Digitized geologic maps covering the NRA; (2) An updated and verified bibliography; (3) Scoping summary (this report); and (4) A Geologic Resources Evaluation Report which brings together all of these products.

Whiskeytown National Recreation Area was established on October 21, 1972, as one unit of the Whiskeytown-Shasta-Trinity National Recreation Area. The Shasta and Trinity units are managed by the Forest Service, U.S. Department of Agriculture. The NRA covers about 42,503 acres including 3200 acres of Whiskeytown Lake at a maximum surface elevation of 1,209 feet. The reservoir has 32 miles of shoreline and was created by diverting water from the Trinity River Basin. The Whiskeytown Dam impounds water from Clear Creek.

Whiskeytown NRA lies entirely within the French Gulch 15-minute quadrangle (1:62,500). This has subsequently been divided into four 7½’ quadrangles: Whiskeytown, French Gulch, Shasta Bally and Igo. Albers, *et. al.* published the geology of the French Gulch 1:62,000 quadrangle in 1964. Kinkel, *et. al.*, published the “Geologic Map of West Shasta Copper-Zinc District” in 1956 at a scale of 1:24,000. This map covers the east two-thirds of the park. Both of these maps have been digitized. Lyndon, 1972, published a geologic map of Shasta County at a scale of 1:250,000.

Physiography

Whiskeytown National Recreation Area lies in the Klamath Mountains physiographic province. The boundaries of the province are not well defined. According to Irwin (2003), the Klamath Mountains extend from about 43º north latitude (near the Umqua River in Oregon), south to about 40º15' (North Fork of the Eel River) a distance of about 190 miles. In an east-west direction, it extends about 70 miles from the Great Valley west to the Coast Ranges. In northernmost California and southwestern Oregon, the Klamaths are bounded on the east by the Cascade Range. The province covers an area of about 11,800 square miles (Irwin, 1966).

The Klamath Mountains have been cut by several rivers to form distinct mountain ranges. In California the northern half is drained by the Klamath River and the southern half by the Trinity River (Norris and Webb, 1976). The principal ranges are the Siskiyou Mountains extending into Oregon and the Trinity Mountains to the south. Other ranges include the Salmon, Marble, South Fork and Scott Mountains. The highest point in the Klamaths in Oregon is Mt. Ashland at 7,530 feet and in California, the highest elevations are Thompson Peak at 9,002 feet and Mt. Eddy, 9,038 feet. General elevations range from 2,000 to 5,000 feet in Oregon and 5,000 to 7,000 feet in California. The topography is rugged and steep.

Geologic History

The Klamath mountains are composed of a series of accreted terranes with rocks ranging in age from Cambrian to latest Jurassic (Irwin, 1997). The distribution of rocks in the Klamath Mountains are divided into four roughly arcuate belts reflecting this accretion of terranes. From east to west they are: (1) the eastern (Paleozoic) Klamath belt; (2) the central metamorphic belt; (3) the western Paleozoic and Triassic belt, and (4) the western Jurassic belt (Irwin, 1966). The belts are separated by thrust faults. The eastern Klamath belt is comprised of an essentially homoclinal sequence dipping to the east and terminating with some deformation against ultramafic intrusive rock. In aggregate the sediments are 40,000 to 50,000 feet thick and range in age from Ordovician to Jurassic, although the Ordovician and Silurian rock are limited to exposures in an isolated northern part of the belt.

The central metamorphic belt consists mainly of the Abrams mica schist and the Salmon hornblende schist. It is separated from the eastern Klamath belt by ultramafic rocks and from the western Paleozoic and Triassic belt by faulting (Irwin, 1966). The Abrams mica schist is a composite unit which includes metasedimentary rocks occurring both above (Grouse Ridge Formation) and below (Stuart Fork Formation) the Salmon hornblende schist. The lower rocks are considered fensters ("windows") in a regional thrust plate formed by Salmon hornblende schist and the Grouse Ridge Formation. The metamorphic history is complex, and generally ranges from upper greenschist to almandine-amphibolite facies with some retrograde metamorphism as well (Davis, 1966).

The western Paleozoic and Triassic belt consists of phyllitic detrital rocks, radiolarian chert, mafic volcanics, and crystalline limestone which have been intruded by ultramafic and granitic rocks. Metamorphism ranges from low-grade greenschist facies to amphibolite facies. Some fossils have been identified including Late Pennsylvanian or Early Permian fusulinids and Permian and Triassic ammonites (Irwin, 1966).

The western Jurassic belt is composed mainly of the Galice Formation and the South Fork Mountain schist. The Galice, dated as Late Jurassic, is composed of a lower metavolcanic unit and an upper metasedimentary unit. The metavolcanic unit is composed mainly of meta-andesite flows and breccias and may be over 7,000 feet thick. The upper unit is mostly slaty mudstone and greywacke. The South Fork Mountain schist is well-foliated quartz-mica schist extending in a narrow north-south band along western boundary of the Klamath Mountains for about 150 miles (Irwin, 1966).

Stratigraphy

The following stratigraphy of the eastern Klamath Mountains and Whiskeytown NRA was taken from Irwin (1966), p.23, Figure 3 and from Albers, *et. al*. (1964). From oldest to youngest:

Copley Greenstone (Devonian?): 3,700+ ft.; Keratophyre, spilite, pillow lavas, pyroclastics, metadacites; includes some tuff, shaly tuff, and shale; intertongues with overlying Balaklala Rhyolite.

Balaklala Rhyolite (Devonian): 0-3,500 ft.; Light-colored porphyritic and nonporphyritic quartz keratophyre flows and pyroclastics; grades upward into the Kennett Formation.

Kennett Formation (Devonian): 0-400 ft.; Dark, thin-bedded gray to black cherty shale; limestone in upper part; corals and brachiopods of Middle Devonian age; probably absent in park.

Bragdon Formation (Mississippian): ~6,000 ft.; Interbedded shale and sandstone; upper unit is conglomerate and sandstone interbedded with siltstone and shale; lower unit is mostly shale, mudstone, and siltstone with some tuff and conglomerate; found in extreme northern part of the park.

Mule Mountain Stock (Devonian, ~ 400 Ma): Light-colored, sodium-rich granite.

Shasta Bally Batholith (Upper Jurassic): Biotite and hornblende-rich granodiorite and quartz diorite; dated at 128 m.y. (Lanphere and Irwin, 1965; Irwin, 1966) to 218 m.y. (Davis, 1966).

Gneiss and amphibolite (Jurassic): Derived from Copley, Balaklala, and Bragdon formations.

Hornblendite (Jurassic-Cretaceous): Small pods of hornblende associated with Copley Greenstone.

Unconsolidated deposits (Quaternary): Soil, landslide material, alluvial gravels.

Most of the park is underlain by three units: granite of the Shasta Bally batholith (approx. SW half); the Copley Greenstone (central ⅓), and granite of the Mule Mountain stock (east ~¼). The Shasta Bally granite is unique in that with such abundant biotite it has weathered very deeply (600'+) and created slope instability in certain areas of the park. The batholith has intruded the Copley Greenstone and there is, for the most part, a sharp contact between the two, although the greenstone has been recrystallized to a fine-grained amphibolite, gneiss, and migmatite as much as 4,000 feet from the contact. The quartz diorite contains about 40% hornblende and biotite. The Shasta Bally batholith is Late Jurassic or Early Cretaceous as it cuts across foliation formed during the Nevadan orogeny.(Kinkel, *et. al*, 1956).

Structure

The overall structure of the Klamath Mountains is that of the four arcuate, concentric, lithic belts discussed above. These lithic belts are separated either by faults or by linear ultramafic bodies or granite plutons (Irwin, 1966). In the park mapping of the French Gulch quadrangle by Albers, *et. al* (1964) shows that the local structure is dominated by the Shasta Bally batholith and other intrusives. The contact between the Bragdon Formation and the underlying intrusives is thought to be a low-angle thrust fault.

The principle structural feature is a broad anticline trending north-northeast, plunging to the north in the Bohemotash quadrangle northeast of the park and plunging slightly to the south across the northeast corner of the Shasta Dam quadrangle and into the Whiskeytown quadrangle where it truncated by the Mule Mountain stock. Two synclines on either side of the anticline also trend in a generally northerly direction.

There are numerous faults running through the park, but many are difficult to locate due to the poor exposures. Most appear to trend northwest to southeast, with secondary faulting trending northeast to southwest. The Hoadley Fault virtually bisects the park from the northwest end to the southeast corner. It is a normal fault with the downthrown side to the northeast and dipping generally 50º-65º to the northeast. It is dated at approximately 140 my.

Significant Geologic Resource Management Issues in Whiskeytown National Recreation Area

1. Restoration of roads.

Whiskey NRA has over 300 miles of logging and mining roads covering over 42,000 acres. In an area of deeply weathered rock on steep slopes with high rainfall, the erosion of these roads has created slope failure and debris flows. Weathering of the granodiorite of the Shasta Bally batholith frees the considerable biotite mica. The hydration of the biotite creates glide planes in the crystal structure allowing the mica particles to slide past one another. On the megascopic scale, this translates to this material sliding down slope, especially in periods of high rainfall. A similar situation exists in shales which comprise some of the Copley Greenstone.

Road construction as well as fires remove the stabilizing vegetation and expose slopes to further hydration and erosion. The result is that these roads have created areas highly prone to down slope movement. This may occur as slow creep or as catastrophic slope failure and debris flows. 70% of down slope movement occurs within the first year after a fire, both from the fire roads and from the denuding of the slopes from fire.

Some of the areas prone to slope failure are also areas of high visitation. For example, the beach area below Brandy Creek Trail, a popular recreation spot, is susceptible to debris flow and may put visitors as risk. Debris flows have occurred on almost all the creeks in the southern half of the park. Although there is difficulty in dating past debris flows, major debris flows have occurred twice in the last 50 years, the last in 1997. There is a need to study and monitor debris flows as well as to map their locations and aerial extent. Also, there is a need to measure soil moisture and to research slope hydrology, although many of these areas are remote and inaccessible.

2. Acid mine drainage

The Klamath Mountains are the second most productive gold producing province in California. Placer gold was first discovered in 1848, and lode gold was discovered in the French Gulch area in 1852 (Clark, 1970). Gold mining in the French Gulch area continued until 1942, with peak activity from 1900 to 1914 and again in the 1930s. There was a resurgence of gold exploration in the 1970s and 80s. Much of the lode gold came from massive sulfide deposits. Copper, iron, zinc, and silver along with considerable pyrite have been also been mined in the French Gulch and West Shasta Districts (Albers, 1965). Today there are over 100 abandoned mines in the NRA.

The result has been acid mine drainage from the oxidation of the pyrite (iron sulfide) to sulfuric acid and transportation of acid solution into streams and rivers. The sources are from the abandoned mines and from the tailings that were produced and then left from the mining and milling of these pyritic ores. This low pH acidic water also mobilizes heavy metals such as lead, cadmium, and arsenic. At the Iron Mountain Mine, an EPA Superfund site in the northeast corner of the park, the water is so acidic that a negative pH (-3.5) has been measured.

There is a need for accurate maps showing the location of abandoned mine sites. Each of these abandoned mines needs on-site characterization. Additional monitoring of water outflow from the mines is also a priority.

3. Mercury contamination

The largest recovery of gold from the Whiskeytown area has been from placer mining (Clark, 1970). As part of the gold recovery process from placer deposits, mercury is used to amalgamate the gold and remove it from the surrounding rock. The gold is then separated from the mercury and most of the mercury can be reused. However, some mercury remains in the waste rock and tailings and additional mercury is lost in the recovery process.

Although placer tailings are one of the likely sources of mercury, the process of removing the tailings and disturbing entrained mercury, could release more mercury into the environment. Nevertheless, mercury has been found in aquatic macroinvertebrates. Additional sampling and monitoring of stream sediment and water is needed.

4. Other Issues

> Abandoned mines: Apart from acid mine drainage and mercury contamination, abandoned mines also present health and safety issues associated with the workings. Open shafts and adits can be hazardous to visitors terms of falling, collapsed workings, and bad air. Some mines have been closed using bat gates to allow access for bats and some have fences to keep visitors out. There are likely many more mines that need permanent closures using polyurethane foam (PUF). These mine sites must be inventoried and characterized before closures can proceed.

Groundwater: Most groundwater is high in iron and aluminum due to the mineralogy of the country rock. Some septic tanks are located too close to water wells in the town of French Gulch, upstream of WHIS on Clear Creek, raising the potential for contamination. These well are closely monitored.

Surface water: Salmonid habitat below the dam on Clear Creek has been degraded by the Whiskeytown Dam reducing gravel input downsteam. Likewise, there has been siltation behind the dam in the lake. There is some shoreline erosion on Whiskeytown Lake. However, the Bureau of Reclamation (BOR) has jurisdiction over the lake and controls the water level. The NPS has little input in the control of the water level and timing of the release of water from the lake. The BOR also has responsibility for the water quality of the lake.

Wetlands: There are some wetlands along the shoreline of Whiskeytown Lake. There may be a need to characterize and monitor these areas, especially as they respond to changes in lake levels.

Seismic activity: Although there are minor earthquakes in Whiskeytown, there are no major active faults. There are frequent minor earthquakes around Lake Shasta. A earthquake of 5.3 magnitude occurred on November 25, 1999. A seismograph has been set up in the area as part of the University of California, Berkley network.

Volcanic hazards: Ashfall from a major eruption of Mt. Shasta or Lassen Peak could impact the park.

Scoping Meeting Participants

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References

Albers, John P., 1961, Gold deposits in the French Gulch-Deadwood district, Shasta and Trinity Counties, California, *in* Geological Survey Research 1961, U.S. Geological Survey Professional Paper 424-C, p.1-4.

______, 1964, Geology of the French Gulch quadrangle, Shasta and Trinity Counties, California, U.S. Geological Survey Bulletin 1141-J, p.1-70.

______, 1965, Economic geology of the French Gulch Quadrangle, Shasta and Trinity Counties, California, California Division of Mines and Geology Special Report 85.

______, 1966, Economic deposits of the Klamath Mountains, California Division of Mines and Geology Bulletin 190, p. 51-69.

Albers, John P., and Bain, John H.C., 1985, Regional setting and new information on some critical geologic features of the West Shasta District, California, *Economic Geology*, v.80, no.8, p.2072-2091.

Albers, John P., Kinkel, A.R., Jr., Drake, A.A., and Irwin, W.P., 1964, Geology of the French Gulch Quadrangle, California, U.S. Geological Survey Geologic Quadrangle Map GQ-336, scale 1:62,500.

Albers, J.P., Kistler, R.W., and Kwat, L., 1981, The Mule Mountain stock, an early Middle Devonian pluton in northern California, *Isochron/West* no. 31 p. 17.

Bailey, Edgar H. (Ed.), 1966, Geology of Northern California, *California Division of Mines and Geology Bulletin* 190, 508p.

Boudier, F., Le Sueur, F., and Nicolas, A., 1989, Structure of an atypical ophiolite: The Trinity complex, eastern Klamath Mountains, California, *Geological Society of America Bulletin*, v.101, no.6 (June), p.820-833.

Brouxel, Marc, and Lapierre, Henriette, 1988, Geochemical study of an early Paleozoic island-arc-back-arc basin system. Part 1: The Trinity Ophiolite (northern California), *Geological Society of America Bulletin*, v.100, no.7 (July), p.1111-1119.

Brouxel, Marc, Lapierre, Henriette, Zimmermann, Jean-Louis, 1989, Upper Jurassic mafic magmatic rocks of the eastern Klamath Mountains, northern California: Remnant of a volcanic arc built on young continental crust, *Geology*, v.17, no.3 (March), p.273-276.

Clark, William B., 1970, Gold district of California, California Division of Mines and Geology Bulletin 193.

Davis, G.A., 1966, Metamorphic and granitic history of the Klamath Mountains, *in* Bailey, E.H., editor, Geology of Northern California, California Division of Mines and Geology, Bulletin 190, p.39-50.

Fagin, Stuart W., and Gose, Wulf A., 1983, Paleomagnetic data from the Redding section of the eastern Klamath belt, northern California, *Geology*, v.11, no.9 (Sept.), p.505-508.

Irwin, William P., 2003, Correlation of the Klamath Mountains and the Sierra Nevada, U.S. Geological Survey Open-File Report 02-490, Sheet 1 scale 1:100,000.

Irwin, William P., comp., 1997, Preliminary map of selected post-Nevadan geologic features of the Klamath Mountains and adjacent areas, California and Oregon, U.S. Geological Survey Open-file Report OF 97-0465, 29p. + 1 over-size sheet, scale 1:500,000.

Irwin, William P., 1966, Geology of the Klamath Mountains Province, *in* Bailey, Edgar H., ed., Geology of Northern California, California Division of Mines and Geology Bulletin 190, p.19-38.

Irwin, William P., 1960, Geologic reconnaissance of the northern Coast Ranges and Klamath Mountains, California, with a summary of the mineral resources, California Division of Mines and Geology Bulletin 179, 80p.

Kinkel, A.R., Jr., Hall, W.E., and Albers, J.P., 1956, Geology and base-metal deposits of West Shasta copper-zinc district, Shasta County, California, U.S. Geological Survey Professional Paper 285, 156p.

Lydon, Philip, and O'Brien, J.C., 1974, Mines and mineral resources of Shasta County, California, California Division of Mines and Geology County Report 6, p. 9-13.

Mankinen, Edward A., and Irwin, William P., 1982, Paleomagnetic study of some Cretaceous and Tertiary sedimentary rocks of the Klamath Mountains province, California, *Geology*, v. 10, no.2 (Feb.), p.82-87.

Miller, M. Meghan, 1989, Intra-arc sedimentation and tectonism: Late Paleozoic evolution of the eastern Klamath terrane, California, *Geological Society of America Bulletin* v.101, no.2 (Feb.), p.170-187.

Norris, R.M., and Webb, R.W., 1976, *Geology of California*, John Wiley and Sons, Inc., p.69-76.

Snoke, Arthur W., Sharp, Warren D., Wright, James E., and Saleeby, Jason B., 1982, Significance of mid-Mesozoic peridotitic to dioritic intrusive complexes, Klamath Mountains - western Sierra Nevada, California, *Geology*, v.10, no.3 (March), p.160-166.

Wallin, E. Timothy, Mattinson, James M., and Potter, A.W., 1988, Early Paleozoic magmatic events in the eastern Klamath Mountains, northern California, *Geology*, v.16, no.2 (Feb.), p.144-148.

Watkins, Rodney, and Flory, Richard A., 1986, Island arc sedimentation in the Middle Devonian Kennett Formation, Eastern Klamath Mountains, California, *Journal of Geology*, v.94, no.5 (Sept.), p.753-761.

Watkins, Rodney, 1985, Volcanoclastic and carbonate sedimentation in late Paleozoic island-arc deposits, Eastern Klamath Mountains, California, *Geology*, v.13, no.10 (Oct.), p.709-713.

Wright, James E., and Fahan, Mark R., 1988, An expanded view of Jurassic orogenesis in the western United States Cordillera: Middle Jurassic (pre-Nevadan) regional metamorphism and thrust faulting within an active arc environment, Klamath Mountains, California, *Geological Society of America Bulletin*, v.100, no.6 (June), p.859-876.

Wright, James E., and Wyld, Sandra J., 1986, Significance of xenocrystic Precambrian zircon contained within the southern continuation of the Josephine ophiolite: Devil's Elbow ophiolite remnant, Klamath Mountains, northern California, *Geology*, v.14, no.8 (August), p.671-674.

Wyld, Sandra J. and Wright, James E., 1988, The Devils Elbow ophiolite remnant and overlying Galice Formation: New constraints on the Middle to Late Jurassic evolution of the Klamath Mountains, California, *Geological Society of America Bulletin*, v.100, no.1, p.29-44.

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