Upper Owyhee Watershed Assessment

II. Background

Contents

The Oregon governor's strategic initiative for ensuring sustainable water resources for Oregon's future, Headwaters 2 Ocean, considers all water resources from the hilltops to the Pacific Ocean. The completion of the assessment of the upper Owyhee subbasin is consistent with the governor's initiative. The upper Owyhee subbasin contains the headwaters of the Owyhee River and two of its principal tributaries.

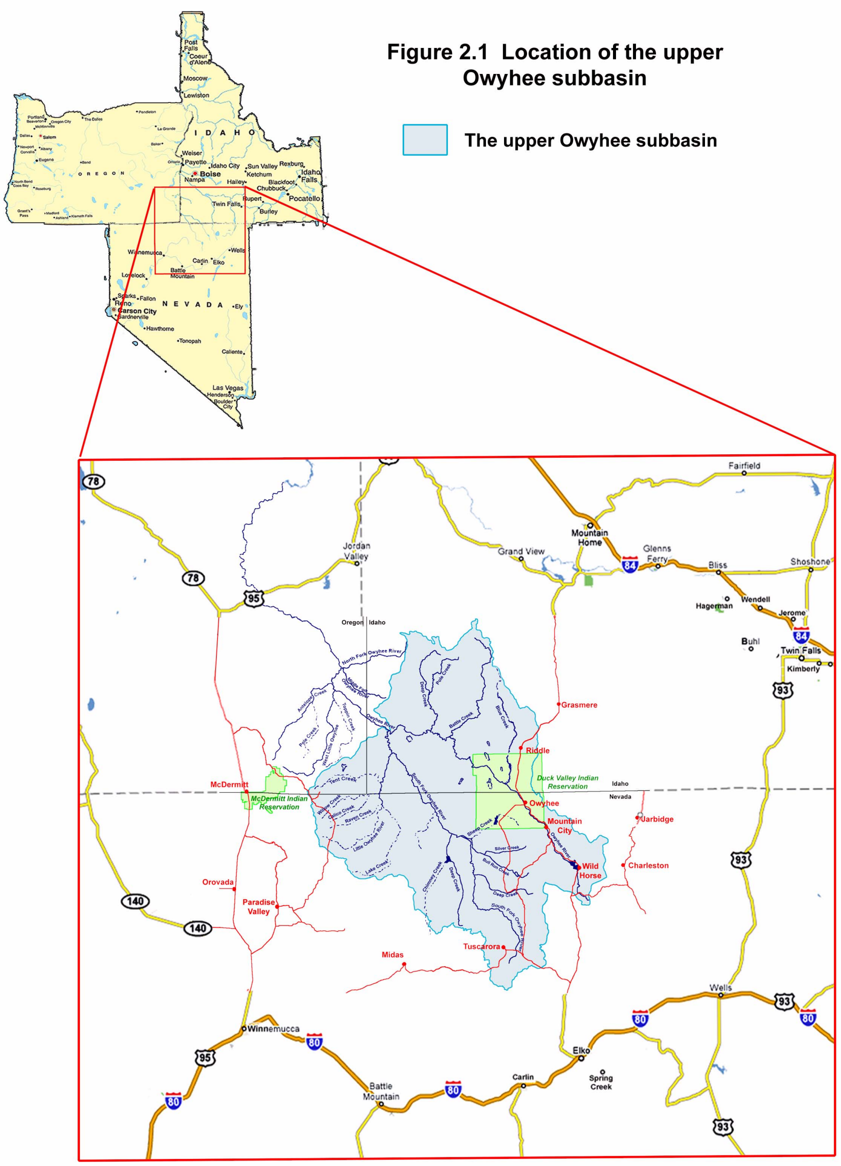

Figure 2.1 Location of the upper Owyhee subbasin

II. Background

A. The upper Owyhee subbasin

1. Location

The upper Owyhee subbasin is located in parts of three states: the southeastern corner of Oregon, the southwestern corner of Idaho, and north central Nevada (Figure

2.1). It covers 3,175,153 acres (4,961 square miles). Parts of the subbasin lie in four different counties: Malheur County in Oregon, Owyhee County in Idaho, and Elko and Humboldt Counties in Nevada.

2. What is the upper Owyhee subbasin?

The upper Owyhee subbasin is a geographic region designated by the United States Geological Survey (USGS). The United States is divided into geographic regions called hydrologic units based on the drainage areas of rivers. The largest units, given first-order hydrologic unit codes (HUC), are areas drained by a major river or series of rivers, such as the Columbia River drainage. These regions are further subdivided into areas drained by a river system. These areas in turn are split into smaller units.[115]

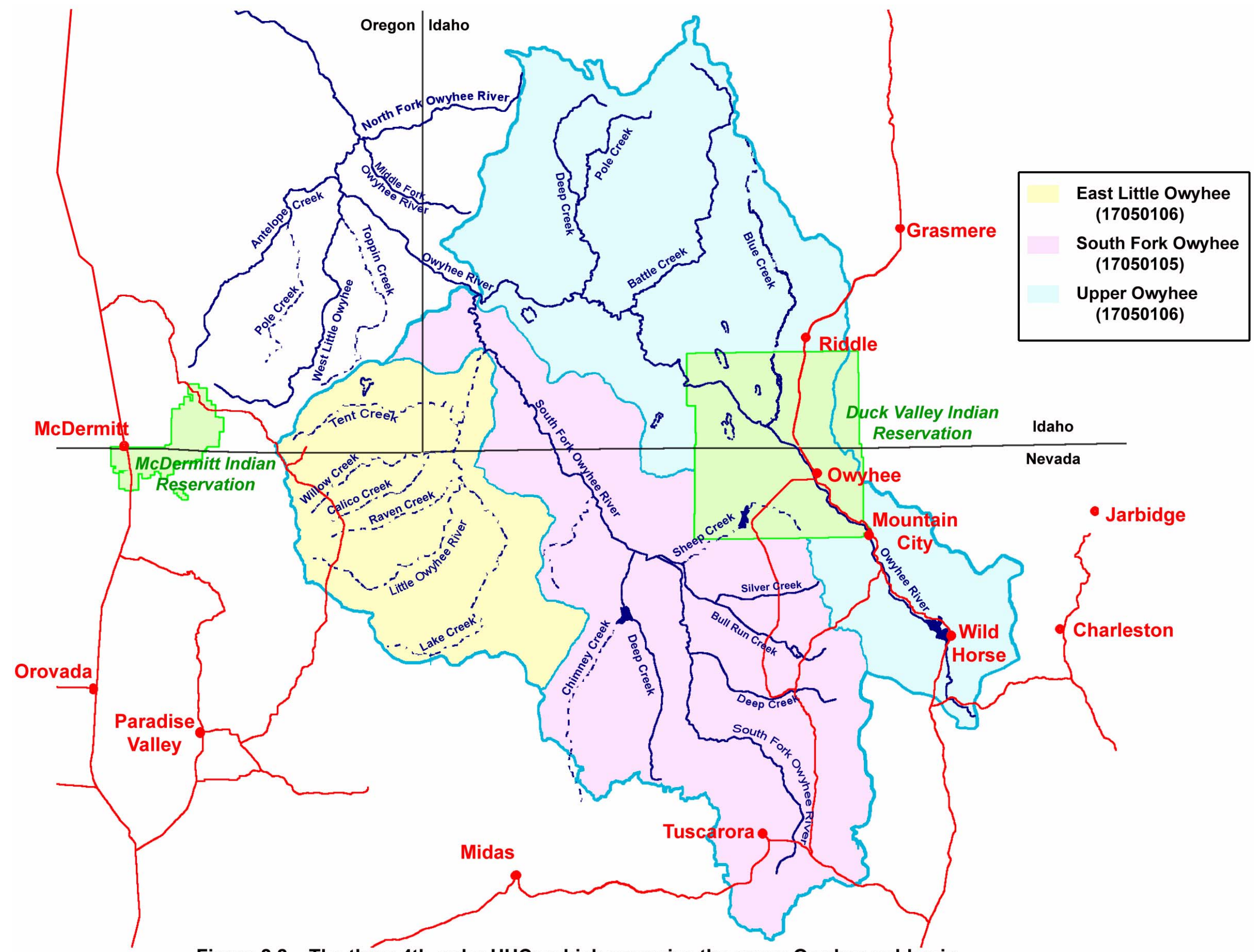

Figure 2.2. The three 4th order HUCs which comprise the upper Owyhee subbasin.

The upper Owyhee subbasin is part of the Columbia River, Snake River, and Owyhee River drainages. Within the Owyhee River drainage, the drainages of several tributary rivers have been designated as fourth-order or eight-digit HUCs. The area considered as the upper Owyhee subbasin for this assessment consists of three of these fourth-order HUCs: the East Little Owyhee (the Little Owyhee River drainage), the South Fork Owyhee, and the Upper Owyhee (Figure 2.2). Within the Owyhee River

Watershed, apart from the upper Owyhee subbasin, there are four other fourth-order HUCs. These are the Lower Owyhee, Crooked/Rattlesnake, Middle Owyhee, and Jordan HUCs (Figure 2.3). These HUCs are all downstream from the upper Owyhee subbasin.

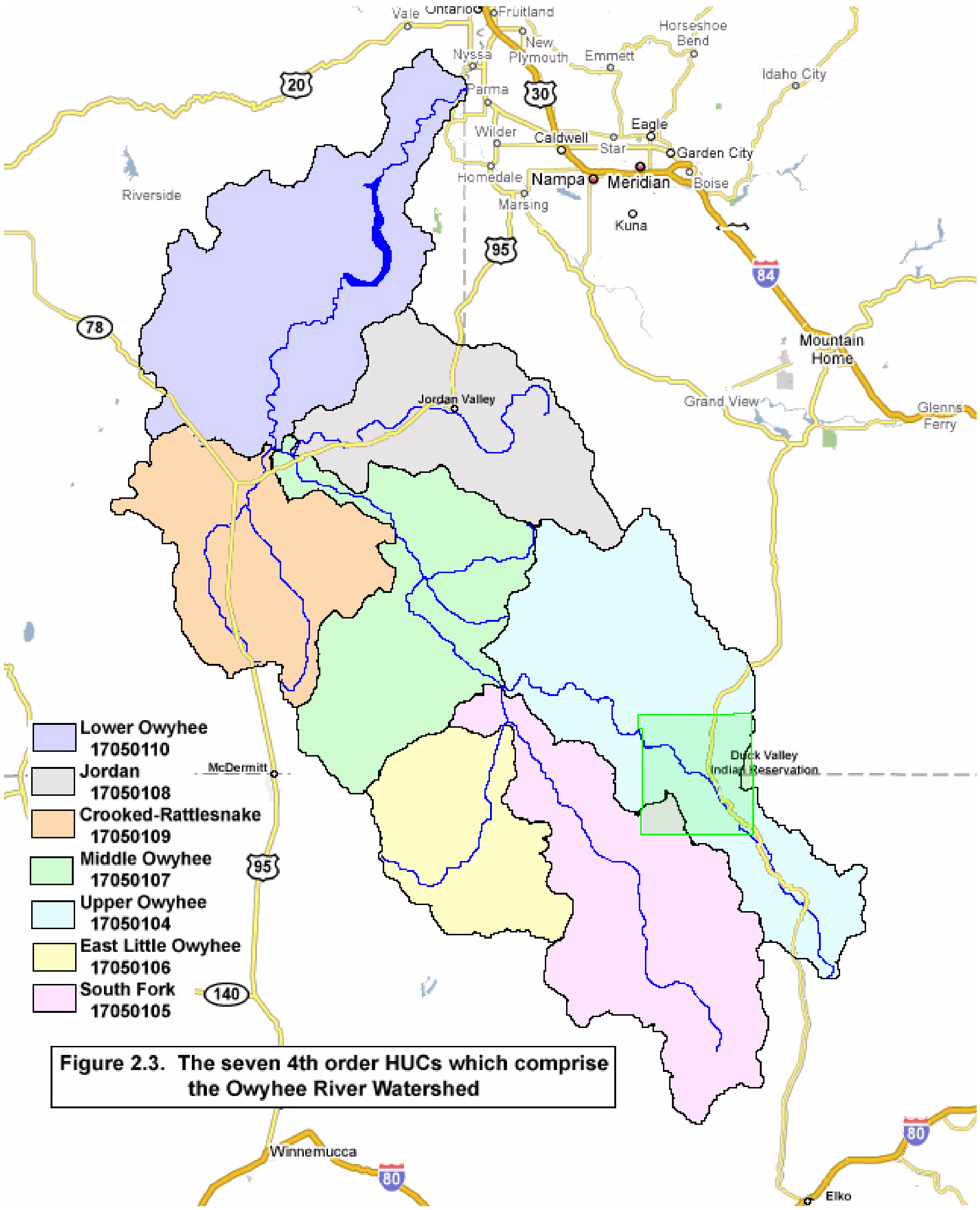

Figure 2.3. The seven 4th order HUCs which comprise the Owyhee River Watershed

3. Geography

Within the geographical area drained by the Little Owyhee River, the South Fork Owyhee River and the Owyhee River, the topography varies. The majority of the land is a gradually sloped plateau. The rivers lie in deep canyons far below the level of the plateau or mesas. The number of perennial streams crossing the landscape is limited and there are numerous intermittent and ephemeral streams.

To the east, the Bull Run and Independence Mountains contain several peaks around 10,000 feet in elevation. Perennial streams drain out of these mountains into the South Fork Owyhee River. To the west, a number of intermittent streams drain into the Little Owyhee River from the east side of the 8,364-foot-tall Capitol Peak in the Calico Mountains.

Gradual rises separate the subbasin from the Humboldt River basin to the south and from the Bruneau River Basin to the northeast. To the northwest, Juniper Mountain separates the subbasin from the drainages of the Middle Fork and North Fork of the Owyhee River (Figure 2.4).

Photo 2.1. Looking southeast across the Owyhee plateau from Juniper Mountain.

4. Ecoregions

Part of the reason for dividing the United States into small units based on some natural feature is the interest by government agencies at all levels in having a way to monitor, inventory, assess and manage resources.[83] The use of HUCs or watersheds was developed because water is a major resource and concern. It is also easy to delineate the boundaries of most watersheds. However, the area within the boundaries of a watershed is not necessarily homogeneous in environment, climate or other aspects. For example, the upper Owyhee subbasin includes forested areas on the Independence Mountains, barren playa lakes, deep river canyons and irrigated hay crop land.

Within a watershed there are not only natural variations but differing impacts from human activities. Ecology is the study of how all the different factors in an area interact. An "ecoregion" includes both abiotic (non-living) and biotic (living) factors. An ecoregion assessment approach to an area recognizes that the different components of a region interact and exist in association with one another.[83] There are potential

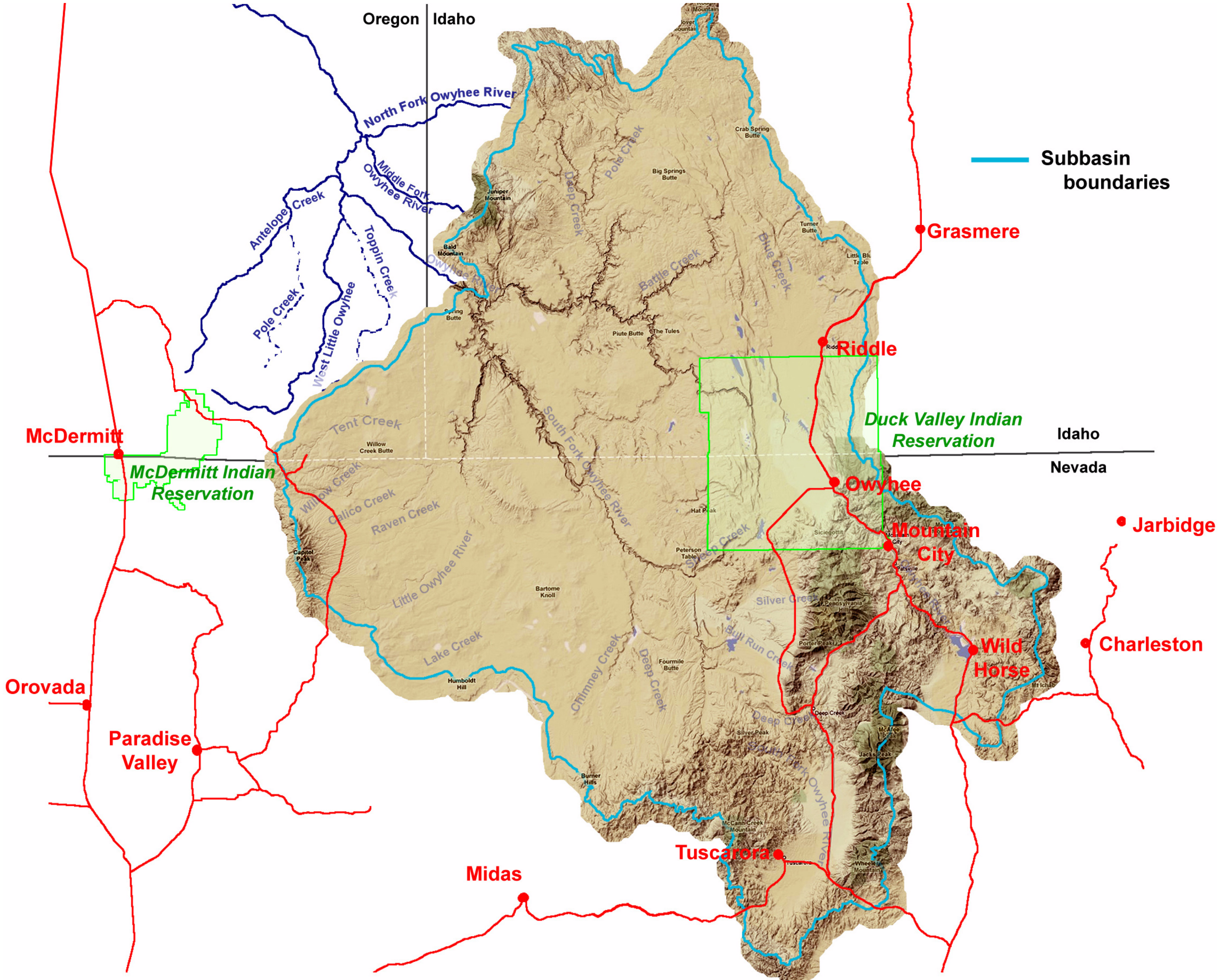

Figure 2.4. Topography of the upper Owyhee subbasin.

misunderstandings as to how watersheds can be used to structure ecological management.[84]

James Omernik of the USGS points out that basins are appropriate units for assessing the relative contribution of human activities at specific points on streams or of evaluating the relative contribution of point and nonpoint source pollutants.[83] However, determining the capacity and potential of a watershed depends on the characteristics of the ecoregions within it. Each ecoregion is defined by a mosaic of factors including climate, geology, soils, land cover including vegetation, human use, wildlife, water chemistry, and topography.[83]

There is a great difference between the geographic unit designated by the watershed and a region based on some other factor such as geology, land use, or vegetation. An ecoregion description includes multiple factors. There is no one accepted definition of the term ecoregion nor one opinion on how they should be delineated.[83] In general an ecoregion is defined as an area with relative homogeneity of biotic and abiotic components which are distinct from adjacent areas.[83,96] Many of the classification systems for ecoregions give preference to specific factors for separating areas. Below we discuss three approaches to describing ecoregions within the upper Owyhee subbasin.

In assessing the upper Owyhee subbasin, the existence of different ecosystems needs to be taken into consideration; recognition and knowledge of these ecosystems enhances the ability to assess, inventory, monitor, and manage the resources of the region. Ecoregions within the upper Owyhee subbasin have been described by the Natural Resources Conservation Service (NRCS), Environmental Protection Agency (EPA), USDA Forest Service, and Bureau of Land Management (BLM).

a. NRCS

The NRCS has developed a land classification system as a resource for farming, ranching, forestry, engineering, recreation, land management, conservation programs, and other uses.[80] This classification divides the United States into land resource regions (LRR), major land resource areas (MLRA), and common resource areas.[80,82] Within each LRR, the major land resource areas are defined as uninterrupted geographical areas without considering political boundaries. The dominant characteristics which determine an MLRA are location and climate, with consideration given to generalized geology, water, soils, biological resources and land use in each area.[80,82] The NRCS has identified 278 major land resource areas in the United States.[82] The upper Owyhee subbasin is part of the Owyhee High Plateaus MLRA.[80]

The MLRAs are further broken down into common resource areas. A common resource area "is defined as a geographical area where resource concerns, problems, or treatment needs are similar."[81] They are created by subdividing MLRAs with consideration for topography, hydrologic units, landscape features, soil, climate, resource concerns, resource uses and conservation needs.[80,81] There are parts of five common resource areas in the upper Owyhee subbasin (Figure 2.5) (Table 2.1).

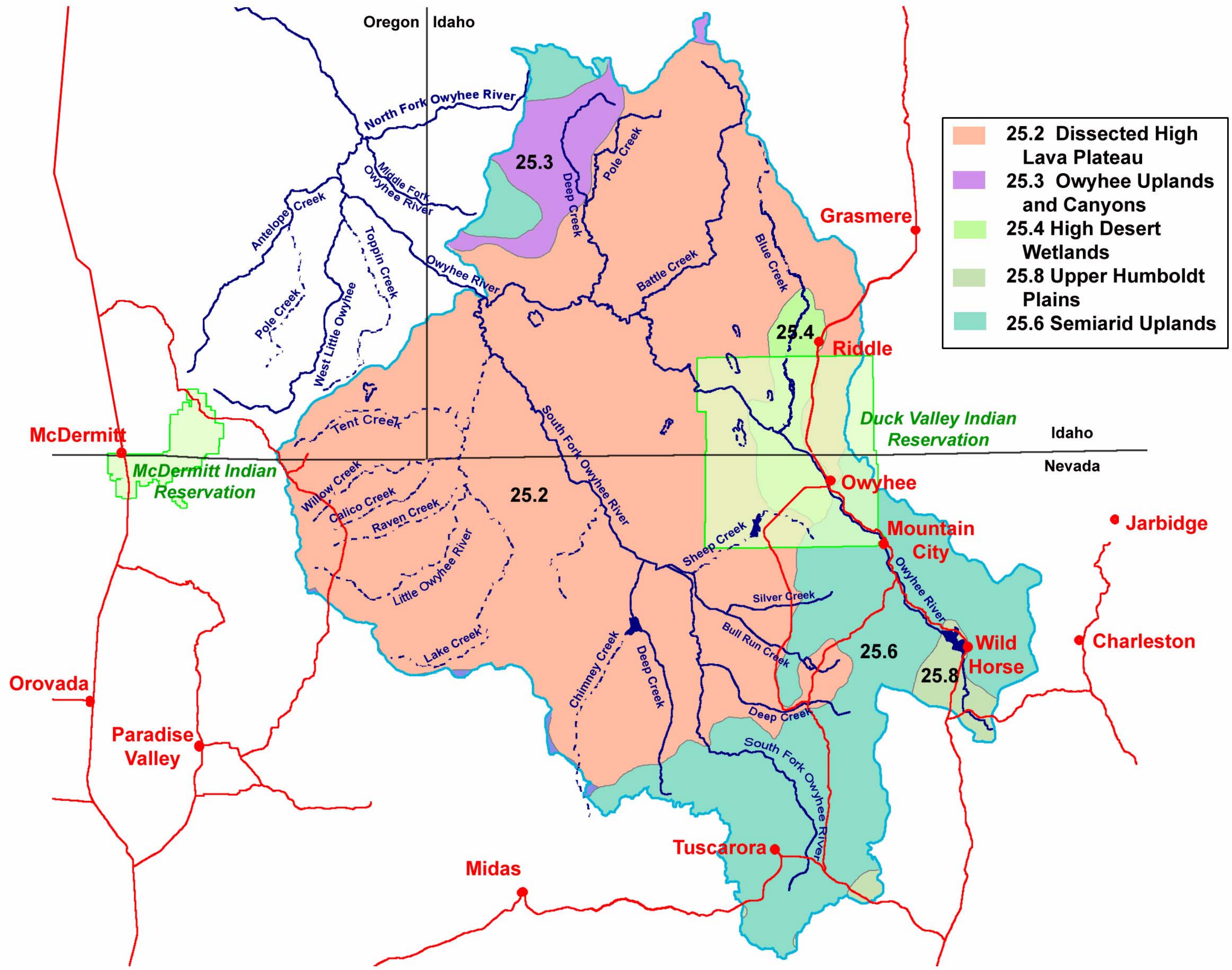

Figure 2.5. NRCS common resource areas in the upper Owyhee subbasin (see Appendix C).

Table 2.1. The NRCS common resource areas in the upper Owyhee subbasin. For descriptions of each ecoregion see Appendix C.[55,79]

25.2	Owyhee High Plateau - Dissected High Lava Plateau
25.3	Owyhee High Plateau - Owyhee Uplands and Canyons
25.4	Owyhee High Plateau - High Desert Wetlands
25.6	Owyhee High Plateau - Semiarid Uplands
25.8	Owyhee High Plateau - Upper Humboldt Plains

b. EPA

The Environmental Protection Agency developed a system of ecoregions to serve as a framework for designing and implementing “ecosystem management strategies across federal agencies, state agencies, and non-governmental organizations that are responsible for different types of resources in the same geographical areas.”[110]

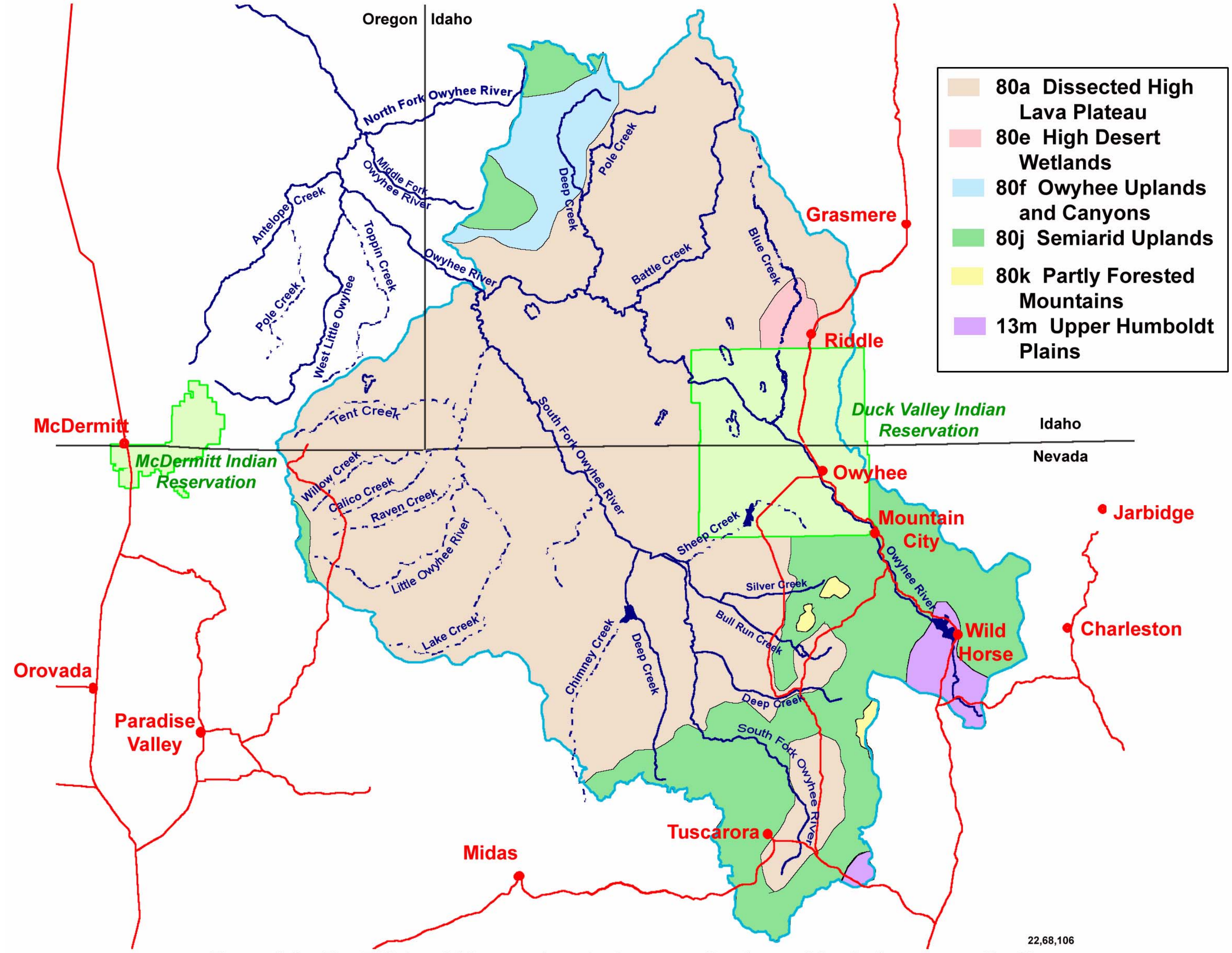

Figure 2.6. The EPA level IV ecoregions in the upper Owyhee subbasin (see Appendix C).

The ecoregion system is intended to provide a structure for research, assessment, monitoring, and management of ecosystems and ecosystem components. The ecoregion boundaries are drawn to delineate areas with a similar response to environmental disturbance. Components considered in determining the location of ecoregion boundaries include geology, vegetation, climate, soils, land use, wildlife, water quality, hydrology, and physiography*. However, the relative importance of each component may vary from one ecoregion to another.[75,110]

The EPA ecoregion system divides North America into 15 broad Level-1 ecoregions which are in turn subdivided into Level II, Level III, and Level IV ecoregions. Level III ecoregions are considered appropriate for regional analysis and decision-making. Most of the upper Owyhee subbasin lies in Level III ecoregion 80, the Northern Basin and Range. A small section of the subbasin at the southern extent lies

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*Physiography is the study of the natural features of the earth's surface, especially in its current aspects, including land formation, climate, currents, and distribution of flora and fauna.

in Level III ecoregion 13, the Central Basin and Range. There are parts of six Level IV ecoregions in the subbasin (Figure 2.6) (Table 2.2). [75,110]

Table 2.2. The EPA ecoregions in the upper Owyhee subbasin. For descriptions of each ecoregion see Appendix C.[22,68,106]

80a	Northern Basin and Range - Dissected High Lava Plateau ecoregion
80e	Northern Basin and Range - High Desert Wetlands ecoregion
80f	Northern Basin and Range - Owyhee Uplands and Canyons ecoregion
80j	Northern Basin and Range - Semiarid Uplands ecoregion
80k	Northern Basin and Range - Partly Forested Mountains ecoregion
13m	Central Basin and Range - Upper Humboldt Plains ecoregion

Photo 2.2 Area of the Independence Mountains in the upper Owyhee subbasin identified under both NRCS and EPA classifications as semi-arid uplands.

c. USDA Forest Service

The United States Forest Service developed a system of classifying ecoregions to provide a tool and scientific basis to plan for and implement ecosystem management.

Their expressed goal is to consider those factors most likely to "directly affect or indirectly express energy, moisture, and nutrient gradients which regulate the structure and function of ecosystems." Ecological units are delineated considering the associations of the primary factors: climate, water, soils, air, hydrology, physiography, and potential natural communities.[112]

The system breaks down the United States into seven progressively smaller types of units. Domain is the largest, followed by Division, Province, Section, Subsection, Landtype association, and Landtype phase.[113] The section level is considered appropriate for forest-wide planning and watershed analysis. This is the smallest unit that is typically defined at present. There are parts of two sections in the upper Owyhee subbasin (Table 2.3).[112]

Table 2.3. The Forest Service ecoregions in the upper Owyhee subbasin. Both sections are in the Temperate Desert Division. For descriptions of each ecoregion see Appendix C.[70,112]

342B	Intermountain Semidesert Province - Northwestern Basin and Range Section
342C	Intermountain Semidesert Province - Owyhee Uplands Section

d. Owyhee Uplands ecoregion

On a different scale, the Bureau of Land Management and the Nature Conservancy have described an Owyhee Upland ecoregion which includes all the drainage area of the Owyhee River, all of Malheur County, parts of Harney and Baker Counties, parts of southwestern Idaho, and part of Nevada north of McDermitt. They are trying to distinguish the Owyhee Upland ecoregion at the regional and national level from the ecoregions of the Great Basin and the Snake River Plain. This is a more general regional distinction on a scale similar to that of a first-order HUC or a land resource unit. The discussion of the characteristics of the Owyhee Upland ecoregion is broad and unspecific.[96]

e. Discussion

It is apparent from the above approaches to describing ecoregions within the upper Owyhee subbasin that factors used in defining an ecoregion depend to some extent on the use to be made of the distinctions. The descriptions of the different ecoregions within the subbasin (Appendix C) illustrate the tremendous variability within the subbasin.

Within each component of this assessment the complexity of the factors which affect that component will determine what combination of geographical and ecological factors needs to be taken into consideration rather than using a predetermined scheme.

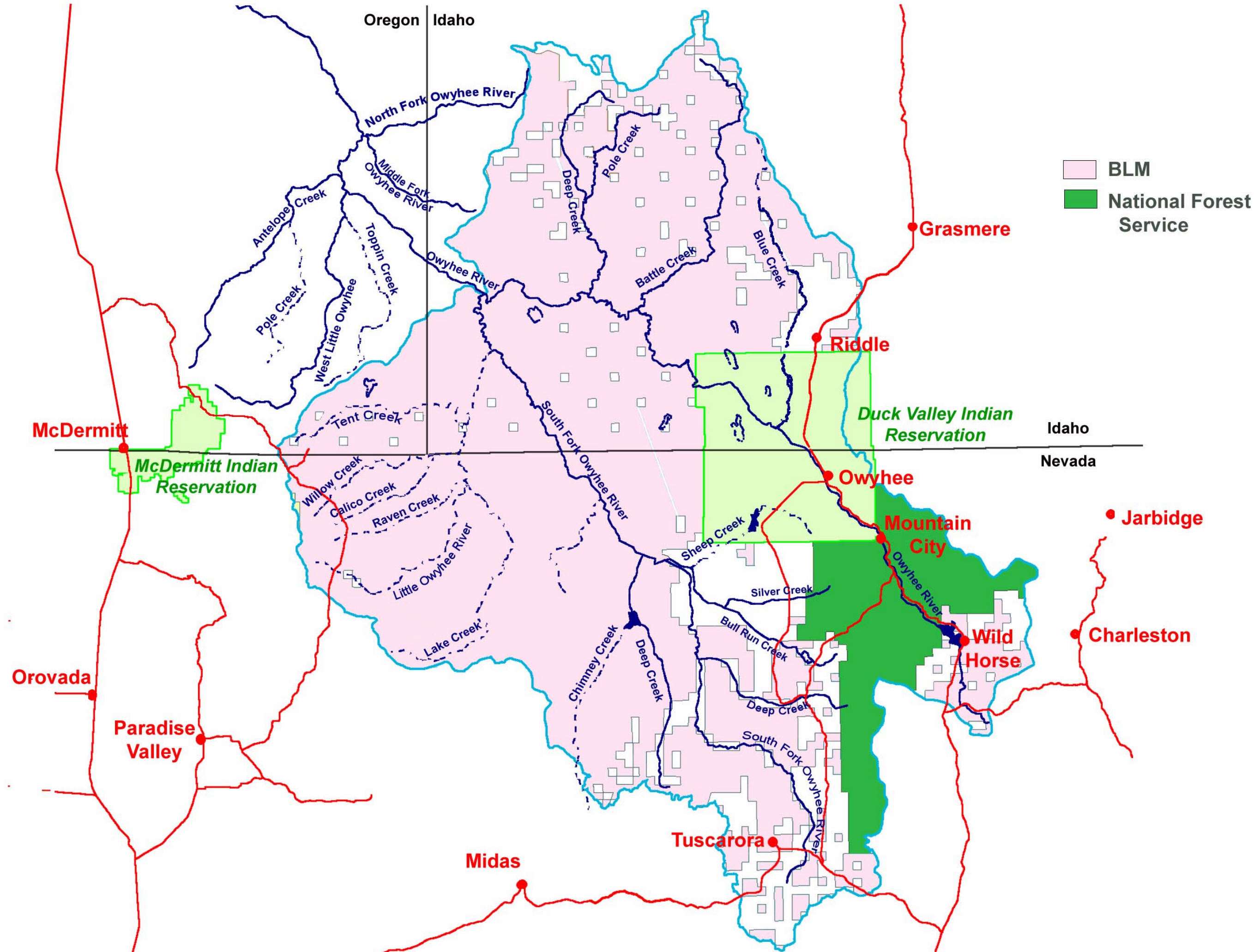

Figure 2.7. Federal land ownership in the upper Owyhee subbasin.

5. Ownership of land

Federal ownership represents 76.8% of the land in the upper Owyhee subbasin. The Bureau of Land Management manages 68.4% of the land in the subbasin, while 8.4% of the land in the subbasin is under the management of the Humboldt National Forest (Figure 2.7).

Of the remaining lands, 8.4% of the total subbasin area is owned and governed by the sovereign Duck Valley Tribal Council. The other 14.8% of the subbasin area is owned by other entities including private landowners and the State of Idaho (Figure 2.8).

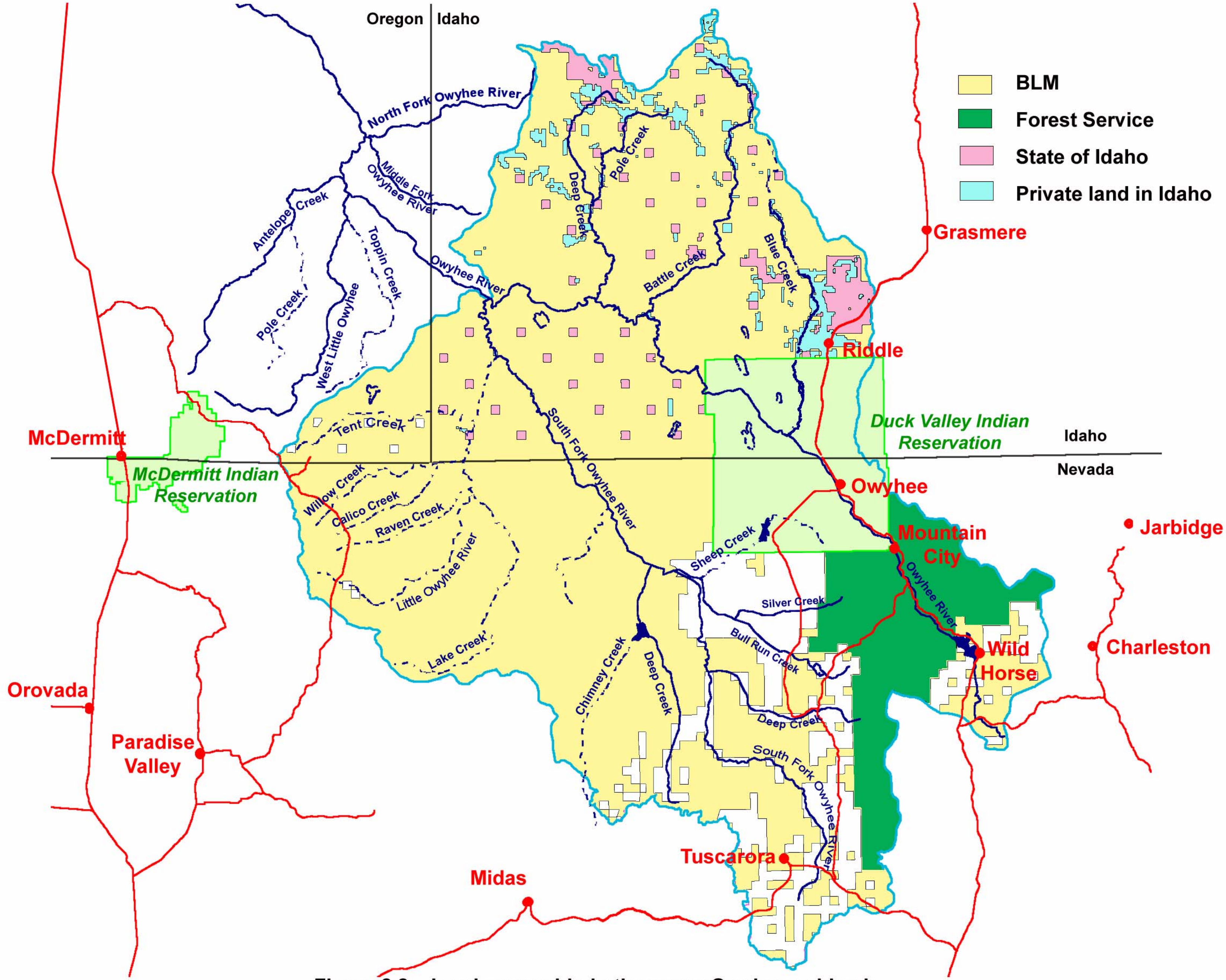

Figure 2.8. Land ownership in the upper Owyhee subbasin.

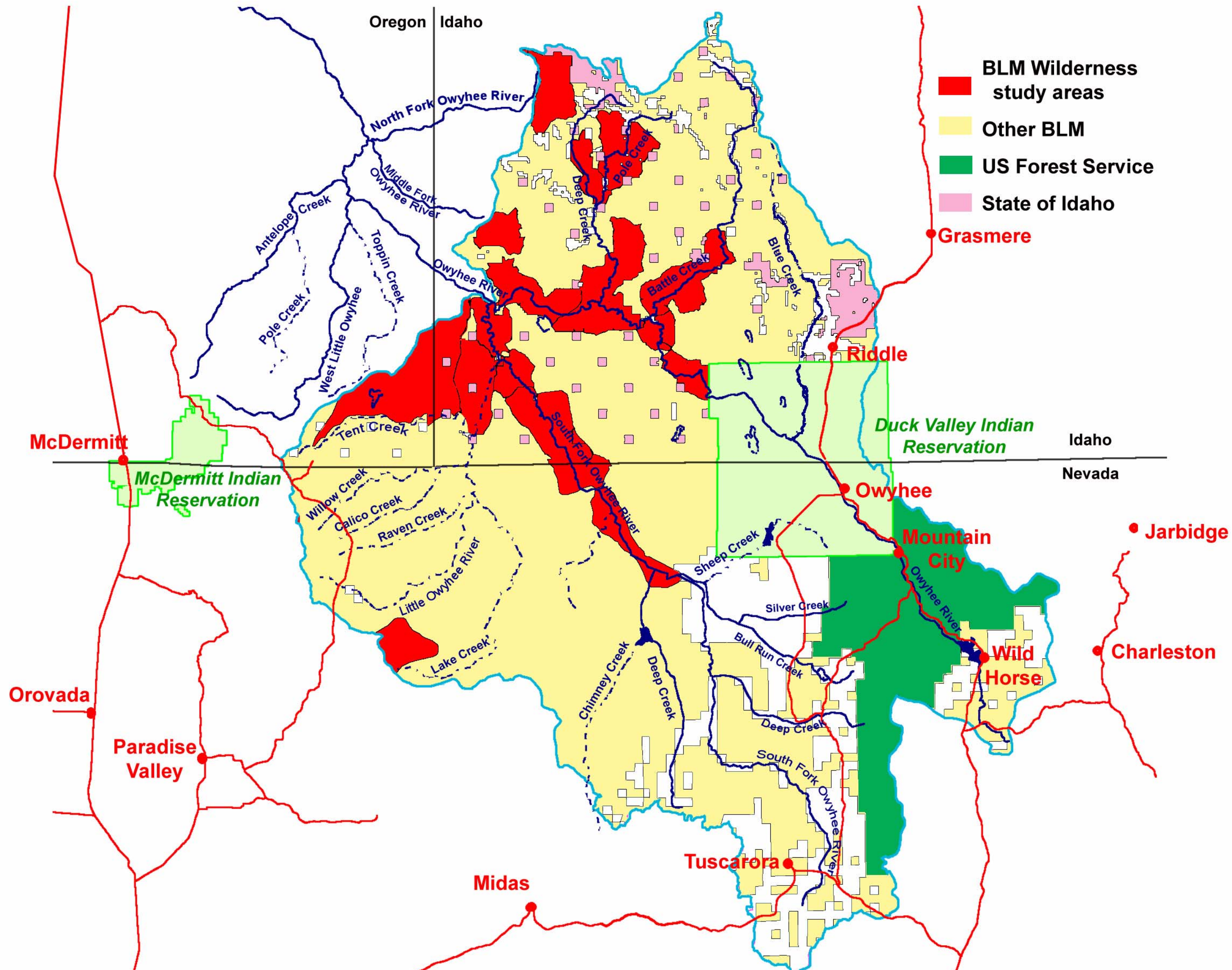

Figure 2.9. Wilderness study areas in the upper Owyhee subbasin.[17,19]

a. Wilderness study areas

Table 2.4. Names of the wilderness study areas in the upper Owyhee subbasin by state.

In Idaho:[19]

Battle Creek	Juniper Creek	Yatahoney Creek
Owyhee River Canyon	South Fork Owyhee River	Little Owyhee River
Upper Deep Creek	Deep Creek	West Fork Red Canyon
Lookout Butte	Pole Creek	North Fork Owyhee River
Owyhee River		

In Oregon:

Lookout Butte		

In Nevada:[17]

South Fork Owyhee River	Owyhee Canyon	North Fork of the Little Humboldt River

Within the BLM managed land, there are a number of wilderness study areas (WSAs). As of the time this assessment was written, the Idaho section of the upper Owyhee subbasin contained all or part of 15 WSAs, there was part of one WSA in the Oregon section, and all or part of three WSAs were in the Nevada section (Figure 2.9) (Table 2.4).

b. Owyhee initiative

The Owyhee initiative is an agreement worked out between the Owyhee County government, the BLM, and the Shoshone Paiute Tribal government to "develop and implement a landscape-scale program in Owyhee County that preserves the natural processes that create and maintain a functioning, un-fragmented landscape supporting and sustaining a flourishing community of human, plant and animal life, that provides for economic stability by preserving livestock grazing as an economically viable use, and that provides for protection of cultural resources."[89]

The three entities have agreed to a process and proposal which includes all of the Idaho section of the upper Owyhee subbasin. If the terms of the proposal were to be implemented as currently written, three wilderness areas would replace the wilderness study areas. Some of the current WSA area would be released from WSA status while the remainder of the current WSAs and some non-WSA land would be included in the new wilderness areas (Figure 2.10).

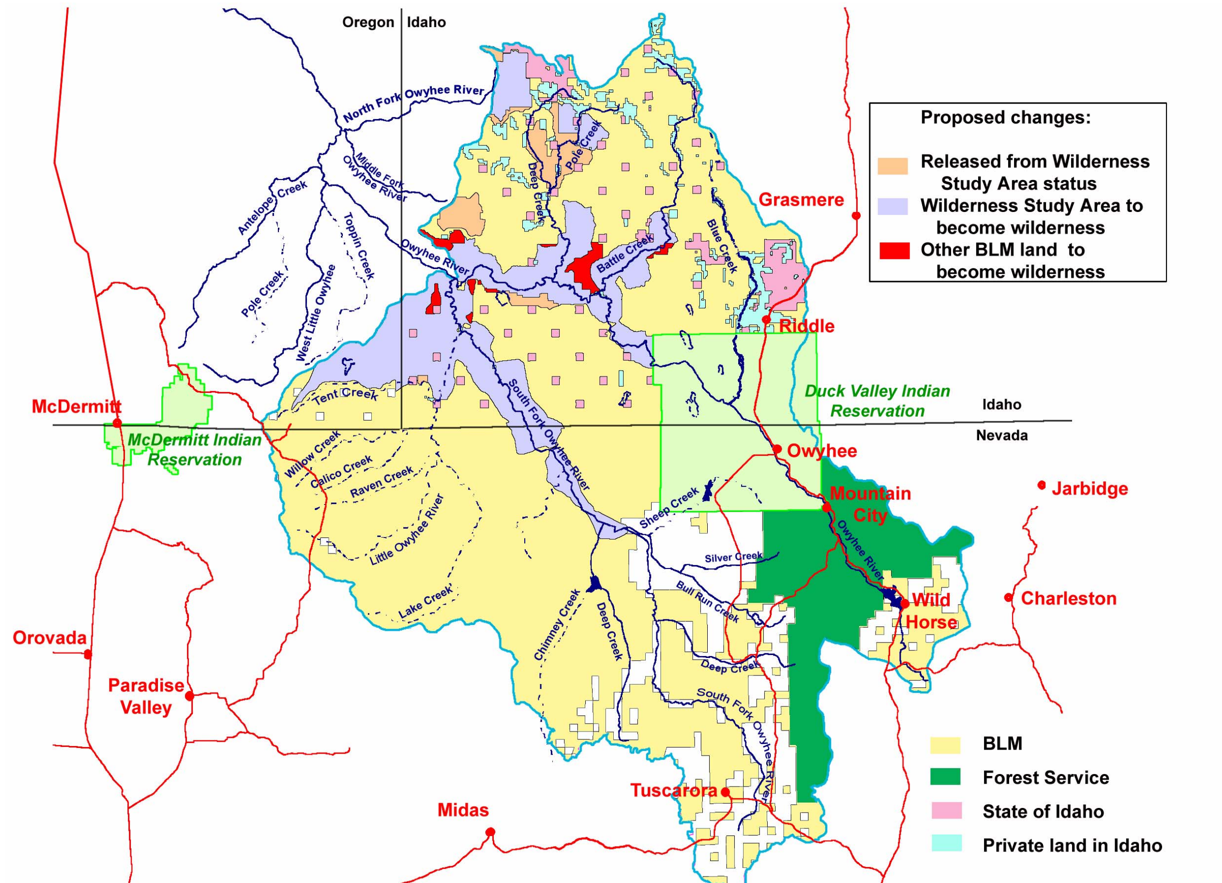

Figure 2.10. Proposed changes in the Owyhee Initiative to WSAs in the upper Owyhee subbasin.[89]

As of the writing of this assessment, the proposal was awaiting congressional action to be implemented. As of the publication of this assessment, congress had approved the proposal and some of the agreements were being implemented.

c. Wild and Scenic Rivers

The National Wild and Scenic River System was established by Congress In 1984. One hundred and twenty miles of the Owyhee River downstream from the upper Owyhee subbasin were designated as a wild river component of the National Wild and Scenic River System. BLM's website states that the "Idaho portions of the Owyhee River have been found to have the same values and await Congressional action."[18]

Within the upper Owyhee subbasin, the BLM has completed wild and scenic river studies. A number of rivers were identified by BLM as fitting the criteria of wild and scenic rivers, possessing "outstandingly, remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values."[122] Rivers included in the wild and scenic river system are preserved in their free-flowing condition. The Owyhee Initiative recommends a number of rivers for inclusion in the system (Figure 2.11) (Table 2.5).

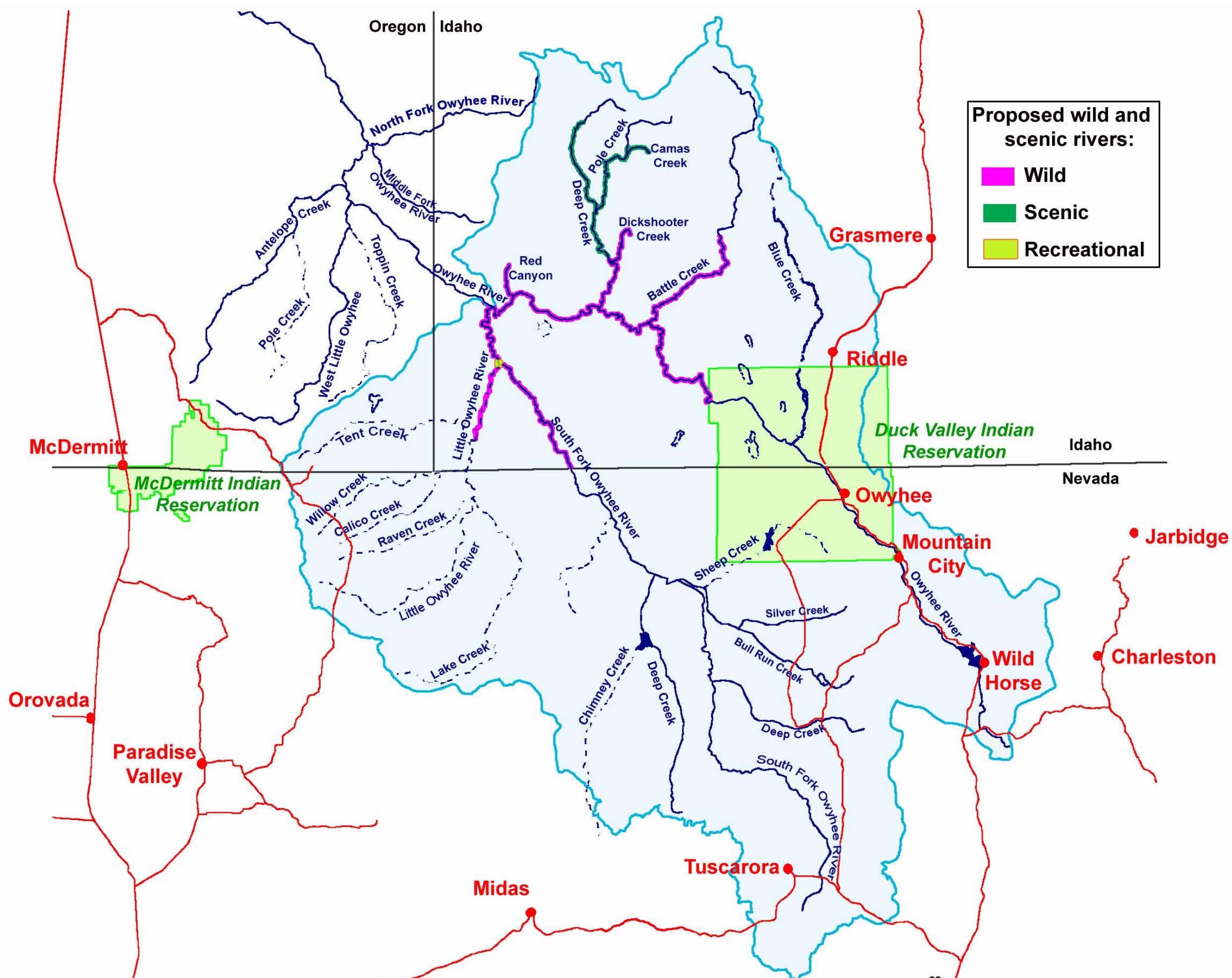

Figure 2.11. Proposed wild and scenic rivers in the Owyhee Initiative.[88]

Table 2.5. Rivers recommended in the Owyhee Initiative for wild and scenic designation in the upper Owyhee subbasin.[88]

River		Outstandingly Remarkable Values
Little Owyhee River	Wild	Wildlife
Battle Creek	Wild	Scenic, recreation (backpacking), geologic
Camas Creek	Scenic	Scenic, recreation, geology, wildlife, prehistoric cultural clues
Deep Creek	Wild	Scenic, recreation (float boating and backpacking), geologic, wildlife
Deep Creek	Scenic	Scenic, recreation (float boating and backpacking), geologic, wildlife
Dickshooter Creek	Wild	Scenic, recreation, geology, wildlife, prehistoric cultural clues
South Fork Owyhee River	Wild	Scenic, recreation (float boating), geology, wildlife
South Fork Owyhee River	Recreational	Scenic, recreation (float boating), geology, wildlife
Owyhee River	Wild	Scenic, recreation (float boating and backpacking), geologic, wildlife, Tules ancient river bed
Pole Creek	Scenic	Scenic, recreation, geology, wildlife, prehistoric cultural clues
Red Canyon	Wild	Scenic, recreation, geology, wildlife

6. Population

US census divisions cut across the boundaries of hydrologic units. The US census does not use hydrologic units as the basis for the data that it analyses. To determine the number of people living within the upper Owyhee subbasin, the smallest census unit, the block was used. Any block which fell at least partly in the subbasin was counted. For purposes of estimation, the boundary of the blocks used roughly follows the subbasin boundary. Since some of the area included in these counts is outside the subbasin there is a chance of overestimating the population. Census under- and over-reporting also may affect these estimates.

Table 2.6. Population distribution in the upper Owyhee subbasin.

Political division within the subbasin	Population counted, 2000 census
Humboldt County, NV	14
Malheur County, OR	0
Owyhee County, ID excluding Duck Valley Indian Reservation	37
Elko County, NV excluding Duck Valley Indian Reservation	396
Total excluding Duck Valley Indian Reservation	447
Duck Valley Indian Reservation, NV	1,017
Duck Valley Indian Reservation, ID	248
Total Duck Valley Indian Reservation	1,265

In the 2000 census of population, 1,712 people were shown as living in the upper Owyhee subbasin or in census blocks partially within the subbasin. Of these only 447 were not residents on Duck Valley Indian Reservation (Table 2.6). Therefore, the population density in the upper Owyhee subbasin is one person per ten square miles.

B. Climate

1. Historical data

Beginning in 1888, data were recorded from a weather station at Tuscarora Andrae Ranch in the upper Owyhee subbasin. In the areas surrounding the upper Owyhee subbasin, weather stations began recording data at McDermitt in 1892, at Paradise Valley in 1894, on the North Fork of the Humboldt River just south of the subbasin in 1901, at Paradise Hill in 1902, and at Orovada in 1911. There were no other weather stations established either within or around the subbasin until 1948 (Table 2.7).[121]

There have been a number of weather stations established in and around the upper Owyhee subbasin over the years. Within the subbasin, only six weather station have operated for more than ten years (Figure 2.12) (Table 2.7). The first weather station to begin operating, at Tuscarora Andrae Ranch, continued recording data until 1942. Only precipitation was measured from 1942 until 1956 when it ceased operation.

Table 2.7. Periods of operation of weather stations measuring temperatures (T) or precipitation (P) within and near the upper Owyhee subbasin.[121]

Within the upper Owyhee subbasin							
Station	Operational	Years		Station	Operational	Years	
Tuscarora Andrae	1888 - 1956	68	P	Wild Horse Rsvr	1982 - 2009	27	T,P
Tuscarora Andrae	1888 - 1942	54	T	Mendive Ranch	1955 - 1960	5	P
Tuscarora	1957 - 2009	52	T,P	North Fork 7NW	1974 - 1982	8	T,P
Mountain City RS	1955 - 2005	50	T,P	I-L Ranch	1962 - 1969	7	T,P
Owyhee	1948 - 1985	37	T,P	North Fork 13N	1973 - 1973	<1	T,P
Around the upper Owyhee subbasin							
McDermitt	1892 - 2009	117	T,P	Midas	1961 - 1969	8	T,P
Paradise Valley 1NW	1894 - 2008	114	T,P	Saval Ranch	1960 - 1967	7	T,P
Orovada 3 W	1911 - 2009	98	T,P	Cliffs	1954 - 1958	4	T,P
N Fork MNTC STN	1901 - 1970	69	P	Fairylawn	1954 - 1958	4	T,P
Paradise Hill	1902 - 1968	66	T,P	Orovada 9SSW	1971 - 1974	3	T,P
McDermitt 26 N	1955 - 2008	53	T,P	Triangle Ranch	1961 - 1964	3	T,P
Rome ST AP	1949 - 2009	50	T,P	McDermitt Indian	1948 - 1949	1	P
Charleston	1961 - 2009	48	T,P	N Fork Spring Ck	1951 - 1952	1	P
Grasmere	1953 - 1974	21	T,P	N Fork 10 S	1971 - 1971	<1	T,P
Paradise Valley	1948 - 1960	18	T,P				

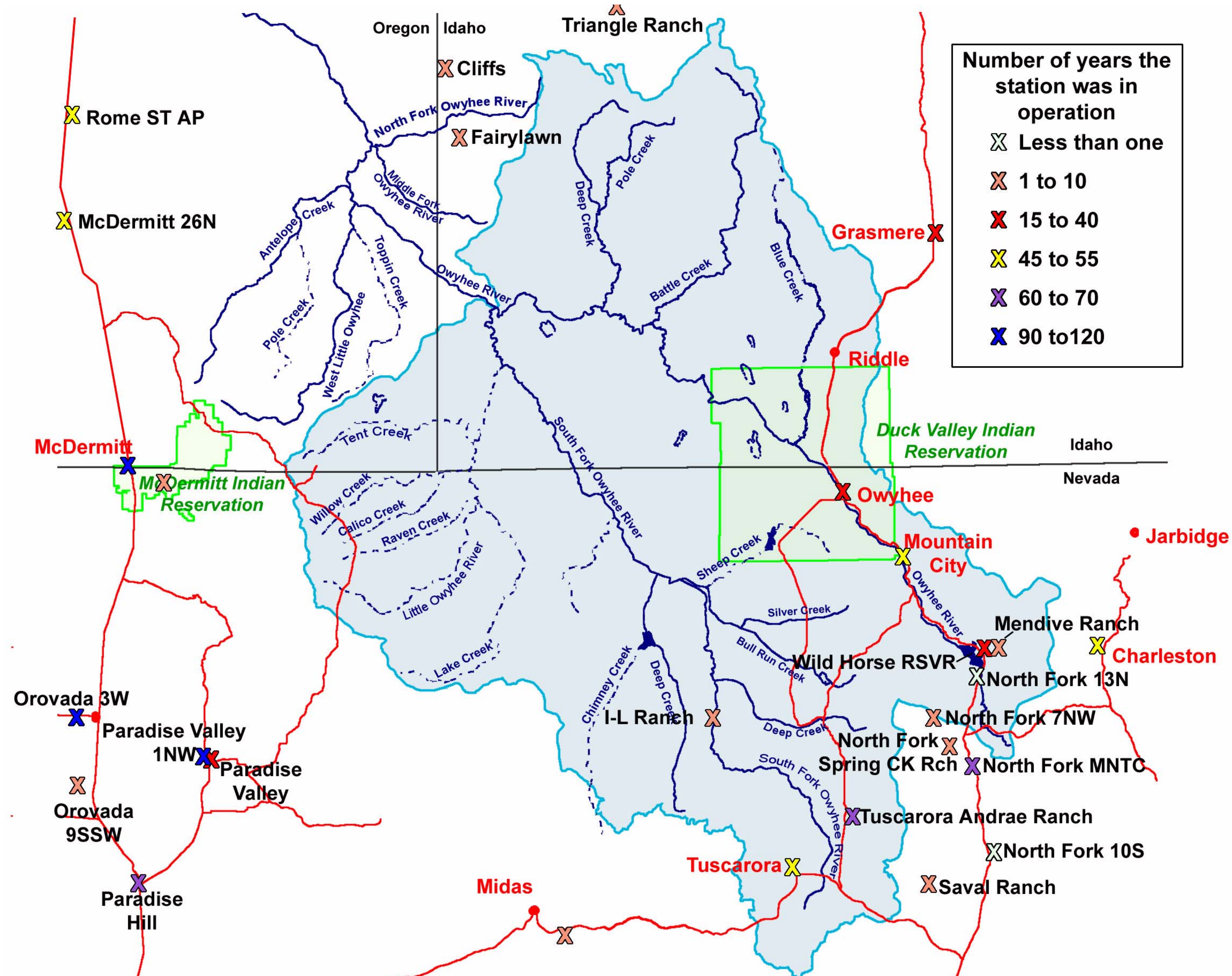

Figure 2.12. Location of all current and historical weather stations around the upper Owyhee subbasin showing the number of years they recorded data.[121]

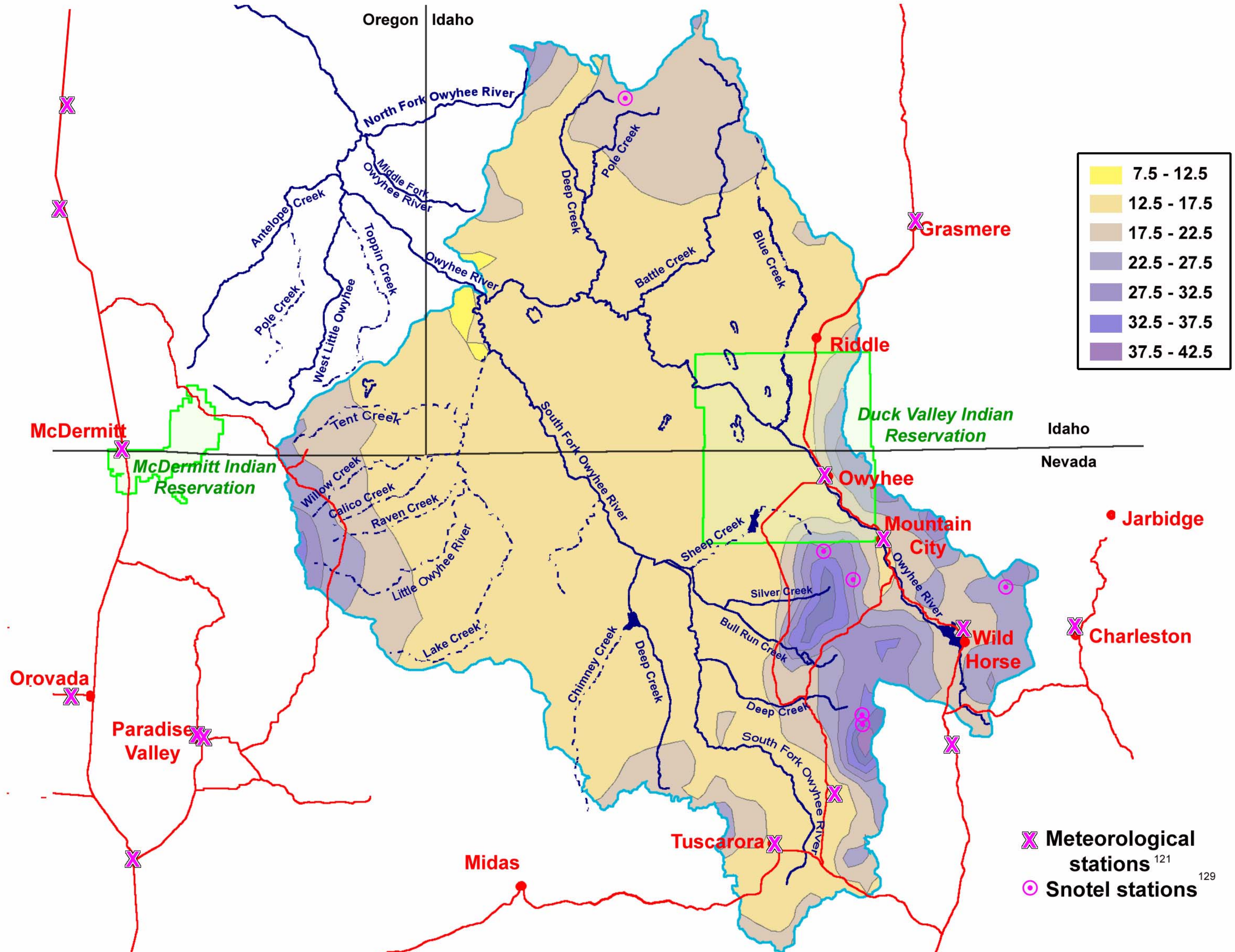

Figure 2.13. Calculated annual rainfall in inches in the upper Owyhee subbasin showing the location of snotel stations in the subasin and of weather stations around the upper Owyhee subbasin with ten or more years of records.

2. Precipitation

a. PRISM model

A research group at Oregon State University have developed a model, PRISM, for using meteorological data to extrapolate to the areas between the data points. The map in Figure 2.13 shows the approximate annual rainfall across the upper Owyhee subbasin developed using PRISM.

Cristopher Daly, one of the developers of the PRISM model, explains that except for the most densely populated regions of developed countries, meteorological stations will be so sparse that they are spaced farther apart than the scales at which elevation, large topographic features and cold air drainage are most important. "This means that climate patterns caused by these factors will likely be incorrectly located, inaccurately represented, or not represented at all, if interpolated with simple methods . . . While PRISM explicitly accounts for more spatial climate factors than other methods, it also requires more effort, expertise, and supporting data sets to take advantage of its full capability."[28]

The PRISM model takes meteorological data from the different stations and transforms the data to account for elevation, climate changes due to topography, and cold air drainage. Cristopher Daly, however, cautions that there are general relationships, such as temperature predictably dropping with elevation, which do not apply on a local scale, for example in temperature inversions when temperature increases rather than decreases with elevation. The relationship of elevation to precipitation is more complex although generally precipitation increases with elevation.[28] Other factors which affect climate include slope and aspect, riparian zones, and land use / land cover. These are not accounted for in PRISM or other statistically interpolated data sets. Slope and aspect influence local precipitation and temperature.[28]

No model like PRISM can be perfect. Since there are no known points between the data points used in the interpolations, there is no satisfactory method for estimating error. Error can also be introduced by errors in the original measuring equipment.[28]

Cristopher Daly concludes "Users are encouraged to think critically when evaluating a spatial climate data set for their needs. None are perfect, but many are useful for a variety of regions and applications, if their limitations and assumptions are understood and respected."[28] The limitations of the annual precipitation map (Figure 2.13) are that it uses data from sparsely located meteorological stations. Local aspects that might affect climate in a given locale are not reflected. Since the map is only the most general representation of rainfall patterns, rainfall at a specific point within the area may differ.

From the PRISM map of average annual precipitation (Figure 2.13), most of the area of the upper Owyhee subbasin averages 15 inches of precipitation per year. However, the Bull Run and Independence Mountains are shown as receiving much greater amounts, up to 42.5 inches of precipitation per year at the highest elevations.

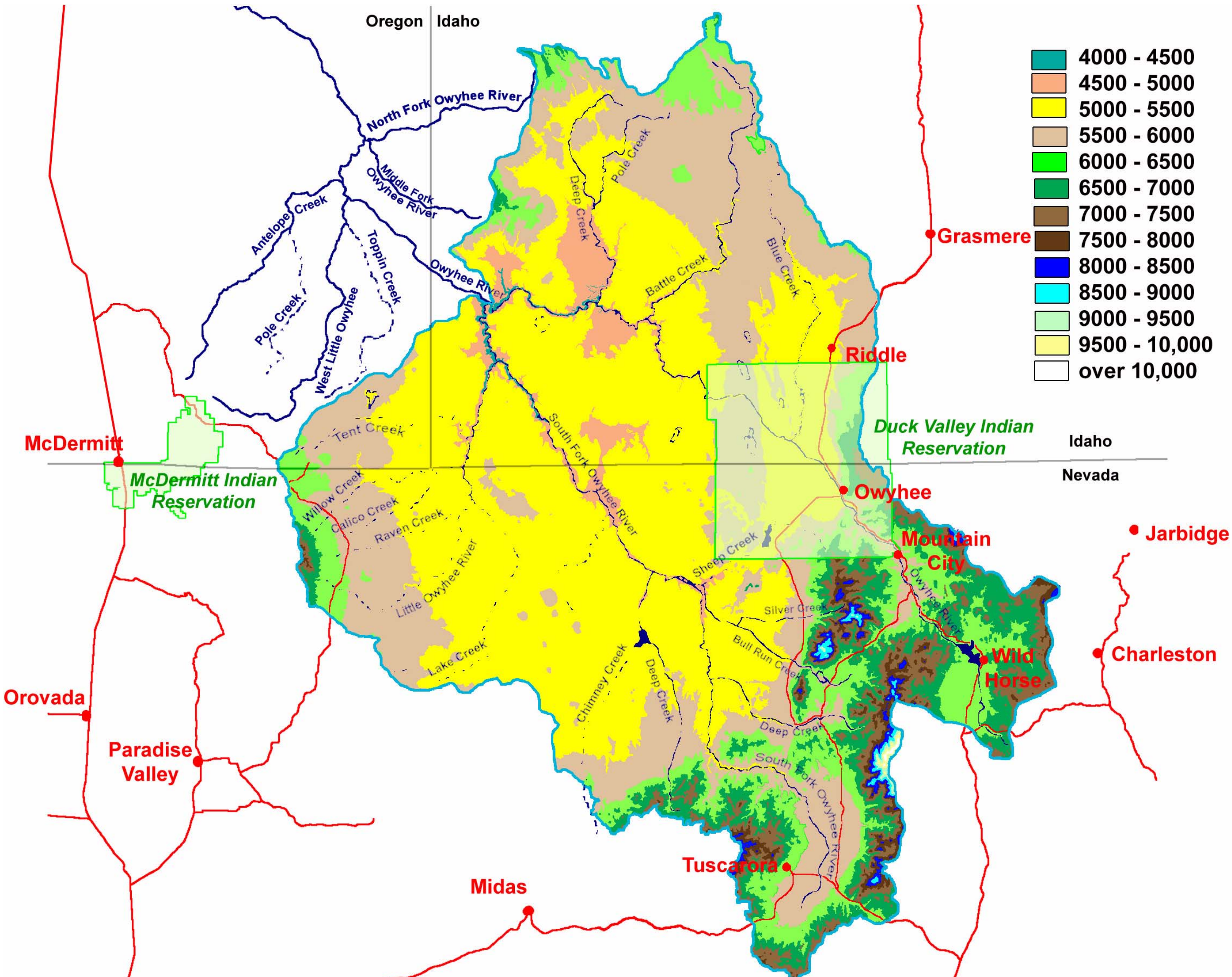

Figure 2.14. 500 foot elevation contours in the upper Owyhee subbasin.

b. Elevation dependent

There have been no weather stations in the mountains with ten or more years of records. However, the Snotel stations at Jacks Peak and upper Jack Creek have been recording precipitation for the last 30 years. In areas shown as receiving less than 17.5 inches of precipitation, there are only two weather stations with at least ten years of data. A comparison of the calculated rainfalls (Figure 2.13) with elevations within the subbasin (Figure 2.14) demonstrates how the calculations of rainfall are largely influenced by elevation using data from scattered weather stations within and around the subbasin.

c. Semi-arid desert

Only an area which generally receives less than 10 inches of precipitation a year is defined by some sources as a desert.[31,82] Other sources define a desert as only areas receiving less than 12 inches of precipitation a year.[111] Many ecologists studying ecosystems classify an area receiving less than 10 inches of precipitation as an "arid" desert, whereas those areas receiving 10 to 20 inches are classified as "semi-arid" deserts.[52,78] The majority of the upper Owyhee subbasin to the west of the Bull Run and Independence Mountains can be classified as semi-arid desert.

Within a desert there is a random spatial variation in rainfall in time and space with differences occurring not only on a regional scale but also on scales of 350 feet to half a mile. Here the direction and speed of wind, the degree of slope, and the angle of the rainfall are important in hilly regions.[78] The random variation in where precipitation falls is greater for summer thunderstorms than for general winter storms. Daily rainfall may be localized to areas less than 1½ to 5 miles across with rain falling on a patch or strip of land. This variability can "hardly be ignored in ecological modeling in arid zones."[78]

3. Meteorological stations

Currently, only meteorological stations at Tuscarora and Wild Horse Reservoir operate within the upper Owyhee subbasin, both within the Nevada section of the subbasin. There are currently operating meteorological stations at four other locations in close proximity around the subbasin (Figure 2.15).[121]

For purposes of looking at weather patterns within the subbasin, it is relevant to consider information not only from the currently operating meteorological stations, but also from stations that are no longer operating. Stations with a greater number of years of records should provide the most representative data (Figure 2.12). There are no stations located at elevations greater than the station at Wild Horse Reservoir, at 6,239 feet.

In the upper Owyhee subbasin, automated SNOpack TELemetry (SNOTEL) stations which record both temperature and precipitation were installed at seven sites: Mud Flat, Fawn Creek, Laurel Draw, Jack Creek Upper, Jacks Peak, Big Bend, and Taylor Canyon (Figure 5.1).[133,134] All of the Snotel stations currently operating in the subbasin have recorded temperatures since at least 1990. The data from Snotel stations is not available in a summary format.[129]

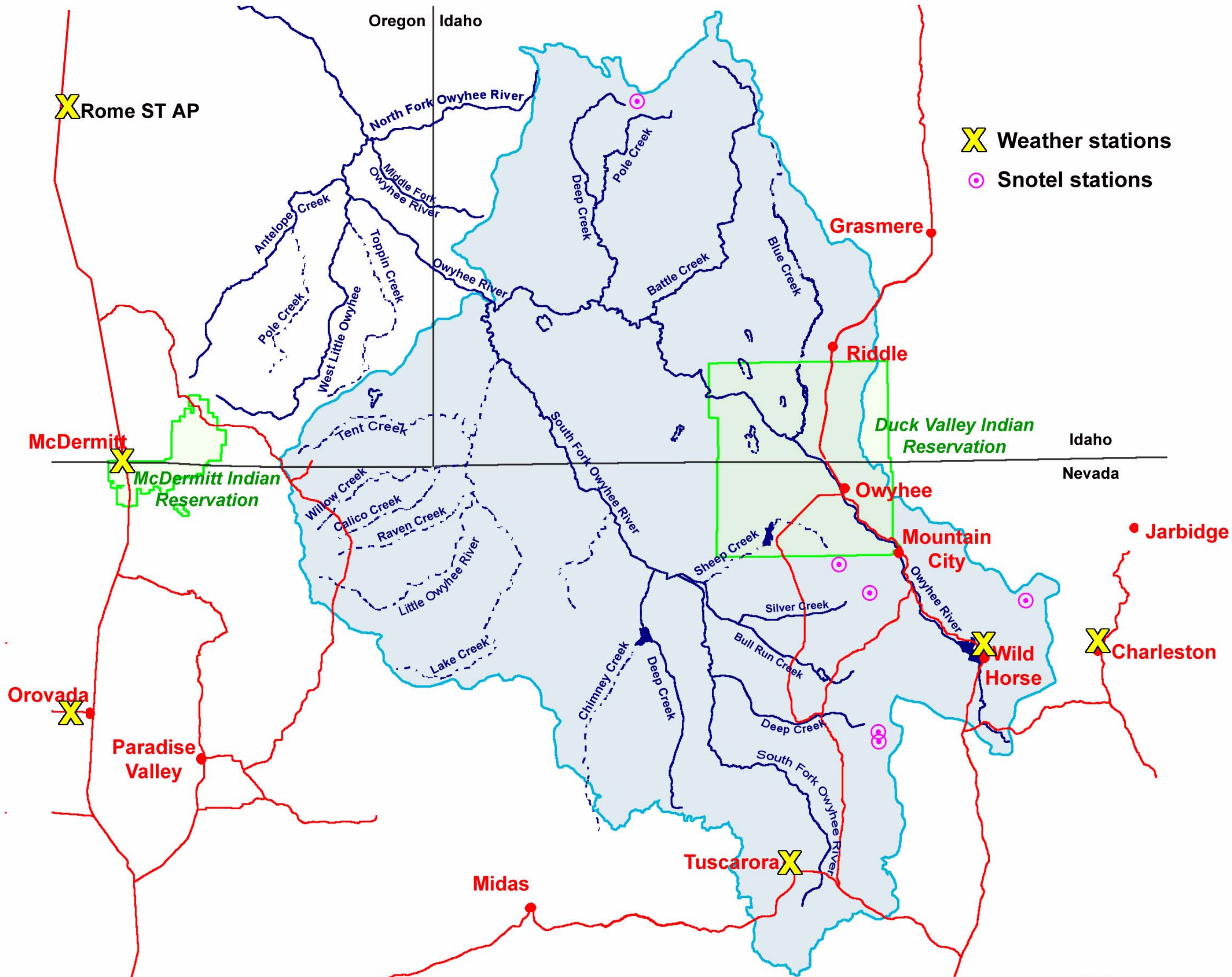

Figure 2.15. Currently operating weather stations in and around the upper Owyhee subbasin.[121,129]

4. Temperature

The data from four meteorological stations within the upper Owyhee subbasin (Tuscarora, Tuscarora Andrae Ranch, Mountain City, and Wild Horse Reservoir) were analyzed for this assessment. In addition, the data from the Owyhee station were included, since it is within the geographical boundaries of the subbasin although it is located within the Duck Valley Indian Reservation (Figure 2.16).[121]

To calculate the mean monthly average, the daily average for each month is calculated for each year. Then, the averages for each month (say for March) are again averaged across the different years to obtain the mean monthly average (for March) at a given station.

a. Elevation differences

The mean monthly temperatures at two stations outside the subbasin, Grasmere and McDermitt 26 N, were compared with the mean monthly temperatures at three stations within the subbasin. These five stations were chosen over a range of elevations: McDermitt 26 N at 4,464 feet, Grasmere at 5,144 feet, Owyhee at 5,397 feet, Tuscarora Andrae Ranch at 5,863 feet, and Wild Horse Reservoir at 6,239 feet (Figure 2.16). The mean monthly temperatures at the five stations increased and decreased through the year in a similar pattern. The station at the highest elevation had the lowest temperatures, with increasing temperatures recorded at the stations located at successively lower elevations (Figure 2.17). This extremely small set of locations indicate that elevation is a major factor in the temperature variations within the subbasin, as would be expected.[12]

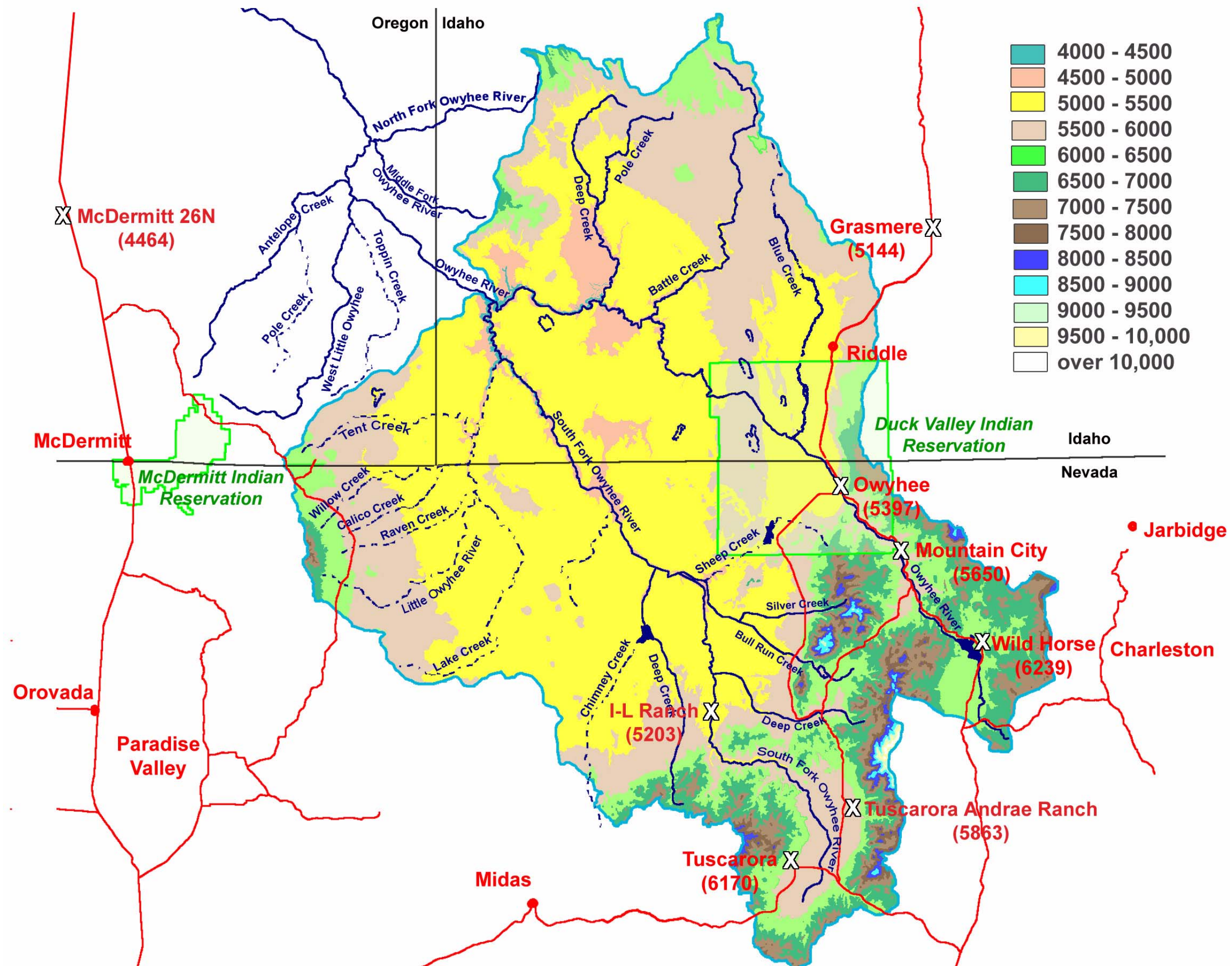

Figure 2.16. Elevation in feet of meteorological stations around the upper Owyhee subbasin.[226]

b. Maximum and minimum temperatures

The monthly average maximum temperatures at the five meteorological stations within the subbasin, Tuscarora at 6,170 feet, Tuscarora Andrae at 5,863 feet, Mountain City at 5,650 feet, Wild Horse at 6,239 feet, and Owyhee at 5,397 feet, not only closely track each other but are almost identical from May through September (Figure 2.18). The average maximum temperatures begin to rise in January, peak in July, and fall between August and January. In July they vary between 83.7°F at Wild Horse Reservoir to 85.5°F at Tuscarora Andrae Ranch.[121]

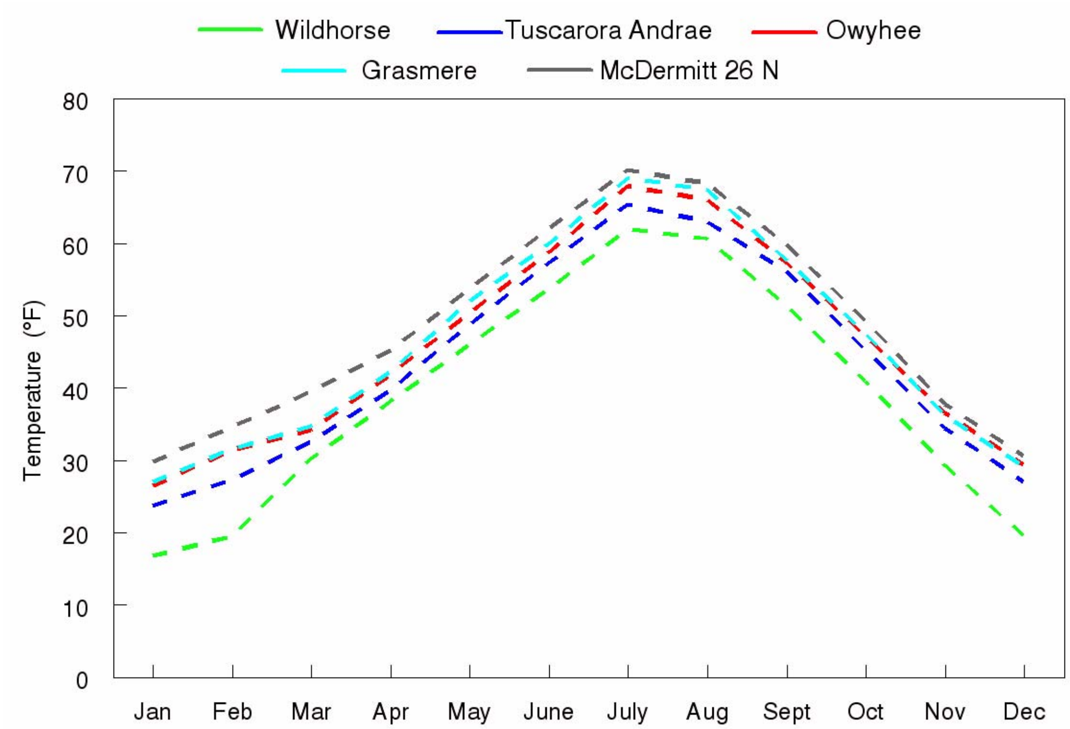

Figure 2.17. Mean monthly temperatures at five weather stations at different elevations.

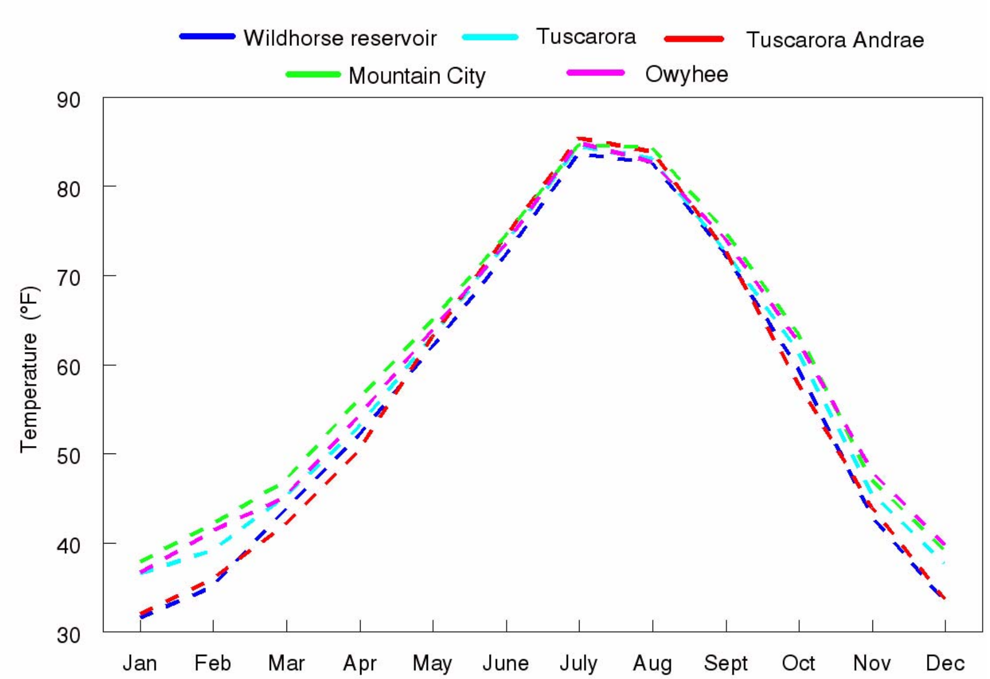

Figure 2.18 Mean monthly maximum daily temperatures at five meteorological stations in the upper Owyhee subbasin.

The average minimum temperatures at the five stations also rise and fall in a similar manner (Figure 2.19). Although the minimum temperatures from the different stations parallel each other, there is a greater spread in the temperatures between different locations. They show a difference roughly corresponding to their elevations. In January the average minimum temperature varies from 2.2°F at Wild Horse Reservoir to 16.6°F at Owyhee. [121]

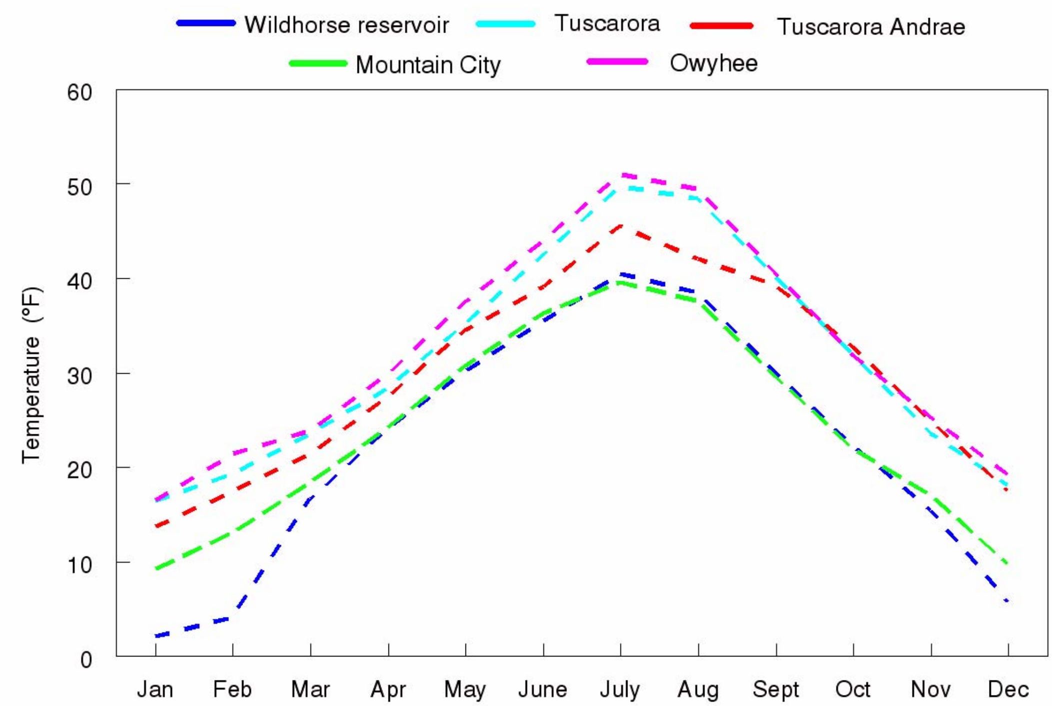

Figure 2.19. Mean monthly minimum daily temperatures at five meteorological stations in the upper Owyhee subbasin.

Factors other than elevation are affecting the average minimum temperature at Tuscarora. At the second highest elevation of the five, it most closely mirrors Owyhee at the lowest elevation.

c. Hottest and coldest

Average monthly maximum temperatures over 90°F are considered to be hot. There is another way of looking at how hot the area gets. On average, how many days each month does the temperature reach 90°F? Figure 2.20 shows the average number of days each month when the maximum temperatures are 90°F or greater. For all five stations in the upper Owyhee subbasin, July is the month with the greatest average number of days when the maximum temperature exceeds 90°F. Only the Tuscarora Andrae station exceeds an average of 7.5 days per month over 90°F.[121] For comparison, in July several stations in the Lower Owyhee fourth-order HUC average in excess of 20 days with maximum temperatures above 90°F in July.[100]

All five of the meteorological stations in the upper Owyhee subbasin show average minimum temperatures below 32°F from October to April (Figure 2.19). In July

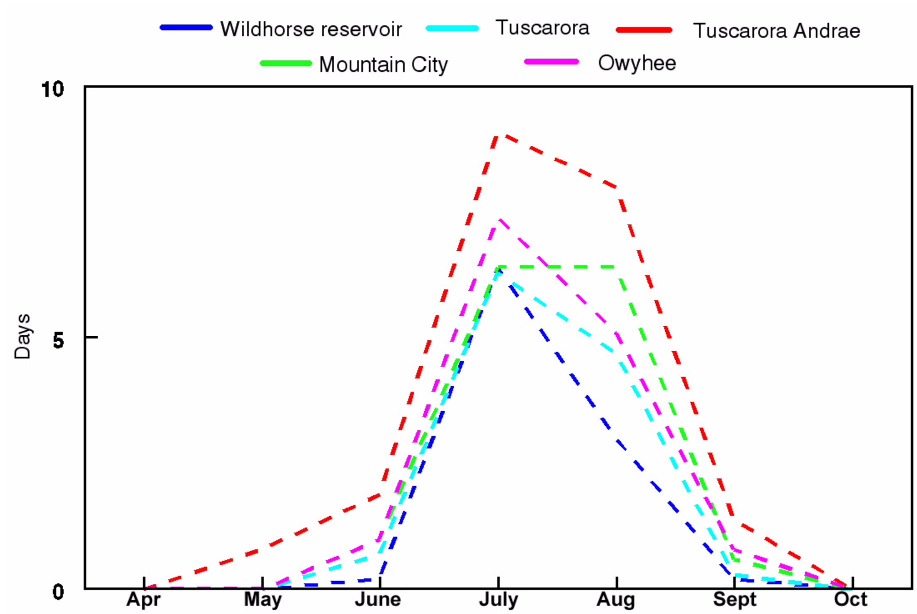

Figure 2.20. Average number of days each month with maximum temperatures greater than or equal to 90°F.

and August, only the Owyhee and Tuscarora stations do not average at least one night per month when the temperature falls below 32°F (Figure 2.21). The dip in the average number of freezing nights in February is due to February only having 28 or 29 days. At Wild Horse Reservoir, January averages 30.7 days (out of a 31 day month) with minimum temperatures below 32°F and February averages 28 days with minimum temperatures below 32°F.[121]

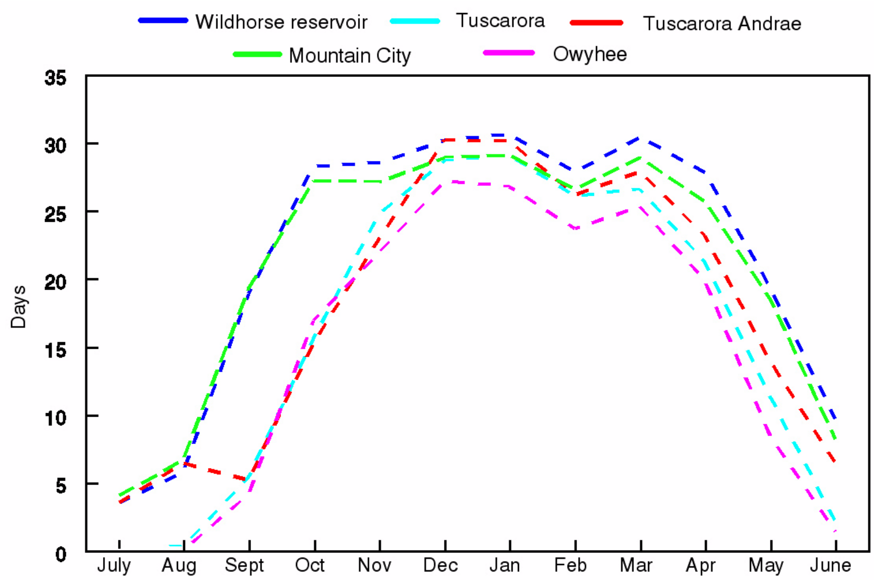

Figure 2.21. Average number of days each month with minimum temperatures less than or equal to 32°F.

Although the average temperatures tend to follow similar patterns, Table 2.8 indicates a greater variability from year to year between the stations. The highest and lowest temperatures at each station don't even occur in the same years at the different stations. Some of this is due to the difference in the years when the stations were operating (Table 2.7). The Tuscarora Andrae station stopped recording temperatures before any of the others commenced recording.

Table 2.8. Extreme daily temperatures at five meteorological stations in the upper Owyhee subbasin.[121]

Station	High	Date	Low	Date
Wild Horse Reservoir	102	July 23, 2003	-42	Dec. 12, 2004
Tuscarora	99	July 13, 2002 Aug. 1, 2000	-25	Jan. 12, 1963 Dec. 10, 1962
Tuscarora Andrae Ranch	104	June 27, 1892 July 22, 1890 Aug. 6, 1892	-27	Feb. 27, 1890
Mountain City	99	Aug. 5, 1994	-48	Jan. 1, 1974
Owyhee	98	July 19, 1960 Aug. 5, 1983	-34	Jan. 25, 1949

5. Semi-arid, cold-winter desert

For most of the upper Owyhee subbasin the average annual precipitation is calculated to be less than 20 inches per year. This area can therefore be classified as a semi-arid desert. Since the winter temperatures in this semi-arid desert section drop as low as they do and there are stark temperature differences from season to season, the area is also classified as a cold-winter desert.[52,120] The majority of the upper Owyhee subbasin is a semi-arid, cold-winter desert.

Since there are few meteorological stations, all that can be done to estimate the temperature and precipitation in the other sections of the subbasin is to extrapolate from the known data. Extrapolations and calculations probably result in figures close to the actual average weather patterns, but the lack of actual records is a data gap.

C. Vegetation

The vegetation distributions in the upper Owyhee subbasin are shaped by the geology, soils, aspect, temperature, and, at the lower elevations, the low quantities and infrequent nature of water availability. The primary plant community at the lower elevations is steppe vegetation dominated by sagebrush scrub and perennial bunchgrass.[101] Among other plant communities are playa vegetation, sagebrush on lava beds and the high-elevation community containing mountain big sagebrush scrub and both mahogany and juniper woodlands. Depending upon soil depth and elevation, different subspecies of sagebrush (*Artemisia tridentada*) flourish.[7,101] Paleobotanical research reflects an environment which has supported *Artemisia* steppe / desert scrub communities for the last 8000 years.[101]

Willows, sedges, rushes, cottonwood trees and other riparian vegetation are found along perennial streams and some intermittent streams.

Throughout a desert environment, there is high spatial variability of plants. Vegetation can differ significantly between patches; patches in close proximity to one another may contain different species compositions.[101] Not all the vegetation is native. Cheat grass has spread over much of the rangeland and other invasive "weed" species are also altering the vegetative communities. The vegetation in the upper Owyhee subbasin is covered in more detail in the rangeland section of this assessment.

D. Wildlife

There are limited perennial sources of water in the upper Owyhee subbasin. Some of these perennial streams and rivers have steep canyon walls which limit wildlife and livestock access to the water. Just like the vegetative distributions, the animal distributions are shaped by the low quantities and infrequent nature of water availability. Since the elevation of the subbasin varies from less than 4,500 feet to over 10,000 feet (Figure 2.14), there are many different ecological niches, which support different species of wildlife.

Other than insects, birds represent the greatest number of animal species found in the upper Owyhee subbasin. Water birds and migratory ducks and geese are not only found in the marshland playas around Duck Valley, but also have been spotted on a playa north of Tent Creek in Malheur County in very wet years. Some bird species are limited to river canyons and others require the open grass and sagebrush lands. Although distant from each other, the Independence and Bull Run Mountains and Juniper Mountain are home to similar bird species found only in more forested areas.

Doe and fawn near Rio Tinto

Blackbirds chasing a sand hill crane near Mountain City

Pronghorn ducking under a barb wire fence along SSR-11

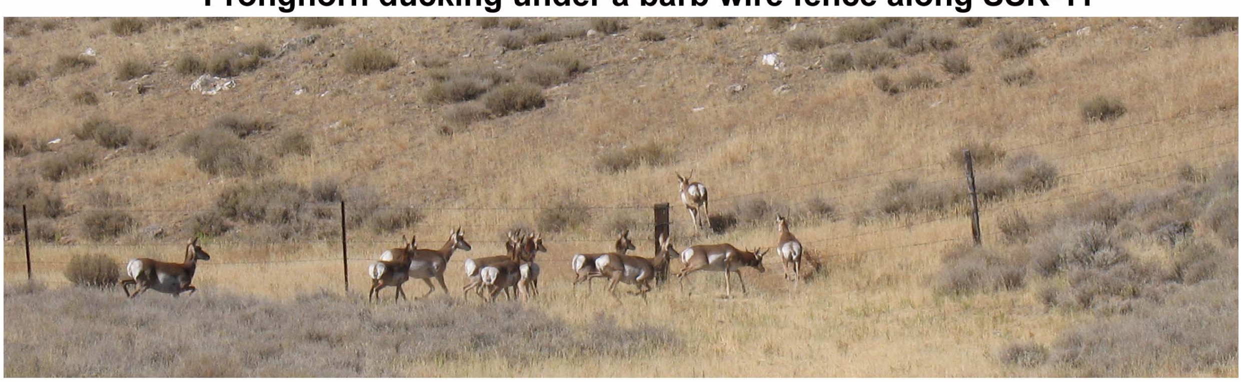

Photo 2.3. Some of the wildlife photographed in the upper Owyhee subbasin

Large animals such as the mule deer, pronghorn, and cougar are found throughout the subbasin. Elk primarily live in the more forested higher elevations. The sparse populations of reintroduced bighorn sheep are restricted to rugged canyons. Beaver and river otter are confined to streams. Smaller mammals such as rabbits, ground squirrels, mice, and voles may be found in grasslands or in sagebrush vegetation complexes. Abandoned mines provide habitat for some of the bat species. Table 2.9 lists some of the wildlife species which are known to inhabit some portion of the upper Owyhee subbasin.

Table 2.9. Some species of wildlife in the upper Owyhee subbasin.

Mammals[27,76,77,99,103]			
elk	long-tailed weasel	muskrat	Merriam's shrew
mule deer	mink	desert woodrat	Preble's shrew
pronghorn	mountain cottontail	bushy-tailed woodrat	vagrant shrew
bighorn sheep	white-tailed jack rabbit	Ord's kangaroo rat	hoary bat
feral horses	yellow-bellied marmot	chisel-toothed kangaroo rat	big brown bat
mountain lion	Townsend's ground squirrel	western harvest mouse	silver-haired bat
bobcat	Belding's ground squirrel	canyon mouse	spotted bat
coyote	Wyoming ground squirrel	northern grasshopper mouse	pallid bat
kit fox	Merriam's ground squirrel	great basin pocket mouse	little brown myotis
red fox	piute ground squirrel	Townsend's pocket gopher	long-eared myotis
American badger	white-tailed antelope squirrel	northern pocket gopher	Yuma myotis
common raccoon	least chipmunk	montane vole	long-legged myotis
common porcupine		sagebrush vole	western small-footed myotis
western spotted skunk		pika	California myotis
striped skunk			western pipistrelle
beaver			Townsend's big-eared bat
northern river otter			

Amphibians and Reptiles[25, 26,27,76]			
western toad	sagebrush lizard	long-nosed leopard lizard	great basin rattlesnake
pacific treefrog	western fence lizard	rubber boa	western rattlesnake
northern leopard frog	side-blotched lizard	racer	western terrestrial garter snake
Columbia spotted frog	western whiptail	gopher snake	night snake
short-horned lizard	western skink		striped whipsnake

Birds[15,27,56,58,99]			
pied-billed grebe	sage grouse	willow flycatcher	orange-crowned warbler
American bittern	sharp-tailed grouse	dusky flycatcher	MacGillivray's warbler
great blue heron	California quail	ash-throated flycatcher	yellow warbler
black-crowned night-heron	Virginia rail	Say's phoebe	black-throated gray warbler
sandhill crane	sora	western kingbird	warbling vireo
turkey vulture	American coot	western wood-pewee	common yellowthroat
Canada goose	killdeer	gray flycatcher	yellow-breasted chat
green-winged teal	black-necked stilt	eastern kingbird	green-tailed towhee
mallard	American avocet	horned lark	spotted towhee
northern pintail	willet	tree swallow	
	spotted sandpiper	violet-green swallow	

blue-winged teal	common snipe	bank swallow	Brewer's sparrow
cinnamon teal	Wilson's phalarope	northern rough-winged swallow	lark sparrow
northern shoveler	mourning dove	cliff swallow	sage sparrow
gadwall	common barn-owl	barn swallow	song sparrow
American wigeon	western screech-owl	American crow	chipping sparrow
canvasback	great horned owl	black-billed magpie	vesper sparrow
redhead duck	burrowing owl	common raven	house sparrow
ruddy duck	long-eared owl	black-capped chickadee	lazuli bunting
lesser scaup	short-eared owl	bushtit	western meadowlark
common merganser	northern saw-whet owl	rock wren	Brewer's blackbird
golden eagle	common nighthawk	house wren	red-winged blackbird
northern harrier	common poorwill	marsh wren	yellow-headed blackbird
Cooper's hawk	white-throated swift	canyon wren	brown-headed cowbird
Swainson's hawk	black-chinned hummingbird	blue-gray gnatcatcher	Bullock's oriole
red-tailed hawk	calliope hummingbird	mountain bluebird	pine siskin
ferruginous hawk	belted kingfisher	American robin	American goldfinch
American kestrel	Lewis' woodpecker	loggerhead shrike	house finch
prairie falcon	red-naped sapsucker	European starling	cedar waxwing
gray partridge	downy woodpecker	sage thrasher	gray catbird
ring-necked pheasant*	hairy woodpecker		ring-necked turtle dove*
chukar*			

*introduced

E. Geology

This section discusses various aspects of geology. The geological history of the upper Owyhee subbasin describes how the rock formations got to be where and what they are today. The rocks found within the upper Owyhee subbasin can be the source for ores and minerals sought by prospectors and rockhounds. The bedrock has weathered to form the soils found within the subbasin. Rocks not only can contain naturally occurring metallic ores, like those of gold and silver, but also can contain chemicals such as mercury and arsenic. Knowing what rocks are found in the subbasin tells us some of the chemicals that will naturally erode and enter the soils and waters.

The discussion will show that the rocks in the upper Owyhee subbasin are part of two geographic provinces (areas): the Basin and Range, and the Owyhee Plateau. Rocks in the Basin and Range are very old and have been faulted to form north-south trending valleys and mountain ranges. In the Basin and Range province, the valleys have filled with sediments eroded from the adjoining mountains. Rocks from the Owyhee Plateau are much newer and were formed by volcanic activity in the recent geological past. Atop the recent geological rock formations of the Owyhee Plateau, the soils have not had time to develop and tend to be shallow and rocky. In older geological areas in the Basin and Range, soils tend to be deeper and richer in nutrients because they have been forming for longer.

1. Basic Geology

Geology is the study of the rocks that are found within a region, what the rocks are made of and how the rocks got to be where they are today. Geology explains scenic vistas, the source of precious metals, and the source of sediments within the watershed.

a. Minerals and rock formations

The term **mineral** is used for naturally occurring, solid compounds with a specific crystalline structure. Minerals can be found in their pure form, like a quartz crystal or gold vein, but more frequently they are mixed together to form rocks.

Rocks are named on the basis of texture, mineral composition and formation processes. Basalt and sandstone are examples of common rocks. Two sandstones may have the same basic mineral composition and similar texture, but they will normally vary in the quantities of trace elements.

"The geologic record is made up of many different kinds of rock layers, some thick, some thin, some widespread, and some extending only a few feet. It is impossible and unnecessary to understand completely the relationships among all individual layers. Instead, geologists mentally gather layered rocks together into manageable units that are called formations. A formation may be a single thick layer or, more commonly, a group of individual layers with more or less consistent characteristics which are recognizable throughout a wide area."[61:3] For example, the lava flows from one volcano or the sediments accumulated in one lake bed may be called a **formation** as they have a similar source, composition and age. Rock formations are given proper names such as “Jordan Craters Basalt”.

b. Rock classes

Geologists classify rocks into three major groups based on how the rocks are formed on the earth.

Igneous rocks are those formed by the cooling of magma. Basalt and granite are both igneous rocks as they are formed from magma: basalt by cooling on the surface of the earth or under the ocean in a lava flow and granite by magma cooling more slowly within a mountain.

Sedimentary rocks are those formed by the accumulation of sediment in layers. Most sediment accumulates on the bottom of the ocean, but it also accumulates in lake beds, on floodplains, on playas and as layered ash.

Metamorphic rocks are those formed when existing rocks or sediments are transformed by extreme pressure and heat, usually deep within the earth’s mantle.

Most of the rocks found within the upper Owyhee subbasin are igneous or sedimentary rocks.

c. Weathering of rocks

Weathering is the process by which rocks are turned into smaller rocks and eventually into soil or sediment.

Physical weathering is the breaking of rock by natural forces such as frost wedging (water in cracks freezing and expanding), exfoliation (outer slabs detaching like onion peels), or wind or water breaking particles off of a rock. The amount of physical weathering depends upon weather conditions and the action of wind and water.

Chemical weathering is when a rock is altered or dissolved by chemical reactions such as the oxidation (rusting) of iron or dissolution of rock from acid produced by fungi. The rate of chemical weathering is determined by heat and humidity, making weathering more rapid in the humid tropics than in cold temperate regions.

In deserts the most common form of weathering is physical weathering. Chemical weathering affects unstable minerals such as halite (common table salt) which dissolves easily in water. By understanding qualities of the original bedrock as well as the forms weathering takes, it is possible to predict the effects of natural weathering processes on a region's rock features.

d. Rocks common in the upper Owyhee subbasin

A variety of igneous rocks are found in the Owyhee watershed because of the active volcanism in the recent geological past. **Basalt** is a common rock of lava flows. It is generally black or dark-gray. Basalt pours out of vents (cracks) in the earth, so the final form looks like the syrup you pour on a pancake: it forms fairly level sheets of rock. Within the sheet the lava can crystallize into hexagonal columns.[10] The dark colors in basalt come from high concentrations of iron and magnesium. **Rhyolite** is the same composition as granite but it cools on the surface; it is composed almost entirely of silica.[90] In a pure form rhyolite will be a white rock; however, it often has small mineral inclusions of iron or magnesium that turn the color reddish brown. Rhyolite doesn't flow as easily as basalt so it moves more like molasses. Often rhyolite is associated with explosive volcanism, like the building of cinder cones. When rhyolite forms, lava flows so slowly that the surface cools and then breaks into chunks that are incorporated within the flow so the surface of rhyolitic flow is not as flat as a basalt lava flow.

Photo 2.4. Rhyolite canyon walls of the Little Owyhee River.

Within the Owyhee uplands some of the volcanic activity was bimodal, with both rhyolite and basalt erupting from the same volcanic vent at different times of activity. There are also many rocks that have a composition between that of basalt and rhyolite due to mixing of the two types of magma. The most recent volcanism at Jordan Craters northwest of the upper Owyhee subbasin provides a nice example of bimodal volcanism because both aspects of the volcanic activity are visible. The cinder and spatter cones are composed of rhyolite. First the cinder cone (Coffeepot Crater) and spatter cones formed on a hill. Then basalt lava flows broke through one wall of the cinder cone, flowing downhill, leaving the earlier phase of explosive rhyolite exposed.[16,87,94]

Molten lava pushes to the surface through already existing rocks. Cracks in rocks often provide a route for the lava. After lava stops flowing on the surface, the lava still within the cracks will cool. These vertical pathways for lava are called **dikes**.[33] Sometimes the lava in cracks will never reach the surface, but it may form a dike underground that is later exposed by erosion. An example of dikes in the upper Owyhee subbasin are those at Capitol Peak in the Calico Mountains of Nevada. Other impressive dikes of basalt are visible along the road through Leslie Gulch and occasionally crossing the Owyhee River upstream in the upper Owyhee subbasin.

Tuff is the term applied to all rocks formed from volcanic ash. When gasses and steam escaping from a volcanic vent come in contact with lava they can blow the lava apart. If these particles are as small as sand or silt they are called ash. This ash can then be moved long distances as flows or may become airborne.[109] When the ash flowing out of a volcanic vent stays very hot it will cool on the surface of the land, becoming a **welded tuff**. In a welded tuff, the heat of the ash particles is sufficient for them to stick, or weld, to each other.[109] Tuffs and welded tuffs are described on the basis of the type of igneous rock from which they are formed. Therefore a rhyolitic tuff is one that has the same minerals found in rhyolite but is in ash form.

Granite is a volcanic rock similar in mineral composition to rhyolite. It is high in silica. However, the formation of granite occurs beneath the earth's surface. Granite forms within large underground reservoirs. The magma cools very slowly and forms large crystals. Granite high in silica will be light, almost white in color. However, granite is often a mix of many minerals. The other common minerals within granite are mica (muscovite and biotite) and feldspar (plagioclase and orthoclase). Granite is a tough rock that isn't very easily eroded. A common location where granite forms is within mountain chains that have formed from intrusive magma such as the Independence Mountains.

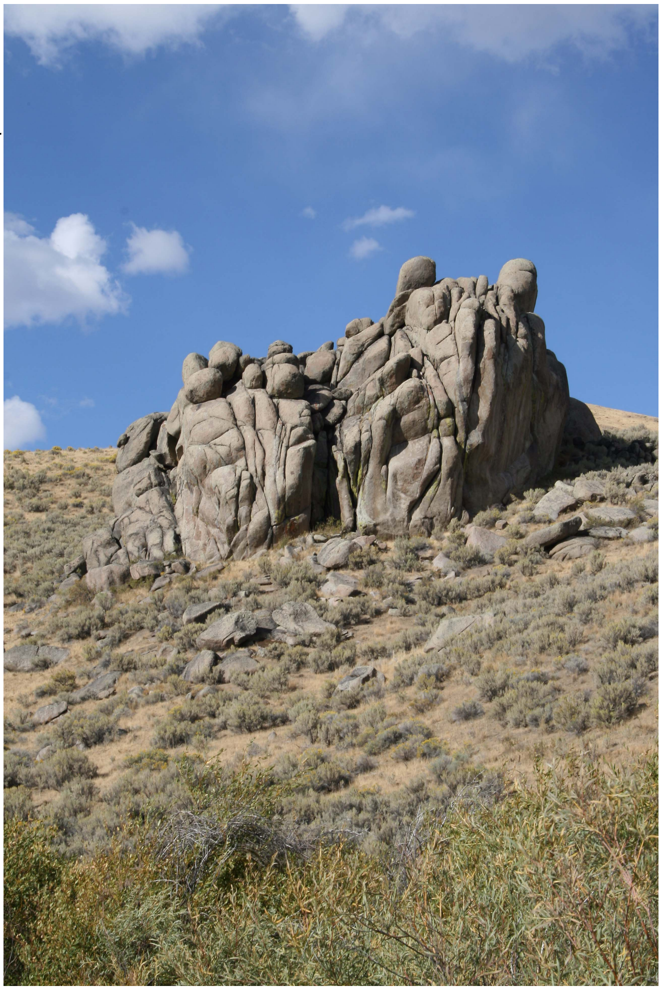

Photo 2.5. Granite outcroppings below Wild Horse Reservoir

Sedimentary deposits important within the Owyhee uplands are primarily lacustrine and alluvial deposits.

Lacustrine sediments are those deposited within a lake. Generally lake sediments are fine grained because they come from material carried by the water. The types of minerals within lake deposits depend upon the rocks eroding around the lake. When a lake bed dries out it is called a playa lake and the minerals within the water are precipitated. The minerals that settle out are generally white in appearance like gypsum; they are salts of sodium, calcium, magnesium and potassium. **Alluvial** sediments are those deposited by running water. Rivers move gravel in their beds and carry small particles in suspension, making them look dirty. The gravel is left in old river courses as the river moves and smaller particles are deposited on floodplains or on lake bottoms where rivers enter lakes.[3] Like lake deposits, the rock materials found in alluvium are derived from other rocks in the area. In many cases these deposits will contain larger chunks, namely gravel and boulders.

Faulting is the process whereby pieces of the earth's surface change position in relationship to one another. Faulting can be caused by large-scale processes such as the movement of tectonic plates on the earth's surface and local processes like the emptying of magma chambers below the ground resulting in an area subsequently dropping. Faults are the lines along which we can see the movement that has occurred. When faulting causes vertical movement of the earth, multiple parallel fault lines can cause areas to rise into mountains while beside them basins are formed. The Basin and Range province is a large series of valleys and mountains formed by faulting. The Bull Run and Independence Mountains in the upper Owyhee subbasin are part of the Basin and Range.

e. Weathering of common rocks

Ash tuffs are soft rocks easily sculpted by wind and water.[16] Basalt lava flows are significantly harder but can be broken down more easily than rhyolitic lava which is mainly silica. All rocks exposed in the Owyhee uplands are susceptible to weathering; however, they will break down more if they are soft or have been exposed for a longer time. It can be expected that soils and water will contain minerals common in the rocks, especially those found in volcanic ash or basalt because these rocks are more easily broken down.

f. History, as geology tells it

Geologists look at the placement of rock formations on the earth's surface to discover in what order events happened. For layered rocks geologists start with the principle of **stratigraphy**, that newer layers accumulate on top of older layers of rocks. This means that in a canyon like those cut by the Owyhee River the rocks at the bottom of the canyon are the oldest and those closest to the rim are the newest.

The geological record can be patchy as the creation of rocks is often followed by periods of erosion. This can be seen when a group of tilted rocks get covered by new flat deposits (Figure 2.22). Past erosional surfaces can also be flat and hard to identify. Geologists call the gaps of time caused by erosional events **unconformities**.

Things on the earth's surface don't always stay in the same place. **Faults** move pieces of the earth's crust past each other or up and down. The well known San Andreas fault in California is one in which the two pieces of the crust are moving past

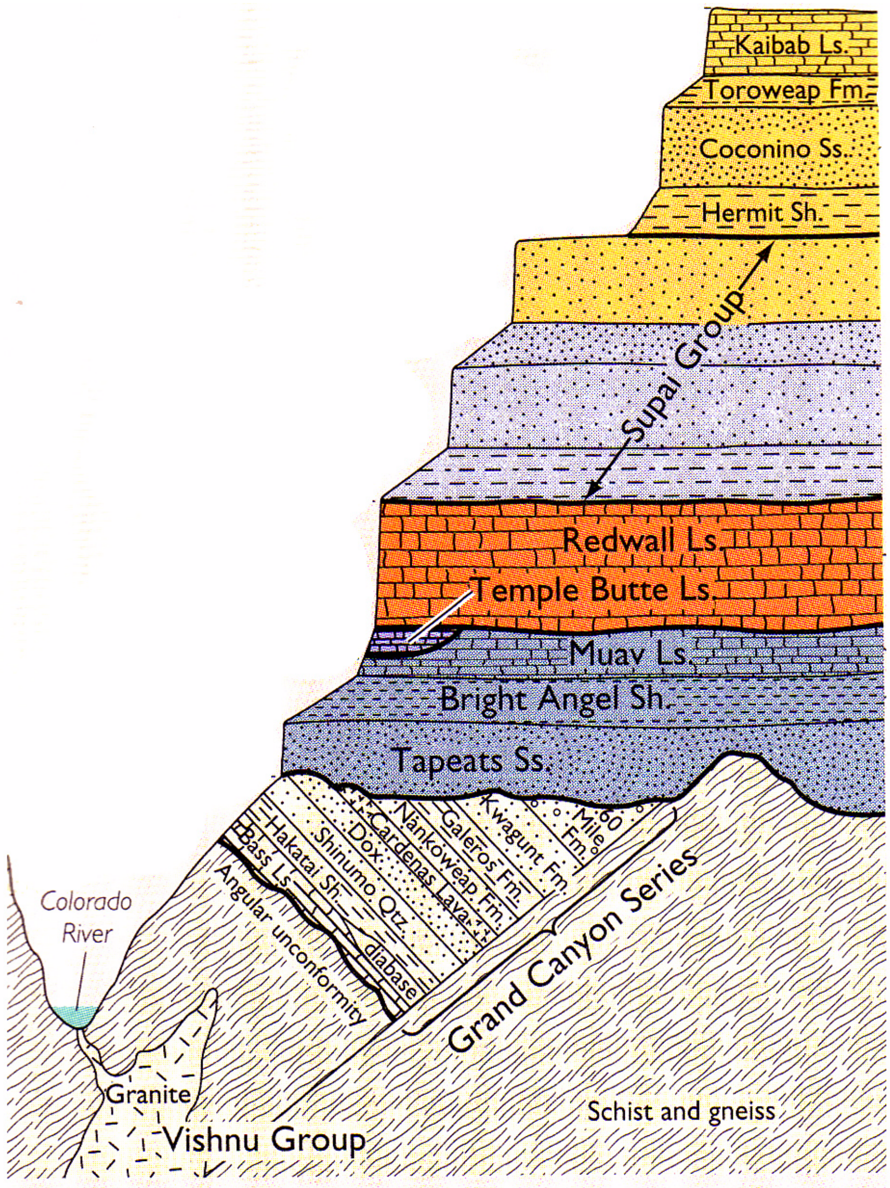

Figure 2.22. Geological series of the Grand Canyon is broken by erosional events (unconformities) seen as darker black lines.
(Adapted from 126:198)

each other. Faults where the crust moves up and down often form mountains and valleys, like Death Valley which has dropped below sea level while the mountains on both sides have moved upwards. Geologists use the rock formations moved by faults to help date when the faults were active.

g. Geological time scale

To compare historical events like the formation of the Grand Canyon or the Owyhee Canyon and the building of the Bull Run, Independence, and the Owyhee Mountains, geologists have developed their own time scale. They divide time into very large periods, **eons**, then **eras**, **periods** and the smallest subdivisions, the **epochs**.[116]

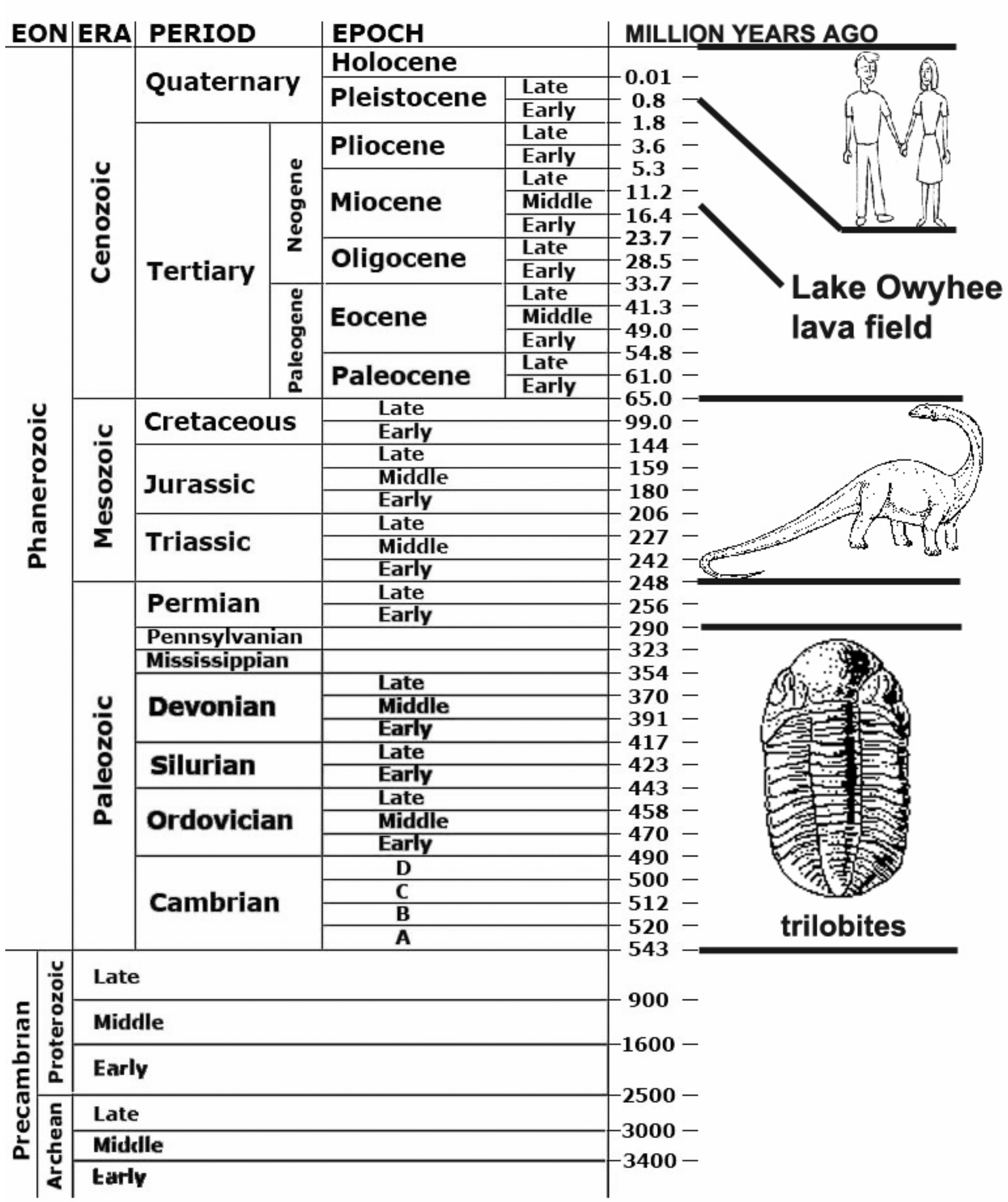

Figure 2.23. Geologic time scale.
(Adapted from 116)

These divisions are marked by major changes in the earth's environment or animal extinctions.[119] In Figure 2.23 you can see that the die off of the dinosaurs at 65 million years ago marks the end of the Cretaceous period and the Mesozoic era. All mammals are thought to have evolved in the last 65 million years, during the Tertiary and Quaternary periods. The Quaternary period, 1.8 million years ago through the present, includes the entire history of modern humans. Together the Tertiary and Quaternary make the Cenozoic era.

After documenting major changes in climate and fossils within the rocks, geologists date the divisions using radioactive decay of naturally occurring minerals within the rocks. Radiocarbon, or C14, is often used to date charcoal from human fires because the rate of radioactive decay is predictable. For example, this is how we know that Native Americans killed mastodon in New Mexico 12,000 years ago. Other radioactive elements also decay at predictable rates but much more slowly so they can be used to date the formation of rocks. The radioactive elements used to date rock formations are potassium 40, rubidium 87, thorium 232, uranium 235, and uranium 238.[47,119]

On the geological time scale the upper Owyhee subbasin is very young. Most of the surface rocks date to the Cenozoic era after the dinosaurs died out 65 million years ago. The high plains north and west of Mountain City, Nevada were formed only 15 million years ago by volcanic activity of the Yellowstone hot spot.

2. Geological data

a. Regional geological background

Before looking at how the Basin and Range and the Owyhee Plateau came to be, we must step back in time to the origin of the rocks within the upper Owyhee subbasin.

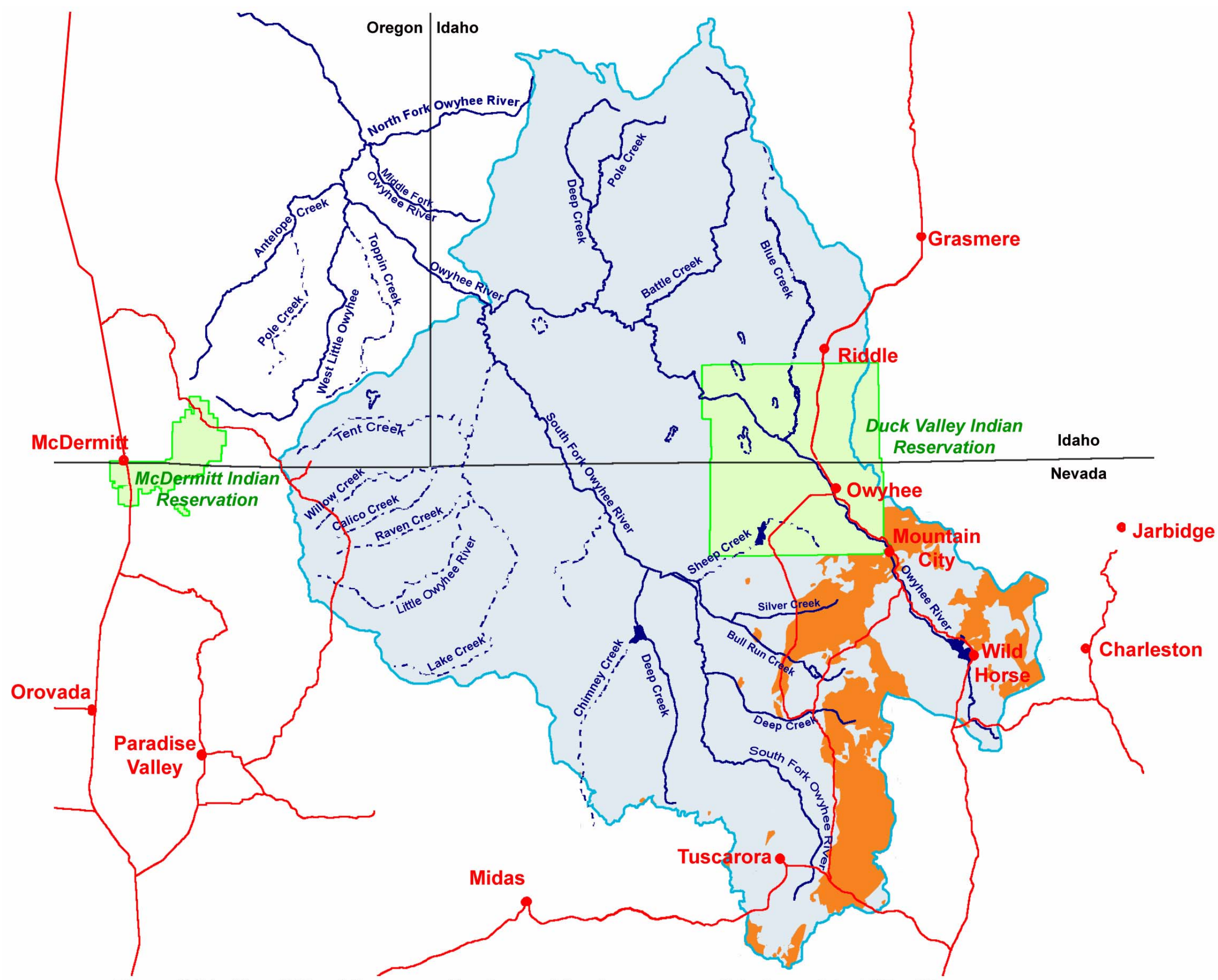

Figure 2.24. Very little of the upper Owyhee subbasin as we see it today existed 65 million years ago. The only portions that existed then are in orange in this figure.[69]

The events in the surrounding region and the western US discussed below are chronologically related to each other on a timeline included just before the bibliography.

In the era of the dinosaurs (Mesozoic) two mountain complexes were forming in what is now the western United States. The boundary of the North American tectonic plate was not at the edge of California, but farther inland. As the oceanic plate to the west collided with the North American continent mountains were formed by the edge of the oceanic plate being forced downward into the mantle below the North American tectonic plate (subduction). The Nevadan Mountains formed between 150 and 90 million years ago.[104] The few areas where rocks from this era are exposed in the upper Owyhee subbasin are shown in Figure 2.24. Along with the volcanism and mountain growth, the subducting oceanic plate brought some islands which stuck to the western shore. These islands are aggregates, rocks consisting of a mixture of minerals.

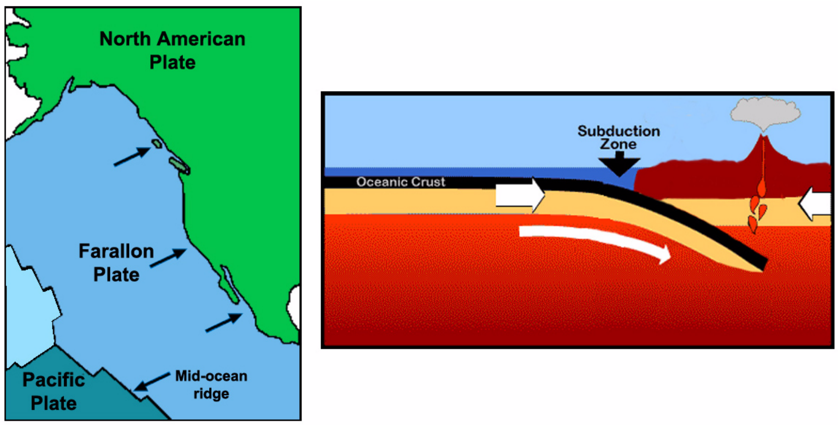

Figure 2.25. The Farallon plate as it would have been before it subducted under the North American plate. Schematic shows subduction.[14,30]

Later in time and farther to the west another set of mountains were built. This was caused by the subduction of the Farallon plate of ocean floor under the North American plate (Figure 2.25).[14,30,69] From 70 to 40 million years ago the Farallon plate was subducted from southwest to northeast under the North American plate, building the Colorado Plateau and Rocky Mountains.[14,69] Farther to the north the Farallon subduction was responsible for some of the granite formed in the Idaho Batholith.[30] This plate is easier to trace than earlier ones because it subducted more recently and geologists have seismically mapped the cold remnants of the plate that are still sinking into the mantel of the earth under eastern North America.[92]

Meanwhile the warm and wet climate had been eroding the Nevadan mountains down into hills, similar to the current day Appalachians. Large rivers associated with the warm and moist climate distributed mountain sediments including many of Nevada's gold bearing gravels.[57] And it was atop these hills that lava and tuffs erupted in association with the subduction of the Farallon plate. These lavas were rich in calcium, a component of the sea floor that was being melted below the surface.[69,85] The location of active volcanism changed over time. In Nevada the dates of the lava have been used to construct regions of activity. The upper Owyhee subbasin lies within a region that had active volcanism around 41 million years ago (Figure 2.26).[66,69] This volcanism is expressed locally at the Tuscarora volcanic field.[49]

The Farallon plate was on the western side of an ocean floor spreading center, similar to that in the center of the Atlantic Ocean today. When the Farallon plate was entirely under the North American plate between 28 and 25 million years ago the

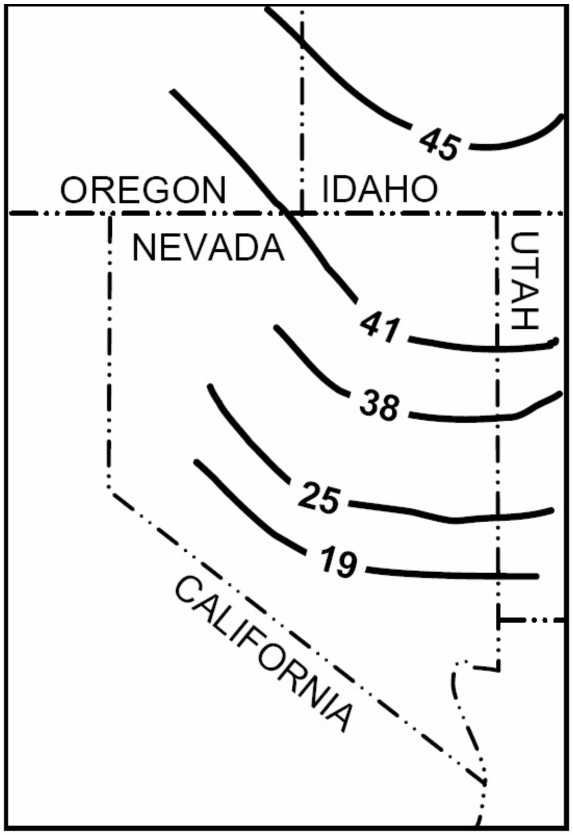

Figure 2.26. Ages in million years ago of volcanism related to the subduction of the Farallon plate.
(Adapted from 69:6-2)

spreading center changed in nature.[14,69] The current contact between the Pacific and North American plates is the San Andreas fault. The spreading force was transferred to another part of the system. Crustal thinning of the North American plate was the result. This crustal thinning formed the Basin and Range province. What became thinned was the earth's crust under a mixture of a part of the Nevadan Mountains, aggregate rocks, and part of the Rocky mountains.

Within the arid areas of the Owyhee River watershed, there are striking similarities between the mountains in the area of Silver City and those around Tuscarora and Mountain City. These similarities are tied to regional geology. All of the underlying rocks that are now found in these mountain ranges were formed before Basin and Range spreading began. These mountains and many others in northern Nevada and south-central Idaho are similar because of their shared history.

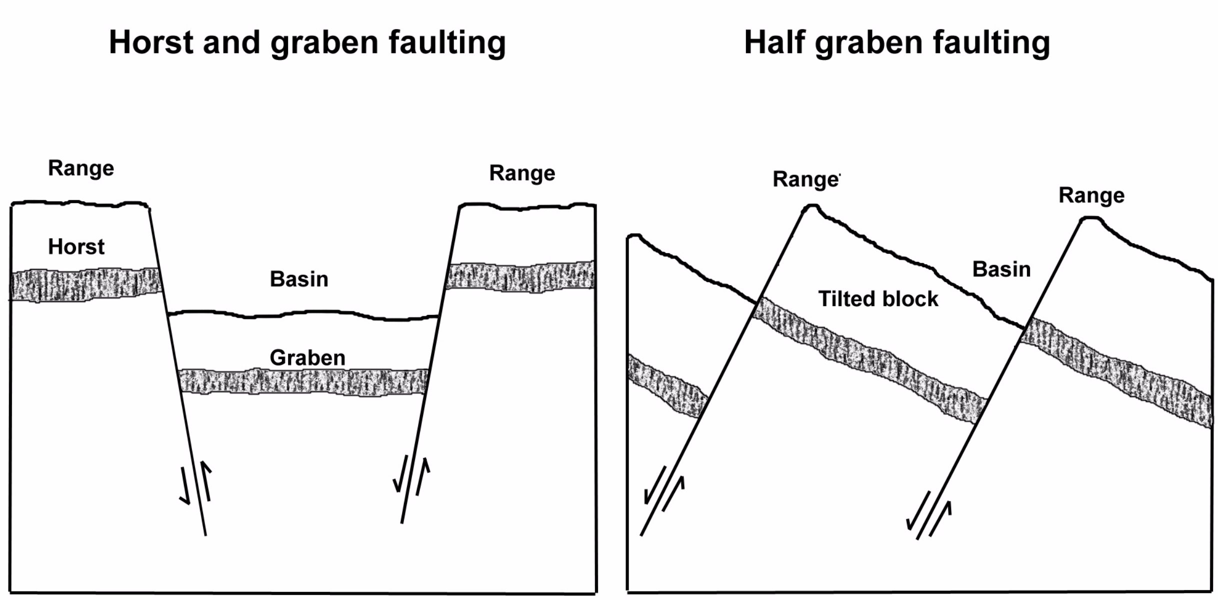

Figure 2.27. These two types of extensional faulting are common in the Basin and Range province.[11,48]

b. Geology of the upper Owyhee subbasin

The upper Owyhee subbasin is in a region where the underlying geology is Nevadan Mountains and aggregate rocks. The Tuscarora volcanic field was active during subduction of the Farallon plate. The Basin and Range province formed and was subsequently covered by volcanic rocks of the Owyhee Plateau.

The Basin and Range province, characteristic of much of the state of Nevada, was formed through crustal thinning. The thinning in the region occurred through two types of faulting. One is where a graben drops between two remaining pieces of land (horsts) and the other is where tilting occurs and a "half graben" is formed creating a series of mountains and valleys (Figure 2.27).[11,48] In either case, the subsequent erosion of the higher piece of land fills the grabens with alluvial sediments. The difference between the two is how the geological layers in the mountains will be oriented. In graben and horst faulting, mountain rocks will lie in flat layers. In tilted extensional faulting (half graben), the mountain rocks' layers will be tilted.

The faults along the Bull Run and Independence Mountains of the upper Owyhee subbasin are depicted in Figure 2.28. Faults mark the edges of the mountains where the grabens dropped down. Hot springs formed in north-south lines running along faults where groundwater could more easily flow down to the hot magma and back up to the

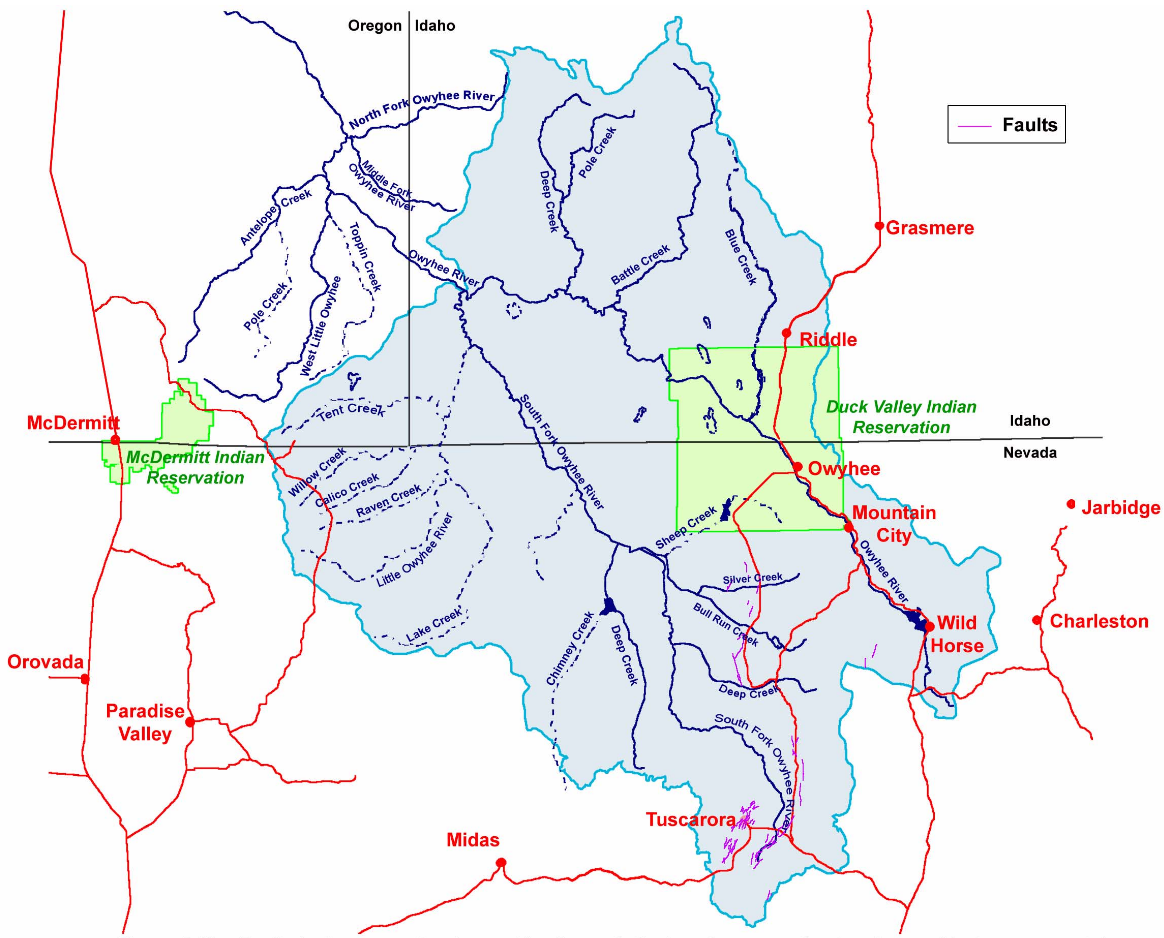

Figure 2.28. Faults in the upper Owyhee subbasin mark the locations were basins dropped between mountain ranges and have not been covered by subsequent lava flows.[35]

earth's surface. Adjacent basins filled with alluvial sediment eroded down out of the mountains.[35]

The land surface today within the basins of the upper Owyhee subbasin is a mix of sediments derived from the mountains on the sides and volcanic lava and tuffs. Active faulting has stopped in the area of the subbasin. Faulting is not consistent across the Basin and Range province as a whole. At present, the central 500 kilometers (of the 800 kilometer wide province) have almost no deformation.[105] Most faulting today occurs on the western edge of the province up against the Sierra Nevada and a smaller amount occurs in the east on the Wasatch front.[105]

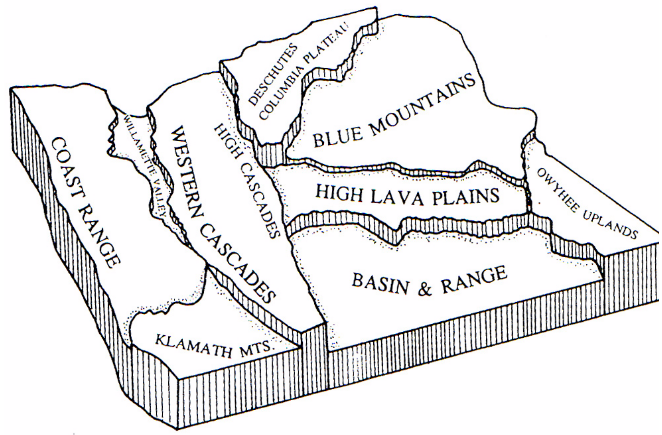

Figure 2.29. Geological areas of Oregon
(Adapted from 86:1)

In Oregon, the stretching and cracking of the crust also provided a way for lava to reach the surface. And it is from Oregon that we can see the events leading up to the building of the Owyhee plateau. Faulting was accompanied by volcanic eruptions on the Columbia River plateau, in the Steens Mountains, at Glass Mountain, and in the Strawberry Mountains.[16,86] This volcanism formed the High Lava Plains in central Oregon and the Columbia Plateau in northern Oregon (Figure 2.29).[118] In southeastern Oregon the Steens Mountain volcano sent basalt and ash into Idaho on the east, Lakeview County on the west, and up to

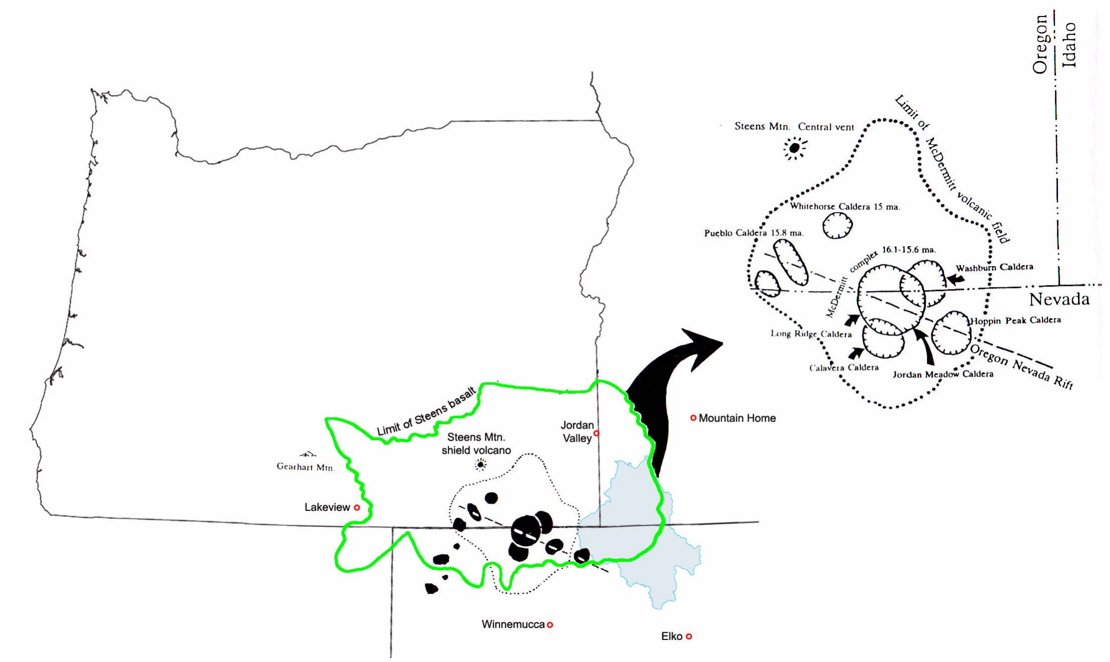

Figure 2.30. The McDermitt volcanic field is located in the Owyhee uplands of southeastern Oregon and northwestern Nevada. Notice that Steens Mountain basalt flows covered much of the upper Owyhee subbasin.

Saddle Butte in the North (Figure 2.30)[86] Basalt and tuff from the Steens contribute to a substantial portion of the basement rock in the upper Owyhee subbasin. In some areas of Idaho these rocks are 1000 meters thick.[38]

The volcanism with the greatest impact on the geology of the upper Owyhee subbasin is that of the Owyhee-Humboldt volcanic field. Welded rhyolitic tuff flows spread across an enormous area around 13.8 million years ago (Figure 2.31). The tuff of Swisher Mountain is a very large geological unit. It has been mapped over an area with a 100 kilometer diameter.[38] The Swisher Mountain tuff erupted from the Juniper Mountain volcanic center. Juniper Mountain is a gentle dome about 30 kilometers in diameter that lies directly in the progression of the Yellowstone hot spot.[12,38] The Swisher Mountain tuff is one of five different rhyolitic tuff sheets which make up the Owyhee-Humboldt volcanic field. The volcanic activity in this area did not create a noticeable crater, but over a 45 mile wide area of the valley to the south was filled with volcanic rocks to great depths.[38] These eruptions ceased with the eastward progression of the Yellowstone hot spot across southern Idaho and northern Nevada.[59]

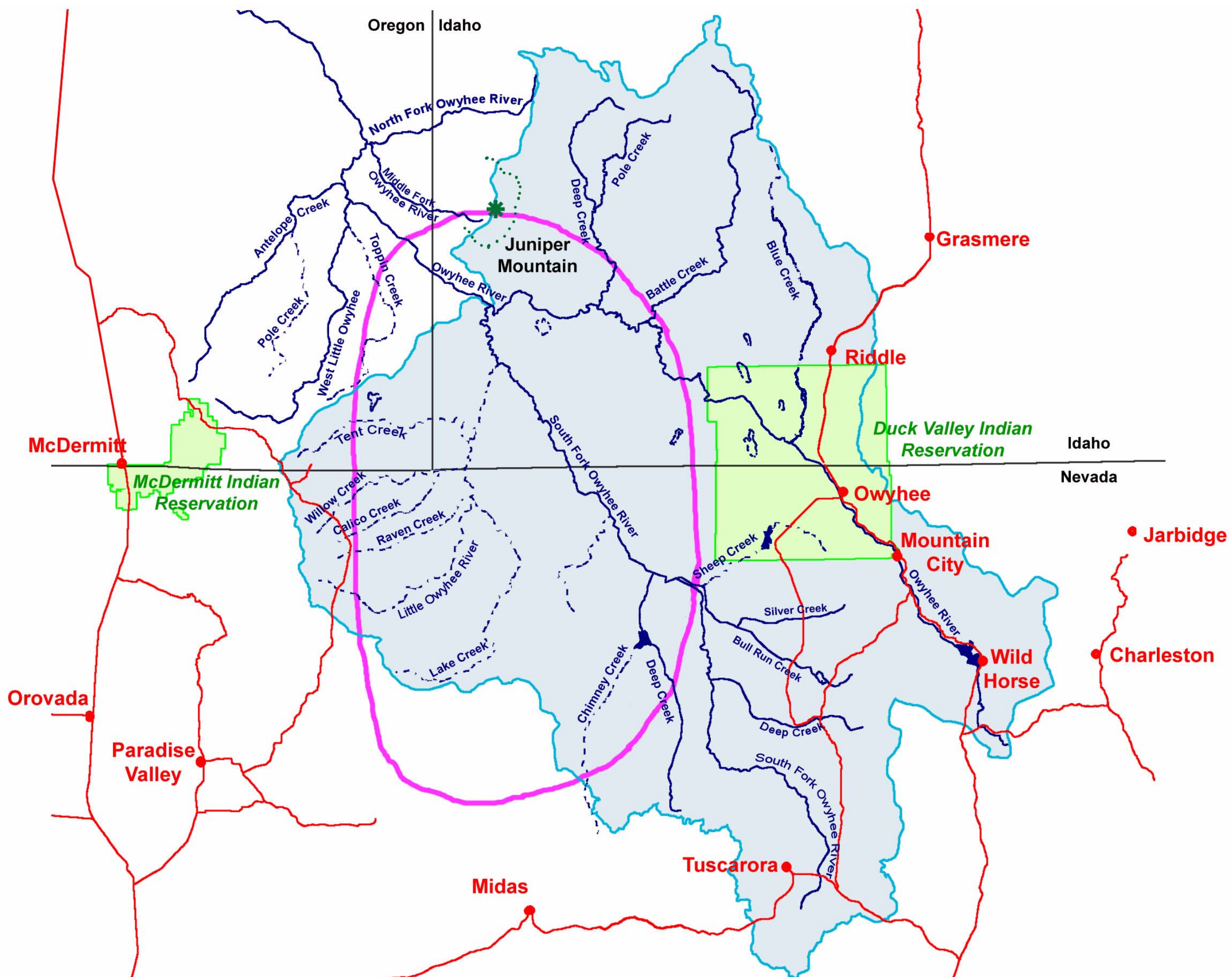

Figure 2.31. **The Owyhee-Humboldt volcanic field dates to 13.8 million years ago. It was formed by five eruptions of tuff and lava from Juniper Mountain, including the "Swisher Mountain tuff". The hotspot that was responsible for this volcanism is now under Yellowstone National Park.[59,60,63]**

The Little Jacks Creek eruptive center was the source of other rhyolitic tuffs of large proportions.[38] The point source of the Little Jacks Creek eruptive center is inferred to be to the east of Owyhee plateau.[38] In respect to the upper Owyhee subbasin, this tuff is found only to the northeast of the Owyhee River.[38] The cause of this volcanism could have been a continuation of the Yellowstone hot spot; however, the two available dates for the flows, from dating in the 1970s, do not corroborate this source.[38,60]

Basalt lava flows of a more recent origin cap (cover) the tuff and rhyolite of the Owyhee-Humboldt volcanic field in some areas.[54,73] Called the Banbury Basalt, the uppermost basalts come from many sources and have many dates.[12,39] Dates between 10 and 8 million years ago are suggested by Ekren.[12] Foord et al. suggest the dates may be more recent between 10 and 6 million years ago.[39] These basalt flows are probably related to Great Basin spreading as the flows are very thin and consist entirely of basalt.[66] Basalt flows of dark hues, with distinctive columnar jointing, cap portions of the upper Owyhee subbasin. Source locations have been suggested along faults for some of these basalt flows, but the origin of all is not known.[12]

Subsequent to the period of volcanism, large lakes formed in many of the basins in Nevada, Oregon and Idaho because warmer climatic conditions with higher rainfall prevailed. Alluvial sediments accumulated in the lake basins and along the stream courses feeding the lakes.[118] It is probable that a lake formed in the basin between modern day Tuscarora and the Independence Mountains. Other lakes may have formed in Idaho along Deep Creek and south of the Owyhee River just east of the Duck Valley Indian Reservation. In both locations the geological material closest to the surface is stream and lake sediments.[54] Fossil finds in Spring Creek Basin suggest that it also may have hosted a lake.[73] Eventually river downcutting connected the lake basins and drained the lakes.

Subsequent to the warm and humid periods that developed lakes, glaciation occurred on the north side of McAfee and Jack Peaks in the Independence Mountains. Remnants of the glaciation are evident today from u-shaped valleys and glacial moraines.

c. How did the Owyhee-Humboldt field volcanism begin?

The Snake River plain is a huge, wide arc of sagebrush-steppe and present day croplands running from the Oregon-Idaho border to central Idaho where the valley continues to the Yellowstone National Park. It is commonly considered that the movement of the Yellowstone "hot spot" caused the creation of this wide valley. Hot spots are deep, hot locations on the earth that always produce volcanoes as the crust moves across them, like the Hawaiian islands. The Yellowstone hot spot was responsible for the valley created in central and eastern Idaho, but the hot spot missed the Treasure Valley northwest of Boise. The Yellowstone hot spot actually followed a straight course out of somewhere in southeastern Oregon or southwestern Idaho (Figure 2.32).[6,12,60,63]

Geologists debate how the Yellowstone hot spot began in southeastern Oregon or southwestern Idaho. Some credit the volcanism to a slab of the earth's crust that broke off as it was being pushed under the North American plate.[16,51,86] It has also been

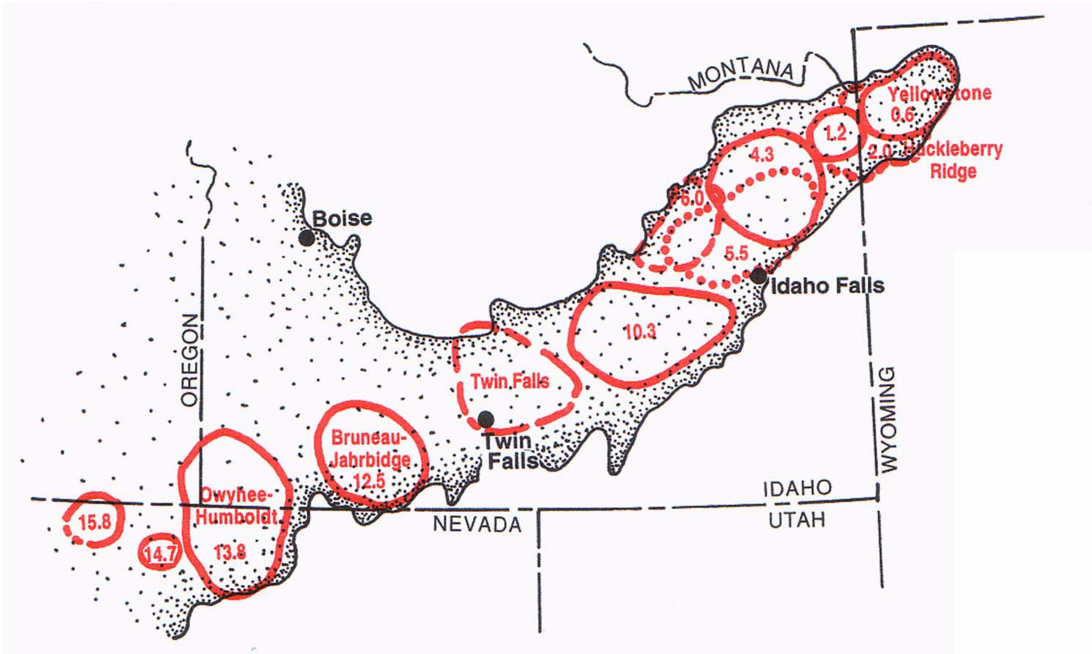

Figure 2.32. Volcanic fields across Idaho mark the movement of the Yellowstone hot spot from its origin at the Idaho, Oregon, Nevada border to its current location in Wyoming.

(adapted from 6:270)

suggested that faulting stretched the crustal sediments in southeastern Oregon thin, allowing for an outpouring of lava.[12,63] And yet others hypothesize the volcanism starting with a meteor impact.[4,5,6] Regardless of the origin of the Yellowstone hotspot, authors agree that volcanic activity began 17 to 18 million years ago and radiated from the Owyhee uplands both east and west. Volcanism, starting at the McDermitt caldera, just west of the upper Owyhee subbasin, followed the Yellowstone hot spot to the east (Figure 2.32).[6,63] And to the west, volcanic calderas spread from Malheur County west across the High Lava Plains to Newberry crater in central Oregon, the most recent caldera eruption (1.7 million years ago).[60,67]

3. Upper Owyhee subbasin geological features

a. Tuscarora volcanic field

Dating to between 39.9 and 39.3 million years ago the Tuscarora volcanic field was contemporaneous to the subduction of the Farallon plate and early extension in the region (Figure 2.33).[49] There are many volcanic episodes and rocks that make up the Tuscarora volcanic field. These include a caldera and the hydrothermal systems that hosted gold and silver deposits.

i. Big Cottonwood Canyon caldera

Calderas form when volcanoes collapse after massive eruptions. Crater Lake in Oregon is a very visible volcanic caldera. A massive explosion of ash and lava left a large empty space inside the volcano and its exterior layer collapsed into a basin. At

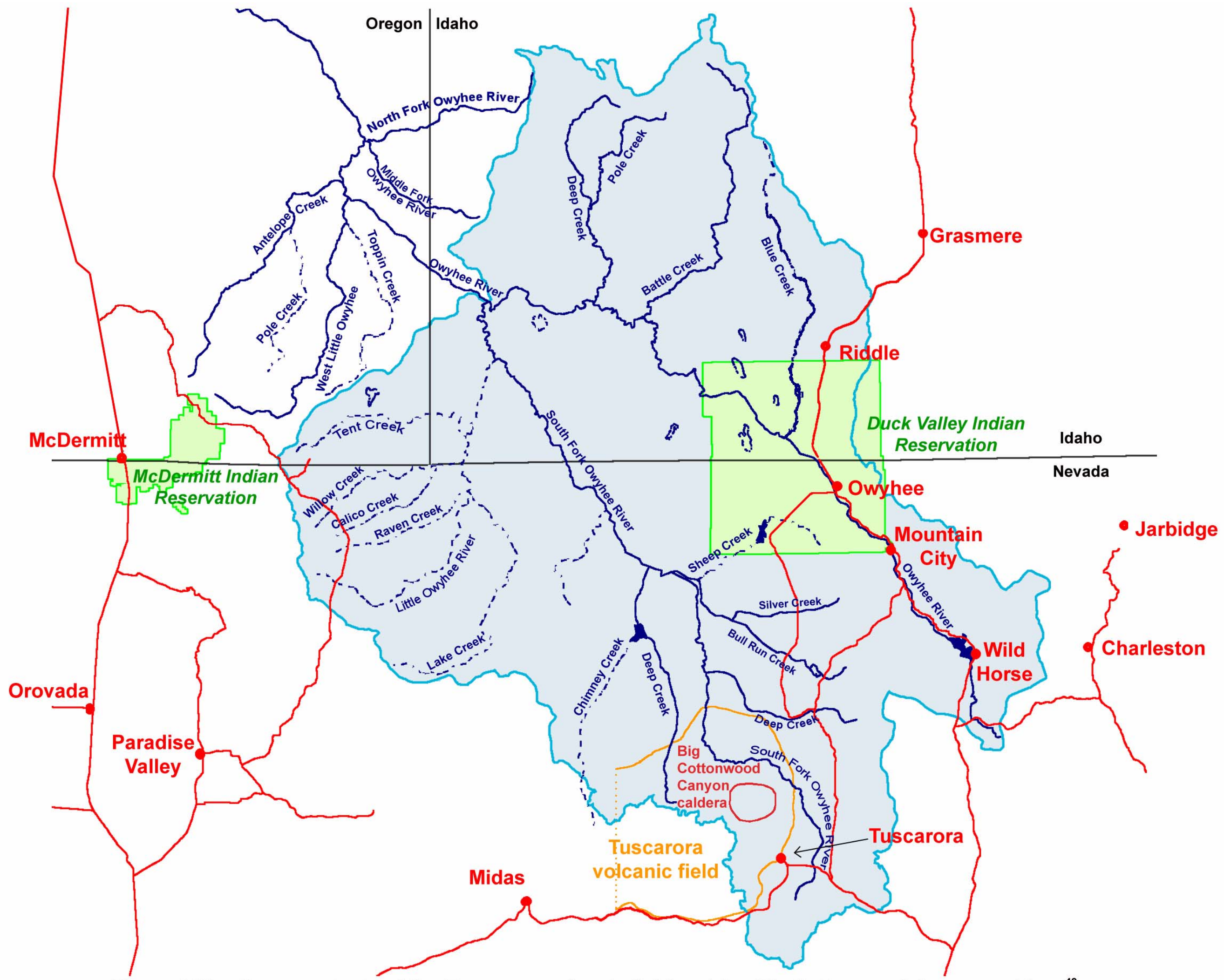

Figure 2.33. Known extents of the Tuscarora volcanic field and the Big Cottonwood Canyon caldera.[49]

Crater lake this basin has since been filled with water.[74] The key for geologists to find a caldera is to locate a rim where the surface material has fallen back into a basin. The Big Cottonwood Canyon caldera is not as obvious as the Crater Lake caldera because it didn't create as large of a basin and parts have since been covered by other material. The caldera is at least 15 kilometers (9 miles) east-west, but the other dimensions are unknown (Figure 2.33).[49] The Big Cottonwood Canyon caldera produced massive rhyolitic ash flow tuff, some of which escaped through failures in the caldera wall and some of which remained, filling the majority of the basin. Tuff flow is encountered 35 kilometers to the southwest of the caldera indicating that the flows were extensive, but the tuff is generally covered by more recent rock so there is no mapping of its extent.[49]

ii. Mount Blitzen volcanic center

Slightly older than the adjacent Big Cottonwood Canyon caldera, the Mount Blitzen volcanic center also produced impressive amounts of tuff (Figure 2.34). The tuff at Mount Blitzen is at least one kilometer thick.[49] The exact nature of the volcanism (vents, volcano or caldera) is unknown. However, the volcanic center was bounded by

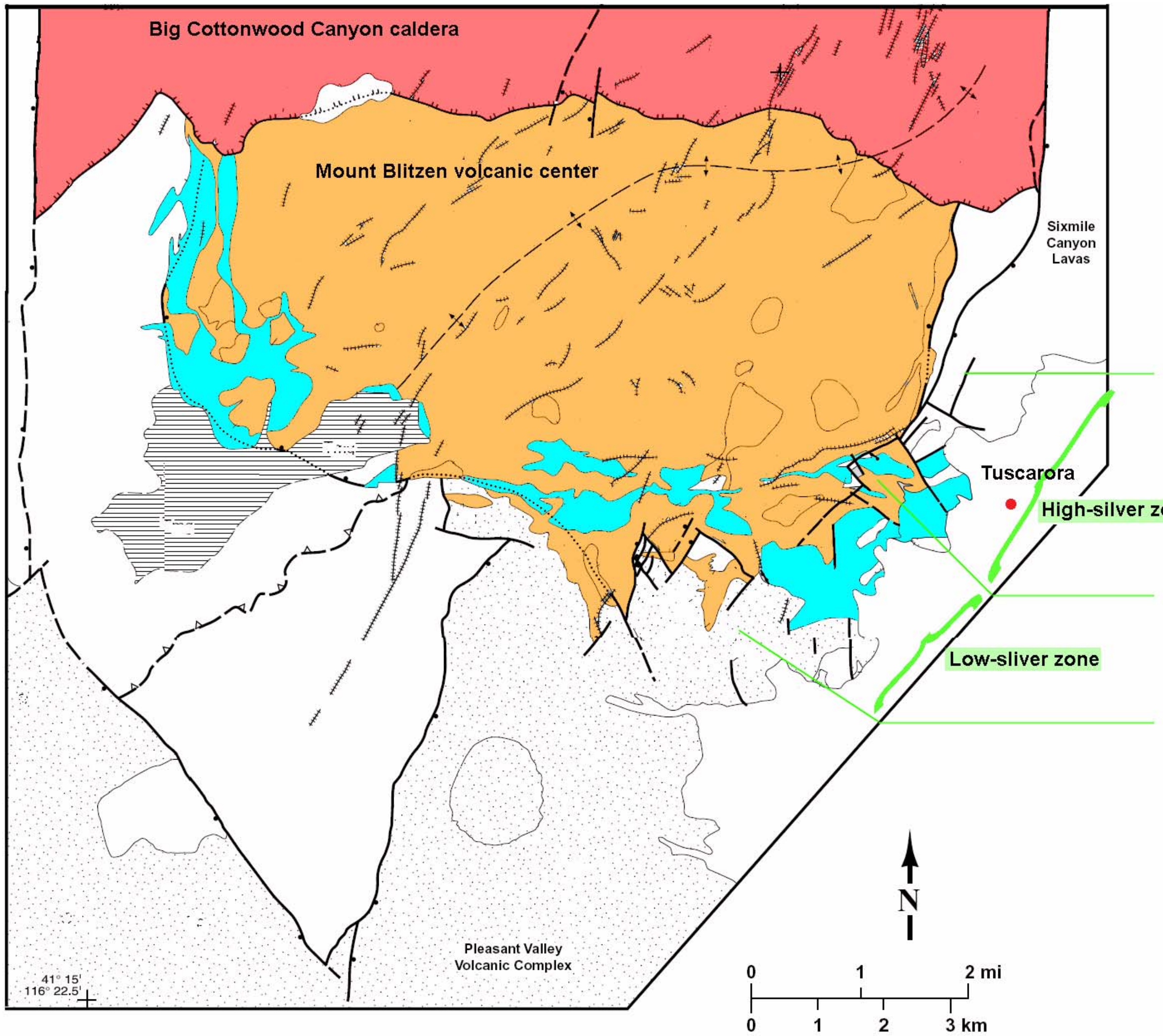

Figure 2.34. Major surface geological features around Tuscarora and approximate location of the two silver zones. Collapse of the Mount Blitzen volcanic center left many faults around its edges, now occupied by lavas (Mount Neva dactite) shown here in blue. Prior to filling with lava, the faults served as passageways for hot-spring fluids which deposited precious metals in the vicinity of Tuscarora. Ores are found in two zones, a high-silver and low silver zone. (Adapted from 49:Figure 2)

faults on the southeast. It was along these faults that hydrothermal activity and magma dikes intruded, leaving the vein deposits of precious metals in the Tuscarora district. The deposits which host the precious metals are Pleasant Valley complex tuff and Mount Neva dacite (Figure 2.34).[49]

b. Hot Sulphur Springs

Hot Sulphur Springs is the hottest of the hot springs in the upper Owyhee subbasin. It is located at the northern end of Independence Valley. The spring temperature was reported to be 194°F and an estimate of 262°F was made for the hot springs reservoir water below the earth's surface.[41] The hot springs currently discharge 1000 gallons per minute of water into Hot Creek.[46]

Hot springs are a renewable energy source and can be used to generate electricity. In the 1970s, AMAX Exploration, Inc drilled holes prospecting for geothermal energy sources in the area of Hot Sulphur Springs. The shallow holes did not produce appropriate fluids. One deep, 5,400-foot, hole encountered suitable hot water under pressure but the well bore collapsed during drilling.[46] No electrical plant was built.

According to the State of Nevada, in March 2003 "Earth Power Resources was awarded a power purchase contract from Sierra Pacific for a 25 MW binary plant."[34] An area of approximately 12 square miles had been leased in Hot Sulphur Springs area for the production of geothermal power. Although Earth Power Resources had begun to explore the area and drill wells,[46] there seems to be no current activity. The plans for the plant called for the drilling of four production wells from which fluid at high temperatures (330°F) from 2500 foot depth would be pumped, fluid used to generate electricity, and the cooled fluid reintroduced into the geothermal system in other wells.[46] However, TG Power currently has permits issued in 2006, 2007, and 2008 for drilling at Hot Sulfur Springs.

c. Capitol Peak

Situated on the western edge of the upper Owyhee subbasin, Capitol peak is part of the Calico Mountains. These mountains in turn form part of the Santa Rosa-Calico volcanic field.[21] This volcanic field lies principally outside of the subbasin to the west. It was active prior to the Owyhee-Humboldt volcanic field, from 16.5 to 14 million years ago. The Calico Mountains are covered with silica rich volcanic materials, predominately andesite, dacite, and tuff. Dacite is like andesite but with more iron. The amount of volcanic material in this area is impressive as can be seen from a geological section drawn from the central Calico Mountains just north of Capitol Peak (Figure 2.35).[21] At this location there are approximately 390 meters (1280 feet) of volcanic rocks from the eruptions at this volcanic field. In addition to the covering of volcanic rocks, at least one volcanic vent and two sets of dikes lie within the upper Owyhee subbasin near Capitol peak.[21] It is unknown how far the eruptive lavas and ash from the Capitol Peak area spread into the subbasin.

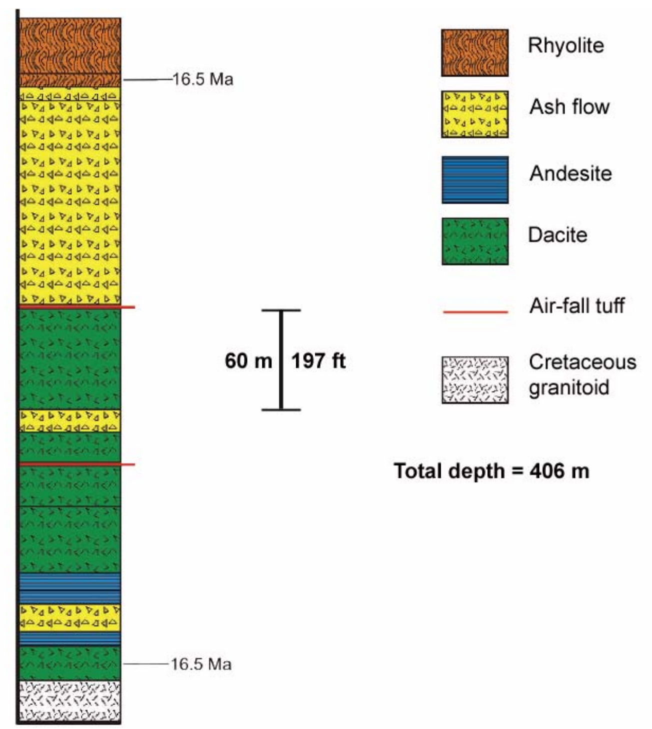

Figure 2.35. Geological section depicting rocks from the Calico Mountains just north of Capitol Peak. The volcanic rocks are from the Santa Rosa-Calico volcanic field which dates to 16.5 million years ago.
(Adapted from 21:Figure 13)

d. Canyon walls

Photo 2.6. Canyon walls of the east fork of the Owyhee River.

The impressive volcanic geology of the upper Owyhee subbasin is on show in the various canyons created by the Owyhee River and its numerous tributaries. In discussing the 45 Ranch Allotment in Idaho, Murphy and Rust wrote that the "Tuff of Swisher Mountain is the most common rock exposed along the 50 to 200 m (160 to 650 feet) deep inner gorges of the South Fork, Main Fork, and Little Owyhee rivers (Ekren et al. 1981). It weathers characteristically into striking reddish-brown colored, vertical canyon walls and picturesque pinnacles, hoodoos, spires, and monoliths (Ekren et al. 1982). The walls drop straight into the rivers or may have a talus toe-slope composed of platy stones."[73:3] In some locations these abrupt canyon walls are offset by one or more shallow basalt flows in a striking almost black creating a second wall. As the basalt breaks apart more easily along its columnar joints it is often eroded farther back from the river with a talus slope separating the basalt cliffs from those of the tuff below.[73]

4. Geologic maps of the subbasin

Photo 2.7. Copper ore debris from the Rio Tinto mine in the upper Owyhee subbasin. This photograph is not typical since almost all the copper ore mined was processed.

Geological maps give a general picture of the type and age of rocks that can be found in an area. Geological maps are often used in environmental and hydrological planning and as guides to the general types of industrial materials that can be found in an area. Examples of industrial materials are rocks good for gravel and granite for making counter tops. General geological maps exist for all of the upper Owyhee subbasin.[32,66,69] The creation of local, specific geological maps is ongoing.

5. Minerals and mining

The distinct division of the upper Owyhee subbasin into the Basin and Range and Owyhee Plateau geological provinces is evident in the location of minerals. Valuable minerals have been found hosted in rocks of Basin and Range origin and the Tuscarora volcanic field. Economically significant mineral deposits are more rarely found in the volcanic rocks of the Owyhee Plateau.

The great geological diversity of rocks from the Basin and Range deposits is reflected in the diversity of mineral deposits. Metals, such as gold, silver, zinc and copper (Photo 2.7), are the most prominent of the minerals that have been mined in the area due to their great value. Other minerals have been mined but in lesser quantities and with less fanfare. These include antimony, arsenic, tungsten and uranium. The location of mineral deposits and the mining histories of some of these locations are discussed below.

The formation of mineral deposits within the upper Owyhee subbasin is poorly understood. Complicating the understanding of deposits is that in one mountain an ore may be found in a given rock and in another mountain it will occur within a different rock layer and possibly in a different format (vein vs. nodule for example). Some of the more studied mineral formations are discussed below.

a. Mineral and rock deposits with economic or scientific value

i. Gold

Gold has been found across the western US. Gold fever and boom-to-bust cities form part of the early history of Oregon, Idaho and Nevada, but there continue to be discoveries and new claims to this day.

Photo 2.8. Quartz near Lime Mountain in the upper Owyhee subbasin.

Gold occurs in many types of geological deposits.[9,45] Gold veins are generally in metamorphic rocks where the gold has accumulated in conjunction with quartz following the intense heating of the rock (Photo 2.8). Placer gold is found in alluvial sediments where gold has eroded out of the rock it was originally in and settled out of the running water along with other heavy metals. Thirdly, gold can be concentrated and deposited by chemical interactions at hot springs around volcanically active areas.[91] This gold may be concentrated in veins or disseminated through large quantities of rock.

ii. Turquoise

Turquoise is one of the preferred jewelry stones. Turquoise is found in various regions of the Basin and Range province. The area around Cortez, Nevada, known as the bullion district, was rich in turquoise. As turquoise from the surface had been collected by Native Americans, it took American prospectors longer to find some of the locations of this stone.[72] Turquoise is found in nodules, veinlets and seams. The stone can be pure, a solid blue, or spider web, with black impurities.

iii. Fossils

"Fossils are the mineralized or otherwise preserved remains or traces (such as footprints) of animals, plants, and other organisms."[40] "Fossilization is actually a rare occurrence because most components of formerly-living things tend to decompose relatively quickly following death. In order for an organism to be fossilized, the remains normally need to be covered by sediment as soon as possible."[40] Fossilized remains of plants and animals can tell us about the type of environments that existed in the past and the changes the environments have undergone.[16] Few fossils have been reported from the upper Owyhee subbasin.

iv. Lapidary (jewelry) stones

Jasper, thundereggs, and petrified wood are all used in the creation of non-precious jewelry due to their fine crystalline structure. This means that they can be polished as attractive surfaces. "A thunderegg is a type of rock similar to a geode but formed in a rhyolitic lava flow and found only in areas of volcanic activity. Thundereggs are rough spheres, most about as big as a baseball. They look uninteresting on the outside, but slicing them in half may reveal highly attractive patterns and colors valuable in jewelry."[107] The thunderegg starts as a cavity in the rock where over time the passage of water allows for the deposition of minerals as crystals.[43] "The size of the crystals, including their form and shade of color, vary – making each geode unique. Some are clear as quartz crystals, and others have rich purple amethyst crystals. Still others may contain agate, chalcedony, or jasper. There is no way of telling what the inside of a geode holds until it is cut open or broken apart."[43]

v. Mercury

Mercury is a commercially valuable metal that is used in batteries, paints and electrical devices.[123] Mercury deposits are formed at shallow depths and at temperatures of 50°C to 200°C (120°F to 400°F). Mercury generally fills in pores and fissures where it was carried by heated water. Mercury is often found in association with uranium and pyrite and nearby hot spring deposits of gold and silver.[98,123]

"Elevated concentrations of mercury in surface water can be derived from many sources, including natural processes and anthropogenic (related to humans) losses. Natural processes include volcanic and atmospheric deposition, degassing, and surface runoff and erosion of mercuric soils. Anthropogenic sources include mercury mining and processing, energy related activities, legacy pesticide application, chloro-alkali operations and small emissions from other industrial processes."[2:1] These other industrial processes include the mercury amalgamation methods used in gold and silver mining prior to the modern cyanide process. Geothermal activity can contribute to the concentration of mercury, so it is often found in regions of current activity or in rocks which developed under geothermal conditions.

vi. Uranium

The most frequently occurring minerals containing uranium are uraninite and coffinite. These minerals form in igneous rocks such as granite and in hydrothermal vents. Uranium is a naturally radioactive element. Radioactive elements are those which naturally break down over time into other elements. Uranium has three isotopic states, U238, U235, and U234, all of which are radioactive. Since U238 takes the longest to decay, it makes up 99.2 percent of all uranium naturally found.[42]

Uranium can be used in energy production, both within nuclear reactors and in nuclear bombs, when the element is artificially induced to break down. Uranium in the isotopic state of U235 can be broken apart to create energy; however, this isotope is rare making up only 0.71 percent of uranium.[42] Prospectors seek geologically recent uranium deposits that have higher concentrations of U235. The radioactivity of U238 can be used for energy production if the uranium is transformed into radioactive plutonium (Pu239). This is accomplished by bombarding the uranium with neutrons.[42]

b. Mining districts in the upper Owyhee subbasin

Mining districts are important to the discussion of geology because they are designated based on the location where a mineral was found. As such the location where a mineral has been found is likely coincident with geological formations containing that mineral. The Nevada mining districts outline some of the different geological areas of the Basin and Range. Most of the mining within the upper Owyhee subbasin is historic in nature. There is only one currently operating metal mine in the upper Owyhee subbasin. There are no operating industrial mineral mines.[29,36]

Mining districts were a California creation of miners to fill the power vacuum left by a lack of local government following the purchase of the territory from Mexico. Organized mining districts made rules for the establishment, marking and working of claims.[108] However, the districts also indicate the presence of the types of rocks within which the mineral was found.

In Nevada (then the Utah territory) mining districts spread out from the Comstock after 1859. While legislation by the federal government regarding mining lands was passed in 1866, Nevada left open the possibility for the establishment of new mining districts. Four of the eleven mining districts within the upper Owyhee subbasin were organized, meaning that the miners met and could set rules for activities within their area (Appendix B).[108] Originally mining districts were only established for areas where metals were extracted. The current usage of the term includes mining districts where industrial minerals (nonmetals) are found. Mining districts have changed names many times with newly prominent mines, the development of new claims, and the merging of adjoining districts. For example, "In the Independence Mountains of northern Elko County, the old Burns Basin district, surrounding some small antimony prospects, has been engulfed by the huge Independence Mountains district that includes extensive disseminated gold deposits developed there."[108:8]

There are eleven Nevada mining districts in the upper Owyhee subbasin (Figure 2.36). The best known mineral commodities are silver and gold; however, many other minerals have been found and are commercially important. The frequently and infrequently occurring mineral commodities are shown in Tables 2.10 and 2.11 by the districts from which they have been extracted.

Table 2.10. Frequently occurring mineral commodities found in the mining districts in the upper Owyhee subbasin.[64,108]

Mining District	Gold	Silver	Copper	Lead	Zinc	Antimony	Arsenic
Aura	x	x	x	x	x	x	
Burner		x		x	x		x
Cornucopia	x	x	x	x		x	
Divide	x	x				x	
Edgemont	x	x	x	x	x		x
Good Hope	x	x				x	x
Independence Mountains	x	x				x	
Island Mountain	x	x	x	x	x	x	x
Lime Mountain	x	x	x				
Mountain City	x	x	x	x	x	x	x
Tuscarora	x	x	x	x			x

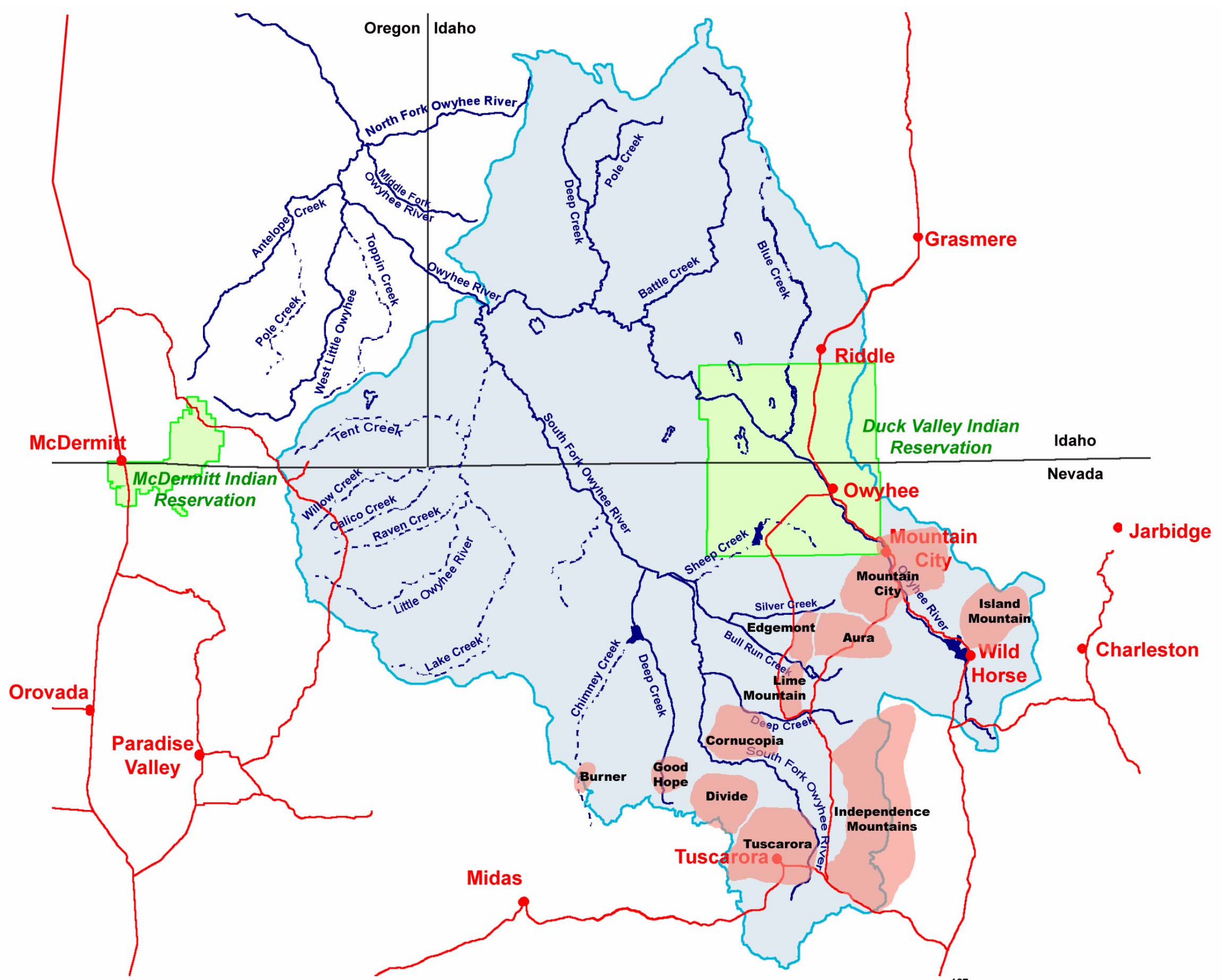

Figure 2.36. Current Nevada mining districts in the upper Owyhee subbasin.[127]

Table 2.11. Infrequently occurring mineral commodities found in the mining districts in the upper Owyhee subbasin.[64,108]

Mining District	Tungsten	Uranium	Molybdenum	Mercury	Barite	Titanium
Aura						
Burner						
Cornucopia						
Divide						
Edgemont	x	x	x			
Good Hope						
Independence Mountains				x	x	x
Island Mountain	x	x			x	
Lime Mountain						
Mountain City	x	x	x			
Tuscarora				x		

i. Aura and Edgemont mining districts

The Aura and Edgemont mining districts are located in an area where the rocks are old.[13,98] These are some of the rocks that were around in the Precambrian and as such are a mix of older rocks that have undergone various transformations. Since the area is a mix, it is difficult for geologists to interpret. The basic sequence of events began with sedimentary rocks, including limestone, sandstone, and dolomite that were partially metamorphized. In areas these sedimentary rocks were transformed into shale and siltstone, but in other areas they remain in their original form. Subsequent volcanism and principally the creation of granitic dikes at depth within the earth's crust formed veins of quartz and quartize that contain gold and silver deposits.[13] Called polymetallic veins, the veins include many other metals with lead, zinc and copper being the most common.[98] At some point these rocks were also deformed, crinkled into waves, and faulted. Deformation and faulting acted on the veins as well as the surrounding rock. As found by miners, the veins varied in size between one and seven feet in diameter but were hard to follow because deformation and faulting made them end and move abruptly.[13] The major distinction between the two districts is that veins of the Aura district were rich in silver while those of the Edgemont district were rich in gold and were discovered almost thirty years later.[13] Mines that exploited polymetallic veins included the California, Humboldt, and Columbia mines in the Aura district and Bull Run and Lucky Girl mines in the Edgemont district (Figure 2.37).[98]

ii. Tuscarora mining district

The Tuscarora mining district is characterized by hydrothermal metal deposits. Specifically the deposits are epithermal, or hot spring, deposits. Epithermal deposits are those where deposition occurred at shallow depths, the pressures were low and the temperatures of deposition were between 150 and 300° Celsius (302 to 572° Fahrenheit).[53] The formation temperature for most gold and silver bearing epithermal deposits is 250° Celsius.[93]

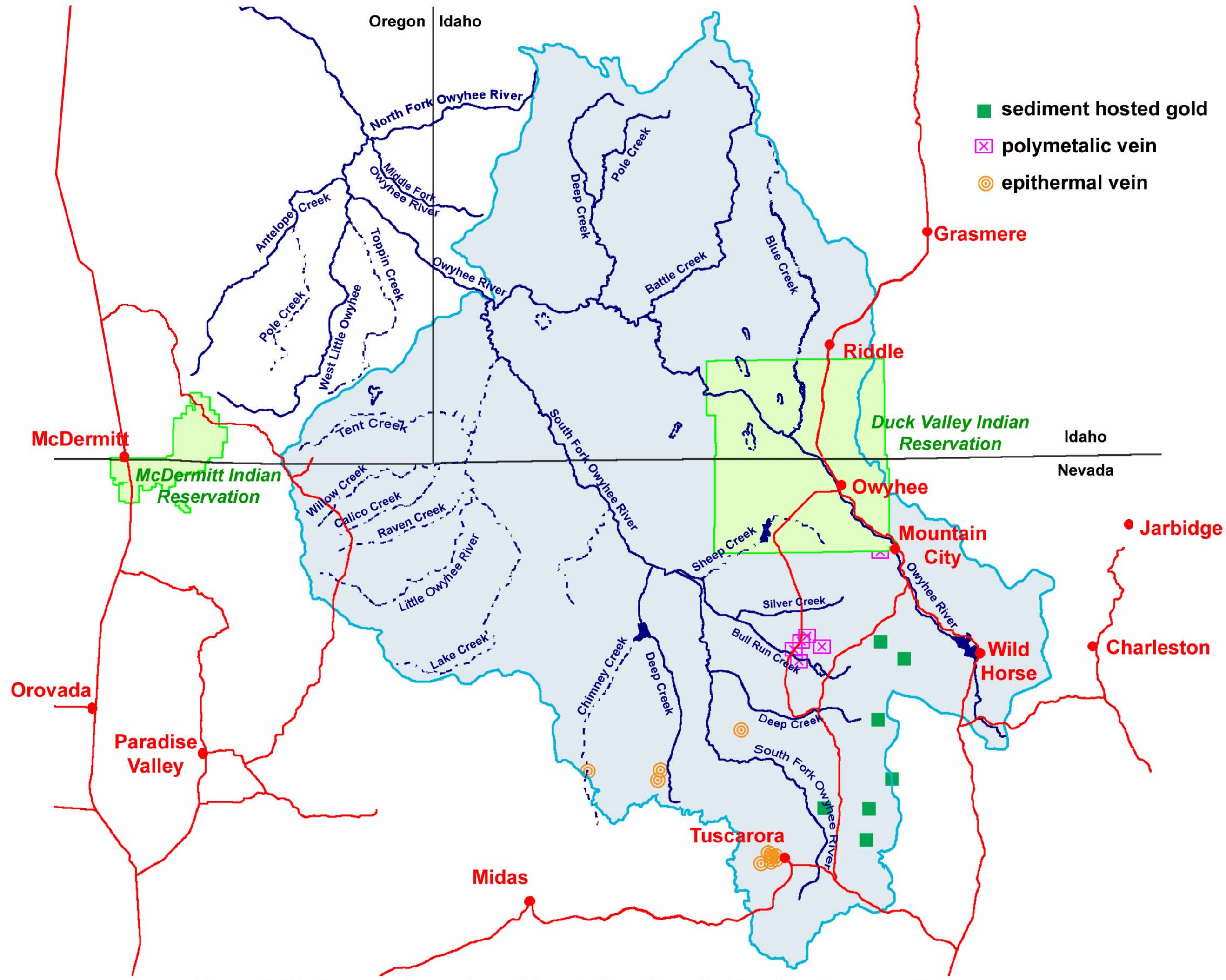

Figure 2.37. Some of the major gold and silver deposits found in the upper Owyhee. Notice the different distribution for each type of deposit.[69,98]

The Tuscarora mining district lies along and just outside the southeastern margin of the Mount Blitzen volcanic center . . . Veins in part occupy faults that make up the boundary of the Mount Blitzen center. Mineralization was contemporaneous with the Mount Neva intrusive episode; those intrusions were likely the heat source for hydrothermal circulation."[49:14-15] The district can be divided into two areas, a low-silver zone to the south and a high-silver zone to the north (Figure 2.34). The gold content of the two is very similar. "Median gold content in samples from the low-silver zone is 0.232 ppm versus 0.341 ppm in the high-silver zone."[49:15] The mineralization could be from one system with different types of deposition; however, some differences in composition suggest that the zones could have been separate hydrothermal alterations. Regardless, the age of mineralization in the two zones is not distinguishable.[49] Geochemical analysis also shows that the deposits in both areas are enriched in arsenic and antimony and slightly enriched in mercury and thallium.[49]

"The Tuscarora [high] silver zone is an area of about 1,200 by 1,500 m [3900 by 4900 ft] centered about 500 m [1640 ft] northwest of Tuscarora."[49:17] Here the median ratio of silver to gold is 110:1. Most of the mines in this zone are flooded and the surface accesses have caved in. Two of the major vein systems were the Navaho lode and the Grand Prize mine area. "The Grand Prize bonanza was discovered in 1876, and the Grand Prize mine operated until 1891, yielding about $2.6 million, the largest recorded production in the high-silver zone. On the basis of descriptions . . . the Grand Prize vein was about 2 m wide."[49:18]

"Mines and prospects in the low-silver zone are widely scattered over an area about 1,500 by 3,000 m that extends from the town of Tuscarora southwest to Battle Mountain and Beard Hill."[49:15] In the low-silver zone the median ratio of silver to gold is 14:1. "The Dexter Mine was the most productive property in the low-silver zone. Estimated historical production (1897-1935) was about 40,000 oz gold and 100,000 oz silver, and modern production (1987-1990) was about 34,000 oz gold and 185,000 oz silver."[49:16]

Aside from silver and gold, "very small amounts of mercury were produced from cinnabar-native mercury-pyrite veins in lavas of Sixmile Canyon at the Red Bird Mine about 1 km northwest of the high-silver zone."[49:19]

Future potential for mineral exploration in the district has been discussed. "Of the two styles of mineralization that took place in the district, the low-silver zone is considered to have the best potential for hosting unexploited mineralization. This conclusion is based on: 1) larger areas affected by this type of mineralization; 2) relatively low Ag/Au ratios and low base metal contents of productive vein and disseminated gold deposits elsewhere (e.g., Sleeper and Round Mountain, respectively); and 3) the presence of altered rocks and mineralized structures that project under pediment gravel along the southern and eastern borders of the district. By comparison, vein deposits in the high-silver zone, although of very high grade, are considerably smaller and more difficult to find."[49:19]

iii. Independence Mountains

The Independence Mountains mining district was known for antimony, but later gold was discovered. "Prospectors explored for antimony in the 1910s. Thirty to forty tons of stibnite as antimony ore were reportedly mined and shipped from the Burns Basin mine in the Jerritt Canyon district between 1918 and 1945. In the early 1970s there was a renewed interest in antimony exploration when its price reached historic highs of $40 per pound. Around 1971, FMC began exploring for antimony in the Independence Mountains. In 1972, FMC, later known as Meridian, discovered a disseminated gold deposit in the Jerritt Canyon area."[102:4-1]

The Independence Mountains have disseminated epithermal deposits. "The term 'disseminated' is now commonly applied to gold deposits in which very fine-grained gold is dispersed through a relatively large volume of rock. Deposits are amenable to bulk-mining methods, allowing profitable extraction from relatively low-grade ores."[9:11]

The Nevada 2007 report of mining showed one active mine in the upper Owyhee subbasin, the Jerritt Canyon mine with headquarters in Elko, NV. This mine operates within the Independence Mountain mining district. In 2007 the mine produced 121,708 ounces of gold and 17,560 ounces of silver and employed 357 people.[36] "The Jerritt Canyon deposits are typical of the Carlin-type deposit of micron to submicron-sized gold particles hosted primarily by . . . Paleozoic calcareous and sulfidic sedimentary rocks."[124] In other words, the gold is in particles so small that it can't be seen by the naked eye and it is found within the Precambrian rocks. The rocks must be crushed to a very find dust in order to extract the gold.[102,124] At Jerritt Canyon, "open pit mining occurred between 1981 and 1999. Portal-accessed, underground mining commenced in 1993 . . . Since mining began, Jerritt Canyon has produced over 8 million ounces of gold."[124]

The Jerritt Canyon mine was closed for parts of 2008 and 2009 by order of the Nevada Division of Environmental Protection (NDEP). The closure followed violations issued "for failure to properly maintain process equipment and air pollution control systems."[130] The reopening of the mine followed a consent decree by NDEP that "requires extensive operational monitoring of process and emissions controls, including monthly mercury emissions testing to ensure the systems are operating as designed. The decree also requires continued improvements of fluids management systems, implementation of environmental audits and compliance plans for air quality, and the addition of emissions controls on supporting process equipment."'[130] Jerritt Canyon operated for only 130 days in 2009 with a production of 9,700 oz of gold.[131,132] Employment was also affected by the partial closure as in 2009 there were 120 employees.[131] As of publication of this assessment, these are the most current economic statistics for the mine.

While the gold in the Independence Mountains is found within Precambrian rocks, the gold is not that old. Gold was transported into the rocks. "The origin of Carlin-type deposits, especially in the Carlin Trend and Independence mountains is controversial, but recent work shows that many formed in the Eocene, contemporaneously with extensive Eocene igneous activity."[49:1] These deposits date to between 42 and 36 million years ago (remember that the activity at the Tuscarora volcanic center occurred during the same time, dating to 39 million years ago).[9,24,49] Hydrothermal activity, in this case hot fluids carrying gold, entered into the existing sedimentary rocks through the pores in the rocks. This hydrothermal activity altered these underground sedimentary rocks by replacing calcium carbonate or other soluble minerals with quartz and by filling pore space in the rocks with quartz.[9,24] This quartz is host to pyrite and small amounts of gold. Locations of other disseminated gold deposits are poorly known, and may bear many metals besides gold.[9,24]

c. Mineral data on the upper Owyhee subbasin

i. Gold and silver

Three major types of deposits host the gold and silver found within the upper Owyhee subbasin: polymetallic veins, epithermal veins, and disseminated epithermal. Polymetallic veins are found in the Aura and Edgemont districts, epithermal vein deposits are found in the Tuscarora mining district and disseminated epithermal metal deposits are found in the Independence Mountain district. Each of these districts is discussed in more detail above.

The upper Owyhee subbasin produced substantial amounts of gold and silver. A conservative estimate for gold production prior to 1976 in the Tuscarora mining district was over 100,000 ounces of gold. Other mining districts within the upper Owyhee subbasin that produced between 10,000 and 100,000 ounces of gold prior to 1976, were Mountain City, Aura, Edgemont, and Cornucopia.[20] At that time the largest area in terms of production was the Tuscarora district.

Historical mining activities took greatest advantage of gold and silver occurring in vein deposits, in part because of the ease of mining vein ores. The only current production of gold and silver is within disseminated deposits of the Independence Mountains.[36] The potential for future gold and silver mining is greatest in disseminated deposits such as those of the Independence Mountains or in smaller, dispersed vein deposits such as the low-silver area of the Tuscarora mining district. In either case the mining efforts would require large-scale processing of rock to extract metals which occur in small quantities per ton of rock.

ii. Oil and Gas

Much of Nevada has been explored for oil and gas. The rock formations that generally contain oil and gas deposits are old Precambrian sedimentary or metamorphic rocks. The upper Owyhee subbasin has not produced any commercial wells.

Oil and gas drilling records for Elko County between 1906 and 1953 show that one well hole was drilled in the upper Owyhee subbasin. George Gilmore of Tuscarora drilled a hole on the western front of the Bull Run Mountains in 1922. The well reached a depth of 800 ft. and had a show of gas from one layer of sedimentary rock.[13,65] No oil or gas prospecting is recorded for the Idaho portion of the upper Owyhee subbasin; however, records are spotty for drilling prior to 1963.[125]

Since 1953 three additional wells have been drilled within the upper Owyhee subbasin.[50] A 1957 well explored the Precambrian formation near the 1922 drilling. The hole had some oil show, but is considered dry.[13,50] The Ellison No. 1 hole was drilled in the center of Independence Valley in 1977, reaching a depth of 4,460 feet. It also had a show of oil but is dry. The Ellison No. 1 drill hole is now used as a water well.[50] The third hole, Four Mile Butte Federal No. 1 hole, drilled by the Exxon Corp. in 1985 was drilled to over two miles of depth, 14,464 feet, on the mesa lands near Deep Creek but the hole was dry.[50]

iii. Turquoise

Turquoise found within the subbasin comes from Nevada. There is one reported mine within the subbasin, the Stampede mine.[23,72] "The mine workings are limited to an open pit about 70 feet long and 40 feet wide near the crest of a southerly trending ridge."[72:8] The turquoise from this mine southeast of Tuscarora is of extreme hardness and includes solid blue, matrix-marked and spider-web varieties. Much of the turquoise found in the region has actually been collected in the gullies where it washed down and was found by placer miners during the Tuscarora gold boom.[72]

iv. Fossils

Fossils have been found at the north end of the Spring Creek Basin.[73] The fossils are found within a mix of stream, ash, and lake sediments. Fossils are of equids (horse family), camelids, proboscideans (elephant family) and rhinoceros that date to the Miocene or Pliocene.[73]

v. Rockhound material

Rockhounds are interested in rocks for collections. Many rockhounds are looking for crystals. Just like a clear quartz crystal, many other minerals can arrange themselves into beautiful shapes, such as the cubes of pyrite (fool's gold), if deposited under just the right conditions. The Basin and Range of Nevada had some of these ideal conditions in geothermal vents. Often, where vein gold and copper were deposited in the same veins, conditions allowed for the accumulation of other minerals. While rockhounds must respect existing mining claims and cannot collect on private land without permission, many find treasures out in the desert. The commercial value of most rocks sought by rockhounds is low.

On the 2001 Nevada rockhound map, the following locations in the upper Owyhee subbasin are listed: Zun claims, Taylor canyon, Murray Mine, Rio Tinto Mine, and the Autinik group. Undoubtedly there are many additional locations known to local residents. The rocks that are sought in these areas include pyrite, copper, quartz, barite, zunyite, rutile, stibnite, stibiconite, chalcopyrite, malachite, autunite, torbernite and metatorbernite.[23]

vi. Lapidary stones

There are many areas within the upper Owyhee subbasin where petrified wood, thundereggs and jasper can be found. In addition to the rock in which they were formed, many pieces wash down the rivers and can be found as pebbles. For example, petrified wood can be found dispersed in the Rock Creek area northwest of Tuscarora.[23]

Opal, chalcedony, and thunder eggs have all been found at the north end of the South Fork Owyhee River. There is an active claim just outside of the South Fork Owyhee River WSA, and there are two abandoned claims within the WSA.[39] "The minerals at all the prospects are similar. The chalcedony is generally translucent to dull gray, milky white, or tan. The common opal is generally light tan and opaque. The lack of bright and interesting colors and patterns in the minerals limits their value and marketability. Any better-quality material that might occur would need to be selectively mined by hand. The material would probably be mined only for recreation by hobbyists."[39:F6]

vii. Tin

Anomalous, high quantities of tin have been found in stream sediment samples from almost all of the WSA's within Idaho.[1,39,44,71,95] It is unknown where the tin comes from although guesses abound.

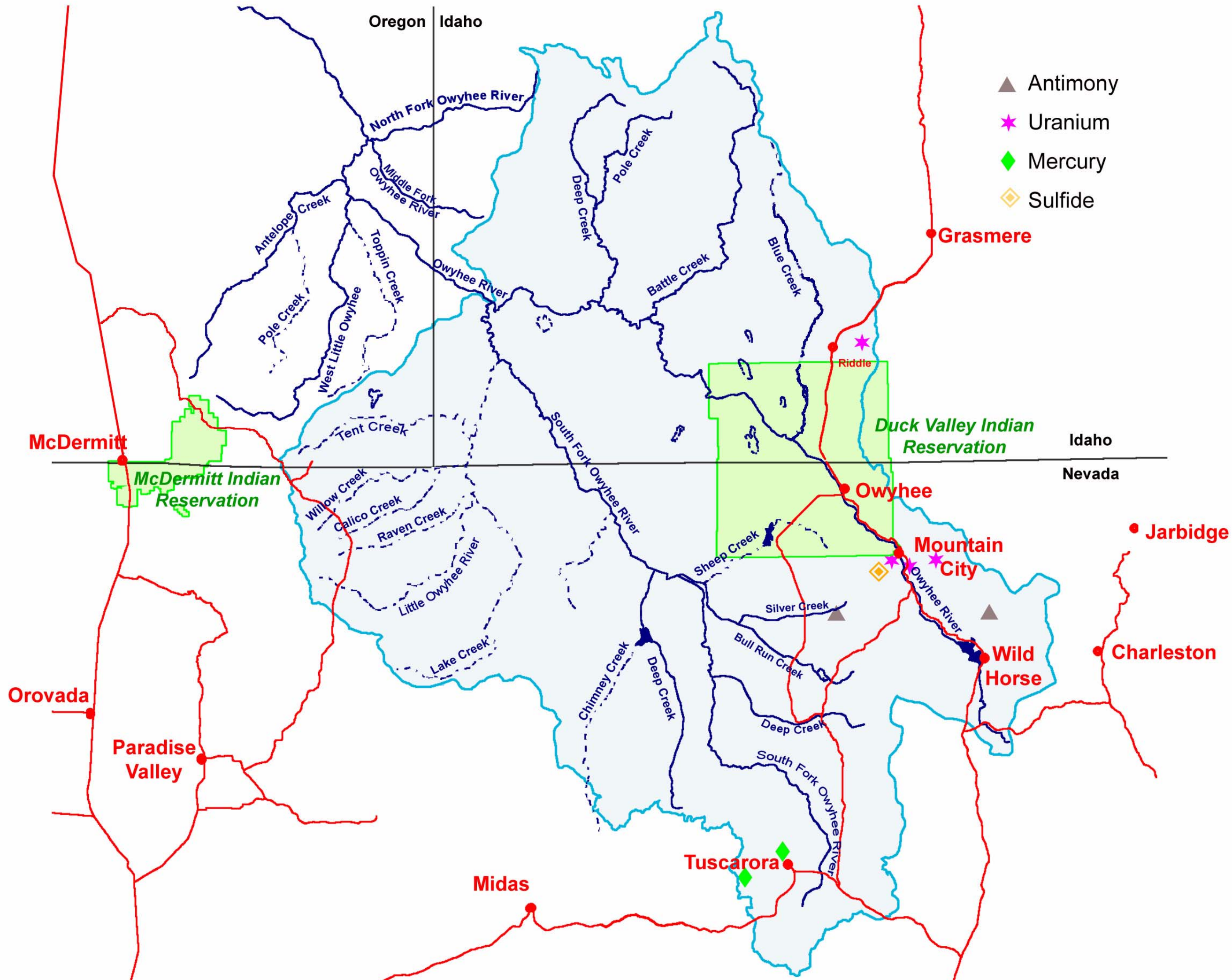

Figure 2.38. Large mineral deposits of antimony, uranium and mercury associated with hotspring systems in the upper Owyhee subbasin. The sulfide deposit is in old marine rocks.[98,128]

viii. Mercury

Mercury occurs in hot spring deposits in the upper Owyhee subbasin. It has been mined within the Tuscarora district at the Red Bird Group and Berry Creek Group mines (Figure 2.38).[98] The quantity of mercury in no way compares to that found and continuing to be mined at the McDermitt volcanic field.[62]

ix. Antimony

Antimony is a metal with numerous commercial uses; for instance, it is used in alloys which expand on solidification, in solders, in some medicines, in the manufacture of enamels, and in the electronics industry in the manufacture of semiconductors. Antimony has been mined at the Foss, Blue Ribbon and Eagle prospect mines within the upper Owyhee subbasin (Figure 2.38).[8,98] The Blue Ribbon mine produced seven tons, a significant quantity.[13] All of these locations have simple antimony that was deposited by hot springs. However, the locations are within the oldest rock formations in the subbasin so the age of the deposits is unknown.

x. Uranium

Uranium has been mined in the Mountain City district and is found in other areas of the upper Owyhee subbasin (Figure 2.38). Eighteen claims and prospects are located in the area.[42] Prospecting for uranium peaked in the 1950s. The amount of uranium produced from the Mountain City area is unknown; however, it pales in comparison to ongoing production at the McDermitt volcanic field.[42,97,98]

The uranium deposits in the Mountain City area occur at the boundary between a granite and a higher unit of ash. The uraninite was probably secondary in nature, meaning that the uranium was transported to these locations.[42] Hydrothermal processes may have been responsible for the uranium deposition and alteration of the host ash tuff where it is found.

Radon is one of the radioactive decay products of uranium 238. Radon and its immediate decay product polonium pose a health risk. Inhaling radon can increase the risk of lung cancer.[92] The Nevada radon pollution hazard map suggests that the Mountain City area is the only one within the upper Owyhee subbasin with a high hazard. A high hazard is based on the soils or surface geological layers exceeding 4 ppm of uranium or radon measurements within houses being high.[92] No specific household measurements were taken in Mountain City, but the uranium deposits in the Mountain City mining district account for the rating,[92] since radon concentration could naturally be high.

6. Erosion of geological deposits within the subbasin

As the rocks within the subbasin erode to form the soils, some of the minerals within the rocks and soils are carried in the water flowing off of the hills for great distances. Rocks and minerals being carried by the Owyhee River when it exits the upper Owyhee subbasin come from geological deposits upstream. Eroding sediments and rocks can carry both materials that are beneficial and harmful. Placer gold, silver, and turquoise all exist in river sands or gravels because they have been eroded from their original geological location. Likewise a pollutant which naturally occurs in a rock or was introduced to soils from antique mining practices can be eroded and carried downstream in river waters.

Many of the geological deposits in the upper Owyhee subbasin are enriched by minerals. The elevated naturally occurring quantities of these minerals means that the background concentration of these minerals that will be found in soil and water is higher than in regions with a different geological history.

The enriched geological deposits allowed for mining to be economically practicable. Antique mining practices have added to the pollutants that now move through the soils and waters by natural erosion. There are two components to mining's impact. First the increased fragmentation of rocks naturally bearing minerals places them at greater risks for erosion. Secondly, some antique mining practices depended upon the addition of cyanide or mercury for the extraction of precious metals.

a. Cyanide

Successful mining of disseminated gold and silver deposits only became economic after 1890 when the cyanide leaching process was introduced commercially in South Africa.[9] Cyanide was used for mining in the Tuscarora and Edgemont mining districts.[64] Cyanide probably escaped from these operations and is an anthropogenic addition to the soils in the areas of the Lucky Girl and McKenzie mines. Other mines may have used the process and would likewise have contaminated soils. The cyanide concentrations in the soil can lead to cyanide entering groundwater and surface water.

b. Mercury

Mercury has two origins in the upper Owyhee subbasin, as naturally occurring deposits and as a human addition to the environment. The natural mercury sources near Tuscarora have undoubtedly contributed mercury to the soils and waters. In addition, mercury was used in the legacy extraction of silver and gold. This is an anthropogenic addition of mercury to the environment. Once mercury or any other heavy mineral pollution is within the sediments, it will behave as if it were derived from a natural deposit and be moved by water flow, both groundwater and runoff.

Photo 2.9. Alluvium deposited below a canyon on Hurry Back Creek

7. Summary

The upper Owyhee subbasin has a long and diverse geological history. Within the geological history we learn how the mountains and basins came to be. Volcanic features of the landscape present striking vistas. Old rocks of the Independence and Bull Run Mountains provide deep rich soils for forests. Rivers are carrying out active erosion that adds mineral-rich soil to their banks and continues the process of canyon creation. The diversity and number of precious metal and heavy metal deposits briefly brought great prosperity to the region at the turn of the 20th century. Naturally occurring and legacy human-introduced heavy metals present a challenge for the environmentally conscious residents and users of the subbasin in the 21st century

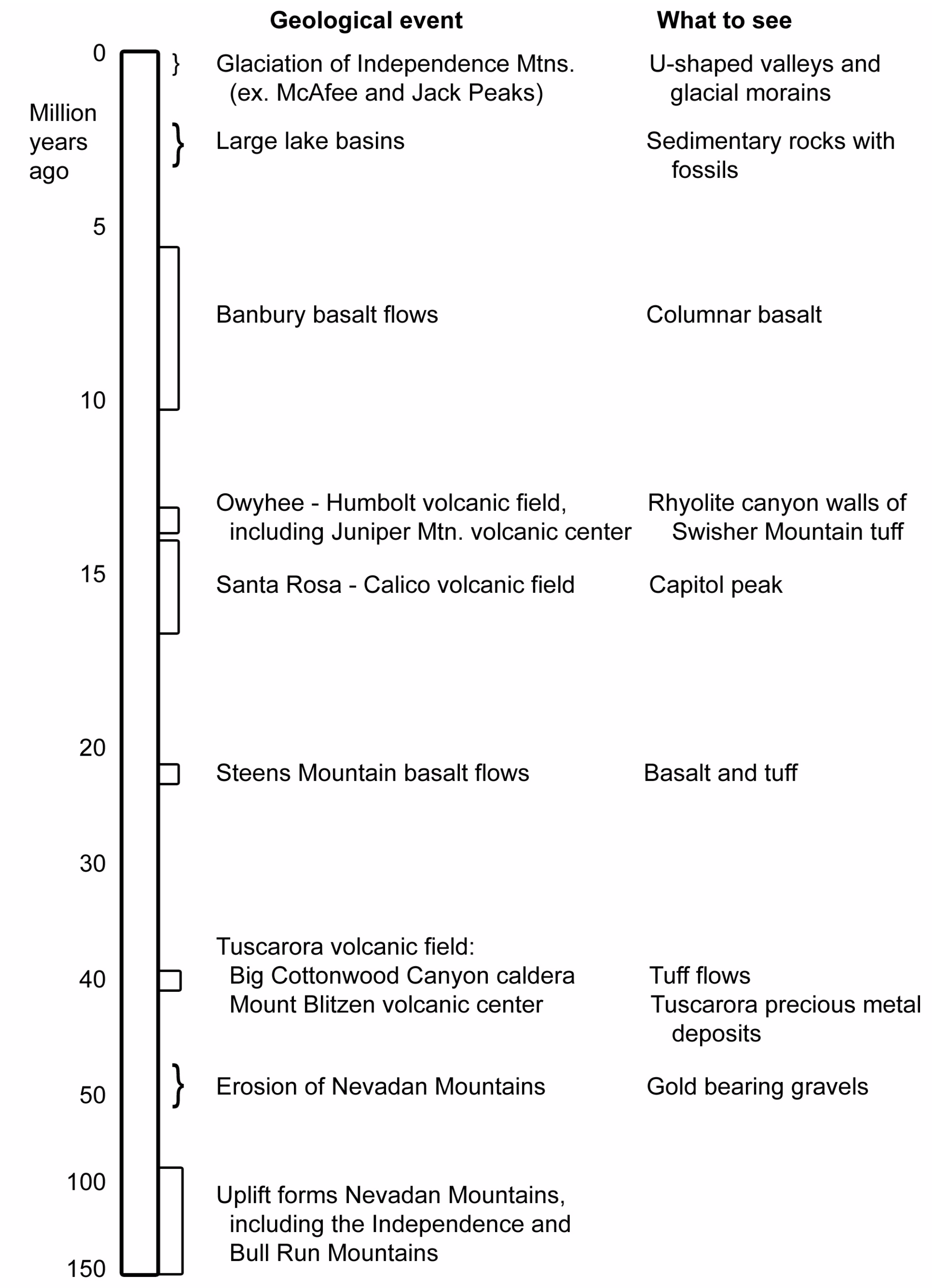

Figure 2.39. Timeline of geologic events in the upper Owyhee subbasin.

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