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GEOLOGY AND MINERAL RESOURCES OF 18 BLM WILDERNESS STUDY AREAS HARNEY AND MALHEUR COUNTIES, OREGON

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NOTICE

The Oregon Department of Geology and Mineral Industries is publishing this paper because the subject matter is consistent with the mission of the department.
To facilitate timely distribution of information, this paper has not been edited to our usual standards.

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MICROFICHE FOR OPEN-FILE REPORT O-83-2

Raw assay and site data, area summary tables, frequency tables, histograms, and scatter graphs were reproduced on four microfiche marked with a "1" in the upper right-hand corner.

Additional microfiche produced after the report was printed are marked with a Fiche # and contain the following maps:

Fiche #	Type and name of map
1.	Sample location maps and locations of soil profiles: Owyhee Res., middle Owyhee, upper Owyhee (N.), upper Owyhee (S.) (scale 1:62,500).
2.	Sample location maps and locations of soil profiles: Trout Creek, Pueblo Mountains, Steens Mountain (scale 1:62,500).
3.	Geologic maps: Owyhee Res., middle Owyhee, upper Owyhee (N.), upper Owyhee (S.) (scale 1:62,500).
4.	Geologic maps: Trout Creek, Pueblo Mountains, Steens Mountain (scale 1:62,500).
5.	Sample location maps: Boise, Jordan Valley, Adel (scale 1:250,000). Sample location maps: Twin Springs, The Elbow, Quartz Mountain Basin, Pelican Point, Three Finger Rock (scale 1:24,000).
6.	Sample location maps: Big Mud Flat, Diamond Butte, Rooster Comb, Bannock Ridge, Rinehart Canyon, Hole-in-the-Ground, Jordan Craters (N.), Wrangle Butte (2 copies), Lambert Rocks (2 copies), Owyhee Butte (scale 1:24,000).
6a.	Sample location maps: Frenchglen, Page Springs (scale 1:24,000).
7.	Sample location maps: McCoy Ridge, Big Pasture Creek, Rome, Scott Res., Dry Creek Rim, Little Grassy Mountain, Roaring Springs, Tombstone Canyon, Fish Lake, Wildhorse Lake, Indian Fort, Skull Creek (scale 1:24,000).
8.	Sample location maps: Whitehorse Butte, Ankle Creek, Alvord Hot Springs, Squaw Flat, Three Forks, Andrews, Little Owyhee River 2 NE, Little Owyhee River 1 NW, Trout Creek 1 SE, Oregon Canyon 2 SW, Oregon Canyon 1 SE, Little Owyhee River 2 SE (scale 1:24,000).
9.	Sample location maps: Little Owyhee River 1 SW, Little Owyhee River 1 SE, Rincon Flat, Lady Comb Peak, Tumtum Lake, Little Whitehorse Creek, Trout Creek 4 NE, Oregon Canyon 3 NW, Oregon Canyon 4 NE, Little Owyhee River 3 NW, Little Owyhee River 3 NE, Little Owyhee River 4 NW (scale 1:24,000).

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18. Element anomaly maps (Ba, Cd, Pb, Mn, U_3O_8): Trout Creek, Pueblo Mountains, Steens Mountain (scale 1:62,500).

GEOLOGY AND MINERAL RESOURCES OF 18 BLM WILDERNESS STUDY AREAS, HARNEY AND MALHEUR COUNTIES, OREGON

EXECUTIVE SUMMARY

At the end of September 1981, a $313,000 contract was signed between the Oregon Department of Geology and Mineral Industries (DOGAMI) and the Bureau of Land Management (BLM). The contract called for the Department to examine the mineral potential of 18 BLM Wilderness Study Areas (WSA's), which were located in Harney and Malheur Counties and which covered 805,000 acres. The study was to be completed by March 15, 1983, and was to include compilation of geological maps and stream-sediment, soil, and rock-chip sampling. The potential for oil and gas and geothermal energy was also to be evaluated. The potential for the non-metallic commodities, such as bentonite and zeolites, was not part of the study.

This project was completed according to the terms of the contract. Geological maps were prepared for the study areas. During the field season, 1,491 samples were taken and assayed for 17 elements. Sample-location maps were prepared. A computer system was used to store, retrieve, and analyze the raw data and to plot element-anomaly maps.

A major result of this project was to prove that Oregon has a new gold province. Only two of the WSA's, Pueblo Mountain (2-811) and Steens Mountain (2-85F), were known to be mineralized, mainly for mercury, before this study was completed. The sampling and assaying has shown that every WSA had at least scattered anomalous gold values. The Owyhee Reservoir and Pueblo Moutains have a high gold potential. The Pueblo Mountains also have a high potential for copper and molybdenum. Several other WSA's have interesting gold anomaly patterns or scattered anomalous gold values.

All of the WSA's also have geothermal potential because all have above-average heat flows and many have warm or hot springs. A few of the WSA's have areas which have been designated by either the Department as being

known or inferred to be underlain by thermal water or by the USGS as a Known Geothermal Resource Area (KGRA).

Because of the nature of known sedimentary formations, possible structural traps (formed by block faulting), and the current interest in leasing, oil and gas development is a possibility for most of the WSA's.

This study was a very fast geological and geochemical reconnaissance survey of an previously unknown gold province. At this point, the information contained in the raw data has barely been examined. The pan concentrates that were taken at each sediment site have not been assayed. As follow up to this study, the raw data should be further analyzed by computer. Pan concentrates from selected WSA's should be assayed. New larger scale geological mapping should be done in such areas as the east and west sides of the Owyhee Reservoir. Each of the places where high gold values form a pattern should be examined, and enough new geochemical sampling should be undertaken to explain those patterns.

INTRODUCTION

General

The Federal Bureau of Land Management (BLM) has the responsibility of managing public domain lands for both surface and subsurface multiple use. The Oregon Department of Geology and Mineral Industries (DOGAMI) has the responsibility of providing a strong mineral base for the State of Oregon's economic well-being. The BLM has determined that the existing mineral data base for most BLM lands, including 18 Wilderness Study Areas (WSA) listed in Table 1 and covering 805,390 acres, is weak. As the BLM does not have staff to do field work and collect data, and as one of the main functions of the DOGAMI staff is mineral data storage and retrieval, a contract was negotiated between the agencies whereby DOGAMI staff would work under BLM monies.

Departmental Qualifications

The Oregon Department of Geology and Mineral Industries (DOGAMI) is uniquely qualified to undertake and complete the mineral evaluation studies. DOGAMI or its predecessor has been engaged in mineral resource evaluations throughout the State since 1913. The Department is responsible under Oregon law for the conduct of geologic research and the regulation of exploration and development of minerals and mineral fuels. The agency has a staff of 15 geologists and engineers; a chemical, fire assay, and spectrographic laboratory; library; cartographic facilities; a publications section; and accounting staff.

DOGAMI has been and is engaged in continuing earth science research involving a variety of geological, geochemical, and geophysical studies. Over the years, the Department has built an outstanding mineral-geology data base through its numerous published studies, its unpublished reports

and files, its three mine-map depositories, and its input to the U.S. Bureau of Mines (USBM) and U.S. Geological Survey's (USGS) MILS and CRIB computer systems, respectively. The Department also places great importance on the professional development of its staff through professional meetings, field work, and frequent contact with the private sector.

Contract

Purpose

The primary purpose of the contract for this project was to have DOGAMI conduct geochemical and geological surveys of the 18 BLM WSA's in order to outline areas exhibiting anomalous amounts of chemical elements, and, through geological inferences and statistical interpretations, define zones where such anomalies might be related to potential economic mineral occurrences. Existing pertinent geophysical information such as aeromagnetic, geothermal heat flow, and gravity surveys were to be integrated and analyzed to arrive at the geological inferences. A representative number of mining prospects and mine workings were to be examined or sampled with permission, when necessary, from the claimant. Mineral production and drilling data, when available, including those for geothermal and oil and gas wells, were also to be utilized for mineral assessment. The main thrust of all the work was to evaluate metallic mineral resources.

Parameters

The Department's tasks were divided into several categories such as geothermal survey, geological mapping, examination of a representative number of mines and prospects, and review and integration of existing geological, geophysical and mineral-occurrence data. The WSA's are located in the southeast corner of the State, in Harney and Malheur Counties, and cover 805,930 acres (see Figure 1). Table 1 gives the BLM numbers, names, and acreages of each of the WSA's. The study of nonmetallic resources such as the bedded bentonite, zeolite, and fluorspar deposits and their economic potential are not part of the contract; however, from the geological map those formations which could contain lake bed deposits can be identified, and inference to their aerial extent can be made.

Deliverables

The contract calls for geological maps, sample location maps, element

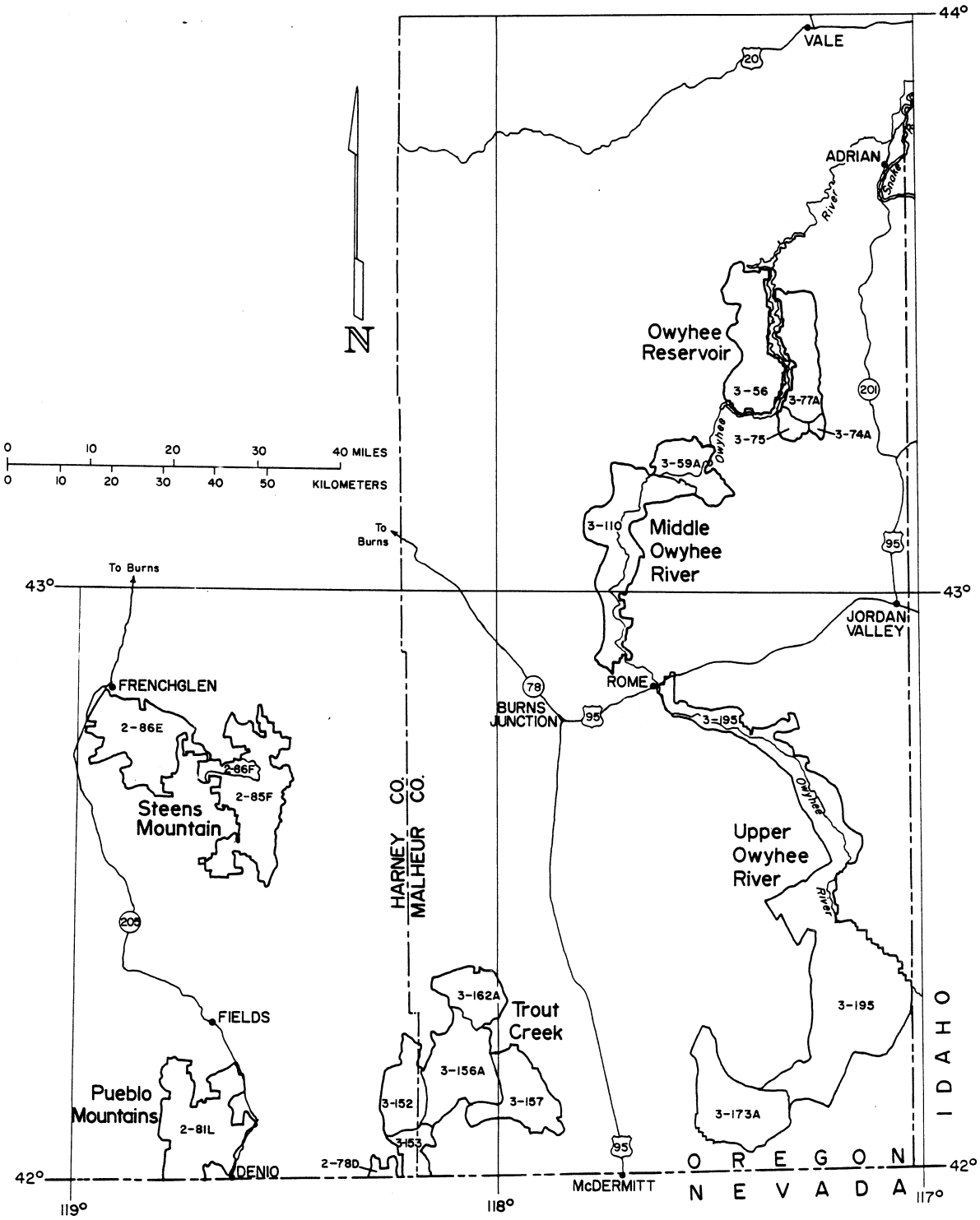

Figure 1. Wilderness study area location map.

Table 1. Names, numbers, and acreages of 18 BLM Wilderness Study Areas in this project

BLM Wilderness Area number and name	Area (acres)
Owyhee Reservoir	
3-56 Dry Creek Buttes	51,000
3-74A Bannock Ridge	3,000
3-75 Slocum Creek	7,600
3-77 Honeycombs	38,200
Subtotal	99,800 (156 mi^2)
Middle Owyhee River	
3-59A Owyhee Breaks	12,800
3-110 Lower Owyhee Canyon	73,200
Subtotal	86,000 (134 mi^2)
Upper Owyhee River	
3-173A Upper West Little Owyhee	66,060
3-195 Owyhee River Canyon	195,400
Subtotal	261,460 (409 mi^2)
Trout Creek	
2-78D Red Mountain	2,720
3-152 Willow Creek	29,800
3-153 Disaster Peak	13,300
3-156A Fifteenmile	48,500
3-157 Oregon Canyon	41,900
3-162A Twelvemile	27,100
Subtotal	163,320 (255 mi^2)
Pueblo Mountains	
2-81L Pueblo Mt.	67,430
Subtotal	67,430 (105 mi^2)
Steens Mountain	
2-85F South Steens	65,940
2-86E Blitzen River	52,060
2-86F Blitzen River	9,380
Subtotal	127,380 (199 mi^2)
Total	805,390 (1,258 mi^2)

anomaly maps, maps showing mineral resource potential, and descriptive text. The Department was to note all mineral occurrences with economic potential that were found in the field. The Department was also to make available to BLM the computer system obtained from USGS for geochemical data, storage, retrieval, and analysis, and put on line at Oregon State University (OSU).

Acknowledgments

Although this report has four authors, the project was a Departmental joint effort. Jerry Gray was designated principal investigator, Norm Peterson had responsibilities for geological mapping, and Janine Clayton was field crew chief. The other two field crew members were James Bela and Mark Ferns. Temporary field crew members included John Leetham and Sandi Johnson. Gary Baxter was in charge of all analytical work. Others from the Department who helped with the project included Beverly Vogt, publications manager; Klaus Neuendorf, editor; Paul Staub and Charles Schumacher, cartographers; and Anne Bradley, Kathleen Mahoney, Barbara DeClue, and Ruth Pavlat, typists. Donna Egland also assisted with the typing.

The help and advice of BLM's contracting officer, Durga Rimal, were invaluable. George Brown, Burns District, and H. Singh Ahuja, Vale District, provided tactical support for the field effort. George Walker (USGS) provided geological mapping notes and advice, and George Van Thrump (USGS) sent a taped copy of the RASS and STATPAC computer systems and guided Robert Brenne and Robert Dahl in getting the systems on line at OSU.

Local ranchers' hospitality in allowing access across their land, providing local road conditions, and in some cases providing room and board was appreciated. Glen Teague (Teague Minerals, Adrian, Oregon) lent a boat and advice. His employee, Wayne Lattin, provided another boat and piloted two of the crew around to the Owyhee Lake sample sites. Several other mining firms provided much needed information and advice.

OFFICE RESEARCH AND ACTIVITIES

General

The work to execute the contract consisted of office research, field surveying, compiling of geological maps, collecting of all published and unpublished data on mines and prospects, and design of a computer system for the geochemical data. Because of late signing of the contract and need for samples to be studied before the 1982 field season, much of the surveying in the Steens Mountain area was completed before the office research was started.

Compilation of Geologic Maps

Seven geologic maps were compiled from original notes of researchers and theses covering each of the wilderness study areas. The names of the areas combined for each of the maps are given in Table 1, and their relative positions are shown in Figure 1.

The geology for the general wilderness study areas was compiled on the standard BLM 30-minute series base maps at a scale of 1"= 1 mi. Reconnaissance geologic maps of the Adel (Walker and Repenning, 1965) and Jordan Valley (Walker and Repenning, 1966) AMS sheets and the geologic map of the Owyhee region (Kettleman and others, 1967) were the basic references used. Graduate student theses and the authors' personal knowledge of southeastern Oregon geology provided additional detail, especially in the Steens Mountain and Pueblo Mountains areas. George Walker (USGS) provided a field map for part of the Boise AMS sheet (G. W. Walker, personal communication, 1981), and a USGS open-file report (Rytuba and others, 1979) provided additional information for the Trout Creek Mountains area. All of the references used are listed in the bibliography.

Literature Search for Geophysical Data

Most of the published geophysical studies in southeastern Oregon are of a regional nature and concerned with geothermal exploration or uranium potential. Aerial gamma ray and magnetic surveys of the Boise (Geometrics,

Inc., 1979 a, b), Jordan Valley (Geodata International, Inc., 1980), and Adel (Geodata International, Inc., 1979), AMS quadrangles are available as a result of the U.S. Department of Energy's (USDOE) National Uranium Resource Evaluation (NURE) program. Reports from these surveys assessing uranium potential have been reviewed to note any uranium anomalies in the wilderness study areas. Detailed interpretation of the magnetic data in relation to potential mineral resources has not been attempted.

Gravity, seismic reflection, and magnetic studies of local areas near Vale were conducted in the mid- to late 1970's by OSU geophysicists to assess the geothermal potential (Boler, 1979; Larson and Couch, 1979). These studies may have some application for the Owyhee Reservoir Wilderness Study Area.

Another series of local geophysical studies by the USGS including gravity, magnetic, and magnetotelluric apparent resistivity are available for the Alvord Valley and the frontal fault area of Steens Mountain (Griscom and Conradi, 1975). These studies were conducted to interpret subsurface structure in assessing the geothermal potential of the Alvord Valley.

Field radiometric surveying and rock sampling for uranium favorability of the Tertiary rocks of Harney and Malheur counties was done by the Bendix Field Engineering Corporation for USDOE (Erikson, 1977; Erikson and Curry, 1977). The conclusions reached in these studies have been reviewed in assessing the mineral potential of the individual study areas. Another regional geochemical study relating to uranium, thorium, and other metal associations of silicic volcanic complexes of the northern Basin and Range Province (Walker, 1981) has also been reviewed for its application to the study areas.

Literature Search for Geothermal Data

In assessing the geothermal potential of the wilderness study areas, all available information has been reviewed. For regional evaluation and where no specific information was available, USGS Circular 790 (Muffler, 1979) and Oregon Department of Geology and Mineral Industries Special Paper 4 (Blackwell and others, 1978) have been used. Private companies have actively explored for geothermal resources in the eastern part of the Steens Mountain study area, but their information was not available for this study. The newly published map of geothermal resources of Oregon (Oregon Department of Geology and Mineral Industries, 1982) also contains the known hot springs and anomalous temperature wells for the region. All of the published geothermal

reports used in this study are listed in the bibliography.

Literature Search for Mines, Prospects, and Mineralization

DOGAMI's published and unpublished reports, other agencies published reports, the reports of USBM MILS computer system, the USGS CRIB computer system, and private mining firms' confidential data were all searched for mines, prospects, and areas of mineralization. The Pueblo Mountains and Steens Mountain (2-85F) metallic mines and prospects are listed in Tables 13 and 15 under their WSA evaluation section. Most of these data came from the USGS CRIB system. Occurrences of mercury, uranium, barium, manganese, copper, gold, and silver are listed on the tables. The locations of each of these occurrences were plotted on the field working maps. Although this study deals primarily with metallic minerals, picture rock (jasperoid) and optical calcite mining sites were also plotted on the field maps because these materials can be pathfinders to gold deposits. In this report the term "picture rock" and "jasperoid" are interchangeable. The term "picture rock" is a local name for silicified sediments and vein jasper that is sold for rockhound use. The term "jasperoid" is defined as a rock composed dominantly of silica, most commonly quartz, that is formed largely by epigenetic replacement.

> "Although jasperoid in the United States is most abundant in limestone and dolomite, it also occurs in shale, mudstone, extrusive igneous rocks, and metamorphic rocks. Most bodies of jasperoid are localized along faults, fracture zones, and shear zones, and they spread laterally from such conduits through beds of favorable lithology or permeability, or beneath impermeable caprocks.
>
> Large masses of jasperoid characteristically form prominent rugged outcrops that shed a talus of angular broken blocks. They tend to be strongly brecciated and recemented by younger quartz. The rock is fine grained to aphanitic in texture; the coarser varieties resemble fine-grained quartzite, and the finer varities resemble chert. Vugs are commonly abundant and conspicuous. Jasperoid in most outcrops is oxidized and is stained by iron oxides in various shades of brown, yellow, and red. Unoxidized jasperoid is predominantly gray or black. Some jasperoid retains both the color and texture of the host rock...." (Lovering, 1972, p.1).

During the field season these mines, prospects, and mineralized areas were visited and sampled. They are listed on rock-chip sample tables for each of the respective WSA's.

Literature Search of Geochemical Surveying Case Studies

An extensive literature search indicated that geochemical sampling is effective in an arid environment, such as that of the southeastern corner of Oregon. Although all of the studies that were reviewed are listed in the bibliography, two (Lovering and McCarthy, 1978; Rimal and others, 1980) were of particular value. Several mining firms described epithermal gold ore deposit models that would have application in this section of Oregon (Eimon, 1981; Berger and Eimon, 1982). These models indicate that gold deposits are most likely to occur within silicified rocks, such as agate and picture rock, areas of metal mineralization, those areas with non-bedded clay and zeolite zones, and in proximity to deep-seated near-vertical structures and zones of hydrobrecciation.

Mining Firm Interviews

Several mining firms were interviewed by telephone and by personal visits. Some were very open with their confidential information, thereby confirming the information gained from the literature search of geochemical case studies and adding other pertinent data. They showed the Department their claim maps, geological maps, and geochemical anomaly maps. This type of data was placed in broad terms on the field maps. During the field season the anomalous areas were soil sampled, and the anomalies were confirmed.

After the field season had ended and this report was in the final stages of completion, Daniel Allen of Vale, Oregon, reported that he ans two associates had staked 90 claims on a breccia zone 3 mi long and one-quarter mi wide. A sample of breccia submitted to the Department showed strong pyrite mineralization. The claim block is against the north edge of WSA no. 3-56 (Dry Creek Buttes)

Computer System

The USGS has developed computer systems (Rock Analysis Storage System (RASS) and Statistical Package (STATPAC)) to store, retrieve, and statistically analyze geochemical and geological assay data. The system can also drive a

plotter so that element data can be plotted on a map.

Since this study may be the prelude for a full-scale USBM and USGS wilderness study, all data collected by DOGAMI should be compatible with the Federal system. Therefore, George Van Trump (USGS) had a copy of the RASS and STATPAC systems sent to DOGAMI. The tape was placed on line at the OSU Computer Center by the time all samples had been assayed. Forms which were prepared for recording locations and physical descriptions of the samples and sample sites and for recording assay data were designed to be compatible with RASS and STATPAC systems. Figure 2 is a completed form which shows how four different cards must be punched to enter on the computer all the location and descriptive information about a sample and a sample site. Card 1 tells the computer that three data cards are to be entered. Card 2 is self-explanatory except for the subsections. A section is quartered, with a "6" equaling the NE 1/4, "7" equaling the NW 1/4, "8" equaling SE 1/4, and a "9" equaling the SW 1/4. The first number is the 1/4 section. The second number is the quarter quarter section. The third number is the quarter quarter quarter section. Therefore, for example, 6,9,9 would be the SW quarter of the SW quarter of the NE quarter. The sample is located within a 10-acre area.

A major problem was that the forms do not have room for 1/2 or 3/4 townships or ranges. In one of the WSA's (Steens Mountain, 2-86E), this created a problem. Table 2 gives the site numbers which are incomplete on the computer entries and indicates the fraction that should be added to the range number.

Card 3 gives the Universal Transverse Mercator (UTM) coordinates of the sample site and the geological map symbols for each of the geological formations which could have contributed to the sample site. The first geological symbol is for the geologic unit where the sample is taken, the next is up stream, and if there is another number, it is from further up stream.

The USGS master code list (U.S. Geological Survey, 1969, 1970) was used to fill in data for Card 5. The "B" under material class means "unconsolidated sediment," "A" under sample type means "single (grab)," "G" under sample source means "other," "E" under rock type means "unconsolidated sediment," "Z" under geologic age means "Holocene," and "SI" under rock name means "silt."

Figure 3 is the heading for the two assay-data computer input forms. Three cards are needed to input assay data for 21 elements. Only 17 elements were actually analyzed. The first card tells the computer that there are two data cards. The second card has data for gold through copper. The third card has data for lead through zinc.

Boolean string 1 T T 5 T Lab # 71 A1474F01 Card # 79 80 1

Sampler's name 1 NORM P 20 Year 28 29 82 Month 30 31 09 Day 32 33 10

T 35 36 30 S R 37 38 41 E Sec. 39 40 04 Subsections: 1st 41 6 2nd 42 9 3rd 43 9

W.S.A. # 45 3110 49 Lab # 71 A1474F01 78 Card # 79 80 2

(Harney=025, Malheur=045)

UTM-E 14 443460 19 UTM-N 21 4758860 27 State 30 31 41 County 32 045 34

Formation name 36 QS QB 59 (continues next line)

60 70 Lab # 71 A1474F01 78 Card # 79 80 3

Material class 11 B Sample type 12 A Sample source 13 G Rock type 14 E

Igneous form 15 Structural setting 16 Matrix 17 Oxidation state 19

Alteration 20 Ore minerals 21 Mineral deposit form 22 Geologic age 24 Z

Rock name 25 26 SI Code 27 Quad name 28 29 30 35 36 37 38 39 60 61 62 63 64 65 OWYHEE BUTTE

Lab # 71 A1474F01 78 Card # 79 80 5

WRITE COMMENTS ON BACK OF PAGE

Figure 2. Sample and sample-site data entry form.

Table 2. Sample site numbers that need a fraction added to the range number

Sample site number	Township (South)	Range (East)	Sample site number	Township (South)	Range (East)
1	32	32½	141	34	32½
2	32	32½	144	33	32-3/4
3	32	32½	145	33	32-3/4
4	32	32½	146	33	32-3/4
5	32	32½	154	32	32½
6	32	32½	155	32	32½
12	33S	32-3/4	156	32	32½
17	32	32½	157	33	32½
18	32	32½	158	33	32½
19	32	32-3/4	159	34	32½
20	32	32-3/4	160	33	32½
21	32	32-3/4	161	33	32½
22	33	32-3/4	162	33	32½
23	33	32-3/4	163	33	32½
24	33	32½	164	33	32½
25	33	32½	165	33	32½
26	33	32½	166	33	32-3/4
27	32	32½	167	33	32-3/4
28	34	32½	168	33	32-3/4
29	34	32½	169	33	32-3/4
30	33	32½	189	32	32½
31	33	32½	190	32	32½
32	33	32½	191	32	32½
33	33	32½	993	35	32-3/4
34	33	32½	994	35	32-3/4
35	33	32½	995	35	32-3/4
36	33	32½			
37	33	32½			
69	32	32½			
70	32	32½			
71	32	32½			
72	32	32½			
83	33	32½			
84	33	32½			
86	32	32½			
87	32	32½			
89	34	32-3/4			
90	34	32-3/4			
92	32	32½			
93	32	32½			
94	32	32½			
95	32	32½			
96	33	32½			
97	33	32½			
98	33	32½			
99	33	32½			
100	32	32½			
101	32	32½			
102	33	32-3/4			
103	33	32½			
104	33	32-3/4			
136	32	32½			
137	32	32-3/4			
138	32	32-3/4			
139	33	32-3/4			
140	34	32½			

ATTN. KEYPUNCH OPERATOR: For each NUMBER (case) listed below please punch a card which will have a "T" in columns 6 and 7 and the NUMBER in columns 71 through 78 and a "1" in column 80. See example below.

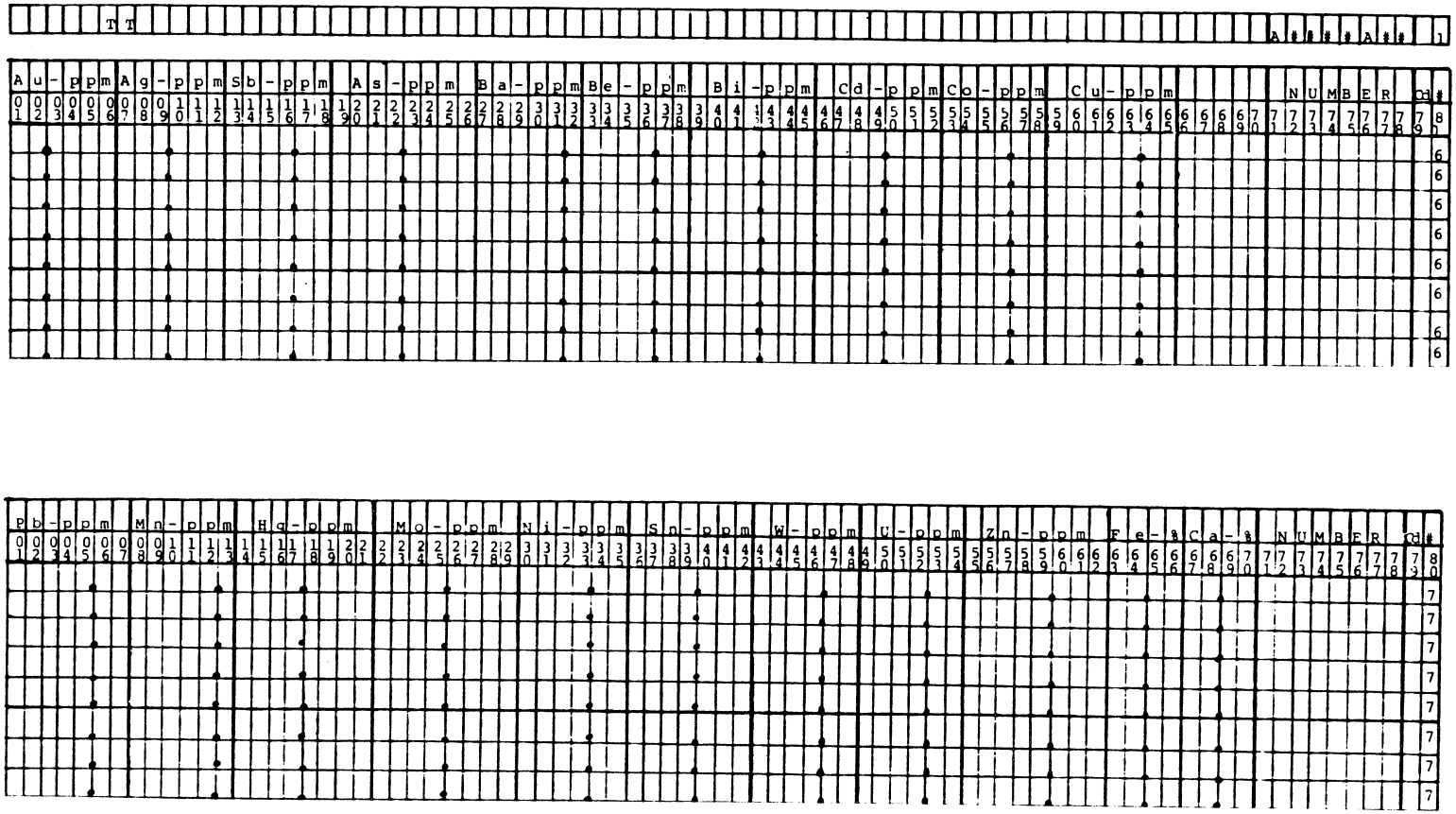

Figure 3. Assay data computer input forms.

This computer system was used to retrieve, analyze, and print out the data. It was also used to plot the data in form of histograms and scatter graphs and on overlay maps. The computer system and data from this study are available from the OSU Computer Center at their cost.

FIELD SURVEYING

General

A field crew of four sampled 1,477 sites scattered over 805,390 acres, 63 7½-minute topographic quadrangle maps, and two 15-minute topographic maps (Figure 4). Field equipment used included three 4X4 vehicles, two dirt bikes, three boats, and one helicopter.

Pilot Study

The Steens Mountain area (WSA's 2-85F, 2-86E, and 2-86F) was selected for a pilot-size field study. The contract between the two agencies was signed after the 1981 normal field season; however, sample data were needed to place the computer system on line and to perfect computer forms. Sampling techniques had to be worked out and samples were needed so that outside assaying laboratories could be selected.

A field crew of three sampled 167 sites between October 3, 1981, and November 26, 1981. From the pilot work, the time required to sample a site was determined. The minimum number of check samples needed for quality control was also ascertained. This allowed planning to proceed for the 1982 field season.

Geochemical Sampling

During the field work, 3,797 samples were taken from 1,477 sites (Table 3); of the 3,797 samples, 1,491 were assayed. From each of the stream-sediment sites, three samples were taken. Two samples weighing one pound each were taken of the silt-size sediment. The first sample was assayed; the second was used as back up and for a random check. The third sample was derived from a gold pan level full of a ¼ inch minus and was panned down when water was available until it weighed about a quarter pound. If the site was dry, a cloth bag 7 in. by 12.5 in. was filled with the gravel. A full bag weighed from 8 to 10 pounds. Later the sample was panned when water was available. The panned concentrates were sent to the DOGAMI Portland warehouse for storage but have not been analyzed. These samples will be visually examined and analyzed at some time in the future. The

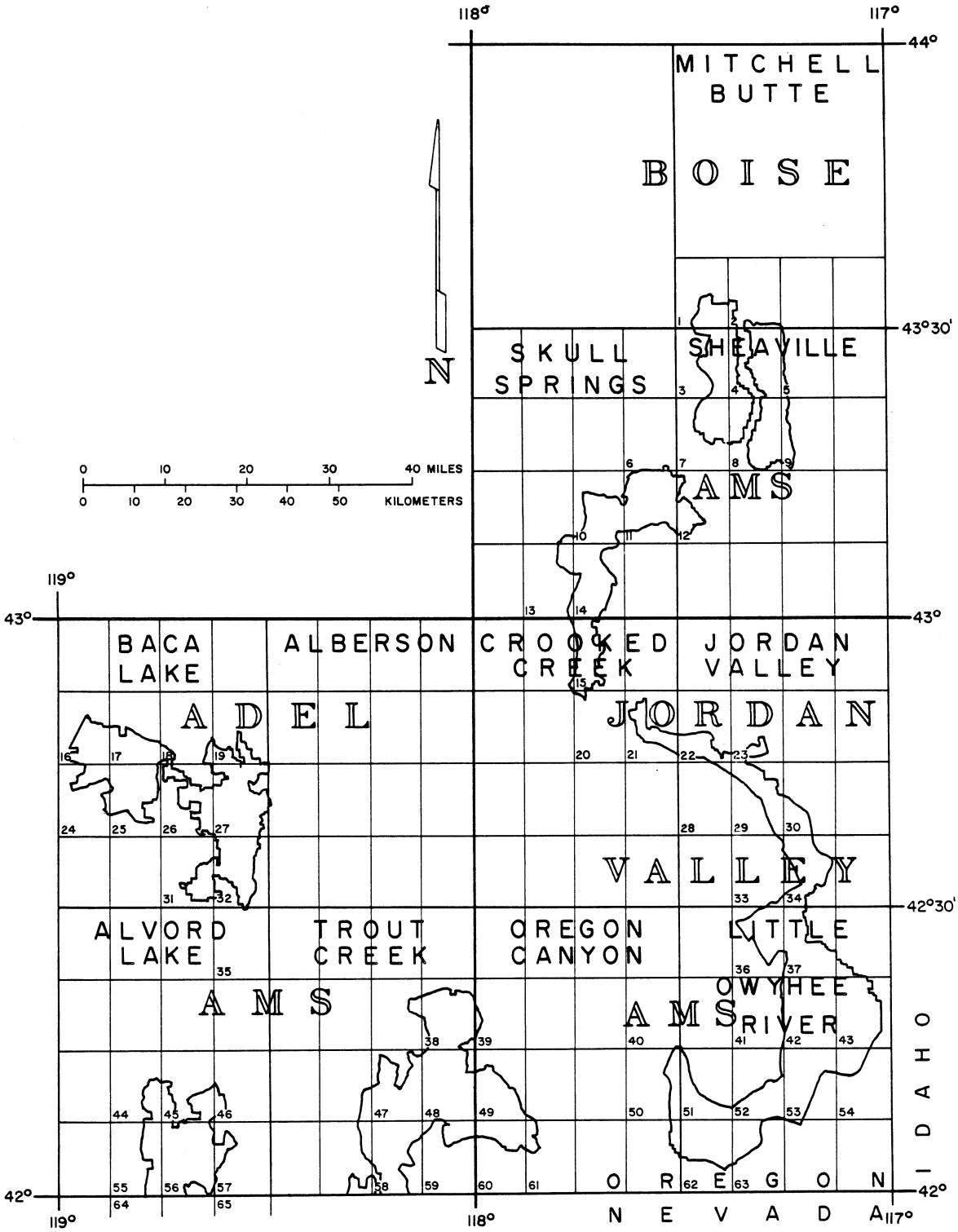

Figure 4. Index to quadrangle map coverage of wilderness study areas. Numbers refer to 7½- and 15-minute quadrangles that are identified by name on p. 105.

Table 3. Numbers and types of samples assayed from each Wilderness Study Area

Wilderness Study Area	No. of checked samples	No. of sedi-* ment sites	No. of rock samples	No. of soil samples	Total no. of samples	Total no. of sample sites
Owyhee Reservoir						
3-56 Dry Creek Buttes (west side)	3	76	19	43	138	134
3-74A Bannock Ridge (east side)	1	8	0	0	8	8
3-75 Slocum Creek (east side)	0	5	0	0	5	5
3-77A Honeycombs (east side)	3	55	4	0	59	59
Subtotal	7	144	23	43	210	206
Middle Owyhee River						
3-59 Owyhee Breaks	1	20	5	0	25	25
3-110 Lower Owyhee Canyon	5	100	6	0	106	103
Subtotal	6	120	11	0	131	128
Upper Owyhee River						
3-173A Upper West Little Owyhee	5	56	1	0	57	57
3-195 Owyhee River Canyon	9	212	13	0	225	223
Subtotal	14	268	14	0	282	280
Trout Creek						
2-78D Red Mountain	0	5	0	0	5	5
3-152 Willow Creek	1	44	0	0	44	44
3-153 Disaster Peak	0	14	1	0	15	15
3-156A Fifteenmile	5	91	1	0	92	91
3-157 Oregon Canyon	7	71	1	0	72	72
3-162A Twelvemile	3	87	2	0	89	88
Subtotal	16	312	5	0	317	315
Pueblo Mountains						
2-81L Pueblo Mt.	7	133	17	207	357	356
Steens Mountains						
2-85F South Steens	3	79	18	0	97	95
2-86E Blitzen River	3	87	0	0	87	87
2-86F Blitzen River	0	10	0	0	10	10
Subtotal	6	176	18	0	194	192
GRAND TOTAL	56	1153	88	250	1490	1477

* At each sediment site, three samples consisting of two silts and one panned concentrate were taken. Total number of sediment samples taken was 3,459; 88 rock samples and 250 soil samples were also collected, making a grand total of 3,791 samples collected for the entire project.

number of stream-sediment sites that were to be sampled was 1,200, or one per square mile. The final count was 1,153 sites.

Of the 1,491 samples assayed, 250 were soil samples taken across mineralized areas in WSA's 2-81L and 3-56.

Eighty-eight rock chip samples were taken. Rock chip sampling was mainly at mines and prospects, geothermal drill sites, and picture rock (jasperoid) outcrops.

The sample numbering system used for this project was designed to be used Department-wide for any area and any type of sample. The number code used eight character spaces and started with a letter: "A" for the Albany, "B" for the Baker office, "G" for the Grants Pass office, and "P" for the Portland office. The next four character spaces were used for the sequential site number; a letter was used in the next space to designate the type of sample being taken ("D" is for dirt (Soil), "C" for concentrates, "F" for fines (silt), "G" for gravel, and "R" for rock). The last two character spaces were for the number of samples taken at the site and for that type of sample. At every stream-sediment site, three numbers were used. For site number 25, for example, the numbers were A0025F01, A0025F02, and A0025C03. If a rock-chip sample was taken at that same site, its number was A0025R04.

At each site, a 6- by 8-in.-wide area was spray painted yellow with a fast drying paint on a nearby rock. The site number was painted on the yellow rectangle with a red jumbo marker. The flagging placed at each site was marked with the site number.

Each of the crew members was expected to average four sample sites per 10-hour day. The average time needed to take a sample was 15 minutes, and another 15 minutes was needed to fill out the sample forms. Therefore, an average of 2 hours per work day was spent actually sampling. The rest of the 10-hour day was used to get to and from the sample sites. The one-way vehicle travel time from sleeping quarters to first sample site was as much as 3 hours. Round trip hiking distances reached as far as 12 mi. In some areas, the sample sites were at the bottom of canyons and the roads were at the top. An up-and-down change in elevation of 1,000 ft was very common. If the sample site had water, 3.25 pounds of material was collected. If the site was dry, 13.25 pounds of material was collected. At the end of a sampling loop, a 40-pound to 50-pound pack was normal.

Field Checking of Geological Maps

The compiled geological maps were field checked. Although the maps were mainly unchanged, the field observations suggest that geological interpretation of some of the formations would be changed if more detailed studies were to be done.

Field Checking of Mines, Prospects, and Alteration/Mineralization

Two tables listing all the mines and prospects that were in the USBM MILS and USGS CRIB computer systems were prepared. These are Tables 13 and 15 that cover the Pueblo Mountains and Steens Mountain sections, respectively. These tables were the starting point for field checking and rock chip and soil sampling. Several private mineral exploration firms had pointed out the importance of agate, jasper, and picture rock deposits as a form of alteration that could be related to gold mineralization. All of the mineralized areas that were pinpointed by the mines and prospects listed in the two tables were visited. About half of those mines and prospects listed were sampled. Seven soil sampling profiles were run in Dry Creek Buttes (WAS 3-56), and seven were run in the Pueblo Mountains (WAS 2-81L).

Additional prospects and agate-picture rock deposits were found during stream-sediment sampling. These deposits also were sampled.

LABORATORY SUPPORT

General

The role of the Department"s laboratory in this project was four-fold. The first was to oversee, from the assaying standpoint, the taking, handling, and storage of the samples. As part of this project, the heavy-mineral pan concentrates that were taken at each stream-sediment site were put in chronological order and stored for future use by the BLM.

The second laboratory task was to perform part of the assaying. The third was to choose outside laboratories to do the rest of the assaying, by calling for bids, narrowing the lists of laboratories, and visiting laboratories in Salem, Oregon; Redding, California; Reno, Nevada; and Vancouver, British Columbia. A total of four outside laboratories were involved in the assaying. The fourth role of the laboratory was the providing of quality control within and between the laboratories, including the Department's laboratory.

Definition of Term "Sample"

In general, the term "sample" has two meanings in this study: (1) the raw or field sample taken, and (2) the analytical sample prepared from the field sample. The latter samples were analyzed to produce the composition data included herein. When the term "sample" is used, the meaning intended should be clear from the context.

The analytical samples for stream sediments and soils were the minus 80 fraction of the raw samples. For rocks, the minus 80 mesh material (pulp) produced by grinding constituted the analytical samples.

Sample Preparation

Sample Preparation Steps

The procedures used in preparing the samples were designed to reduce or eliminate contamination and to prevent loss of the more volatile elements. The last few steps were for rock-chip samples. Examples are:

1. The compositions of the various materials coming in contact with the samples were selected so that the metal load would not be increased.
2. Samples were air dried at room temperature rather than oven dried to minimize the loss of mercury.
3. All equipment was blown free of dust with compressed air before and after each sample was treated.
4. Affected surfaces were frequently vacuumed to pick up material lost in the inevitable "dusting" as samples were being prepared.
5. Waste rock, followed by quartz, was used to wash (by grinding) the residue left on the grinding plates after grinding gummy samples.
6. Grinding was done on an interrupted schedule to prevent heat build-up in the grinding plates.
7. Larger than necessary volumes of rock samples, many of which were obviously mineralized, were ground. The object was to dilute any material left in the pulverizer after grinding the prior sample.

Stream Sediments

Compacted samples were first broken up with a pestle in an unglazed porcelain mortar and gently ground. The samples were then sieved with all-stainless steel sieves to produce minus 80 mesh material for analysis. Each minus 80 mesh fraction was then split with an all stainless steel splitter into four equal parts, and each part was transferred to a prenumbered pulp envelope.

Soils

Because in many of the study areas, even though a 17 mesh screen was used to fill a sample sack, the samples did not contain enough minus 80 mesh sample. Therefore, each sample was lightly ground in a Bico pulverizer to produce a greater amount of material for analysis. The ground sample was then sieved as above. The sample was split using the equipment indicated above, but here two one-eighth splits and two three-eighths splits were made and packaging was done as above. In this manner, the sample weights required for the various analyses could be accommodated.

Rock Chips

All of each rock sample (1 to 3 kg) was crushed in a Bico chipmunk jaw crusher to minus 1/4 inch mesh. The crushed material was split repeatedly in an all-stainless steel splitter until the desired mass of about 1 kg was obtained. This portion was stored in a plastic bag prior to grinding; the balance of the crushed material was discarded. Each crushed portion was then ground to about minus 80 mesh in a Bico pulverizer, split into two one-eighth and two three-eighth parts, and packaged as above.

Analytical Program

The concentrations of 16 elements were determined in most samples; a few field samples produced insufficient material for the determination of all sixteen elements. The elements determined included:

Au (gold)	Be (beryllium)	Mn (manganese)	Sn (tin)
Ag (silver)	Co (cobalt)	Hg (mercury)	W (tungsten)
As (arsenic)	Cu (copper)	Mo (molybdenum)	U (uranium)
Ba (barium)	Pb (lead)	Ni (nickel)	Zn (zinc)

Based on the methods required to adequately characterize these elements and the equipment required by these methods, the following analytical program was devised:

Group I Elements:	As - Hg - Mo - Sn - W
Group II Elements:	U (as U_3O_8)
Group III Elements:	Ba - Be - Co - Cu - Mn - Ni - Zn
Group IV Elements:	Ag - Pb
Group V Elements:	Au

The elements of Groups III and IV were determined in the Department laboratory. Three separate commercial laboratories provided analyses for one each of the three remaining groups.

Analytical Methods

General

The purpose of an analytical method for geochemical exploration is the determination of the concentration of an element. The method must have sufficient specificity, accuracy, detection limit, and precision so that the

data are amenable to statistical analysis when a number of samples are compared for that element. In order to characterize a given element, a specific method must be employed. The difficulty is that this method can rarely be extended to all of the other elements to be determined. Therefore, to produce analytical results for a large number of elements in a large number of samples at a reasonable cost and within a reasonable time, compromise analytical methods must be employed.

The (compromise) analytical methods used for this study were based on the literature, information from mining and exploration companies, and current commercial laboratory practice. Detection limits were set for Au at 0.005 ppm; Ag, 0.01 ppm; As, 0.2 ppm; Ba, 1.0 ppm; Be, 0.05 ppm; Cd, 0.02 ppm; Co, 1.0 ppm; Cu, 1.0 ppm; Pb, 0.5 ppm; Mn, 5.0 ppm; Hg, 0.002 ppm; Ni, 1.0 ppm; Sn, 0.1 ppm; W, 1.0 ppm; U_3O_8, 0.1 ppm; and Zn, 1.0 ppm.

Decomposition Methods

Various decomposition methods were employed to put the metals of interest into the forms required for instrumental analysis. In summary these were:

1. Acid decomposition. Used for the "extractable" metals (Ag-As-Ba-Be-Co-Cu-Pb-Mn-Hg-Mo-Ni-Sn-U-Zn) in sediments and soils.
2. Hydrofluoric acid decomposition. Used for "total" metals (Ag-As-Ba-Be-Co-Cu-Pb-Mn-Hg-Mo-Ni-Sn-U-Zn) in rocks.
3. Fusion decomposition. Used for "total" W in sediments, soils, and rocks.
4. Fire assay fusion decomposition. Used for "total" Au in sediments, soils, and rocks.

In sediments and soils, part of the contained metals is derived from external sources and is bound up by the clay, organic matter, and/or hydrous iron and manganese oxide. Use of a mild decomposition reagent allows these adsorbed metals to be extracted preferentially to the metals contained within the mineral fragments. Various combinations of hydrochloric acid + nitric acid and nitric acid alone are commonly used to extract a number of metals. The extracted metals are in turn treated singly or in groups by appropriate chemical and instrumental techniques.

For total metal determinations, more drastic chemical treatment is necessary to free the metals contained within individual grains of sample. Here either hydrofluoric acid (in combination with other acids) or fusion with various fluxes is common practice.

Instrumental Methods of Analysis

All of the metals were determined by instrumental methods after appropriate decomposition. Gold, silver, barium, beryllium, cobalt, copper, lead, manganese, molybdenum, nickel, and zinc were determined by atomic absorption spectrometry (AAS or AA). Arsenic and tin were determined by hydride/AA. Mercury was determined by cold vapor/AA. Tungsten was determined by UV-VIS spectrophotometry. Uranium was determined by fluorimetry.

Specific Methods

Detailed instructions for the Department's laboratory procedures and the contracted laboratories are contained in the Department's files. The following groups of elements are combined by the different means of decomposition:

1. Group I Elements: As - Hg - Mo - Sn
   a. For sediments and soils, decomposition was with hydrochloric acid + nitric acid. For rocks, decomposition was with hydrofluoric + nitric + perchloric acids.
   b. Arsenic and tin were determined by the hydride/AA method. Mercury was determined by the cold vapor/AA method. Molybdenum was determined in the acid solution by AA.
2. Group I Element: W
   a. For all samples, decomposition was with a potassium pyrosulfate fusion; the tungsten was extracted from the aqueous solution with dithiol/amyl acetate, and the tungsten (colored complex) was determined by spectrophotometry.
3. Group II Element: U (reported as U_3O_8)
   a. For sediments and soils, decomposition was with nitric acid. For rocks, decomposition was with hydrofluoric + nitric + perchloric acids, solution taken to dryness, and finally taken up with nitric acid. The uranium was extracted with ethyl acetate and an aliquot was fused with sodium and potassium carbonates + sodium fluoride. The uranium was determined by fluorimetry.
4. Group III Elements: Ba - Be - Co - Cu - Mn - Ni - Zn
   a. For sediments and soils, decomposition was with nitric + hydrochloric acids + potassium chlorate. For rocks, decomposition was with hydrofluoric + hydrochloric acids, taken to dryness, and finally taken up with the same reagents as used for sediments and soils. All

elements were determined by AA on the resulting solution.

5. Group IV Elements: Ag - Pb
   a. For sediments and soils, decomposition was with hydrochloric acid + potassium chlorate. For rocks, decomposition was with hydrofluoric acid taken to dryness, a solution of aluminum chloride was added and taken to dryness again, and the dried residue was taken up with hydrochloric acid + potassium chlorate as with sediment and soil samples. For all samples at this point, an ascorbic acid + potassium iodide solution was added, and the metals were extracted with a tri caprylyl methyl ammonium chloride + methyl isobutyl ketone solution. The two metals were determined in the organic solution by AA.
6. Group V Element: Au
   a. Gold was gathered by a fire assay fusion decomposition with added silver. The resulting bead was dissolved in hydrochloric + nitric acids. Gold was determined by AA.

Quality-Control Program

For this study, precision -- the reproducibility of analytical results -- was of primary importance. To measure precision the following procedures were implemented:

1. Precision within an individual laboratory.
   a. The two laboratories responsible for providing the original data for 14 of the 16 elements ran replicate analyses (two or more analyses on separate portions of the same sample) on every twentieth sample.
   b. The laboratory determining gold could not provide replicate analyses on the sediment and soil samples because of the limited sample available. The rock samples were not so limited, so replicates could be provided.
   c. The laboratory providing uranium analyses was not asked to provide replicate analyses.
2. Intralaboratory precision.
   a. Using identical or virtually identical methods, other laboratories provided analyses for the 16 elements for comparison with the

original data. Again every twentieth sample was analyzed. A very limited number of samples were rechecked by yet another laboratory.

3. Blind Samples.
   a. Fifty-six samples were submitted to the lab. No information was available to the lab concerning these samples.

4. Development of Department's Standard.
   a. No standard reference materials were available for the determination of the extractable metals. In lieu of such a standard, a large sample was taken at one site, sieved, and split into 20 parts. At least one split was analyzed along with every 25 to 50 samples (for Ag-Ba-Be-Co-Cu-Pb-Mn-Ni-Zn only) by the Department lab. Assuming that the sample was homogeneous, it was felt that the resultant large body of data would give some overall measure of the precision to be expected.

   b. Standard reference materials were available from the USGS for comparison with the rock samples. Unfortunately the compositions of these standards were not adequate for comparison with all 16 elements.

Petrographic Services

Most petrographic examinations were done in the field with a 10-power hand lens. A few unusual rocks and minerals were informally examined petrographically at the USBM Albany Research Center.

GEOCHEMICAL DATA

General

The following steps were taken to interpret the mass of data generated by the taking and analyzing of the 1,491 samples over an area of 800,000 acres:

1. The computer printed out the tabulated assay and site data.
2. The computer plotted a "+" for each site on one of three overlays at a scale of 1:250,000.
3. The random resampling assay data was compared to the original sampling assay data.
4. The computer-printed summarized assay data table was analyzed.
5. The computer-printed silt-sample frequency tables and histograms of each element in logarithms were studied.
6. An anomalous threshold value for each of the elements was assigned.
7. A stepwise multiple regression was run for gold and silver against the rest of the elements.
8. Fourteen soil sampling profiles were graphed using elements selected from the stepwise multiple regression.
9. The soil profile graphs were studied in relation to the elements' assigned anomalous values.
10. Least squares correlations were run, and scatter graphs were plotted between each of the elements.
11. Using the correlation R^2, it was decided which elements should be plotted together on the 1 in. = 1 mi overlays.
12. The computer plotted four overlays for each of the seven 1 in. = 1 mi maps. The Upper Owyhee area was so large that it had to be prepared in two maps--the north half and the south half.

Tabulated Assay and Site Data

The computer printout generated by this study consists of the raw assay,

site data, area summary tables and frequency tables, histograms, and scatter graphs. The printout appears on the microfiche included with this report. The first part of the computer printout is arranged in the same order as Table 1: Owyhee Reservoir, Middle Owyhee River, Upper Owyhee, Trout Creek, Pueblo Mountains, and Steens Mountain. Under each of the study areas, the first data given are silt-sample assay data for gold through copper in numerical order by site number. A summary table for the silt samples is next. For each element, the number of samples, the mean assay value, the minimum assay value, the maximum value, the range, and standard deviation are given. The next data set is for rock samples and is for gold through copper. The next data set is for soil samples, again for gold through copper. The next data set is for silt-sample assay data for lead through the zinc/cadmium ratio. If the computer sheets are torn apart between the silt and soil sample data, the two silt-sample data sets will line up, so that all the data for one sample beginning with gold values and ending with the zinc/cadmium ratio can be seen. The rock-sample data and soil-sample data for lead through zinc/cadmium ratio will also line up. The next three data sets give site data by silt, rock, and soil. The site numbers are in the same order as the assay data given above. At the top of each page, column headings are given.

Sample Location Maps

Three 1:250,000 overlay maps were plotted by the computer. The computer plotted a "+" for each of the 1,477 sample sites. One map covers part of the Boise AMS map and includes the Owyhee Reservoir and half of the Middle Owyhee River. The second map is for the Jordan Valley AMS map and includes the rest of the Middle Owyhee River, the Upper Owyhee River, and half of the Trout Creek. The last map is for the Adel AMS map and includes the rest of the Trout Creek, the Pueblo Mountains, and the Steens Mountain areas.

A set of these maps is available for inspection in the DOGAMI library in Portland.

Random Resampling

After all the silt (stream sediment) sampling had been completed, a table of random numbers was used to select fifty-six sites to be resampled for quality control. A few sites which came up on the table of random numbers were rejected because of the high cost of getting to them. At each resampling site, a new

number was used for the sampling. The samples were completely blind to the assayer. Table 4 shows the summary of the assay statistics for the test of two means. With this test the random sample assay is subtracted from the original sample assay. The differences are then treated as a new statistic. The obtained "t" value is compared to a table of "t" values. For a two-tailed test at the 98-percent level, if the value is less than 2.4 for a sample size of 40 to 60, then the two assays were taken from the same population. Only arsenic and zinc fell out of a single population. In general, the random sampling showed that both the work of the samplers and the assayers was reproducible.

Assay Data Summary by Sample Type and by All Samples

Table 5 gives a statistical summary of the assay data by silt (stream sediment) samples, rock-chip samples, and soil samples and for total (every sample). The row showing number of samples indicates how many samples had values above the detection threshold. A row is given for the means, the minimum values, the maximum values, the ranges, and the standard deviations.

Frequency Tables and Histograms

The computer program was used to generate frequency tables and histograms three different ways: (1) using raw data from all of the samples; (2) using raw data from just the silt samples, and (3) by converting the silt-sample raw data to logarithms. A good histogram could not be generated by methods 1 or 2 because very high values occurred in a few of the rock and soil samples. The silt samples were the only unbiased samples. The other samples were taken because they were expected to carry values. Therefore, further analysis was on just silt-sample data. The frequency tables and histograms were better but not as bell shaped as they should have been. The logarithms of silt data were then run, producing good bell-shaped histograms.

Stepwise Multiple Regression with Silver as the Dependent Variable

The next step was to determine if any element could be a pathfinder for gold. For the silt samples, a stepwise multiple regression was run with values in logarithms, with gold as the dependent variable and the rest of the elements as independent variables. The first variable to come into the regression was silver; however, the correlation was very poor. Only 130 samples out of a

Table 4. Summary of assay statistics for the test of two means

	AU -PPM	AG -PPM	AS -PPM	BA -PPM	BE -PPM	CD -PPM	CO -PPM	CU -PPM	PB -PPM
NUMBER OF SAMPLES*	1	50	51	56	56	6	56	56	56
MEAN OF SET A	.0250	.0542	4.0941	199.2857	.8654	.1233	15.1964	26.6429	10.7571
MEAN OF SET B	.0050	.0802	3.1137	206.7857	.8279	.1000	14.6786	29.0536	10.4786
MEAN DIFFERENCE	.0200	-.0260	.9804	-7.5000	.0375	.0233	.5179	-2.4107	.2786
STD. ERROR OF DIFF	0.0000	.0158	.3978	7.6923	.0259	.0206	.6669	1.4887	.4229
TVALUES	0.0000	-1.6456	2.4644	-.9750	1.4501	1.1326	.7765	-1.6194	.5587

	MN -PPM	HG -PPM	MO -PPM	NI -PPM	SN -PPM	W -PPM	U3O8-PPM	ZN -PPM
NUMBER OF SAMPLES*	56	51	3	56	51	0	56	56
MEAN OF SET A	751.2500	.1536	4.6667	24.1786	1.3586	0.0000	1.7464	42.2500
MEAN OF SET B	700.4821	.1858	1.3333	26.0536	1.2508	0.0000	1.7964	50.3929
MEAN DIFFERENCE	50.7679	-.0321	3.3333	-1.8750	.1078	0.0000	-.0500	-8.1429
STD. ERROR OF DIFF	24.8558	.0181	2.8480	2.0639	.3716	0.0000	.1889	1.5913
TVALUES	2.0425	-1.7702	1.1704	-.9085	1.3050	0.0000	-.2764	-5.1173

* The number given in the "number of samples' row is the number of matching pair for that element. A matching pair is a sample site where both the original sample and the resample had assay values above the detection limits for a particular element.

Table 5. Statistical overview of assay data for all sample types and areas

SILT SAMPLES

	AU -PPM	AG -PPM	AS -PPM	BA -PPM	BE -PPM	CD -PPM	CO -PPM	CU -PPM	PB -PPM	MN -PPM	HG -PPM	MO -PPM	NI -PPM	SN -PPM	W -PPM	U3O8-PPM	ZN -PPM	ZN/CD
NUMBER OF SAMPLES	130.	1007.	1112.	1151.	1151.	758.	1150.	1151.	1151.	1151.	1116.	282.	1151.	1028.	29.	1151.	1151.	758.
MEAN VALUES	.017	.062	3.636	195.285	.880	.199	15.771	30.873	9.532	715.014	.214	3.189	26.295	2.166	2.738	1.469	46.974	304.665
MINIMUM VALUES	.005	.010	.200	20.000	.240	.020	1.000	2.000	.600	120.000	.002	.700	1.000	.100	1.000	.100	5.000	29.268
MAXIMUM VALUES	.05	1.220	111.000	900.800	2.890	1.640	89.00E	163.000	53.000	4710.000	12.100	25.600	148.000	61.500	6.400	12.000	132.000	2850.000
RANGES	.400	1.210	110.800	880.300	2.650	1.620	88.000	161.000	52.400	4590.000	12.098	24.900	147.000	61.400	5.400	11.900	127.000	2820.732
STANDARD DEVIATIONS	.040	.067	4.650	83.928	.358	.119	9.278	29.045	5.072	309.359	.412	3.334	24.615	3.490	1.633	1.182	18.041	267.764

ROCK SAMPLES

	AU -PPM	AG -PPM	AS -PPM	BA -PPM	BE -PPM	CD -PPM	CO -PPM	CU -PPM	PB -PPM	MN -PPM	HG -PPM	MO -PPM	NI -PPM	SN -PPM	W -PPM	U3O8-PPM	ZN -PPM	ZN/CD
NUMBER OF SAMPLES	28.	86.	61.	87.	67.	0.	87.	87.	86.	87.	81.	76.	87.	76.	7.	87.	87.	0.
MEAN VALUES	.150	4.275	119.128	296.356	1.917	0.000	20.747	4114.310	17.919	283.678	145.844	9.046	27.782	5.079	1.229	9.968	64.954	0.000
MINIMUM VALUES	.005	.020	1.500	20.000	.060	0.000	1.000	4.000	2.000	30.000	.062	3.000	5.000	.500	1.100	.100	4.000	0.000
MAXIMUM VALUES	2.070	225.280	2440.000	1150.000	7.440	0.000	222.000	95500.000	176.000	1370.000	8340.000	72.600	132.000	109.000	1.400	354.000	1590.000	0.000
RANGES	2.065	225.260	2438.500	1130.000	7.380	0.000	221.000	95496.000	174.000	1340.000	8339.938	69.600	127.000	108.500	.700	353.900	1586.000	0.000
STANDARD DEVIATIONS	.389	25.235	415.141	273.536	1.333	0.000	33.080	13908.403	21.986	257.095	933.299	10.251	23.347	12.441	.256	38.801	188.851	0.000

SOIL SAMPLES

	AU -PPM	AG -PPM	AS -PPM	BA -PPM	BE -PPM	CD -PPM	CO -PPM	CU -PPM	PB -PPM	MN -PPM	HG -PPM	MO -PPM	NI -PPM	SN -PPM	W -PPM	U3O8-PPM	ZN -PPM	ZN/CD
NUMBER OF SAMPLES	83.	246.	244.	249.	249.	2.	249.	249.	249.	249.	220.	74.	249.	240.	2.	244.	249.	2.
MEAN VALUES	.038	.059	5.016	183.133	.809	.160	21.482	57.494	5.884	692.863	5.002	6.123	40.663	1.214	3.950	.770	46.353	191.991
MINIMUM VALUES	.005	.010	.600	10.000	.310	.110	4.000	7.000	1.000	60.000	.019	.700	6.000	.200	2.800	.100	8.000	147.619
MAXIMUM VALUES	1.220	.560	39.200	1030.300	2.100	.210	56.000	442.000	39.000	3850.000	1060.000	112.000	129.000	5.900	5.100	7.100	216.000	236.364
RANGES	1.215	.550	38.600	1020.300	1.790	.100	52.000	435.000	38.000	3790.000	1059.981	111.300	123.000	5.700	2.300	7.000	208.000	88.745
STANDARD DEVIATIONS	.139	.066	5.497	103.006	.248	.071	8.310	44.200	3.543	414.821	71.453	17.797	25.259	.927	1.626	.730	23.805	62.752

TOTALS

NUMBER OF SAMPLES	241.	1339.	1417.	1487.	1487.	760.	1486.	1487.	1486.	1487.	1417.	352.	1487.	1344.	38.	1482.	1487.	760.
MEAN VALUES	.040	.332	8.846	199.163	.929	.199	17.019	274.240	9.406	686.069	9.282	5.070	28.788	2.161	2.524	1.852	47.922	304.369
MINIMUM VALUES	.005	.010	.200	10.000	.060	.020	1.000	2.000	.600	30.000	.002	.700	1.000	.100	1.000	.100	4.000	29.268
MAXIMUM VALUES	2.070	225.280	2440.000	1150.300	7.440	1.640	222.000	95500.000	176.000	4710.000	8340.000	112.000	148.000	109.000	6.400	354.000	1590.000	2850.000
RANGES	2.065	225.270	2439.800	1140.000	7.380	1.620	221.000	95498.000	175.400	4680.000	8339.998	111.300	147.000	108.900	5.400	353.900	1586.000	2820.732
STANDARD DEVIATIONS	.162	6.444	88.727	110.295	.523	.119	12.119	3480.420	7.481	341.677	226.133	10.019	25.208	4.330	1.601	9.632	49.281	267.483

possible 1,151 samples had gold values above the detection limit (0.005 ppm). Silver was selected to be a stand-in for gold. A stepwise multiple regression was run with assay values in logarithms, with silver as the dependent variable and with Be, U_3O_8, Zn, Pb, Cu, Hg, As, Co, Ni, Mn, Ba, and Sn as the independent variables. This regression is listed in Table 6. The stepwise equations are given in order of the appearance of an element. The bottom line of the table is the R^2 of each of the equations and shows the amount of correlation added by each element. The correlation starts at 0.19 and ends at 0.27, which means at the start, 19 percent of the variation of silver could be explained by beryllium, and, after the other eleven elements were added, 27 percent of variation of silver could be explained.

Least Squares Correlations and Scatter Graphs

For a study of this kind, it is necessary to determine which elements follow which other elements--and how well they follow. The last part of the computer printout contains the least-square correlations and scatter graphs for each element against every other element. All values are in logarithms. The R^2 of each of the least squares is given in Table 7. The series of 1's that go diagonally down and across the table illustrates that an element is 100 percent correlated with itself. From Table 7 all pairs of elements that had an R^2 of 0.1 were picked for Table 8, which in turn, contains the least squares equation for each of the pairs, the number of observations from which the equation was drawn, and the R^2 of the equation. The samples were assayed for seventeen elements. If two element values are highly correlated (high R^2), then not many are lost by not assaying one of the elements. The R^2 between nickel and cobalt is 0.79, which means that for this report it was not necessary to assay one of these two elements.

Anomalous Value Thresholds

The next step was to assign a value to each element over which an assay value would be considered anomalous. For each of the silt-sample elements from Table 5, the mean and two standard deviations were added together as the first attempt to obtain the threshold values. These values were then compared to the corresponding frequency tables and histograms, which were in logarithms. To make the comparison, the antilogarithms of the values shown in the frequency tables and histograms had to be figured. The comparison was too high. Values were picked from frequency tables and histograms, and they were about the same as the means with one and one-half standard deviations. The threshold values

Table 6. Stepwise multiple regression analysis with assay values in logarithms using silver as the dependent variable and beryllium, uranium oxide, zinc, lead, copper, mercury, arsenic, cobalt, nickel, manganese, barium, and tin as the independent variables*

$Ag = -1.25477 + 0.825547\ Be$

$Ag = -1.28414 + 0.621207\ Be + 0.181202\ U_3O_8$

$Ag = -1.72858 + 0.412034\ Be + 0.239508\ U_3O_8 + 0.261227\ Zn$

$Ag = -2.05949 + 0.289244\ Be + 0.229002\ U_3O_8 + 0.339984\ Zn + 0.200928\ Pb$

$Ag = -2.19420 + 0.269735\ Be + 0.265301\ U_3O_8 + 0.114893\ Zn + 0.368334\ Pb + 0.25999\ Cu$

$Ag = -2.15370 + 0.255195\ Be + 0.247292\ U_3O_8 + 0.135000\ Zn + 0.387869\ Pb + 0.236679\ Cu + 0.0706949\ Hg$

$Ag = -2.16175 + 0.259153\ Be + 0.240203\ U_3O_8 + 0.147491\ Zn + 0.401072\ Pb + 0.227804\ Cu + 0.0663993\ Hg - 0.0356599\ As$

$Ag = -2.19118 + 0.252992\ Be + 0.252399\ U_3O_8 + 0.163416\ Zn + 0.395352\ Pb + 0.179534\ Cu + 0.0670665\ Hg - 0.0409950\ As + 0.0667244\ Co$

$Ag = -2.22032 + 0.231871\ Be + 0.242774\ U_3O_8 + 0.173621\ Zn + 0.391204\ Pb + 0.209629\ Cu + 0.0614821\ Hg - 0.0332432\ As + 0.112314\ Co - 0.0679952\ Ni$

$Ag = -2.06058 + 0.249225\ Be + 0.247044\ U_3O_8 + 0.175669\ Zn + 0.396239\ Pb + 0.199944\ Cu + 0.0641249\ Hg - 0.0322238\ As + 0.169190\ Co - 0.0798640\ Ni - 0.079926\ Mn$

$Ag = -2.12794 + 0.237199\ Be + 0.239183\ U_3O_8 + 0.191345\ Zn + 0.391412\ Pb + 0.203426\ Cu + 0.0645486\ Hg - 0.0341032\ As + 0.173238\ Co - 0.0868606\ Ni - 0.103271\ Mn + 0.0608589\ Ba$

$Ag = -2.12049 + 0.242190\ Be + 0.238634\ U_3O_8 + 0.191608\ Zn + 0.390874\ Pb + 0.200928\ Cu + 0.0664689\ Hg - 0.0340659\ As + 0.170929\ Co - 0.0870112\ Ni - 0.101879\ Mn + 0.0599091\ Ba - 0.00821436\ Sn$

R^2 as each element added	0.188	0.212	0.226	0.240	0.261	0.268	0.269	0.269	0.270	0.271	0.272	0.272

* Au, Cd, Mo, W, Zn/Cd were not used because too few assay values were above level of detection.

Table 7. Correlation R^2 values between the logarithms of the element assays

	Au	Ag	As	Ba	Be	Cd	Co	Cu	Pb	Mn	Hg	Mo	Ni	Sn	W	U_3O_8	Zn
Au	1	0.0169	0.000	0.004	0.032	0.002	0.005	0.004	0.000	0.007	0.014	0.019	0.002	0.014	0.790	0.035	0.008
Ag		1	0.003	0.040	0.176	0.138	0.003	0.000	0.071	0.028	0.009	0.013	0.022	0.009	0.189	0.135	0.048
As			1	0.038	0.024	0.078	0.034	0.141	0.191	0.020	0.081	0.211	0.023	0.000	0.203	0.001	0.000
Ba				1	0.045	0.118	0.011	0.061	0.156	0.156	0.000	0.029	0.065	0.002	0.122	0.150	0.009
Be					1	0.161	0.011	0.000	0.166	0.147	0.006	0.014	0.058	0.055	0.061	0.307	0.209
Cd						1	0.094	0.164	0.453	0.062	0.001	0.005	0.282	0.052	0.025	0.213	0.002
Co							1	0.651	0.228	0.298	0.023	0.005	0.738	0.064	0.000	0.204	0.191
Cu								1	0.377	0.116	0.076	0.000	0.650	0.039	0.059	0.096	0.381
Pb									1	0.003	0.051	0.007	0.338	0.027	0.148	0.177	0.020
Mn										1	0.033	0.031	0.070	0.000	0.052	0.003	0.123
Hg											1	0.028	0.004	0.027	0.000	0.004	0.014
Mo												1	0.057	0.042	0.001	0.066	0.005
Ni													1	0.077	0.009	0.310	0.192
Sn														1	0.151	0.048	0.000
W															1	0.000	0.050
U_3O_8																1	0.000
Zn																	1

Table 8. Least squares equations for each pair of elements with an R^2 of 0.1 or better

Equation		No. of observations	R^2
Au(log) = - 2.52527 + 1.0000	W(log)	4	0.790
Ag(log) = - 1.27011 + 0.790697	Be(log)	1007	0.176
Ag(log) = - 0.995574 + 0.493686	Cd(log)	643	0.138
Ag(log) = - 1.65881 + 1.0000	W(log)	22	0.189
Ag(log) = - 1.35334 + 0.352587	U_3O_8(log)	1007	0.135
As(log) = 0.929300 - 0.376604	Cu(log)	1112	0.141
As(log) = - 0.131657 + 0.602022	Pb(log)	1112	0.191
As(log) = 0.446191 + 0.532349	Mo(log)	201	0.211
As(log) = 0.490188 + 1.00000	W(log)	29	0.203
Ba(log) = 0.228908 + 0.471602	Be(log)	1151	0.145
Ba(log) = 2.46435 + 0.271861	Cd(log)	758	0.118
Ba(log) = 1.93739 + 0.337667	Pb(log)	1151	0.156
Ba(log) = 0.822743 + 0.504541	Mn(log)	1151	0.156
Ba(log) = 1.78240 + 1.0000	W(log)	29	0.122
Ba(log) = 2.23566 + 0.246119	U_3O_8(log)	1151	0.150
Be(log) = 0.093795 + 0.258123	Cd(log)	758	0.161
Be(log) = - 0.346552 + 0.281553	Pb(log)	1151	0.166
Be(log) = - 1.21079 + 0.397618	Mn(log)	1151	0.147
Be(log) = - 0.101746 + 0.285344	U_3O_8(log)	1151	0.307
Be(log) = - 0.794276 + 0.431253	Zn(log)	1151	0.209

Equation	No. of observations	R^2
Cd(log) = - 0.353472 - 0.323478 Cu(log)	758	0.164
Cd(log) = - 1.48963 + 0.755837 Pb(log)	758	0.453
Cd(log) = - 0.325359 - 0.359852 Ni(log)	758	0.282
Cd(log) = - 0.781532 + 0.388379 U_3O_8(log)	758	0.213
Co(log) = 0.322824 + 0.597804 Cu(log)	1150	0.651
Co(log) = 1.58115 - 0.492028 Pb(log)	1150	0.228
Co(log) = 1.24328 + 0.840091 Mn(log)	1150	0.298
Co(log) = 0.403735 + 0.575495 Ni(log)	1150	0.738
Co(log) = 1.14591 - 0.345547 U_3O_8(log)	1150	0.204
Co(log) = 0.124238 + 0.613588 Zn(log)	1150	0.191
Cu(log) = 2.13112 - 0.851309 Pb(log)	1151	0.377
Cu(log) = - 0.641553 + 0.704807 Mn(log)	1151	0.116
Cu(log) = 0.431789 + 0.727684 Ni(log)	1151	0.650
Cu(log) = - 0.562713 + 1.16701 Zn(log)	1151	0.381
Pb(log) = 1.39556 - 0.378268 Ni(log)	1151	0.388
Pb(log) = 0.714891 + 1.0000 W(log)	29	0.148
Pb(log) = 0.903556 + 0.313432 U_3O_8(log)	1151	0.177
Ni(log) = 1.29135 - 0.636727 U_3O_8(log)	1151	0.310
Ni(log) = - 0.241232 + 0.916638 Zn(log)	1151	0.192
Sn(log) = - 0.303882 + 1.0000 W(log)	25	0.151

(assay values which are equal or greater are considered anomalous) are gold, 0.005 ppm; silver, 0.1 ppm; arsenic, 4.5 ppm; barium, 250 ppm; beryllium, 1 ppm; cadmium, 0.3 ppm; cobalt, 24 ppm; copper, 45 ppm; lead, 10 ppm; manganese, 800 ppm; mercury, 0.2 ppm; molybdenum, 7 ppm; nickel, 25 ppm; tin, 2 ppm; tungsten, 1 ppm; uranium oxide, 2 ppm; zinc, 60 ppm; and zinc/cadmium ratio, 700.

Soil-Sample Profiles

Fourteen soil-sampling traverses were completed: seven in the Owyhee Reservoir (WSA 3-56) and seven in Pueblo Mountains (WSA 2-81L). Six elements were picked to be plotted on semilogarithm graph paper. Beside gold and silver, the other four were the first to come into the stepwise multiple regression. They were beryllium, uranium oxide, zinc, and lead. The 14 profiles, given letters "A" through "N", are shown in the following figures: Figure 5, profiles A-A' through G-G'; Figure 6, profiles H-H' and I-I'; Figure 7, profile J-J'; Figure 8, profile K-K'; Figure 9, profile L-L'; and Figure 10, profiles M-M' and N-N'. A scale is given for each profile along with the starting and stopping site numbers for each traverse. If there is a change in a numerical series within a traverse, the change in site numbers will also be shown. Figure 5 is located in the Owyhee Reservoir section, and Figures 6 - 10 in the Pueblo Mountains section.

If the soil profiles are compared with the threshold anomalous value listed in the previous section, only the top of the peaks would be considered anomalous. The threshold values used in this study were a good compromise for the total picture, but as the soil profiles show, the values may have been much too high for some local areas.

Computer-Plotted Anomaly Overlays

Using the R^2 from Table 7, decisions were made on which elements were to be plotted together. The 18 elements were plotted on four overlays for each of the seven base maps. To show anomalous values for each of up to five elements on a single overlay, a nested system of symbols were used. The symbols, large to small, were an octagon, square, diamond, plus, and a cross. For the first set of overlays, gold values equal to or greater than 0.005 ppm were shown by the octagon, tungsten values equal to or greater than 1 ppm by the square, silver values 0.1 ppm by the diamond, beryllium values equal to or greater than 1 ppm by plus, and tin values equal to or greater than 2 ppm by the cross. These overlays

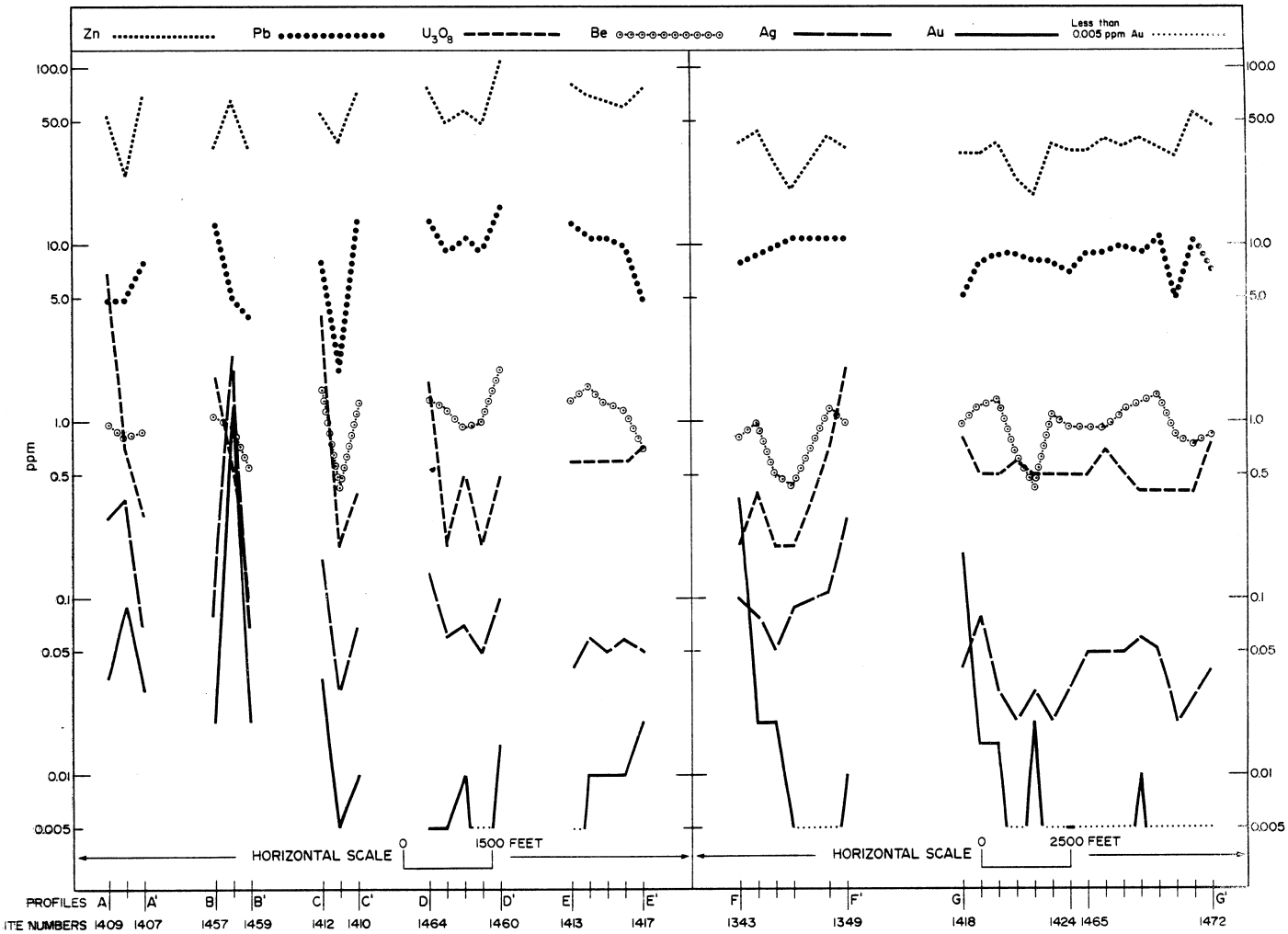

Figure 5. Owyhee Reservoir area (WSA 3-56), soil profiles A-A' through G-G', showing zinc, lead, uranium oxide, beryllium, silver, and gold.

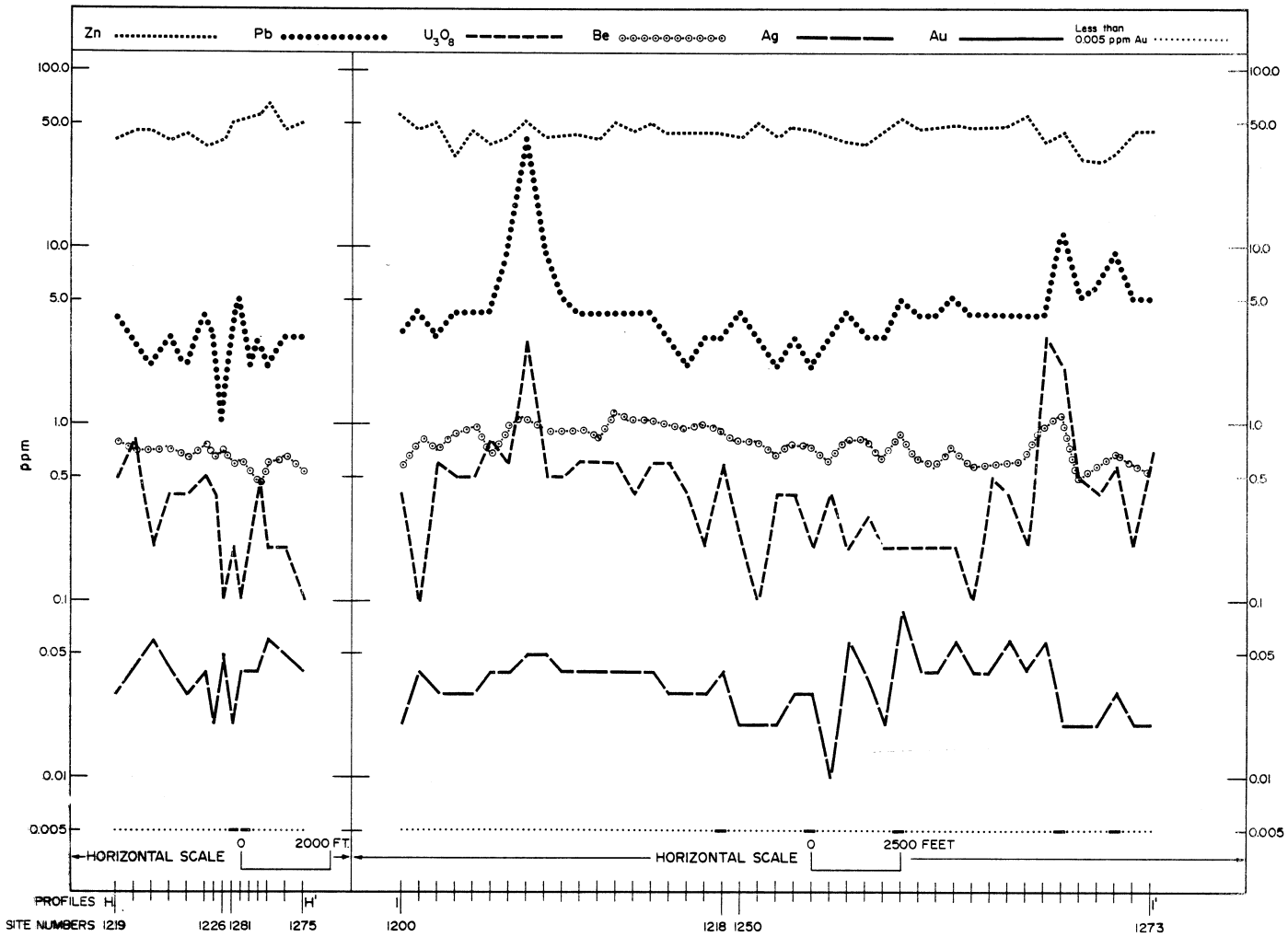

Figure 6. Pueblo Mountains area (WSA 2-81L), soil profiles H-H' and I-I', showing zinc, lead, uranium oxide, beryllium, silver, and gold. Note: sample no. 1200 had 103 ppm Ni, 1275 had 104 ppm Ni, 1277 had 90 ppm Ni and 109 ppm Cu, and 1278 had 129 ppm Ni.

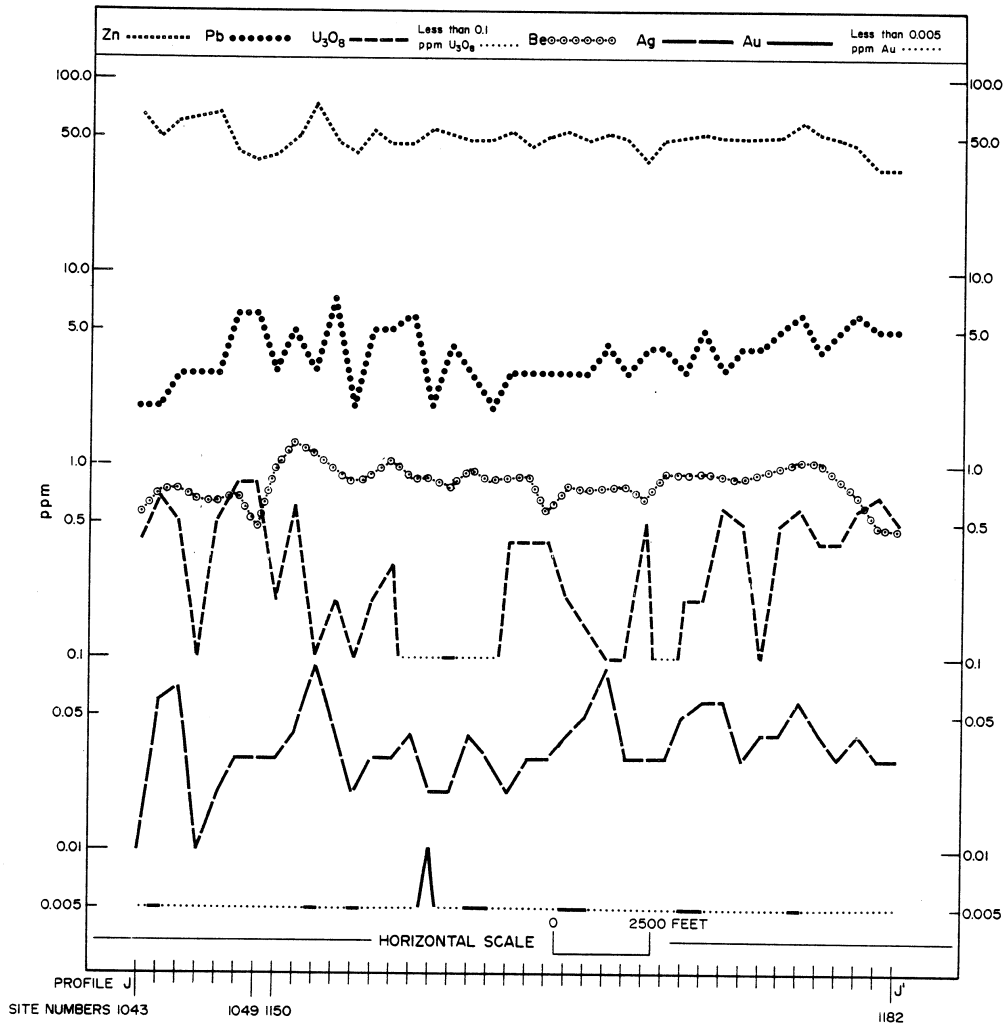

Figure 7. Pueblo Mountains area (WSA 2-81L), soil profile J-J', showing zinc, lead, uranium oxide, beryllium, silver, and gold. Note: sample no. 1043 had 100 ppm Ni, 1044 had 129 ppm Ni, 1049 had 1060 ppm Hg, 1151 had 290 ppm Cu, 1206 had 410 ppm Cu, 1207 had 220 ppm Cu and 12 ppm As, 1208 had 320 ppm Cu and 14 ppm As, and 1209 had 21 ppm As.

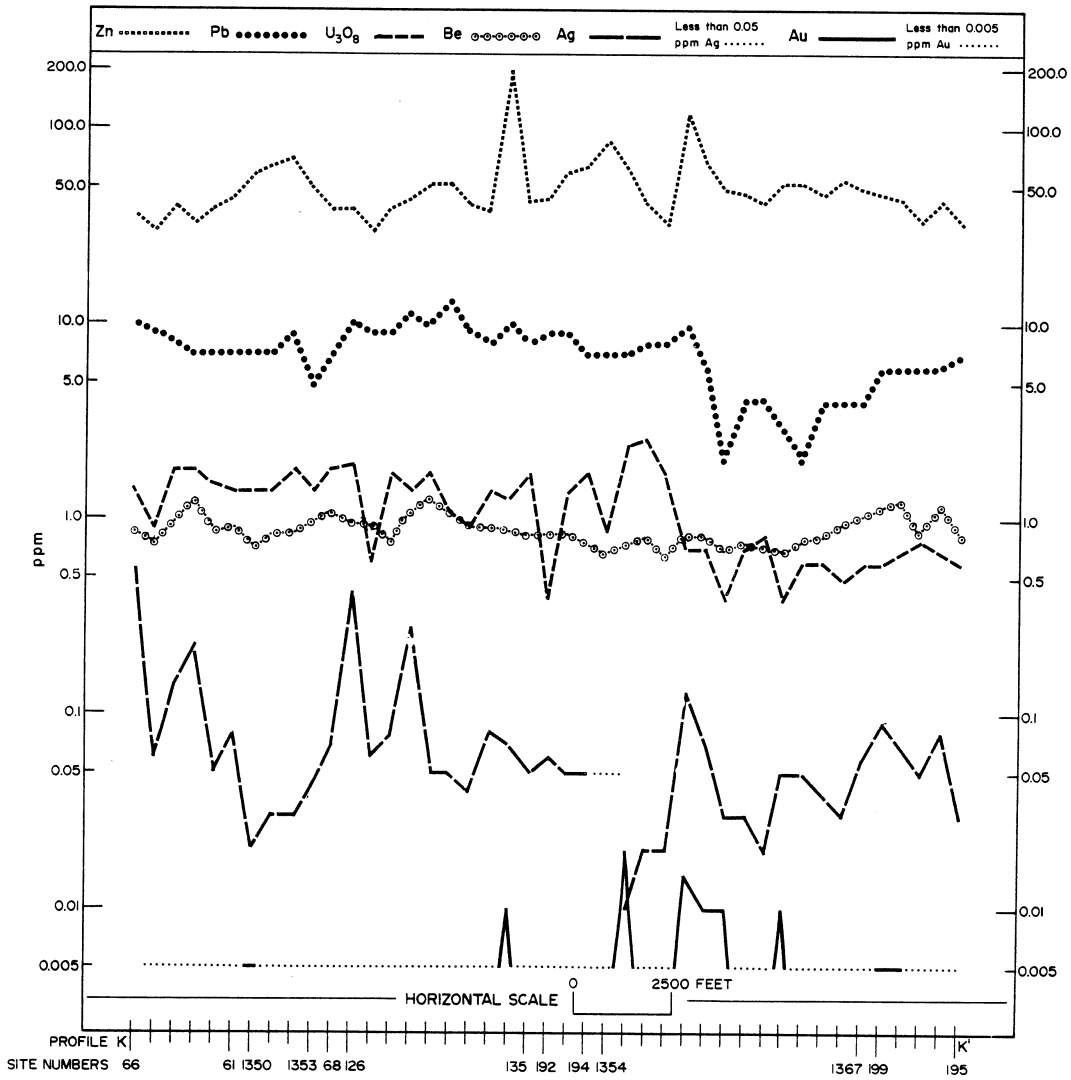

Figure 8. Pueblo Mountains area (WSA 2-81L), soil profile L-L', showing zinc, lead, uranium oxide, beryllium, silver, and gold. Note: sample no. 62 had 92 ppm Mo, 130 had 60 ppm Mo, 134 had 119 ppm Cu, 1353 had 111 ppm Ni, 1354 had 15 ppm Mo and 16 ppm As, and 1358 had 12 ppm Mo and 18 ppm As.

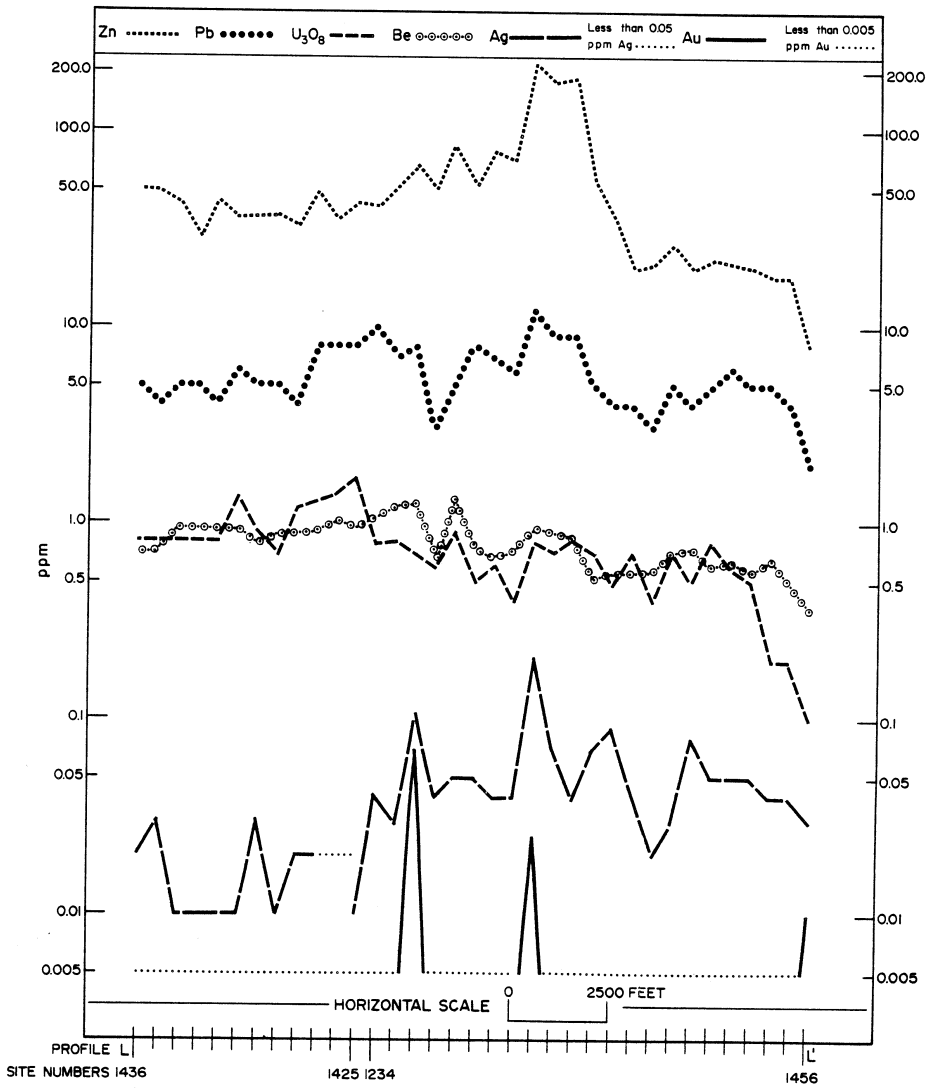

Figure 9. Pueblo Mountains area (WSA 2-81L), soil profile L-L', showing zinc, lead, uranium oxide, beryllium, silver, and gold. Note: sample no. 1229 had 144 ppm Cu, 1234 had 144 ppm Cu, 1235 had 367 ppm Cu, 1241 had 17 ppm As, 1242 had 1030 ppm Ba and 442 ppm Cu, and 1245 had 118 ppm Cu.

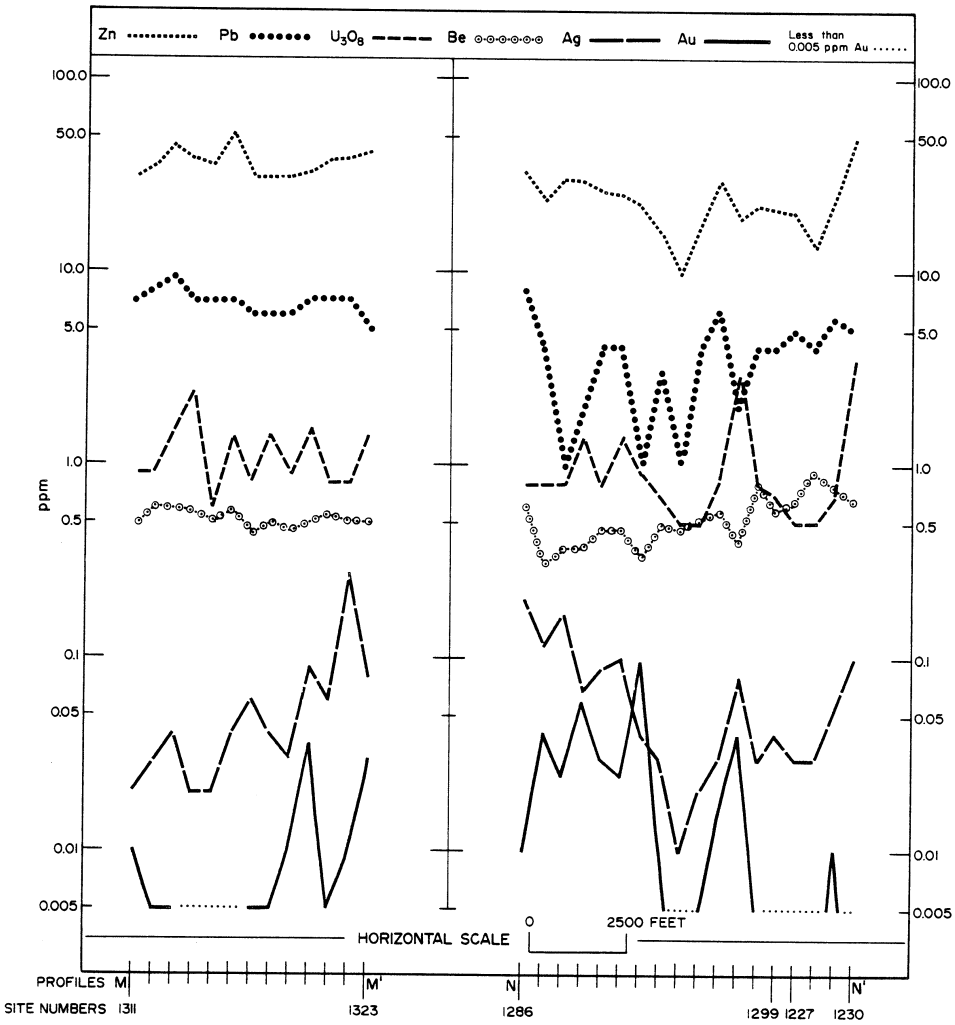

Figure 10. Pueblo Mountains area (WSA 2-81L), soil profiles M-M' and N-N', showing zinc, lead, uranium oxide, beryllium, silver, and gold. Note: sample No. 1230 had 125 ppm Cu and 112 ppm Mo, 1317 had 11 ppm As, 1322 had 14 ppm As, and 1323 had 106 ppm Cu.

are marked with the name of the study area and the elements shown. For the second set of overlays, arsenic values equal to or greater than 4.5 ppm were shown by the square, mercury values equal to or greater than 0.2 ppm by the diamond, molybdenum values equal to or greater than 7 ppm by the plus, and zinc/cadmium ratio equal to or greater than 700 by the cross. For the third set of overlays, barium values equal to or greater than 250 ppm are shown by the octagon, cadmium values equal or greater than 0.3 ppm by the square, lead values equal to or greater than 10 ppm by the diamond, uranium oxide values greater than 2 ppm by the plus, and manganese values greater than 800 ppm by the cross. For the fourth and last set of overlays, cobalt values equal to or greater than 24 ppm are shown by the square, copper values equal to or greater than 45 ppm by the diamond, nickel values equal to or greater than 25 ppm by the plus, and zinc values equal to or greater than 60 ppm by the cross.

WILDERNESS STUDY AREA SUMMARY REPORTS

General

The 18 WSA's were grouped into six reporting areas on the basis of their proximity and their similar geology. The areas are discussed in this report in the order listed in Table 1, starting with the Owyhee Reservoir area, moving upstream for the Middle Owyhee area and then to the Upper Owyhee area. The discussion turns clockwise through the Trout Creek Mountains, the Pueblo Mountains, and ends with Steens Mountain.

Owyhee Reservoir Area

(WSA Unit Nos 3-56, Dry Creek Butte; 3-74A, Bannock Ridge; 3-75, Slocum Creek; 3-77A, Honeycombs)

General

The Owyhee Reservoir general area covers about 100,000 acres, or 156 mi^2, and is made up of four individual wilderness study areas that are located along and adjacent to the Owyhee Reservoir in north-central Malheur County. Three of the individual areas, Honeycombs, Slocum Creek, and Bannock Ridge, are contiguous and form a roughly 5-mi-wide and 20-mi-long strip along the east side of the Owyhee Reservoir. The Dry Creek Buttes area is also a long narrow strip of about the same size along the west side of the reservoir. Access to the west side of the reservoir is from the north via U.S. Highway 20 and then from a secondary road which turns southward 4 mi west of Vale through Sand Hollow and Negro Rock Canyon. Access to the area east of the reservoir is by an unimproved gravel road that leaves Oregon State Highway 201 about 25 mi south of Nyssa and parallels Sucker Creek. The Sucker Creek road continues southward and joins U.S. Highway 95 20 mi north of Jordan Valley. Another unimproved road trends westward from near this junction to the upper end of the Owyhee Reservoir. In late summer and low water this road crosses the river at a ford and joins the southern extension of the Sand Hollow-Negro Rock Canyon road. Elevations range from the normal pool elevation of the Owyhee Reservoir at 2,655 ft to about 5,500 ft on the northwest flank of Mahogany Mountain and Bannock Ridge. The climate is one of desert (10 in. or less of annual precipitation), with cold winters and hot, dry summers. The vegetation reflects the climate, and low-growing sage brush and cheat grasses are predominant. The general area is in the Owyhee Uplands physiographic province, a rolling to rugged upland of 4,000 to 5,000 ft elevation which has been moderately to deeply dissected by the north- to northeastward-flowing Owyhee River and its tributaries.

Geology

The geological map was compiled from the work of Walker and Repenning (1966), Walker (1977), Kittleman and others (1967), and Corcoran and others (1962), who have completed reconnaissance studies that cover or border the Owyhee Reservoir area. The general stratigraphic column developed for all the wilderness study areas in southeastern Oregon contains information from these reports. Formational names have been used where possible; however, emphasis

has been placed on descriptions of the various lithologies as they relate to potential mineral deposits. The region is underlain by a thick section of middle to upper Cenozoic volcanic and associated pyroclastic and sedimentary rocks. These rocks, which include resistant lava and ash-flow tuffs as well as poorly cemented and easily eroded sediments and tuffs, now display a varied landscape of rounded hills, flat-topped mesas, and deep gorges.

All the rocks within the area are Miocene or younger in age and include rhyolite and basalt flows, airfall and ash-flow tuffs, and tuffaceous sedimentary rocks. There are also large areas underlain by a variety of Pleistocene and Recent surficial sediments. The rocks were all deposited in a broad, north-plunging basin or basins that evolved in eastern Oregon and western Idaho beginning in late Miocene time. The Miocene sedimentary rocks and lava flows have been moderately deformed and broken into several separate fault blocks. These blocks are not as large or the displacements as great as in the Basin and Range terrain to the south and west. The Pliocene and Pleistocene rocks of the adjoining Rome basin just to the south are only slightly deformed and indicate a lessening of the stresses in the late Cenozoic tectonic history of the general area.

Stratigraphy

The oldest rocks of the area are a 2,000-ft-thick sequence of varicolored, thin- to thick-bedded tuffaceous lake-bed deposits, a massive ash-flow tuff unit, and some interbedded basalt and rhyolite flows. These have been designated as units Tsc and Tlg on the geologic maps. The underlying basement rocks are unknown but probably are Mesozoic metamorphic and granitic rocks similar to those that crop out in southwestern Idaho and northern Nevada.

Kittleman (1962) first proposed the name Sucker Creek Formation for these light-colored bedded deposits. The sediments include brown to yellowish to greenish tuffaceous volcanic and arkosic sandstones, waterlaid tuffs, carbonaceous shales, massive siltstones, and very minor conglomerates. They are basically nonindurated and in many places more or less altered to clay minerals (bentonite), which gives their surface a cracked or expanded appearance. The prominent ash-flow tuff layer is called the Leslie Gulch member by Kittleman for prominent outcrops along that creek. It is reported to be a complexly zoned rhyolitic ash-flow tuff. This thick (as much as 1,000 ft) pinkish deposit was apparently erupted from an unknown source nearby. It is now somewhat

indurated, and differential erosion has carved it into a maze of steep (even overhanging) cliffs, spires, and pinnacles. It is present over an area of at least 100 sq mi and represents a volcanic eruption or several closely spaced eruptions of tremendous magnitude.

The fine-grained basalt flows of the formation are low in the section and are not known to crop out in the study area.

Reddish to brownish domes, flows, and breccia of rhyolitic, rhyodacitic, and dacitic composition are widespread in the upper part of and just above the Sucker Creek Formation. Corcoran and others (1962) suggest they may be a part of a large mass of acidic lavas that occur south of the reservoir in Oregon and extend into the Silver City quadrangle in southwestern Idaho. They are designated as unit Trh on the geologic maps, and include the Jump Creek Rhyolite and Littlefield Rhyolite of Kittleman and others (1965) and the extensive unnamed domes, intrusives, and flows mapped by Walker and Repenning (1966) in the southeastern corner of Oregon. Potassium-argon dates range from 13 to 16 m.y.B.P.

Overlying the Sucker Creek Formation and rhyolite (unit Trh) unconformably is a thick sesion of westward-dipping basalt flows and interbedded tuffs of late Miocene age. The Owyhee Basalt type section in the Owyhee Canyon downstream from the north boundary of the study area reaches a thickness of about 1,500 ft. Individual flows are dark gray to black, dense to scoriaceous olivine-free basalt. The Owyhee Basalt, unit Tbo on the geologic maps, appears to have the same stratigraphic position and age as a part of the Columbia River Basalt Group and the Steens Basalt and probably correlates with them. Interbeds of reddish tuff, cinders, and scoria are common between the individual flows of dark-gray to black, dense, olivine-poor basalt. Small basaltic intrusions, volcanic necks, dikes, and sills (unit Tbi) on the geologic maps) may have been feeders for the Owyhee Basalt flows.

Upper Miocene sedimentary rocks with some thin interbedded basalt flows disconformably overlie the Owyhee Basalt and Sucker Creek Formation. Corcoran and others (1962) named this sequence of rocks, designated as units Tds and Tdb on the geologic maps, for strata exposed in Deer Butte and Mitchell Butte north of the Owyhee Reservoir. They underlie most of the area west of the reservoir, and well-cemented arkose sandstones and conglomerates make up many of the prominent hills such as Dry Creek Butte, Burnt Mountain, and Pinnacle Point. The basalt flows (unit Tdb) are intercalated in the lower part of the formation with tuffaceous siltstones, claystones, and shales probably deposited

in a lacustrine environment. Calcite veins as much as 25 ft wide and traceable for up to half a mile are characteristic for this part of the formation. The upper part of the formation is coarser and contains massive beds of arkosic sandstone and well-cemented conglomerate that contains cobbles of granite, rhyolite, quartzite, and quartz. The source area for these constituents of the rocks is not positively known but believed to be the Silver City, Idaho, area, where a Mesozoic granitic pluton and metamorphic rocks are present. Some dikes and masses of intrusive olivine basalt (unit Tdbi) intrude the Deer Butte sediments and probably are sources for the Deer Butte lava flows.

The youngest rocks in the are thin flows of olivine basalt (unit QTb) of Pliocene(?) or Pleistocene age that cap low mesa-like landforms (North Table and South Table) in the southern part of the area. Surficial alluvium and colluvium (unit Qalc) of the present streams and terrace deposits associated with them are shown on the geologic maps only where they are conspicuous or cover large areas.

Structure

ERTS high-elevation photographs show the overall grain of the Owyhee Reservoir area to be about north-south to slightly west of north.

The large-scale structure of the Owyhee Reservoir area appears to have some relationship to the much larger Snake River downwarp to the northeast. The Miocene lavas and sediments have been moderately deformed and broken into a number of separate fault blocks. The predominant trend of the faults is northerly, and though the pattern resembles that of the extensional tectonism of the Basin and Range Province, the displacement on individual faults is not nearly as great. It cannot be determined directly, but several segments of the river canyon appear to be controlled by this alignment of ridges and valleys. The area as a whole is a northward-plunging faulted basin which began to form at least as early as mid-Miocene time. The depression continued to grow and fill with lava and sediments; however, the Pliocene sediments show less displacement on the northerly-trending normal faults, and since Pleistocene time, there appears to have been little or no deformation. Volcanic activity has been voluminous and continuing. It is probably episodic like the Basin and Range Province to the west. Of the several episodes of late basalt flows, those of the Cow Lakes area just to the southeast are the youngest and may be as young as 10,000 years ago.

Geophysical Data

Heat-flow geophysical data are discussed in the later section on geothermal energy.

Mines, Prospects, and Mineralized Areas

Along and slightly within the east edge of the boundary of the Honeycombs (3-77A) WSA, many mines and prospects for picture rock (jasperoid) have been located. The picture rock is a jasperoid which is a bright-colored silicified sediment. The bright colors are caused by the weathering of pyrite. Four sites were sampled, and all had anomalous metal values. One site (no. 321) had unweathered disseminated sulfides. Calcite veins, another indicator of mineralization, which were prospected for optical-grade calcite in the early 1940's, are found a short distance to the north of this WSA in secs. 26 and 27, T. 23 S., R. 44 E. Other calcite veins were sampled (sample no. A0443R01) along the west boundary of Dry Creek Buttes (3-74A). Both sets of calcite occurrences are described by Lowry (1943). Quartz Mountain (sec. 6, T. 25 S., R. 43 E.), a short distance to the west of the study area, was soil sampled because a mining firm had blocked out a group of claims around a mercury-gold anomaly. The sample, no. A0467D01, confirmed the anomaly.

After the field season, a block of 90 claims was staked adjacent to and north of the north boundary of WSA 3-56. The claims were reported to cover a silicified breccia zone 3 mi long and a quarter mile wide. Many rock-chip samples and two soil profiles were taken near and across Red Butte (secs. 26, 27, 34, and 35, T. 25 S., R. 43 E.). Red Butte is a large, bright-colored silicified area which stands up in relief. There is an old prospect pit at the top, and along the east side a hydrofractured breccia is exposed. A basalt dike to the west of the butte was partly silicified and was therefore also soil profiled and rock-chip sampled. Other isolated picture rock outcrops were also sampled. A reported mineralized sandstone a short distance west of the boundary and south of Quartz Mountain was also sampled (sample no. A1382R01) and was found to be mineralized.

The rock-chip data are given in Table 9. All of the samples had anomalous values in one or more elements.

Geochemical Sampling Results

The computer-generated overlay map for gold, tungsten, silver, and tin indicates that the total area is highly mineralized both east and west of the

Table 9. Rock-chip sample data for the Owyhee Reservoir area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec.	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
3-56 Dry Creek Buttes	A0378R04	24	43	14	7 7 7	Outcrop	Igneous	Calcite	Au, Ni	———
	A0396R01	25	43	22	9 9 9	Outcrop	Sedimentary	Silica	Au, Ag, As, Ba, Be, Ni, Sn, U_3O_8	———
	A0397R01	24	43	25	7 6 6	Outcrop	Igneous	Silica, sulfides	Ag, As, Cu, Pb, Ni	———
	A0443R01	23	43	21	6 8 9	Outcrop	Unidentified	Calcite	Ag, Mo, Ni, Sn	———
	A0447R01	24	43	12	9 9 9	Outcrop	Jasperoid	Silica	Au, Ag, As, Ba, Cu, Mo, U_3O_8	———
	A0448R01	24	43	14	6 9 7	Outcrop	Jasperoid	Silica	Au, Ag, As, Cu, Ni	———
	A0458R02	25	43	35	7 8 9	Outcrop	Jasperoid	Silica, calcite	Au, Ag, Be, Cu, Mo, Ni, Sn	———
	A0458R03	25	43	35	7 8 9	Outcrop	Jasperoid	Silica	Au, Ag, As, Ba, Be, Cu, Pb, Mo, Sn, U_3O_8	———
	A0458R04	25	43	35	7 8 9	Outcrop	Jasperoid	Silica	Au, Ag, Be, Cu, Mo, Ni, Sn	———
	A0461R01	25	44	19	7 8 7	Outcrop	Jasperoid	Silica	Ag, As, Be, Cu, Hg, Mo, Ni, Sn	———
	A0466R01	26	43	11	8 8 9	Outcrop	Sedimentary	Iron	Ag, Be, Pb, Hg, Sn, U_3O_8, Zn	———
	A1382R01	25	43	17	8 6 9	Outcrop	Sandstone	Iron	Au, Ag, As, Ba, Be, Cu, Pb, Hg, Mo, Ni, U_3O_8	———
	A1383R01	25	43	22	7 8 9	Outcrop	Jasperoid	Silica	Au, Ag, As, Ba, Cu, Pb, Hg, Ni, U_3O_8	———
	A1384R01	25	43	22	9 9 6	Outcrop	Jasperoid	Silica	Au, Ag, As, Ba, Be, Hg, Mo, U_3O_8	———
	A1385R01	25	43	22	7 8 7	Outcrop	Siltstone	Iron	Au, Ag, As, Ba, Be, Cu, Pb, Hg, Sn, U_3O_8, Zn	———
	A1386R01	25	43	35	7 6 9	Outcrop	Jasperoid	Silica	Ag, As, Ba, Be, Cu, Hg, Ni, Sn, U_3O_8	———
	A1387R01	25	43	34	8 6 7	Outcrop	Sandstone	Silica	Ag, Be, Cu, Pb, Hg, U_3O_8	———
	A1388R01	25	43	34	8 6 7	Outcrop	Jasperoid	Silica	Au, Ag, As, Be, Cu, Pb, Hg, Mo, Sn, U_3O_8	———
	A1389R01	25	43	34	8 8 6	Outcrop	Jasperoid	Silica	Au, Ag, Cu, Pb, Hg, Mo	———
3-77A Honeycombs										
	A0207R01	24	45	19	6 7 8	Outcrop	Jasperoid	Silica	Ag, As, Be, Cu, Pb, Sn, U_3O_8, Zn	Painted Rock Canyon no. 1 claim
	A0316R01	25	45	32	7 6 6	Prospect pit	Jasperoid	Silica	Ag, Be, Cu, Pb, Hg, U_3O_8	Unknown claim
	A0317R01	25	45	29	7 6 9	Outcrop	Jasperoid	Silica	Ag, Be, Cu, Pb, Hg, Sn, U_3O_8, Zn	Owyhee Green claim
	A0321R01	25	44	25	7 9 6	Prospect Pit	Jasperoid	Silica, sulfides, limonite	Ag, As, Ba, Be, Cu, Pb, Sn, U_3O_8	Unknown claim

reservoir. There were anomalous gold values in the stream sediments of most of the drainages entering the reservoir. All rock-chip samples were anomalous in at least two to 11 different elements. The soil sampling traverses (Figure 5) showed that a large area around Red Butte has anomalous values in gold. The soil profiles in Figure 5 show that most of the traverses were not long enough, particularly F-F' and G-G', which were taken across the top of Red Butte. The other five profiles were across a basalt dike that appeared to swing to the south of Red Butte, which would put it in front of two gold highs shown in profiles F-F' and G-G'. All anomalies found in this study area were not related to any previously known mineralization, mines, or prospects.

Mineral Potential

General: This project examined the potential for oil and gas, geothermal energy, and metallic minerals. It was not designed to consider the nonmetals such as bentonite and zeolite or fuels such as oil shale or coal. It must be noted in passing that bentonite and zeolite beds were seen during field work. Also this area might have a potential for oil shale, because in a similar basin to the north in Wallowa County, a large coal field has been found.

For the full mineral potential of the area to be determined, a detailed study should also be made of the nonmetallic and fuel commodities.

Oil and gas: This area, the Middle Owyhee River area, and the northern half of the Upper Owyhee River area are all part of a large sedimentary basin. Since about 1900, there have been 20 to 25 oil and gas wildcat wells drilled in the Vale-Ontario area. Several of these wells produced small but significant flows of natural gas.

It would appear that about half of the federal lands in these areas are under oil and gas leases or are covered by applications to lease. Those lands not covered by leases or applications to lease are surrounded by lands that are. The facts that these areas are basins, a nearby area has been drilled, small gas shows have been found, and land has been or was wanted for lease all indicate that these areas have good potential for oil and gas.

Geothermal energy: The potential for geothermal energy is high (Oregon Department of Geology and Mineral Industries, 1982). Hot springs are present a short way to the north of the area and on the south edge of the area. Blackwell and others (1978) report anomalously high heat flow of 100 mW/m^2 for this area. The high geothermal gradients are also anomalous.

Metallic commodities: The Owyhee Reservoir study area, which includes WSA's 3-56, 3-74A, 3-75, and 3-77A, has a high potential to have a major gold mine.

The geochemical sampling of the silt (stream sediments), rock chips, and soil all show that the total study area is highly mineralized. Gold values up to 1.2 ppm and silver values up to 1.7 ppm were obtained. The rock-chip sampling (Table 9) and soil profiling (Figure 5) in the Red Butte area indicate a major gold exploration target. If gold values were to rise at the south end of traverses F-F' and G-G' they would be in the ore range. On the ground Red Butte shows several of the classical features of a hot-spring deposition model for an epithermal gold deposit, such as steeply dipping faults, a silica cap, hydrobrecciation, and anomalous values in several metals over a large area.

Middle Owyhee Area

(WSA Unit Nos. 3-59, Owyhee Breaks; and 3-110, Lower Owyhee Canyon)

General

The Middle Owyhee general area covers about 86,000 acres (134 mi^2) and includes about 30 mi of the Owyhee River Canyon and a variable-width strip of the upland on both sides, but mostly west, of the river. The southern boundary is about 10 mi north of Rome, and the area extends north and eastward as far north as the Owyhee Breaks in T. 27 S., R. 42 E. Most of this area is rather inaccessible except by secondary roads along the western boundary that extend northward from U.S. Highway 95 west of Rome and by similar roads that make a loop from Rome northward and eastward to the Cow Lakes and Jordan Valley.

This general area is also in the Owyhee Upland physiographic province, a more or less rolling plateau with elevations from 3,500 to 4,500 ft. The Owyhee River has eroded a steep and sinuous canyon through the thick section of middle to upper Cenozoic volcanic rocks that are present. As in the Owyhee Reservoir area to the north, the dissection by the river and its tributaries is responsible for the considerable relief in the topography. The lowest elevation on the river where it leaves the area near the mouth of Birch Creek is about 2,700 ft and the highest 4,870 ft in hills of Miocene ash-flow tuff just south of the canyon rim near the headwaters of Birch Creek.

Climatic conditions are similar to those mentioned for the Owyhee Reservoir area - a harsh desert one where temperatures even in summer can range widely

from near freezing to 100° F.

The topography of this area, especially of that part called the Owyhee Breaks and the Hole-in-the-Ground in T. 27 S., R. 42 E., exhibits landsliding on a grand scale. The thick layers of poorly cemented tuffaceous fine-grained sedimentary rocks overlain by thin resistant layers of basalt lava, when eroded by a vigorous youthful stream, are very susceptible to mass wasting or slumping of small to large areas. The Owyhee River within this area trends generally northward from the southern boundary until it reaches Jackson Hole, where it abruptly swings to the east as it traverses the 6 to 7 mi through the Hole-in-the-Ground. As it leaves that area at the south end of the Owyhee Breaks, a steep meandering canyon has been cut in resistant Leslie Gulch ash-flow tuff, and then a north trend is again established.

Geology

Very little geology of a detailed nature has been done within the area. The geologic map for this area is based on unpublished reconnaissance work by Walker (late 1960's), which he used in compiling the geologic map of the eastern half of Oregon (Walker, 1977). The geologic map by Kittleman and others (1967) of the Owyhee Reservoir extends nearly to the northern boundary of this area, and the same rock units continue southward into this area.

This area is basically a broad north-plunging basin filled with upper Miocene to Recent lacustrine and fluvially deposited sediments with interbedded and mesa-capping lava flows. In this part of the basin, known as the Rome Basin, the rocks are somewhat younger, and the "Rome Beds" of middle Pliocene age are prominent. Deformation is less severe, and only a few northwest- and north-trending normal faults of minor significance are present.

Stratigraphy

The oldest rocks are in the northern part of the area where the Owyhee River has carved a steep canyon in the upper Miocene Leslie Gulch member of the Sucker Creek Formation (unit Tlg). The basement rocks are not known; however, pre-Tertiary granitic plutonic and metamorphic rocks occur to the east and south in Idaho and Nevada and could be present in the subsurface. The Leslie Gulch tuff is a thick, complexly zoned brownish to tan to white ash flow with small crystals of quartz and sanidine. It is moderately resistant to erosion and has the ability to stand as steep slopes. The ash flow is as much as 1,700 ft thick in the Owyhee River canyon walls in the north part of

the area near the mouth of Birch Creek.

Rhyolite flows (unit Trh) in the upper part of the Sucker Creek Formation occur in two small outcrops: one near the mouth of Crooked Creek in the south part of the area and the other covering an area of about 2 sq mi and making up Iron Point in sec. 14, T. 28 S., R. 14 E. We have found no detailed information about these rocks; however, the outcrop at Iron Point is about 1,400 ft thick and dark reddish-brown in color. They probably are a part of the extensive unnamed domes, intrusives, and flows mapped by Walker and Repenning (1966) in the southeast corner of Oregon that have K-Ar dates of 13 to 16 m.y.B.P.

The upper Miocene Owyhee Basalt (unit Tbo) is missing in this area. The next overlying rocks are sediments of the Deer Butte Formation (unit Tds) with some interbedded basaltic lava flows (unit Tdb). The Deer Butte Formation within this study area occurs mainly west and north of the Owyhee River in the vicinity of Hole-in-the-Ground. The sediments are mainly tuffaceous siltstones, claystones, and mudstones (unit Tds) capped by olivine basalt flows (unit Tdb). The well-cemented arkosic sandstones and conglomerates that are prominent farther north in the Deer Butte Formation are subordinate in this area; however iron-stained, well-cemented sandstones that may be Deer Butte in age crop out near the mouth of Bogus Creek and in the Chalk Basin.

Above the Deer Butte is another unit of partly consolidated tuffaceous sandstone and siltstone, with minor amounts of conglomerate, tuff breccia, and pumice lapilli tuff (unit Tsb), which are in turn overlain by thin to thick, dark-gray to black, dense to open-textured (diktytaxitic) olivine basalt flows (unit Tob). These two units, which are believed to be mid-Pliocene in age, are correlated with the Kern Basin Formation and Chalk Butte Formation of Corcoran and others (1962), the Bully Creek Formation and Grassy Mountaion Formation of Kittleman and others (1965), and the "Rome Beds" of Baldwin (1964). The basalt flows are similar to those mapped as Grassy Mountain Basalt by Corcoran and others (1962) and the Antelope Flat Basalt of Kittleman and others (1965). K-Ar ages for the unit Tsb sediments range from 4.0 to 9.7 m.y. and the unit Tob basalt flows from 6 to 7 m.y.

Above the mid-Pliocene rocks are Pliocene-Pleistocene semiconsolidated ashy to palagonitic sedimentary rocks, mostly tuffaceous sandstone and siltstone (unit QTs), that grade laterally into unit QTb, which consists of thin flows of open-textured (diktytaxitic) basalt. Pleistocene sedimentary rocks, unit Qs, and thin gray to black diktytaxitic olivine basalt flows cover large areas of the upland surface north of Rome. The sediments are lacustrine clay and

silt, with some sand and gravel. Some layered chert-quartz pebble conglomerate is reported in this unit. The lava flows are young enough to retain their original surface features. Bogus Rim and Bogus Bench are capped by Pleistocene (unit Qb) lavas whose origin was probably in the Cow Lakes area. Unit Qb lavas surround Saddle Butte to the west and also the area around Burns Junction. The only younger rocks aside from the Quaternary alluvium are thin flows of scoriaceous, olivine-bearing basalts (unit Qhbf), whose blocky spiny or pahoehoe surfaces with their pressure ridges and tumuli are essentially unmodified by erosion. The absolute age of these young lavas, especially those of Cow Lakes, is not known, but their fresh surfaces indicate they are probably less than 10,000 years old - and could be considerably younger. Otto and Hutchinson (1977) suggest that, based on growth rates of lichen and weathering rates of exposed and unexposed basalt, the Cow Lakes lavas are between 4,000 and 9,000 years old. Minor amounts of Quaternary alluvium (unit Qalc) occur within the Owyhee River canyon and the main tributary streams. As noted previously, landsliding of the partially consolidated sedimentary rocks adjacent to the Owyhee River is widespread in this study area. Rapid erosion and undercutting of the sedimentary rocks with thin interbeds and capping lava flows could be the cause of the large volumes of landslide material. Temporary damming of the river by the young lava flows could also have saturated the sedimentary beds and led to slumping as the lake that formed drained quickly by breaching of the dam.

Structure

Major structural features are not evident, although the area is part of the overall broad northward-plunging basin in this part of Oregon. Walker (1977) indicates a synclinal structure extending into the area from the south. This is probably the so-called Rome Basin of several authors including Baldwin (1964). The axis crosses the Owyhee River near the mouth of Crooked Creek. A few minor, nearly east-west-trending normal faults and others that trend nearly north-south occur with only minor displacement of the rock units. High-elevation ERTS photographs show a subdued N. 10° W. grain underlying the young surficial rocks. Several segments of the Owyhee Canyon also appear to be aligned in this direction; however the reason for the several nearly right-angle turns in the river canyon in this area is not known.

Volcanic activity has been voluminous and may have been episodic as in other parts of eastern Oregon. The latest episodes have been basaltic,

with relatively quiet outflow of fluid lavas that covered large areas. The Cow Lakes-Jordan Craters lava flows are probably the most recent.

Geophysical Data

Heat-flow geophysical data are discussed in the geothermal section below.

Mines, Prospects, and Mineralized Areas

Eleven rock-chip samples (see Table 10) were taken of the mineralization within this area, which was exhibited by outcrops and float of jasper (picture rock) and calcite veining. Within Birch Creek Canyon (WSA 3-59A, Owyhee Breaks), two outcrops of jasperoid were sampled (nos. A0407R01 and A0410R01). A small amount of picture rock had been mined and shipped from the outcrops. Two rock-chip samples (nos. A1391R01 and A1392R01) were taken from an area of silicification a short way north of this WSA. The jasperoid had been mined by two open pits.

The calcite veining was found at the south end of the WSA 3-110, Lower Owyhee Canyon.

Geochemical Sampling Results

The overlay map for gold, tungsten, silver, and tin indicates that anomalous values are scattered all over the study area. One pattern that seems to be present is the concentration of gold anomalies in WSA 3-59 following the shape of the landslide areas. Another pattern is that other metal anomalies seem to cluster near Lambert Rock. Many of the gold anomalies are associated with unit Tdb (Deer Butte Formation). All of these anomalies were unknown before this study. The area had no known metallic mineralization, mines, or prospects.

Mineral Potential

General: As with the Owyhee Reservoir area, only oil and gas, geothermal energy, and the metallic commodities were to be studied. However, the Rome zeolite, bentonite, and fluorite beds should be considered as part of the mineral potential. Deposits of these commodities have been described by Santini and LeBaron (1982), Campion (1979), Sheppard (1974), and Sheppard and Gude (1969). As with the previous area, this one is part of a sedimentary basin, and therefore has oil shale and coal potential.

Table 10. Rock-chip sample data for the Middle Owyhee River area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec.	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
3-59A Owyhee Breaks	A0407R01	27	43	19	6 7 9	Float	Jasperoid	Silica	Ag, As, Be, Cu, Pb, Hg, Sn, U_3O_8	——
	A0410R01	27	43	19	9 9 6	Outcrop	Jasperoid	Silica	Ag, Ba, Be, Cu, Pb, Hg, Sn, U_3O_8	——
	A0422R01	27	42	11	8 6 8	Outcrop	Jasperoid	Silica	Ag, Cu, W, U_3O_8	——
	A1391R01	27	43	8	8 7 7	Prospect pit	Jasperoid	Silica	Ag, Be, Cu, Hg	——
	A1392R01	27	43	8	8 9 6	Prospect pit	Jasperoid	Silica	Ag, Ba, Be, Cu, Hg	——
3-110 Lower Owyhee Canyon										
	A0324R04	31	41	8	7 6 7	Float	Mafic igneous	Calcite	Ag, Mn	——
	A0340R01	28	41	32	9 9 8	Outcrop	Igneous	Silica, iron	Ag, As, Be, Cu, Pb, Mo, Sn, W, U_3O_8	——
	A0403R01	28	41	33	8 7 8	Outcrop	Jasperoid	Silica	Ag, As, Be, Pb, Mo, Sn, U_3O_8	——
	A0403R02	28	41	33	8 7 8	Outcrop	Tuff	Calcite crystals	---	Not assayed
	A0419R04	27	42	21	6 8 6	Float	Jasperoid	Silica	Ag, Be, Cu, Ni, U_3O_8	——
	A0503R01	28	41	33	8 6 6	Outcrop	Jasperoid	Silica	Ag, As, Be, Cu, Pb, Mo, Sn, U_3O_8	——

Oil and gas: As shown by the interest in leasing federal lands for oil and gas, over half the area is leased or has been requested to be leased. As the study area is part of a basin in which drilling has found gas shows, this area has a potential for oil and gas.

Geothermal energy: The Middle Owyhee River area has two unnamed hot springs located in secs. 4 and 9, T. 29 S., R. 41 E., along the Owyhee River near Lambert Rocks and one located in sec. 18, T. 27 S., R. 43 E. The areas around these three springs are categorized as areas known or inferred to be underlain at shallow depth (less than 1,000 m) by thermal water of sufficient temperature for direct-heat applications (Oregon Department of Geology and Mineral Industries, 1982). Heat flow (Blackwell and others, 1978), is anomalous at 80 to 100 mW/m^2 for all of the study area. Therefore, this study area has a potential for the production of geothermal energy.

Metallic commodities: This area has many anomalies in all of the metals. It was beyond the scope of this study to do the large-scale sampling needed to tell why those anomalies are there. The Middle Owyhee River area is part of the general hot-spring gold province. There is a warm spring within the area, which proves the presence of a thermal system. If the large landslide which contains downdropped blocks of rocks and jasperoid float is the top of a collapse feature, the gold anomalies in that area should be further studied.

Upper Owyhee River Area

(WSA Unit Nos. 3-173A, Upper West Little Owyhee; and 3-195, Owyhee River Canyon)

General

The Upper Owyhee River general area is the largest of the general areas and covers about 261,460 acres or 409 sq mi. It is in the southeastern corner of both Malheur County and the state. It includes a narrow strip of land 2 to 5 mi wide adjacent to the Owyhee River canyon from just south of Rome to Three Forks; from there southward, the main Owyhee River and South Fork canyon rims are the eastern boundary, and the western boundary is 1 to 2 mi west and parallel to the West Little Owyhee River. These boundaries form a broad hook-shaped area that includes the drainage of Toppin Creek, the headwaters of Antelope Creek, and the West Little Owyhee River. The north part of the area is accessible from U.S. Highway 95 near Rome by secondary roads that trend southward and more or less parallel the river canyon. Few if any roads

have river crossings in the canyon. The southwestern part of the area can be reached by a network of secondary roads that extend eastward from U.S. Highway 95 between Burns Junction and McDermitt. The southeast part of the area is least accessible but can be reached by a secondary road along the Nevada border east of McDermitt or from poorly maintained roads that extend east and north from Anderson Crossing.

This part of southeastern Oregon, like the areas to the north, is a part of the Owyhee Upland physiographic province, a rolling lava-covered plateau with narrow steep-sided river canyons and isolated low shield-shaped volcanic eruptive centers. Elevations range from about 3,400 ft on the river at Rome to 6,440 ft at Horse Hill near the headwaters of West Little Owyhee River northeast of McDermitt. In this part of the Owyhee Upland, elevations increase generally from about 3,900 ft in the north near Rome to 5,500 to 6,000 ft near the Oregon-Nevada border.

The Owyhee River and the main tributary canyons for most of their lengths are steep-walled gorges seldom over ¼ mi wide, and in some places it is as much as 1,000 ft from the canyon rims to the stream below.

The climate is harsh with large diurnal variations in temperature and low annual precipitation (less than 10 in. annually). Vegetation is mainly low-growing sagebrush and native grasses. In most places the soil zone is thin with lag gravels, boulders, and near-surface bed rock.

Geology

The two geologic maps (top half and bottom half) for this area have been adapted from Walker and Repenning (1966). To our knowledge, no other more detailed maps have been published for this remote area.

The area is underlain by a thick sequence of upper Miocene and younger volcanic rocks, mainly rhyolitic ash-flow tuffs and flows and basaltic lava flows and their vents, with only minor tuffaceous sedimentary rocks.

The evolution of the northwestern part of the Great Basin of which the Owyhee Upland and adjacent Snake River Basin are a part is the subject of continuing studies. Stewart (1978) in a review of reports on the subject indicates that the Basin and Range Province is characterized by: "(1) low seismic velocity of the upper mantle indicative of partial melting; (2) thin crust; (3) high heat flow; (4) regional uplift and extension; (5) previous history of deformation in Mesozoic and earliest Cenozoic time, and of widespread

siliceous volcanism in middle Cenozoic time; and (6) position inland from a transform plate boundary."

The rocks of this area are typical of those generated in a tensional tectonic regime; however, the youthful pattern of linear fault-bounded ranges separated by elongate alluviated valleys is conspicuously absent in this transitional area.

Stratigraphy

The oldest and most widespread rocks in the area are upper Miocene siliceous volcanic rocks (unit Trh). These have been described by Walker and Repenning (1966) as "partly to densely welded tuffs and rhyolite or dacite flows.... Some glass partly or complete converted to alkali feldspar and cristobalite either from gas phase alteration or devitrification. Locally contains layers of fresh vitrophyre and vitrophyre breccia...."

Walker (1981) also described samples collected in southern Malheur County as "vitrophyre or rhyolite obsidian from glassy selvages on either flows or possibly ash-flow tuffs. These glassy selvages, which occur in places on tops of flow units, are thought to represent chilled upper surfaces of flows, inasmuch as eutaxitic textures are not recognizable in thin section; however, they may be chilled parts of thick, thoroughly remobilized ash-flows in which vitro-clastic (eutaxitic) textures have been largely or completely destroyed through remelting and flowage."

The rocks mapped as unit Trh underlie about 250 sq mi of the Little Owyhee River general area and extend eastward into western Idaho and south into northern Nevada. Total thickness of the unit is unknown; however, at least 800- to 1,000-ft masses are exposed in the walls of the main Owyhee River Canyon in the Three Forks area and at Five Bars and the South Fork Owyhee River. Zones of porphyritic vitrophyre and vitrophyre breccia occur at the top, within, and in the lower parts of the thick masses of rock. Flow banding is prominent throughout the unit but appears to be the result of nearly complete melting and of subsequent flowage of a massive ash-flow tuff. A large silicic volcanic center appears to be needed as a source for such a large volume of rock, but so far none has been identified in southeastern Oregon. There are large silicic volcanic centers reported in the southwestern corner of Idaho and northern Nevada that could be the source. The rhyodacite to dacite composition rocks weather to a dark-gray to brownish-red color and form rounded

to steep-sided low-lying outcrop land forms. The relatively rapid uplift of this part of the Great Basin has allowed the main streams to cut steep-walled (vertical, even overhanging) canyons, especially in these indurated massive ash-flow tuff rocks. Some silicification has taken place, but by far the majority of the unit appears fresh and unaltered. No metallic mineralization is known or reported. The only K-Ar age reported for these siliceous rocks is 13.3 m.y. from a black glassy porphyritic zone at Anderson Crossing.

Overlying unit Trh are basalt flows and minor tuffaceous sedimentary rocks of various ages: (1) 10 m.y. for a flow (unit Tdb) near the base of a 500-ft-thick section exposed in the Owyhee River Canyon south of Rome; (2) 5 m.y. for thin flows (unit Tob) that unconformably overlie the unit Trh ash-flow tuff at Anderson Crossing; (3) 0.91 m.y. for rimrock capping basalt flows (unit Qb) in the vicinity of Rome. In a recent detailed study of some of the basaltic lavas of this area, Hart (1982) shows their composition to be mainly a low-K, high-alumina olivine tholeiite. Hart compares these lavas to mid-ocean ridge basalts and back-arc basin basalts and supports an idea that this part of the Great Basin represents a continental back-arc basin.

Thin- to thick-layered sedimentary units composed mainly of tuffaceous sandstone and siltstone with minor conglomerate (units Tts, Tsb, and Qs) separate the generally flat-lying basalt flows. Low shield-shaped vents like Horse Hill, Toppin Creek Butte, Black Butte, and Sacramento Hill in the south part of the area and Grassy Mountain, Round Mountain, and Jackies Butte in the north are some of the vents for the basalt flows. Hart (1982) also indicates that the basaltic lava flows occurred in three major pulses 0 to 2.5 m.y., 3.5 to 6 m.y., and 7 to 10 m.y. ago.

Structure

Like the rest of the Great Basin, the Owyhee Upland is an area of broad uplift, as shown by the youthful topography in the main river canyons. Unlike the typical Basin and Range structure of youthful linear basins and fault-block mountains, the north- to northwest-trending pattern of normal faults is subdued to missing in most of this area. No major structural features are apparent in the upper Owyhee River area. The previously mentioned broad northward plunging basin (Rome basin) begins in the northern part of the area, but overall it appears to be a relatively structureless uplifted plateau. As noted previously, the northwestern Great Basin including the Owyhee Uplands

during late Cenozoic time is characterized by extensional tectonics, a thin crust, high heat flow, and bimodal rhyolite-basalt volcanic rocks.

Geophysical Data

Aerial radiometric and magnetic surveys of the Jordan Valley AMS sheet (Geodata International, Inc., 1979) have been completed by Geodata International, Inc., a subcontractor for Bendix Engineering for USDOE. A review of their summary and recommendations shows many low anomalies of ^{208}Tl, ^{214}Bi, and isotope ratios in the Tertiary units. "....The resource potential for these units is considered fair to poor, due in part to the general character of the deposits. Localized, economically significant deposits may occur, however." A careful review of individual flightline data from this report (GJBX-95-80) will be required before any further exploration is contemplated. All the anomalies except in the extreme southwest corner (McDermitt Caldera) of the quadrangle appear to be of low intensity, making the uranium potential of the Upper Owyhee area of low priority.

Heat-flow data are discussed under the geothermal section.

Mines, Prospects, and Mineralized Areas

Fourteen rock-chip samples (see Table 11) were taken. All but two were jasperoids. One silicified zone (sample no. A0518R04) could be traced for 1,000 ft. The zone has been mined and the jasper-opal material sold for cutting usage. The remains of a miner's cabin were found at the junction of Long Canyon and Owyhee River. The silt sample (no. A0437F01) taken from this site shows anomalous values in As, Ba, Mn, Hg, and Ni. A sample (no. A0288R01) taken from ferruginous-cemented gravels was anomalous in 11 elements. All of the rock-chip samples were anomalous in one or more elements, including sample no. A0734R01, which was of fresh-looking rhyolite.

Geochemical Sampling Results

The two overlay maps for gold, tungsten, silver, and tin indicate that the gold and other metal anomalies are scattered, except for three areas: Five Bars (sample site nos. 584, 920, 919, and 918), Toppin Creek (sample site nos. 909, 916, 914, 912, and 913), and Antelope Creek (sample site nos. 603, 285, and 711). All anomalies in this area were identified by work done for this study. There were no previously known metallic mineralized zones, mines, or prospects.

Table 11. Rock-chip sample data for the Upper Owyhee River area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
3-173A Upper West Little Owyhee										
	A0288R01	38	44	24	7 9 9	Outcrop	Igneous	Iron	Ag, As, Be, Co, Cu, Mn, Mo, Ni, W, U_3O_8, Zn	———
3-195 Owhyee River Canyon										
	A0290R04	37	47	19	6 9 9	Outcrop	Igneous	Silica	Ag, Ba, Be, Pb, Hg, Sn, U_3O_8	———
	A0296R01	37	47	5	9 8 6	Float	Igneous	Silica	Ag, Ba, Be, Cu, Pb, U_3O_8, Hg	———
	A0442R01	33	45	30	7 9 8	Float	Jasperoid	Silica	Ag, Cu, Ni, U_3O_8	———
	A0475R01	39	46	26	6 7 7	Float	Jasperoid	Silica, iron	Ag, Ba, Cu, U_3O_8	———
	A0483R01	37	47	5	6 6 9	Outcrop	Igneous	Silica	Ag, Ba, Be, Pb, Sn, U_3O_8	———
	A0499R01	37	47	23	6 6 7	Float	Jasperoid	Silica	Ag, Ba, Be, Cu, Pb, Sn, U_3O_8	———
	A0518R04	32	42	6	8 7 8	Float	Igneous	Silica	Ag, Cu, Sn, U_3O_8	———
	A0635R01	36	47	16	6 7 9	Outcrop	Felsic igneous	Silica	Ag, Ba, Be, Cu, Pb, Sn, U_3O_8	———
	A0734R01	36	47	16	8 7 8	Outcrop	Felsic igneous	None	Ag, Ba, Be, Cu, Pb, Sn, U_3O_8	Background for unit Trh
	A0901R01	37	47	11	8 9 8	Outcrop	Jasperoid	Silica	Ba, Be, Cu, Pb, Sn, U_3O_8	———
	A0917R01	35	45	33	7 9 7	Outcrop	Jasperoid	Silica	Ag, Ba, Be, Cu, Pb, Ni, Sn, U_3O_8	———
	A0920R01	35	45	29	6 8 7	Outcrop	Jasperoid	Silica	Ag, Ba, Be, Cu, Pb, Ni, Sn, U_3O_8	———
	A0928R01	36	48	31	7 7 6	Outcrop	Jasperoid	Silica	Ag, Ba, Be, Cu, Pb, Sn, U_3O_8	———

Mineral Potential

General: This report was not to consider the fuels such as oil shale and coal and nonmetallics such as bentonite, fluorite, and zeolite. However, the top half of this study area, as the previous two areas were, is part of a sedimentary basin. Therefore, it has a potential for bentonite, fluorite, zeolite, oil shale, and coal.

Oil and gas: Oil and gas leasing activity in the northern part of this study area, which is a sedimentary basin, indicates that there is a potential for oil and gas.

Geothermal potential: The geothermal potential of this large area is perhaps less well known than for any of the other wilderness study areas and will have to wait until additional information is available. There is a hot-spring zone with multiple orifices of moderate temperature water (35° C) and an estimated flow of 3,750 liters/min on the banks of the Owyhee River just above Three Forks, south of Rome. Reported heat flow of 100 mW/m^2 for all of the study area (Blackwell and others, 1978) is anomalous.

Metallic commodities: Anomalous values that were found include the following: gold, ranging up to 0.4 ppm; silver, 1.2 ppm; arsenic, 17 ppm; barium, 900 ppm; beryllium, 3.5 ppm; cobalt, 104 ppm; copper, 318 ppm; lead, 24 ppm; manganese, 960 ppm; mercury, 0.3 ppm; molybdenum, 9 ppm; nickel, 132 ppm; tin, 22 ppm; tungsten, 1.2 ppm; U_3O_8, 29 ppm; and zinc, 76 ppm. Except for the three areas mentioned in the geochemical section, there does not seem to be a clear pattern to the anomalies.

Field evidence suggests that unit Trh (rhyolite welded tuffs or flows) may have been a single ash-flow tuff. If that had been the case, the flow may have been deposited into a rift valley, completely filling it. The anomalous values may be leaking up along fractures from below unit Trh. In any event a second look at the three areas with clusters of gold anomalies would be worthwhile.

Trout Creek Area

(WSA Unit Nos. 2-78D, Disaster Peak; 3-152, Willow Creek; 3-153, Red Mountain; 3-156A, Fifteenmile; 3-157, Oregon Canyon; and 3-162A, Twelvemile)

General

The Trout Creek general area covers about 162,320 acres, or 255 sq mi, and is made up of five individual study areas just north of the Nevada border in the southeast corner of Harney County and the southwest corner of Malheur County in southeastern Oregon. Much of the area is remote but generally accessible by ridge roads and jeep trails. A boundary road parallels the west side from the Trout Creek-Whitehorse road to the Nevada border. This furnishes access to the Willow Creek and Disaster Peak/Red Mountain individual areas. A road from Denio up Cottonwood Creek also connects with the west boundary road. The Oregon Canyon area is accessible from the Oregon Canyon road or from the roads that lead northward from the McDermitt Caldera. The central and northwest areas, Twelvemile and Fifteenmile Creeks, can be reached by unimporved single-lane roads and jeep trails up Willow Creek, from near Whitehorse Ranch, and Twelvemile Creek.

The Trout Creek Mountains are a part of a broad uplifted area in the northern part of the Basin and Range Province. The Trout Creek Mountains rise abruptly from the Pueblo Valley on the west and are bounded on the east by Oregon Canyon, another broad northwest-trending valley that extends southward into northern Nevada. The southern border is the arcuate-shaped northern part of the large McDermitt Caldera, a complex Miocene volcanic structure, half of which is in Oregon and half in Nevada. Highest elevations are in the southern part bordering the McDermitt Caldera, where the tops of the ridges range from 7,000 to 8,000 ft. Elevations gradually decrease to 5,000 to 6,000 ft northward across the dissected plateau before merging into the relatively flat lava-covered plain in the vicinity of the Whitehorse Ranch. The northwestern boundary of the wilderness study area extends into the southern part of another large collapse caldera structure that has recently been described by USGS geologists and named the Whitehorse Caldera.

The Trout Creeks have a middle latitude desert climate with cold winters and warm to hot, dry summers. In this climate, vegetation is mainly of low-growing sagebrush and short native grasses. The only trees are willows and cottonwoods (quaking aspen) along the perennial streams and mountain mahogany

thickets on higher elevation slopes. Beaver activity (dams and burrows) was noted in and along some of the perennial streams at higher elevations.

Geology

Most of the area has been studied only in reconnaissance; the geology map in this study was compiled and adapted from Walker and Repenning (1965, 1966), who published reconnaissance geologic maps of the Adel and Jordan Valley AMS quadrangles. The geology of Whitehorse Caldera was described by Rytuba and others (1981). Earlier Smith (1927) described sedimentary rocks along Trout Creek and named the Trout Creek Formation, and MacGinitie (1933) described a fossil flora from the Trout Creek beds.

All the rocks exposed are Miocene and younger and consist of older basaltic and andesitic lava flows and overlying ash-flow tuff sheets with occasional domes and extrusive masses of rhyolite and dacite. The high-angle normal faulting of north- to northwest-trend that is usually so common in the Basin and Range Province is not nearly so well developed in the Trout Creek Mountains. Instead the structure seems to be controlled by the two large collapse caldera features, one on the southeast and the other on the northwest.

The bordering area to the south within the McDermitt Caldera has been studied in detail, first by Schuette (1938) and then by Yates (1942), who described the Bretz and Opalite mercury mines. Brooks (1963) also described the mercury deposits near McDermitt. The mercury, uranium, and lithium occurrences in the McDermitt Caldera complex have been the subject of several reports by Rytuba and other USGS scientists during the late 1970's, and studies are continuing. Greene (1972, 1976) did a preliminary geologic map of the Jordan Meadow quadrangle, Nevada, and described the volcanic rocks of the McDermitt Caldera.

Stratigraphy

The rocks of the Trout Creek Mountains appear to reflect events in the early formation of the Basin and Range Province.

The oldest rocks shown on the geologic map (unit Taf) are mid to late Miocene age and are mainly platy andesite and basalt flows that are correlated by Walker (1977) with the Steens Basalt, Owyhee Basalt, and Columbia River Basalt Group. These large outpourings of basaltic lava mark a transition from calc-alkaline volcanism in the Great Basin about 17 m.y. ago. A major

change from compressional to extensional tectonism occurred at this time because of changes in relative motions of the Pacific and North American Plates, and that change is believed to be the beginning of the bi-modal (basalt-rhyolite)-type volcanism and the development of typical horst and graben topography of the northern Great Basin.

Walker and Repenning (1965, 1966) have described the thick section of basic lavas in the Trout Creeks as follows: "Mostly platy andesite flows but also some flows of porphyritic olivine basalt, basaltic and andesitic flow breccia, and minor amounts of interbedded tuffaceous sedimentary rocks and tuffs. Near top of unit some layers of silicic (dacitic?) tuffs, breccias and brecciated flows(?). Texture of andesite flows commonly pilotaxitic; some are hyalopilitic to intersertal. Rocks low in the unit are generally altered and contain small to moderate amounts of montmorillonite. Glass in groundmass, fresh to only slightly altered in andesitic flows near top of unit." Rytuba and others (1981) report an age of more than 16 m.y. for the andesite and basaltic flows in the north part of the wilderness study area.

The unit Taf rocks are the main rocks exposed in the highlands of the southwest, west, and southeast parts of the Trout Creek Mountains. They are also present in the central and northern parts of the area beneath a variable cover of the siliceous ash-flow tuffs from the McDermitt and Whitehorse Caldera complexes. The type of basement rocks beneath the basalt and andesite flows is unknown. The closest pre-Tertiary rock outcrops are 10 mi to the southwest on the Oregon-Nevada border and consist of metamorphic and plutonic rocks of Permian to Cretaceous age similar to those exposed in the Pueblo Mountains. No metallic mineral occurrences or hydrothermally altered zones have been reported from the unit Taf rocks within the wilderness study areas.

Overlying the basalt and andesite flows is a sequence of partly to densely welded ash-flow tuffs (unit Ttr). Preliminary information indicates that all of the thin to thick widespread ash-flow tuff sheets were erupted either from the McDermitt Caldera to the southeast or the Whitehorse Caldera in the northwest. Their chemical compositions, peralkaline rhyolite, are basically the same. The youngest ash-flow tuff from the Whitehorse Caldera has been dated at about 15.0 m.y., while those flows from the McDermitt Caldera are about 16.0 m.y. old. Minor north- to northwest-trending faults offset some of the essentially horizontal deposits. It is interesting to note that the Whitehorse Caldera is younger than the McDermitt, which parallels the age

trend of other rhyolite rock sources in the Basin and Range Province in Oregon. Walker (1974) documented this progression of younger rocks to the northwest and older ones to the southeast beginning at about the Oregon-Idaho-Nevada corner. Rytuba and others (1981), in their descriptive map of the Whitehorse Caldera, suggest that the silicic vent masses in most cases probably postdate the ash-flow tuff layers and were erupted relatively quietly as domes and thick flows within and after collapse occurred in the calderas. Some isolated masses such as the rhyolite dome in the eastern part of the area (sec. 14, T. 40 S., R. 41 E.) appear to have no caldera associations and may be older or a part of unit Taf.

Thin veneers of fine-grained tuffaceous sedimentary rocks and tuffs of flood plain or shallow lake deposit origin (unit Tts) are found covering the ash-flow tuff layers and in thicker layered deposits within the two large calderas. Gravelley colluvium of similar age occurs in bahada-type sloping deposits along the eastern highlands adjacent to Oregon Canyon. Lake-bed deposits around Flagstaff Butte, now known to have been deposited in the Miocene Whitehorse Caldera, were first described by Smith (1927) and named the Trout Creek Formation. Rytuba and others (1981) described a 135-m-thick section of the Whitehorse Caldera-fill deposits from one drillhole and found clay and zeolite mineralization.

Similar lake beds and volcanic breccia deposits filled the large McDermitt Caldera during late Miocene time and were altered and mineralized by hydrothermal solutions.

Alluvium and colluvium (unit Qalc) continue to be transported and deposited in the stream valleys and broad upland flats.

Structure

The two large late Miocene caldera structures are the dominant structural features in the overall wilderness study area. The overall area also is a part of a large uplifted and dissected tilted plateau separated by Basin and Range faults from the Alvord-Pueblo Valley on the west and Oregon Canyon valley on the east. Walker and Repenning (1965) also mapped a relatively broad syncline that plunges gently to the northwest, with the axis of the downfold trending north-northwest and paralleling Little Whitehorse Creek through the central to western part of the area. Minor northwest- and northeast-trending normal faults are present in the eastern and western parts of the

area, with the central area relatively free of faults.

Geophysical Data

A regional aeromagnetic map including the Adel and parts of the Burns, Boise, and Jordan Valley AMS quadrangles is available as an open-file report (U.S. Geological Survey, 1972).

NURE studies of the area include a radiometric survey and an aerial magnetic survey at a scale of 1:125,000 of both the Adel and Jordan Valley AMS quadrangles (Geodata International, Inc., 1980a,b).

Private company studies around the north border of the McDermitt Caldera are reported, as well as some drilling activity. So far the results of the drilling or the data of geophysical studies are not available.

Mines, Prospects, and Mineralized Areas

Five rock-chip samples (Table 12) were taken in the Trout Creek Area. Sample no. A0664R01 was taken of fresh platy andesite basalt to provide background data for unit Taf. All of the rock-chip samples had anomalous values in one or more elements.

Geochemical Sampling Results

The overlay map for gold, tungsten, silver, and tin has some interesting patterns. One pattern is the N. 35° E. line of gold values above anomalous levels that cuts across the center of the Trout Creek study area. The second is the cluster of gold values to the east of the opalite mine. Overall this area seems to have high general background in mercury.

Mineral Potential

General: The mineral commodities of oil and gas, geothermal energy, and metallic minerals will be discussed at length. Because of the lack of sedimentary rocks, the potential is low for nonmetallic minerals, oil shale, and coal.

Oil and gas: One oil and gas test well has been drilled by the Standard Oil Co. of California on the west flank of Blue Mountain about 10 mi northeast of the north part of the wilderness study area. The 8,400+ ft drill hole reportedly encountered volcanic rocks (mainly basalt) to 8,200-ft depth,

Table 12. Rock-chip sample data for the Trout Creek area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec.	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
3-153 Diaster Peak										
	A0657R01	39	41	17	8 6 8	Outcrop	Igneous	Silica	Ag, As, Be, Cu, Pb, Hg, Sn, U_3O_8	—
3-156A Fifteenmile										
	A0938R04	40	39	11	7 7 6	Float	Jasperoid	Silica	Ag, Be, Pb, Sn, U_3O_8, Zn	—
3-157 Oregon Canyon										
	A0664R01	39	41	8	9 6 6	Outcrop	Intermediate igneous	None	Ag, Ba, Be, Pb, Sn, U_3O_8	Background for unit Taf
3-162A Twelvemile										
	A0949R04	37	40	29	7 9 8	Outcrop	Igneous	Iron	Ag, Ba, Be, Co, Pb, Mn, Sn, U_3O_8, Zn	—
	A0965R01	37	39	11	8 8 7	Outcrop	Jasperoid	Silica	Ag, Be, Cu, Sn, U_3O_8	—

where the drill encountered granite (diorite) of probable pre-Tertiary age to the total depth. The presence of pre-Tertiary metamorphic rocks just to the southwest in both Oregon and northern Nevada and the extrusive and intrusive nature of the thick pile of Tertiary volcanic rocks make the area one of relatively low priority for the finding of oil and gas. None of this study area has been leased for oil and gas.

Geothermal energy: The heat flow shown by Blackwell and others (1978) is about 100 mW/m^2 for this study area. Maps of the area indicate that hot springs occur in both McDermitt and Whitehorse Calderas as well as in the Oregon Canyon valley (Oregon Department of Geology and Mineral Industries, 1982).

The ring-fracture systems generated by the two calderas are near-vertical and deep seated. These might provide pathways for geothermal fluids.

Metallic commodities: Just to the south of the study area within the McDermitt Caldera there has been and continues to be major production of mercury. Also right at the south boundary line of the study area a large uranium deposit has been drilled out. The mineralization has been in the lake-bed sediments of the caldera. With the one very strong gold trend and the high background in mercury, this area could prove to be interesting for further gold exploration. Each of the five rock-chip samples had anomalous values in five or more elements including the "fresh" rock taken to provide background data for unit Tat (airfall tuff).

Pueblo Mountains Area

(WSA Unit No. 2-816, Pueblo Mountains)

General

The Pueblo Mountains general area covers about 67,400 acres or 105 sq mi just north of the Nevada border in south-central Harney County. It is roughly 10 mi wide in an east-west direction and 15 mi long from north to south and includes most of the higher elevations of the Pueblo Mountains in Oregon. The eastern and central parts of the area are accessible from a network of unmaintained secondary roads and jeep trails that lead from an all-weather gravel road that parallels the east side of the mountain range. The western part of the area is less easily visited, but a few unimproved single-track roads extend for short distances up the main drainages from the Bog Hot Valley-Oregon End Table Ranch road.

The Pueblo Mountains are the southern part of a large north-trending westward-dipping elevated fault block that includes the Steens Mountain to the north. The steep eastern mountain front is bounded by a high-angle normal fault that separates it from the broad alluviated Pueblo Valley. Together these are typical of the topography of the Basin and Range Province in the northern part of the Great Basin.

An erosional median valley divides the mountain mass into two distinct elongate north-trending ridges. The highest and most rugged ridge lies to the east and is underlain by a variety of Paleozoic to Mesozoic metamorphic and plutonic rocks, while the western parallel ridges and terraces are formed by the tilted edges of layered basalt flows, ash-flow tuffs, and interbedded tuffaceous sedimentary rocks of Tertiary age.

Elevations range from about 4,200 ft on the Pueblo Valley floor to 8,650 ft at the top of Pueblo Mountain. As in most of Oregon east of the Cascades, the Pueblo Mountains have a desert climate with cold winters and hot, dry summers. The eastern and western slopes have a thin rocky soil and in this climate support only low-growing sagebrush and native grasses. The medial valley in some parts has thicker soils that support slightly more vigorous growth of the same vegetation plus mountain mahogany thickets at higher elevations. There are also clumps of willow and cottonwood trees along the perennial streams.

Geology

The geology map was compiled from several previous studies made in the

general area including reports on the geology and mercury deposits in both the Steens and Pueblos by Ross (1942) and Williams and Compton (1953). The geology is included in the reconnaissance map of the Adel quadrangle by Walker and Repenning (1965). There are three Oregon State University masters' theses that include parts of the wilderness study area: Rowe (1971), Tower (1972), and Harrold (1973); a University of Washington doctoral dissertation by Avent (1965) also covers part of the area in detail.

The Pueblo Mountains area is one of the two places in southeastern Oregon where basement pre-Tertiary rocks are exposed. Much of the eastern part of the large tilted fault block is underlain by an assemblage of moderately to steeply dipping Permian and Triassic metamorphic rocks including quartzite, graywacke sandstone, greenstone, sericite schist, quartz-muscovite schist, argillite, and minor marble. Cretaceous-age gneissic granodiorite and quartz diorite are intrusive into the metamorphic rocks.

To the west, the pre-Tertiary metamorphic and intrusive rocks are overlain unconformably by tuffaceous sedimentary and silicious volcaniclastic rocks and a thick layered sequence of andesite and basalt flows of early to mid-Tertiary age. The east flank of the range is blanketed by a thick colluvium deposit of Pliocene age that is also tilted to the west, indicating that much of the uplift and tilting of this fault block is geologically young.

Stratigraphy

The oldest rocks exposed are moderately to steeply dipping Permian and Triassic metamorphic rocks (℞ Pm) that include schists, phyllites, quartzite, and greenstone. Minor rock types in the 10,000-ft-thick assemblage are meta-conglomerate, meta-graywacke, and meta-diorite(?). The metamorphic rocks are probably derived from interbedded basaltic to intermediate lava flows, graywacke sandstones, mudstones, volcanic breccias, and conglomerates deposited in a mobile eugeosynclinal belt. Regional metamorphism appears to have occurred sometime during Jurassic time. Rocks in the metamorphic assemblage range in color from almost white for the schists to grays for the quartzite and pale-purplish grays for the phyllite to various shades of gray, gray-green, and green for the meta-graywackes, conglomerate, and greenstones. Detailed descriptions of the various rock types in the metamorphic sequence are contained in the graduate student theses. Tower (1972) subdivided the metamorphic rocks into three units based on differences in color, texture, lithology, and structure. Most of the metamorphic rocks are relatively resistant to erosion and form

rugged, narrow ridges, and steep-walled canyons. Quartz veins and isolated masses of quartz are common throughout and generally parallel the foliation. Metallic mineralization occurs at several horizons in the metamorphic rock sequence, and there has been extensive exploration for gold-bearing quartz veins and disseminated copper occurrences.

Associated with the metamorphic rocks are plutonic rocks that include quartz diorite, quartz monzonite, granodiorite, and minor aplite. Some of the dikelike and irregular masses are intrusive with contact aureoles. The plutonic rocks have not been differentiated on the geologic map and are shown as unit Ki where the masses are of sufficient size. K-Ar dates for the intrusive rocks of 90 to 95 m.y. B.P. indicate they are of mid-Cretaceous age. Mineralization in the metamorphic greenstones and schists adjacent to the largest plutonic mass along Denio Creek in the southeast part of the area may have some relation to the granitic-type rocks. Exploration drilling has been done in recent years at this location (Farnham Prospect).

The pre-Tertiary rocks are truncated abruptly on their eastern contact by a prominent frontal fault. On the west side they are overlain unconformably by the same Tertiary volcanic and volcaniclastic rock section as that in the Steens Mountain. This section is described below.

A basal sedimentary and volcanic unit can be correlated with the Pike Creek Formation (unit Tpc), which in the Pueblo Mountains consists of conglomerate, interbedded light-colored tuffs, volcanic sandstone, and an andesite flow of variable thickness. The formation, which forms a narrow outcrop pattern that trends north-south and dips to the west at 20° to 25°, appears to have been deposited on a surface with considerable relief. The rhyolite flows and thick ash-flow tuffs so prominent in the makeup of the formation farther north in the southeast part of the Steens are missing in the Pueblo Mountains. A smaller area of reddish rhyolite, light-colored tuffs, and greenish ash-flow tuffs near Red Point has been mapped by some authors as equivalent to the Pike Creek Formation, but later information shows this mass of basically siliceous rocks is probably late Miocene in age and equivalent to the unit Ttr rocks that are widely exposed in the Trout Creek Mountains.

The extensive thick section of Steens Basalt (unit Ttb) overlies the Pike Creek Formation in the Pueblo Mountains and is the underlying rock type in the median valley and west ridge. There are some minor thin ash-flow and air-fall tuffs of siliceous composition interbedded in the mainly basalt flow unit. The

Steens Basalt pile in the Pueblos is as much as 6,500 ft thick and basically has textures and structures similar to those seen at Steens Mountain. Details of the petrography and petrology are contained in several of the graduate theses and references in the bibliography. Numerous widespread vertical basalt dikes, 5 to 20 ft wide, that trend from N. 20° to 50° E. and east-west may be feeders for individual flows of the Steens Basalt.

Overlying the Steens Basalt with no apparent discordance is a sequence of rhyolite ash-flow tuffs and volcaniclastic sediments (unit Tts) that occur in a north-south belt along the top and upper slope of the west ridge of the Pueblos. Another smaller area of unit Tts occurs on the east side between Willow and Cottonwood Creeks. Here the rocks are fine-grained and light-colored thin- to thick-bedded tuffs. Walker and Repenning (1965) correlate these rocks with the Trout Creek Formation and Virgin Valley beds of late Miocene age. The unit Tts rocks are essentially unaltered, and there are no reported mineral occurrences in the unit in the Pueblo Mountains.

Along the lower flanks of the west ridge of the Pueblo Mountains and paralleling the western boundary of the wilderness study area along Rincon Creek is a younger (upper Miocene and Pliocene) pyroclastic-sedimentary unit (unit Tsb). Thin-bedded to massive beds of pumiceous ash-fall tuffs and poorly indurated to welded rhyolite ash flows form a rolling subdued topography. No extensive alteration other than to clay has been reported for this relatively thin (850 ft) sequence of rocks.

At about the same stratigraphic position in the northeast part of the area is a 2-mi-wide area of tilted, uplifted, low rolling hills underlain by thick to massive, crudely layered, somewhat consolidated conglomerate and interbedded mudstone and sandstone. The unit is made up of angular to rounded, locally derived cobbles and boulders in a matrix of sand and silt-size particles. The unit ranges up to 2,000 feet in thickness. It is friable to moderately consolidated and forms low rounded hills which are draped with a heterogeneous assortment of volcanic, plutonic, and metamorphic cobbles and boulders. The angularity of the rock fragments, poor sorting, and lack of uniform bedding indicate a local source for the deposit, and other workers suggest it has been deposited rapidly in coalescing alluvial fan-type deposits along an active mountain front. Avent (1965) has studied the deposits in detail. On the basis of its stratigraphic position and vertebrate fossils, a middle Pliocene age has been proposed for the formation. The conglomerate has a strike of about N. 15° W. and dips westward at angles up to 25°, indicating the formation has been involved

in Basin and Range tectonism. At least part of its western contact with the Steens Basalt and pre-Tertiary metamorphic rocks is a normal fault that dips steeply to the east. The east edge of the conglomerate is cut by the north to northwest-trending range-front fault and uplifted above the alluvium of the valley floor. No mineralization is reported within; however, at the western faulted contact the metamorphic rocks exhibit brecciation and slickensides and have been hydrothermally altered over a broad zone.

A variety of alluvial deposits (unit Qalc) including Pleistocene lake beds, alluvial fans, small landslides, and colluvium abut the range fronts on both east and west sides. The eastward- and westward-flowing streams continue to deposit coarse and fine detritus.

Structure

The prominent tilted fault block structure with the roughly north-trending frontal fault is the main structural feature of the Pueblo Mountains. Tensional tectonic forces which have tilted the fault block about 20° westward and uplifted the block by as much as 10,000 ft is believed to have started very late in Miocene time and continued to the present. Most of the uplift, however, appears to have taken place before the onset of glaciation as there is evidence of glaciation high on the western ridge of the Pueblo Mountains as well as the large glacial canyons on the west side of Steens Mountain. A faulted alluvial fan of Pleistocene to Recent age at the mouth of Cottonwood Creek indicates a continuing tensional tectonic pattern.

Geophysical Data

Regional NURE geophysical studies cover the Steens and Pueblo Mountains (Geodata International, Inc., 1980 a,b). A list of anomalous radioactive readings is summarized generally, and a paragraph under the summary and recommendations for the Adel quandrangle states: "The southern part of the surveyed area would appear to have considerable potential for radioactive mineral deposits" (Geodata International, Inc., 1980 a).

Mines, Prospects, and Mineralized Areas

The east half of the Pueblo Mountains is highly mineralized. The mines, prospects, and mineralization were described by Ross (1941), Williams and Compton (1953), and Bradley (1982). Table 13 summarizes the data from these three reports and from the USGS CRIB system. The reported mineralized zone

Table 13. Mines and prospects in the Pueblo Mountains area

Name	CRIB no.*	Location T.(S.)	R.(E).	Sec.	Commodities	Ore minerals	Gangue minerals	Host rock type	Production
Pueblo Group (Pueblo Mining Co.)	MO 20001	40	35	17	Hg,Au,Cu,Ag	Chalcopyrite, cinnabar, schwatzite, pyrite, hematite, copper oxides	Quartz, carbonates	Meta-andesite	Some gold is reported milled
Farnham property	MO 20002	41	34	13	Au, Cu	Chalcopyrite, pyrite	Quartz, sericite, biotite, potassium feldspar	Metamorphic rocks	None
Spring Creek	MO 54930	39	35	12	Hg, Cu	Cinnabar	Chalcedony, quartz	Andesite, basalt	None
Red Hill (Red Bull)	MO 54933	39	34	14	Hg, Cu	Cinnabar, copper minerals	Copper minerals	Andesite	None
Pueblo Mining Co. claims	MO 54934	40	35	7,8 9	Hg	---	---	---	None
Arizona (Valley View)	MO 54945	40	35	6	Hg, Cu, Mn, Au	Malachite, chrysocolla, azurite, Mn oxides, siderite	Quartz, chalcedony, calcite, siderite	Meta-andesites	None
Apache	MO 54946	40	35	7	Hg, Cu	Cinnabar, chalcopyrite, schwatzite, pyrite, limonite, Cu oxides	Chalcedony, quartz, limonite	Metamorphic rocks	None
Double Link	MO 54952	41	34	12, 13	Hg, Cu	Cinnabar, schwatzite, chrysocolla, malachite	Opal, chalcedony	Andesite, basalt	None
Farnham (Wonder Rock)	MO 54953	40	35	8,17	Ag	Chalcopyrite, malachite, chrysocolla, schwatzite, free gold, pyrite	Quartz, carbonates, limonite	Meta-andesite, quartz feldspar schists	Some Hg and Au
Cash Group (Cottonwood)	MO 54954	39	34	25	Hg, Cu	Copper staining, chalcopyrite, Cu oxides, pyrite	Kaolinite, limonite, carbonates	Andesite, shale, tuffaceous sandstone	None
Blue Bull	MO 54955	39	34	24	Hg, Cu, As	Cinnabar, malachite, azurite, chrysocolla, schwatzite, chalcopyrite	Kaolinite, limonite, opal, chalcedony	Meta-andesite porphyry	None
Rabbit Hole (Spring Creek)	MO 54956	39	34	12	Hg, Cu, Ba	Cinnabar, secondary Cu minerals	Calcite, kaolinite, opalite	Basalt, andesite	0.001 fl. Hg
Red King (O'Keefe Copper)	MO 54957	39	34	11	Hg, Cu	Cinnabar, schwatzite, chalcopyrite, malachite, azurite	Quartz, dolomite	Andesite	None

* Listing taken from USGS CRIB system.

strikes north-south and is on the east side of the Pueblo Mountains. Five east-west soil profiles were run across the zone. These profiles are shown graphically by Figures 6 through 10.

Seventeen rock-chip samples were taken of the mineralization (Table 14). Most of the samples were taken from prospect pits, mine shafts, and dumps, but a few were taken from outcrops. All of the rock chips showed anomalous values for one or more elements. Gold values ranged up to 2.1 ppm and copper up to 96,000 ppm.

A reconnaissance geochemical sampling program (stream sediment) was conducted by Harrold (1973). The samples were analyzed for copper, nickel, zinc, and lead. Several above-background copper anomalies are cited along with recommendations for more detailed sampling.

Geochemical Sampling Results

The soil profiles (Figures 6 through 10) show most convincingly that the east side of the Pueblo Mountains is a major mineralized zone. One of the profiles confirmed the gold-mercury anomalous area staked by a major mining firm. Other profiles seemed to have even higher gold values. The east side of the Pueblo Mountains has been known as a mineralized area for a long time; however, this study has shown that the soil profiles with the stronger and higher anomalies may not have been recognized by the mineral exploration firms.

Mineral Potential

General: This study was not to be concerned with commodities such as oil shale, bentonite, and zeolite. In NW¼ sec. 21, T. 39 S., R. 35 E., small tonnages of zeolite have been mined. To determine the mineral potential, a detailed study should be made of this type of commodity.

Oil and gas: Three-fourths of the study area have been leased or requested to be leased for oil and gas. Although the east side of the Pueblo Mountains has a predominance of pre-Tertiary metamorphic and plutonic rocks overlain by the thick Tertiary lava-flow sequence, the Pueblo Mountains structurally is a tilted fault block which dips to the west. This would make a good trap for oil and gas if there were sediments below the units exposed at the surface.

Geothermal energy: The northeast part of the Pueblo Mountains has been classified as an area known or inferred to be underlain at shallow depth (less than 1,000 m) by thermal water of sufficient temperature for direct heat application (Oregon Department of Geology and Mineral Industries, 1982). Heat-flow values are

Table 14. Rock-chip sample data for the Pueblo Mountains area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec.	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
2-81L Pueblo Mountains										
	A0067R01	40	35	7	6 9 7	Outcrop	Quartz	Silica, copper	Au, Ag, As, Cu, Hg	———
	A1078R01	41	35	17	9 7 9	Outcrop	Diabase	---	Au, Ag, Co, Cu, Hg, Ni, Sn, Zn	———
	A1083R01	41	34	12	9 9 7	Prospect pit	Basalt	Silica, copper	Au, Ag, As, Be, Co, Cu, Pb, Hg, Ni, Sn	Tiller prospect
	A1084R01	41	34	13	7 7 6	Prospect pit	Basalt	Silica	Ag, As, Be, Co, Cu, Pb, Hg, Ni, Sn, Zn	———
	A1140R01	41	35	18	7 7 8	Drill core	Schist	---	Au, Ag, Co, Cu, Mo, Ni, U_3O_8	Farman prospect
	A1233R01	40	35	30	7 7 8	Outcrop	Greenstone	Silica	Ag, Ba, Be, Co, Cu, Pb, Hg, Ni, Sn, U_3O_8	———
	A1302R01	40	35	31	8 7 9	Mine dump	Schist	Silica	Au, Ag, As, Ba, Be, Co, Cu, Pb, Mn, Ni, W, U_3O_8, Zn	———
	A1304R01	41	35	5	6 6 8	Mine dump	Schist	Silica	Au, Ag, As, Co, Cu, Mo, Ni, W, U_3O_8	———
	A1305R01	41	35	4	9 8 9	Mine dump	Schist	Silica	Au, Ag, Co, Cu, Mo, Ni, U_3O_8	———
	A1305R02	41	35	4	9 8 9	Prospect pit	Schist	Silica, copper	Au, Ag, Co, Cu, Mo, Ni, U_3O_8	———
	A1308R01	40	35	29	6 9 7	Mine dump	Schist	Silica	Au, Ag, As, Ba, Cu, Pb, Hg, Ni, U_3O_8, Zn	———
	A1310R01	41	35	8	8 6 6	Mine dump	Schist	Silica	Au, Ag, As, Co, Cu, Ni, U_3O_8	———
	A1368R01	40	35	5	8 9 9	Prospect pit	Quartz	Silica	Au, Ag, As, Co, Cu, Pb, Mo, Ni, U_3O_8, Zn	———
	A1370R01	39	35	28	6 6 7	Outcrop	Quartz	Silica	Au, Be, Cu, Pb, U_3O_8, Zn	———
	A1376R01	39	35	31	8 8 7	Prospect pit	Metamorphic	Iron, copper	Au, Ag, As, Ba, Co, Cu, Mo, U_3O_8	Arizona prospect
	A1380R01	39	34	11	8 7 9	Prospect pit	Quartz	Silica, copper, mercury	Au, Ag, As, Be, Co, Cu, Pb, Hg, Ni, Zn	Red King prospect
	A1381R01	39	34	24	7 7 8	Prospect pit	Quartz	Silica, copper, mercury	Au, Ag, As, Ba, Cu, Pb, Hg, Ni, U_3O_8, Zn	Blue Bull prospect

in the anomalous range of 80 to 100 mW/m^2.

A warm spring (Pedro Spring) near Fields about 10 mi north of the study boundary has a temperature of 32° C and a flow rate of about 100 1/m.

A mineral exploration hole in sec. 13, T. 39 S., R. 34 E., when measured for geothermal gradient by the Oregon Department of Geology and Mineral Industries, showed a temperature of 35° C at a depth of 380 m. The temperature gradient of this well was measured at 60°/km. From all indications this wilderness study area should have a high potential for geothermal energy.

Metallic commodities: The geochemical sampling and the past mining activities can only lead to the conclusion that this is a highly mineralized area. Minable deposits of gold, mercury, and copper-molybdenum could be hidden in the east half of the Pueblo Mountains. The soil profiles and the other sampling have proved the existence of several major exploration targets. Both the epithermal gold model and the copper-molybdenun porphyry model fit for this study area.

Steens Mountain Area

(WSA Unit Nos. 2-85F, South Steens; 2-86E, Blitzen River; and 2-86F, Blitzen River)

General

The Steens Mountain general area covers about 127,380 acres (199 sq mi) and is made up of three individual wilderness study areas located generally in the central part of Steens Mountain in south-central Harney County.

The South Steens individual study area straddles the rugged crest and includes the steep east-facing escarpment and flanks from near Andrews northward to the headwaters of McCoy and Kiger Creeks. The other two study areas include (1) the area high on the western slope that makes up the headwaters of Little Indian and Big Indian Creeks and their tributaries and Little Blitzen River, and (2) a slightly larger area on the lower west slope that straddles the Donner and Blitzen River almost to Frenchglen. Both areas are accessible from north-south trending roads that parallel Steens Mountain on the east and west sides. On the east side the county-maintained gravel road leaves Oregon Highway 58 at the Folly Farm junction and connects to Fields at the southern end of Steens Mountain. Access roads extend short distances across coalescing alluvial fans generally only to the mouths of the steep stream canyons that drain the east-facing escarpment. On the west side, accessibility is by way of Oregon Highway 205 from Burns to Frenchglen, a county road that is paved along the east side of the Catlow Valley as far as Roaring Springs, and then an all-weather gravel road that skirts the south end and connects with Fields. During late spring and summer, the Steens Mountain Loop Road with shorter spur roads makes most points on the western slope accessible, including the highest elevations along the crest.

Situated in the northern part of the Basin and Range Province, Steens Mountain and the adjoining Pueblo Mountains to the south are an impressive north- to northeast-trending, 9,700-ft high, tilted fault block with a long gentle dip slope on the west. The long, east-facing steep escarpment rises abruptly from the Alvord-Pueblo Valley. The Alvord Valley is essentially flat with interior drainage, as is the Catlow Valley which bounds the mountain block on the south and west. The northwest flank dips into the Harney Basin, another large valley of interior drainage.

Glaciated surfaces are common in the high Steens, and several spectacular U-shaped valleys drain the crest and western slopes.

The Steens Mountain area has a middle latitude desert climate with wide variations in temperatures. Sagebrush and native grass vegetation is typical with scattered juniper trees on the higher western slopes and canyon walls.

Geology

The geological map was compiled from various workers including Russell (1884, 1903a,b), Smith (1927), and Fuller and Waters (1929). Fuller (1931) studied the rocks and described the petrography and petrology in great detail. Ross (1941) examined the Steens and Pueblo Mountains for quicksilver and other mineral deposits and suggested there might be large quantities of low-grade material present. Williams and Compton (1953) followed with a more comprehensive study which discussed the stratigraphy, structure, and mineral deposits and concluded that despite the great length and width of some occurrences, no large bodies of ore had been found and no promising reserves were foreseen. Several graduate students, including Wilkerson (1958), Fryberger (1959), Avent (1965), and Cleary (1976) have studied and presented theses on the geology of parts of the Steens Mountain and Alvord Valley. Walker and Repenning (1965) have published a regional reconnaissance geologic map which includes the area. Also during the 1970's, the USGS and DOGAMI reviewed the geothermal potential and published several reports that contain information about the water chemistry, geothermal gradients, heat flow, and geophysical parameters of the general area. Most of these are listed in the bibliography.

The Steens Mountain escarpment exposes a truly impressive sequence of Tertiary volcanic rocks. All are Miocene and younger in age, and although light-colored tuffaceous sediments, rhyolite and dacite flows, and ash-flow tuffs are present low in the section, by far the majority of the exposed rocks are andesitic and basaltic lava flows. Baksi and others (1967), who studied them in detail, suggest that the Steens Mountain Basalt escarpment may be the world's largest exposure of successive Tertiary lava flows.

On the west side the gently dipping basalt surfaces are overlain by patches of upper Miocene and Pliocene ash-flow tuffs that are believed to have originated from caldera-type vents in the Harney Basin to the northwest. Coalescing alluvial fans blanket the foot of the escarpment along the east side, and small areas of glacial gravels and lake beds are present on the west slope.

Extensional tectonic forces that began about 14 m.y. B.P. and that have become progressively more youthful and concentrated toward the margins are believed to be responsible for the large parallel linear basins and ranges in this part of Oregon and the northwestern part of the Great Basin in general.

Stratigraphy

The geologic map for this study was compiled and adapted from many of the

reports noted above but mainly those of Walker and Repenning (1965), Williams and Compton (1953), Wilkerson (1958), and Gryberger (1959). A personal knowledge of the geology and field checking are also reflected in the geologic map.

In the study area all the rocks are volcanically derived and of Miocene and younger age. Fuller (1931) was the first to study the sequence in detail and divided them basically as described below.

The oldest (unit Tac) is a sequence of light-colored, fossiliferous silicic tuffs, claystone, opaline chert, and conglomerate in thin to thick beds, totaling 500 to 800 ft and named the Alvord Creek Formation. There has been much controversy about the age of this formation, but K-Ar dates of 21 m.y. B.P. reported by Evernden and James (1964) and the determination that the overlying Steens Basalt flows are all pre-Pliocene have established an early Miocene age of the Alvord Creek Formation.

Overlying the Alvord Creek Formation are rhyolite and dacite flows, ash-flow tuffs, and interbedded tuffaceous sediments and breccias with a total thickness of 1,000 to 1,500 ft and named the Pike Creek Formation (unit Tpc). Dating has also established an early to middle Miocene age for the Pike Creek rocks. Occurrences of mercury and uranium present in faults and breccia zones of the Pike Creek rocks have resulted in numerous prospects and workings.

Overlying the Pike Creek and older rocks unconformably is an extensive section of andesite and basalt flows (unit Tfb) that may be as thick as 5,000 ft. As originally described by Fuller (1931), a lower andesite unit of 2,000-ft thickness was called the Steens Mountain andesitic series, and an upper unit of 3,000 ft of thin regularly bedded flows of basalt was called the Steens Basalt. Later work by Wilkerson (1958) and Avent (1970) has shown that the two units are essentially a part of the same sequence, and the name Steens Basalt should be applied to the whole volcanic assemblage in Steens Mountain as well as the Pueblo Mountains to the south to which the rocks can be traced directly. The report by Avent (1970) contains a comprehensive discussion of the Steens Basalt problem.

The Steens Basalt consists of literally hundreds of individual flows ranging from 2 to 100 ft in thickness but averaging about 5 to 10 ft thick. They are generally vesicular and dark-gray to black in color with some reddish parts. There are occasional zones of scoria and brecciated scoria between flows, but rarely are there interbedded sediments. Columnar jointing is also generally lacking. Fine-grained varieties predominate, but textures vary widely, and a notable feature of some flows is the large size and amount of feldspar phenocrysts. In some the thin-bladed plagioclase crystals are as much as 2 in. long. A diktytaxitic or sievelike crystalline texture was first described by Fuller (1931)

for some of the Steens Basalt flows. K-Ar dates for the bottom and top of the section of 16 and 14.5 m.y. B.P. indicate that this thick section of basaltic lavas was extruded rapidly and regularly during middle Miocene time. There is now general agreement that the Steens Basalt is a lateral time equivalent of the Columbia River Basalt Group.

Thin discontinuous patches of light-gray to reddish rhyolite ash-flow tuffs (unit Tat) occur on the lower western flank of Steens Mountain. Most previous workers have correlated these ash-flow tuffs with thicker, more widespread mid-Pliocene deposits (Rattlesnake Tuff) in the Harney Basin. There are similar ash-flow tuffs present farther south in the Pueblo Mountains and in Virgin Valley, Nevada. Walker and Repenning (1965) report K-Ar dates of about 10 m.y. for similar ash-flow tuffs.

In both of the bounding basins (Catlow Valley on the west and Alvord Valley to the east), there are Quaternary lake sediments (unit QTs) that lap onto the faulted escarpments. These thin-bedded deposits vary from coarse gravels to fine sands and silts. Wave-cut terraces around the basins are evidence for large shallow lakes during glacial times.

Quaternary alluvium and colluvium (unit Qalc) that include large landslide masses are the products of continuing erosion and deposition which drape the mountain flanks and contribute to the basin fill.

Structure

As noted previously, Steens Mountain is in the north part of the Basin and Range Province; the prominent horst and graben features present are characteristic of the rest of the province and resulted from considerable east-west extension during late Cenozoic time.

An examination of the satellite imagery shown on ERTS Landsat color photographs of southeastern Oregon tends to confirm the observations of early-day workers like Russell (1884) who suggested that the Steens-Pueblo Mountain range is the western flank of an arch, the keystone of which dropped down to form the Alvord Valley. The photos show a large part of the high Steens to have been an elongate, dome-shaped mass before it became the complex horst and graben structure it is today. A set of north-northeast and north-northwest faults is well developed, especially at the north end of the Alvord Valley.

Lawrence (1976) interprets the pattern of faulting in the Basin and Range of southeast Oregon to be zones of east-west extension that lie between prominent right-lateral strike-slip faults that trend N. 50° W. to N. 60° W. The Steens-Pueblo

area lies between the northernmost of these zones, called the Vale zone, and another that Lawrence called the Eugene-Denio zone. Farther west the northward extent of the Basin and Range topography is terminated by the Brothers fault zone, which Lawrence suggests ends at or near the range-front fault of Steens Mountain.

Other regional studies of the Basin and Range Province point out (1) the characteristic pattern of youthful linear basins and ranges that are clearly related to late Cenozoic tectonic events, and (2) normal faulting that has continued virtually to the present. The studies also point to a high heat flow, a thin crust, and a low upper-mantle seismic velocity. Faceted spurs along the range front and offsets in layered alluvial fans are reported, indicating that the tectonic regime which offset the Steens Mountain fault block as much as 5,500 ft from the Alvord Valley floor is still active today.

Geophysical Data

Geophysical studies conducted during exploration for geothermal resources have mainly been concerned with the subsurface structure of the Alvord Valley. A gravity study by Cleary (1976) confirms the complex graben structure of the valley and indicates the boundary faults. A regional magnetic survey by the USGS (1972) more or less confirms the presence of a large fault along the east side of Steens Mountain. Other detailed magnetotelluric and resistivity surveys are concerned with parts of the Alvord Valley and hot-spring locations.

Mines, Prospects, and Mineralized Areas

The east side of the Steens Mountains is highly mineralized. The mines, prospects, and mineralization have been described by Ross (1941), Williams and Compton (1953), and Bradley (1982). Table 15 summarizes the data from these three reports and from the USGS CRIB system. Eighteen rock-chip samples (Table 16) were taken. Four of the rock-chip samples were from piles of discarded drill cuttings from four different geothermal prospect holes. The holes varied in depth from 500 to 2,000 ft. All of these samples had anomalous values in one or more elements.

Geochemical Sampling Results

Geochemical sampling has shown that the east side of Steen Mountain is mineralized. It has also shown a few gold anomalous values on the west side, as well. Some of the rock-chip samples had very high values in high-temperature

Table 15. Mines and prospects in the Steens Mountain area, (WSA 2-85F)

Name	CRIB no.*	Location T.(S.)	R.(E.)	Sec.	Commodities	Ore minerals	Gangue minerals	Rock type	Production years	Production amounts
Timberbeast	MO 20004	34	34	7	U	Ilsemannite, autunite, torbenite, manganese oxides	Clay, silica	Dacite, rhyolite, bedded tuffs	None	None
Rhoads Prospect	MO 20005	34	34	7	U, Mn	Ilsemannite, manganese oxides	---	Rhyolite breccia, tuff	None	None
Pike Creek Carnotite Group (Kiska, Carnotite Group)	MO 20006	34	34	18	U, Hg	Autunite, unidentified black oxide, manganese oxide	Silica	Rhyolite breccia, rhyolite tuff	None	None
Upper Pike Creek	MO 20007	34	33, 34	12,13, 18	U	Iron-manganese oxides	---	Biotite dacite	None	None
Alex-Ladd	MO 20008	34	34	20,29	U, Cu, Ag	Autunite	---	Rhyolite dike	None	None
Alvord Cave Claims	MO 20009	34	34	---	U	Autunite	---	Rhyolite	None	None
Jackpot	MO 54966	34	34	30	Hg	Cinnabar, limonite	Chalcedony, clay	Rhyolite, rhyolite tuff	None	None
Stewart (Aile-Rogue Claim)	MO 54967	34	34	30	Hg	Cinnabar	---	Biotite dacite	None	None
Pot Hole	MO 54968	34	34	29	Hg	Cinnabar	---	Rhyolite	None	None
Last Chance (Indian Chief)	MO 54969	34	34	30	Hg	Cinnabar	Chalcedony, quartz calcite	Rhyolite	None	None
Pike (Indian Chief)	MO 54970	34	34	30	Hg	Cinnabar, native mercury, limonite	Clays, chalcedony	Rhyolite	None	None
Weston Bros. (Alexander)	MO 54971	34	34	30	Hg	Cinnabar	Chalcedony, limonite, clay	Rhyolite basalt	1941-42	0.006 fl.Hg
Steens Mountain (Stephanson & Bradley)	MO 54972	34	34	19,20	Hg	Cinnabar, limonite	Clay	Rhyolite	1941-42, 1961	0.036 fl.Hg
Rhoads	MO 54973	34	34	18	Hg, Ba	Cinnabar, barite	---	Rhyolite	None	None

* Listing taken from the USGS CRIB system.

Table 16. Rock-chip sample data for the Steens Mountain area

WSA no. and name	Sample no.	Location T.(S.)	R.(E.)	Sec.	Sub sec.	Sample source	Rock name or type	Mineralization or alteration	Anomalous elements	Comments
2-85F South Steens										
	A0055R01	34	34	32	7 6 9	Drill cutting	Unidentified	Silica	Ag, Be, Co, Zn, Ni, Cu, Pb, Hg	Cutting from ANADARKO hole no. 79-4, 2,000' deep.
	A0056R01	34	34	30	8 9 6	Drill cutting	Unidentified	Silica	Ag, Be, Cu, Zn, Pb, Hg, U_3O_8	Cutting from ANADARKO hole no. 80-6, 500' deep.
	A0057R01	34	34	30	6 9 8	Drill cutting	Unidentified	Silica	Ag, Be, Cu, Pb, Hg, Ni, Sn, U_3O_8	Cutting from ANADARKO hole no. 81-7, 1,000' + deep.
	A0058R01	34	34	29	6 9 9	Drill cutting	Unidentified	Silica	Ag, Ba, Be, Pb, Hg	Cutting from ANADARKO hole no. 81-5, 500' + deep.
	A0981R01	35	34	17	9 6 8	Float	Jasperoid	Silica	Ag, Be, Cu, Pb, Hg, Sn	———
	A0982R01	34	34	18	8 8 7	Outcrop	Rhyolite	Silica	Ag, Be, Cu, Pb, Hg, Ni, Sn, U_3O_8	———
	A0983R01	34	34	8	7 9 7	Outcrop	Rhyolite	Silica	Ba, Pb, Hg, Sn, U_3O_8	———
	A0984R01	34	34	8	7 9 7	Outcrop	Rhyolite	Silica	Ag, As, Ba, Be, Cu, Pb, Mo, Sn, U_3O_8	Roads prospect
	A0984R02	34	34	8	7 9 7	Mine	Rhyolite	Copper	Ag, As, Ba, Be, Cu, Pb, Hg, Mo, Sn, U_3O_8, Zn	Steens Mountain
	A0985R01	34	34	19	6 8 9	Mine	Rhyolite	Silica	Au, Ag, As, Be, Cu, Pb, Hg, Sn, U_3O_8	Weston Bros.
	A0986R01	34	34	30	6 6 9	Mine	Rhyolite	Silica, mercury	Ag, Be, Cu, Pb, Hg, Ni, Sn, U_3O_8	Unnamed
	A0987R01	34	34	29	9 7 7	Mine	Rhyolite	Silica, molybdeum	Ag, As, Ba, Be, Pb, Hg	Unnamed
	A0987R02	34	34	29	9 7 7	Prospect pit	Rhyolite	Clay	Ag, As, Ba, Be, Pb, Hg, Sn	———
	A0988R01	34	34	4	6 7 7	Ouctrop	Rhyolite	Silica	Ag, Ba, Be, Cu, Pb, Sn, U_3O_8	———
	A0989R01	33	34	28	6 7 9	Outcrop	Rhyolite	Silica	Ag, Cu, Hg, Sn	
	A0990R01	33	34	33	6 8 6	Float	Rhyolite	Silica	Ag, As, Be, Hg, Mo, Sn, U_3O_8	———
	A0991R01	33	34	16	7 9 7	Outcrop	Rhyolite	Silica	Ag, As, Be, Pb, Hg, Sn, U_3O_8, Zn	———
	A0992R01	34	34	20	7 6 7	Mine dump	Rhyolite	Clay, uranium	Ag, As, Be, Cu, Pb, Hg, Mo, Sn, U_3O_8	Pike Creek Carnotite Group

metals such as tin and molybdenum. The zinc/cadmium ratio showed that the area may be temperature zoned.

Mineral Potential

General: This study was not designed to consider oil shale, coal, or the nonmetallic minerals; however, some of the sediments that crop out near the valley floor on the east front of Steens Mountain act very bentonitic, as shown by road cuts. Sheppard and Gude (1969) reported a zeolite deposit in the W½ T. 34 S., R. 34 E. To assess the total mineral potential, these mineral commodities should be studied in detail.

Oil and gas: Over one-half of this study area has been leased or applications have been filed for oil and gas. Steens Mountain is a tilted fault block with sedimentary rocks below mainly Tertiary volcanic extrusives. This area may have a potential for oil and gas.

Geothermal energy: The east side of Steens Mountain is part of the Alvord KGRA and has been identified as a prime Basin and Range geothermal prospect (Oregon Department of Geology and Mineral Industries, 1982). It has thus attracted considerable exploration and lease interest.

Some exploration by a private company has been accomplished in the study area in the vicinity west of the Alvord Hot Spring. Exploratory drill holes of at least 1,000-ft depth have been drilled. No information about bottom-hole temperatures or stratigraphy is available from this work. There are three warm springs in the vicinity of Frenchglen north and west of the study area that have temperatures of about 30° C and water flows of 400 to 500 liters/min. All are associated with normal faults and believed to be of deep circulation type. Peterson and Brown (1980) discuss the geothermal potential of the Alvord Valley in detail.

Metallic commodities: This study area had a few silt sample sites with anomalous gold values. Only one rock-chip sample carried gold. The area seems to have more of uranium oxide and molybdenum potential than gold. However, the east side of Steens Mountain has the requirements to fit the epithermal gold deposit model. The model does not call for anomalous values in gold if very little erosion of the system has taken place.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This project was completed according to the terms of the contract between the BLM and DOGAMI. Geological maps were prepared for the study areas. During the field season, 1,491 samples were taken over 805,000 acres. Sample location maps were prepared. Those samples were assayed for 17 elements. A computer system was used to store, retrieve, and analyze the raw data and to plot element-anomaly maps.

Table 17 summarizes the study's findings. The summary statement for each WSA was the result of the criteria shown as columns on the table. Oregon has a new gold province. Only two of the WSA's, Pueblo Mountains (2-81L) and Steens Mountain (2-85F), were known to be mineralized before this study was completed. Every WSA had at least scattered anomalous gold values. Figure 11 illustrates the metallic findings. The Owyhee Reservoir and Pueblo Mountains have a high gold potential. The Pueblo Mountains also have a high potential for copper-molybdenum. The other WSA's have interesting gold anomaly patterns or scattered anomalous gold values.

Although from this study very positive statements have been made about the metallic commodities, the other commodities should not be slighted. All of the WSA's have anomalous high heat flows. Many have warm or hot springs. Geothermal energy that could be used either in direct applications or in a power plant has high potential of being present. Because of the sedimentary formations that occur in this region, possible structural traps formed by block faulting, and the interest in leasing, oil and gas development is always a possibility for most of the WSA's.

This study was a very fast geological and geochemical reconnaissance survey of an unknown gold province. The information contained in the raw data has barely been touched. The pan concentrates that were taken at each sediment site have not been assayed. As followup to this study, the raw data should be further analyzed by computer. Selected pan concentrates should be assayed. New larger scale geological mapping should be done in such areas as the east side of the Owyhee Reservoir. Each of the anomaly patterns should be resampled, and enough new geochemical sampling should be completed to explain each pattern.

Table 17. Summary of Mineral Potential for 18 WSAs

WSA no.	Oil and gas: Sedimentary formations	Oil and gas: Mineral lease applied for or given	Oil and gas: Closest drilling (kilometers)	Geothermal: No. hot or warm springs	Geothermal: Anomalous rate of heat flow (mW/m²)	Geothermal: Exploration drilling	Geothermal: Some of the WSA has been determined to be underlain or inferred to be underlain by thermal water	Geothermal: Part of KGRA	Nonmetallic: Possible deposits of bentonite and/or fluorite and/or zeolite	Nonmetallic: Picture rock (semiprecious gemstone)	Metallic: Au model: Some anomalous Au geochemical values	Metallic: Au model: Vertical structures	Metallic: Au model: Large scale silicification and/or other alteration	Metallic: Au model: Hydrobrecciation	Metallic: Cu-Mo model: Anomalous Cu and/or Mo geochemical values	Metallic: Cu-Mo model: Porphyritic granitic intrusive	Metallic: Cu-Mo model: Exploration drilling	Reported mines and prospects	Summary statement
Owyhee Reservoir																			
3 - 56	Yes	Yes	65	Yes	80-100	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	--	--	No	No	High potential for Au, bentonite, zeolite, and geothermal. Possibility for oil and gas.
3 - 74A	Yes	Yes	65	No	80-100	No	No	No	Yes	Yes	Yes	Yes	Yes	--	--	--	No	No	High potential for Au, bentonite, zeolite, and geothermal. Possibility for oil and gas.
3 - 75	Yes	Yes	65	Yes	80-100	No	No	No	Yes	Yes	Yes	Yes	Yes	--	--	--	No	No	High potential for Au, bentonite, zeolite, and geothermal. Possibility for oil and gas.
3 - 77	Yes	Yes	65	No	80-100	No	No	No	Yes	Yes	Yes	Yes	Yes	--	--	--	No	No	High potential for Au, bentonite, zeolite, and geothermal. Possibility for oil and gas.
Middle Owyhee River																			
3 - 59A	Yes	Yes	80	Yes	90-100	No	Yes	No	Yes	Yes	Yes	--	--	--	--	--	No	No	High potential for bentonite, zeolite, and geothermal. Strong Au anomaly patterns. Possibility for oil and gas.
3 - 110	Yes	Yes	80	Yes	90-100	No	Yes	No	Yes	Yes	Yes	--	--	--	--	--	No	No	High potential for bentonite, fluorite, zeolite, and geothermal. Strong Au anomaly patterns. Possibility for oil and gas.
Upper Owyhee River																			
3 - 173A	No	No	--	No	100	No	No	No	Yes	Yes	Yes	--	--	--	--	--	No	No	Strong Au anomaly pattern. Possibility for geothermal.
3 - 195	Yes	Yes	--	Yes	100	No	No	No	Yes	Yes	Yes	--	--	--	--	--	No	No	High potential for bentonite, fluorite, zeolite, and geothermal. Strong Au anomaly patterns. Possibility for oil and gas.
Trout Creek																			
2 - 78D	No	No	80	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Possibility for geothermal. Scattered Au values.
3 - 152	No	No	50	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Strong Au anomaly pattern. Possibility for geothermal.
3 - 153	No	No	40	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Possibility for geothermal. Scattered Au values.
3 - 156A	No	No	30	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Strong Au anomaly pattern. Possibility for geothermal.
3 - 157	No	No	30	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Strong Au anomaly pattern. Possibility for geothermal.
3 - 162A	Yes	No	20	No	100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	High potential for bentonite, zeolite. Possibility for oil and gas and geothermal. Scattered Au values.
Pueblo Mountains																			
2 - 81L	Yes	Yes	--	No	80-100	No	Yes	No	Yes	--	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	High potential for Au, Cu-Mo, bentonite, zeolite, and geothermal. Possibility for oil and gas.
Steens Mountain																			
2 - 85F	Yes	Yes	--	No	90-100	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	--	--	Yes	Yes	High potential for Au, bentonite, zeolite, and geothermal. Possibility for oil and gas.
3 - 86E	No	Yes	--	Yes	80- 90	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Possibility for oil and gas and geothermal. Scattered Au values.
2 - 86F	No	Yes	--	No	90-100	No	No	No	No	--	Yes	--	--	--	--	--	No	No	Possibility for oil and gas and geothermal. Scattered Au values.

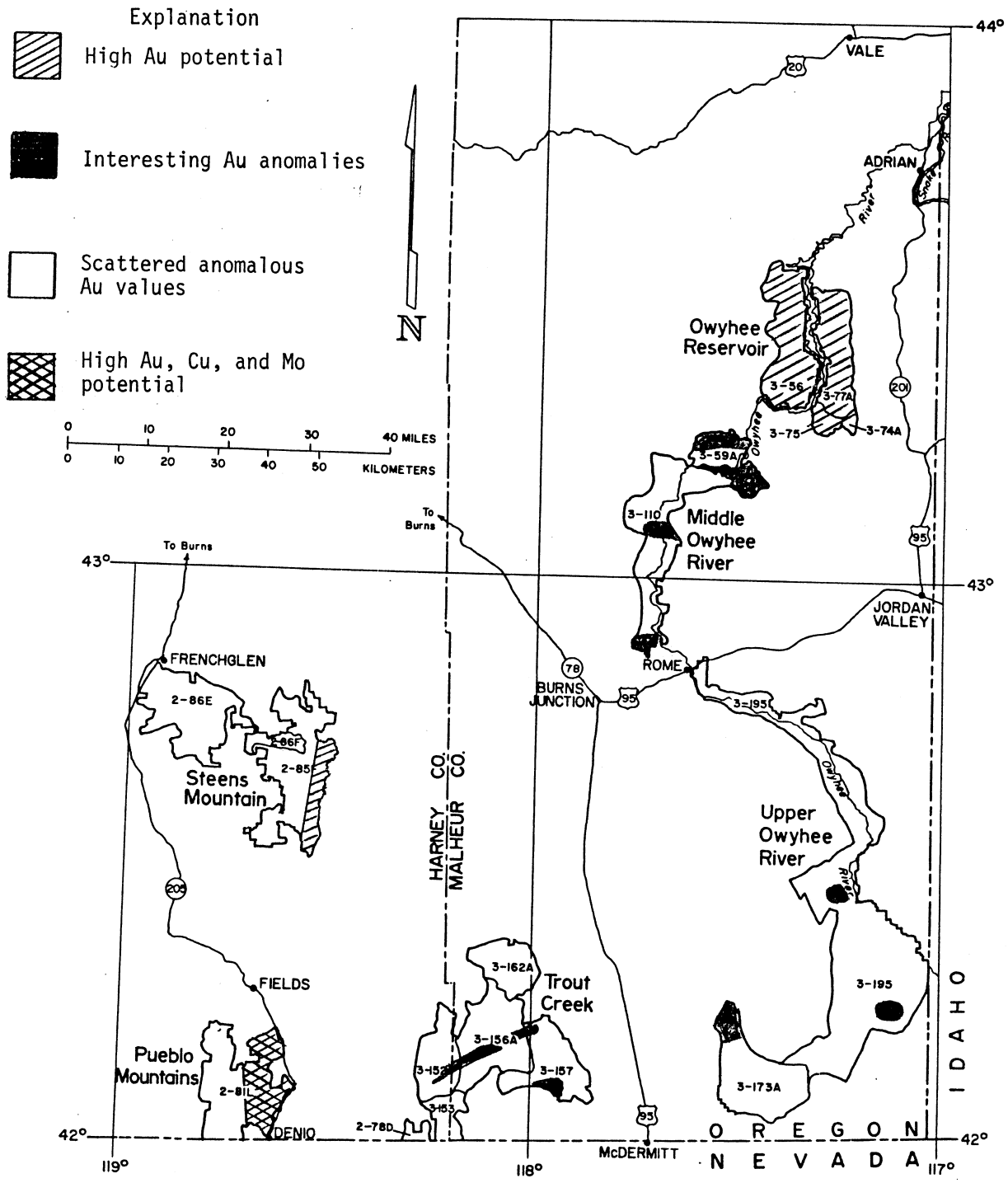

Figure 11. Generalized metallic potential rating for 18 BLM wilderness study areas, southeastern Oregon.

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APPENDIX A. MICROFICHE COPY OF COMPUTER PRINTOUT

Included in an envelope as part of this report is a microfiche copy of the computer printout. Included in the microfiche are raw assay and site data, area summary tables, frequency tables, histograms, and scatter graphs.

A list of all the microfiche included with this report is printed on p. vi-vii.

APPENDIX B. LIST OF MAPS PRODUCED FOR THIS STUDY

Several sets of maps were produced for this study and are available for inspection at the DOGAMI library in Portland.

Geologic Maps (Scale 1 in. = 1 mi)

Geology of the Owyhee Reservoir area
Geology of the Middle Owyhee River area
Geology of the Upper Owyhee River (N) area
Geology of the Upper Owyhee River (S) area
Geology of Trout Creek area
Geology of the Pueblo Mountains area
Geology of the Steens Mountain area

Sample Location Maps (Scale 1:250,000)

Boise, Idaho, Oregon
Jordan Valley, Oregon, Idaho
Adel, Oregon

Sample Location Maps (Scale 1 in. = 1 mi)

Owyhee Reservoir area
Middle Owhyee River area
Upper Owyhee River (N) area
Upper Owyhee River (S) area
Trout Creek area
Pueblo Mountains area
Steens Mountain area

Sample Location Maps (Scale 1:62,500 or 1:24,000)*

1. Twin Springs
2. The Elbow
3. Quartz Mountain Basin
4. Pelican Point
5. Three Fingers Rock
6. Big Mud Flat
7. Diamond Butte
8. Rooster Comb
9. Bannock Ridge
10. Rinehart Canyon
11. The Hole-in-the-Ground
12. Jordan Craters North
13. Wrangle Butte
14. Lambert Rocks
15. Owyhee Butte
16. Frenchglen
17. Page Springs
18. McCoy Ridge
19. Big Pasture Creek
20. Rome
21. Scott Reservoir
22. Dry Creek Rim
23. Little Grassy Mountain
24. Roaring Springs
25. Tombstone Canyon
26. Fish Lake
27. Wildhorse Lake
28. Indian Fort
29. Skull Creek
30. Whitehorse Butte
31. Ankle Creek
32. Alvord Hot Springs
33. Squaw Flat
34. Three Forks
35. Andrews
36. Little Owyhee River 2 NE
37. Little Owyhee River 1 NW
38. Trout Creek 1 SE
39. Oregon Canyon 2 SW
40. Oregon Canyon 1 SE
41. Little Owyhee River 2 SE
42. Little Owyhee River 1 SW
43. Little Owyhee River 1 SE
44. Rincon Flat
45. Ladycomb Peak
46. Tumtum Lake
47. Little Whitehorse Creek
48. Trout Creek 4 NE
49. Oregon Canyon 3 NW
50. Oregon Canyon 4 NE
51. Little Owyhee River 3 NW
52. Little Owyhee River 3 NE
53. Little Owyhee River 4 NW
54. Little Owyhee River 4 NE
55. Oregon End Table
56. Van Horn Basin
57. Colony Ranch
58. Trout Creek 4 SW
59. Trout Creek 4 SE
60. Oregon Canyon 3 SW
61. Oregon Canyon 3 SE
62. Little Owyhee River 3 SW
63. Little Owyhee River 3 SE
64. Railroad Point (1:62,500)
65. Denio (1:62,500)

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*Map scale is 1:24,000 except as indicated. Map numbers correspond to map locations shown on Figure 4 in text.

Element Anomaly Overlay Maps (Scale 1 in. = 1 mi)

1. Owyhee Reservoir
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay
2. Middle Owyhee River
   a. Gold, silver, beryllium, tin, and tungsten overlay

b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
c. Cobalt, copper, nickel, and zinc overlay
d. Barium, cadmium, lead, manganese, and uranium oxide overlay

3. Upper Owyhee River (N)
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay
4. Upper Owyhee River (S)
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay
5. Trout Creek
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay
6. Pueblo Mountains
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay
7. Steens Mountain
   a. Gold, silver, beryllium, tin, and tungsten overlay
   b. Arsenic, mercury, molybdenum, and zinc/cadmium ratio overlay
   c. Cobalt, copper, nickel, and zinc overlay
   d. Barium, cadmium, lead, manganese, and uranium oxide overlay