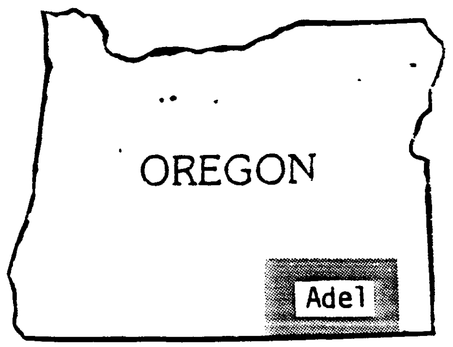
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

ASSESSMENT OF THE MINERAL RESOURCES FOR THE ADEL 1° x 2° QUADRANGLE, OREGON



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This report (map) is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards (and stratigraphic nomenclature).

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PROLOGUE

The U.S. Geological Survey has initiated a new program which is meant to complement the already existing Conterminous United States Mineral Assessment Program (CUSMAP). This new program consists of a short term commitment by earth science specialists including geologists, geochemists, geophysicists, and mineral resource analysts to evaluate two degree quadrangles with respect to their mineral resource potential.

The Adel, Oregon two degree quadrangle is the subject of one of these studies and of this report. The Adel team assembled all relevent geology, geochemistry, geophysics, and mineral deposit information; identified existing and proposed mineral deposit types; delineated tracts which are permissible environments for identified deposit types; and made recommendations as to further studies within the Adel quadrangle.

This document has been written for and directed towards an audience with some background knowledge in the geological sciences. Introductory material concerning regional geology, ore deposits, and the techniques involved in the use of geology, geochemistry, and geophysics were addressed only in the broadest sense.

All results presented within this report are tentative and subject to change or reinterpretation as more information is gathered. Due to the short time frame in which this study was conducted, no new information has been added to that already in the public domain and therefore, this study is dependent upon our current knowledge.

Personnel and areas of responsibility in order presented within this Adel preassessment report:

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EXECUTIVE SUMMARY

Introduction

The Adel 1 x 2 degree quadrangle lies in the southeastern corner of Oregon within the northern limit of the Basin and Range province. This area is sparsely vegetated, semi-arid, and has a very low population density. The topography is characterized by north-trending block-faulted mountains, plateaus, and intervening basins which contain playa lakes and large playa deserts.

Mineral deposits found within the Adel quadrangle are typical of those deposits which occur in relatively young Cenozoic volcanic rocks of the Basin and Range province. Base and precious metal occurrences and deposits are found in epithermal vein systems and are associated with several generations of faults within the area; Basin and Range faults, range-front faults, and caldera-related faults. Due to the high degree of porosity and permeability of the volcanic and sedimentary rocks in contact with the fault system, hydrothermal alteration and related deposits are also present. Mercury, uranium, lithium, gold, silver, copper, lead, zinc, antimony, arsenic, molybdenum, barium, manganese and borates have either been mined or are reported to occur within the Adel quadrangle. However, the only significant production reported within the Adel quadrangle is from the Opalite mercury district, which is associated with the McDermitt Caldera Complex and is located in the extreme southeast corner of the quadrangle.

The scientific benefits gained by conducting a resource assessment of the Adel quadrangle would enhance two avenues of geologic research: the exploration of buried or "blind" ore deposits in young volcanic rocks; and the improvement of existing, and the development of new mineral deposit and grade-tonnage models for non-metallic commodities. The potential for new metallic mineral deposits lies mostly under the Cenozoic basalt and within ash-flow tuffs which cover the surface, and under the basinal sedimentary rocks found between the north trending fault-bounded horsts and plateaus within the quadrangle. Geochemical exploration techniques, currently existing and newly developed, would be utilized in the exploration and understanding of these buried ore deposits and their associated geochemical halos, pathfinder elements, and solutions. It should be emphasized that the volcanic rocks in the area are one of the largest peralkaline volcanic fields in the world. The unique chemistry of these rocks offers an opportunity to study a special class of processes that would likely lead to new types of ore deposits. Some of the "new" deposits might include light REE and "high tech" elements used in superconductors such as Nb, Ta, Zr, etc., and specialty clays presently being mined in the McDermitt calderas (J. Rytuba, personal communication). Geophysical research would include airborne and remote sensing techniques for which extensive coverage is relatively easy to acquire, ground surveys for those techniques that normally are not flown, and site-specific ground surveys at targets detected by airborne techniques. The validation of existing, and development of new mineral deposit and grade-tonnage models for the Adel quadrangle would not only be of benefit here, but would also be applicable in other areas. The eventual development of these types of models for the non-metallic commodities is critical.

The economic benefits which would be gained by conducting a resource assessment of the Adel quadrangle cannot be guaranteed in the form of discovering new deposits. However, a CUSMAP study could stimulate the mining industry with its new products, and through the use of cooperative geologic studies benefit the State of Oregon and academic institutions working in the area.

Specific recommendations as to how a mineral resource assessment would proceed with respect to the geology, geochemistry, geophysics and mineral resources are contained within this report. Areas of additional geologic mapping; additional geochemical sampling; geophysical surveys of gravity, magnetics, and radioactivity; and additional mineral deposit and grade-tonnage models are delineated. The successful completion of a CUSMAP study within the Adel quadrangle would result not only in resolving the mineral potential of the area and enhance exploration techniques in volcanic terraines of buried deposits, but would also add significantly to our understanding of the regional geology, structural history, and dynamics of plate boundary environments.

OVERVIEW

Introduction

The Adel 1 x 2 degree quadrangle lies in the southeast corner of Oregon along the Nevada border (fig. 1) and is included in the northern most extension of the Basin and Range province. The region is semi-arid, sparsely vegetated, and has a very low population density.

The data coverage for the geology, geochemistry, geophysics, and mines and prospects are discussed in detail later in this report. In many instances the level of information is too general, at too small a scale, not extensive enough to cover the entire quadrangle, or not examined for parameters which are relevent to mineral deposits. Only a small part of the Adel quadrangle has been mapped in detail; more mapping will be required in areas deemed critical for a better understanding of the geology and potential mineral deposits; geochemical sampling has not been as dense, extensive, nor analysed for all relevant elements; and the gravity and magnetic data for the Adel quadrangle is too coarse to define other than very large features.

Mineral deposits and occurrences within the Adel quadrangle are typical of deposits in relatively young Cenozoic volcanic rocks of the Basin and Range province. Epithermal deposits containing mercury, uranium, and other related mineral deposit types have been documented. Except for the production of mercury and clay from the Opalite mercury district, in the McDermitt Caldera Complex, other minerals have not been found within the Adel quadrangle in large enough tonnages and grades to warrant large scale mining. Grade-tonnage models for many of these deposit types already exist, but need to be improved upon to become useful. Deposit types for which grade-tonnage models do not exist include non-metallic industrial and construction materials, which could be a very important resource of the Adel quadrangle. Grade-tonnage models should be developed for the industrial and construction materials deposit types for use within the Adel quadrangle.

Scientific Benefits Expected

The scientific benefits expected from a formal Adel quadrangle CUSMAP study are diversified and numerous. This is in part due to the tremendous amount of work which is left to be done within Adel to gain a better understanding of the geology, geochemistry, geophysics, and mineral resources; and the diversity of mineral deposits and geologic environments which are present.

Additional geologic mapping within the Adel quadrangle to investigate potential mineral resources and to unravel geologic questions would be restricted to specific target areas. Questions to be addressed include the age and sequence of faulting; their depth; and the source of metalliferous solutions. It is important that the structural history for the Adel quadrangle be incorporated into the regional geology for the northwestern United States for a better understanding of the regional geology and related plate boundary environments. It should be emphasized that the volcanic rocks in the area are one of the largest peralkaline volcanic fields in the world. The unique chemistry of these rocks offers an opportunity to study a special class of processes that would likely lead to new types of ore deposits. Some of the "new" deposits might include light REE and "high tech" elements used in

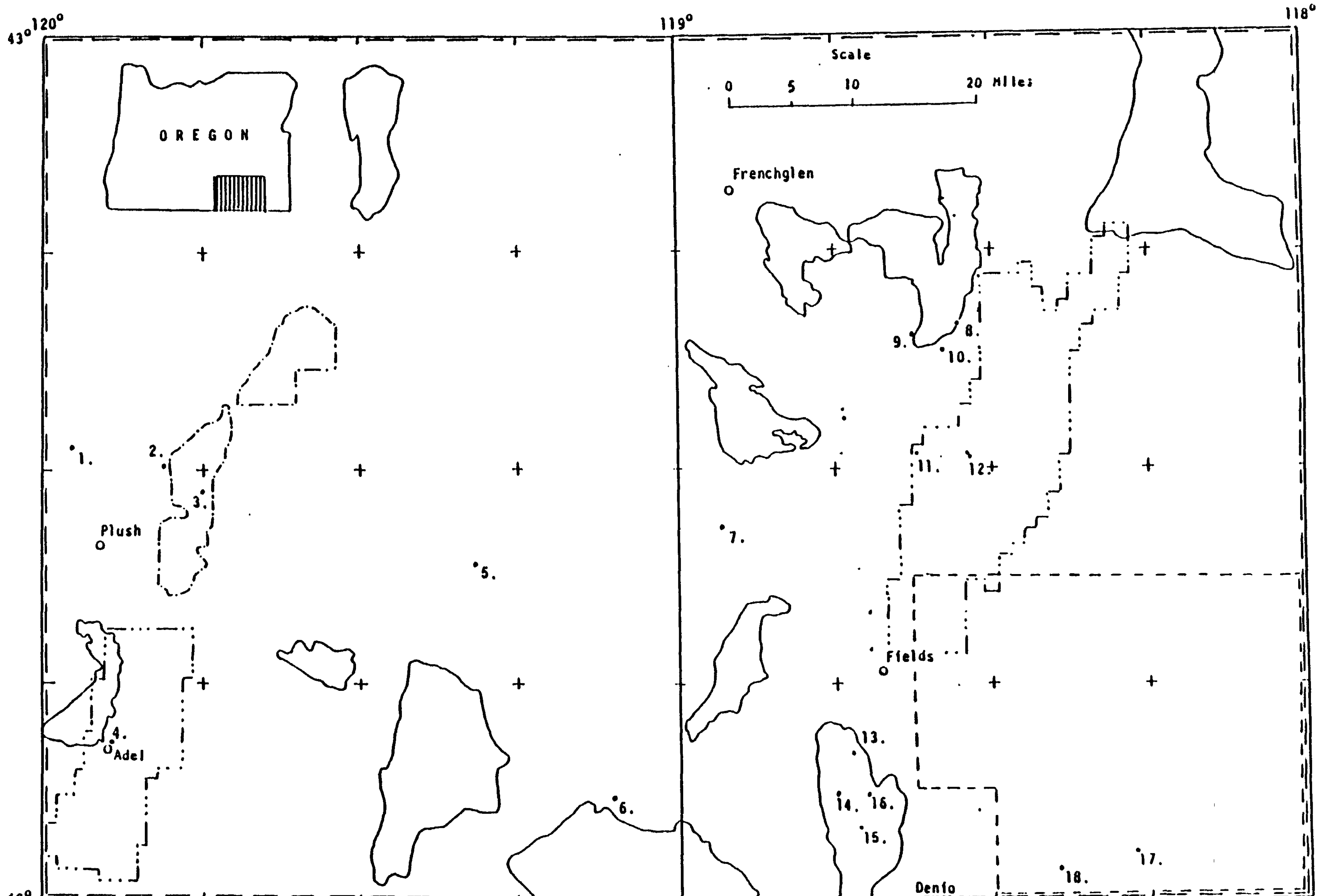


Figure 1.- Geologic mapping and related studies, Adel quadrangle, Oregon

FIGURE 1 - EXPLANATION

Rapid reconnaissance mapping, including extensive photogeology, at 1:250,000 (Walker and Repenning, 1965)

Geologic mapping at 1:24,000 as part of McDermitt caldera complex and wilderness investigations

Geologic mapping at 1:24,000 for mineral resource assessments of wilderness areas

Assessment of wilderness areas based on existing (1:250,000) geologic map. No additional field work. (Walker and Swanson, 1968)

Known geothermal resource area (KGRA)

• 1, 2, Theses (area covered and character of geologic mapping largely unknown; mostly unpublished data)

1. Thomas, T. H., 1981, Geology and mineral deposits of the Coyote Hills mining district, Lake County, Oregon: Corvallis, Oregon, Oregon State University Masters thesis, 137 p.

2. Weide, D. L., 1974, Post glacial geomorphology and environments of the Warner Valley-Hart Mountain area, Oregon: Los Angeles, Calif., University of California doctoral dissertation, 311 p.

3. Larson, E. E., 1965, The structure, stratigraphy, and Paleomagnetics of the Plush area, southeastern Lake County, Oregon: Boulder, Colo., University of Colorado doctoral dissertation, 166 p.

4. Schaff, S. C., The 1968 Adel, Oregon, earthquake swarm: Reno, Nevada, University of Nevada Master thesis, p.

5. Wallace, R. E., 1946, A Miocene mammalian fauna from Beatys Butte, Oregon: Pasadena, California, California Institute of Technology doctoral dissertation, p.

6. Maloney, N. J., 1960, Geology of the eastern part, Beatys Butte Four quadrangle, Oregon: Corvallis, Oregon, Oregon State University Masters thesis, 87 p.

7. Johnson, G. D., 1960, Geology of the northwest quarter Alvord Lake Three quadrangle, Oregon: Corvallis, Oregon, Oregon State University Master thesis, 75 p.

8. Fuller, R. E., 1930, The petrology and structural relationship of the Steens Mountain Volcanic Series of southeastern Oregon: Seattle, Washington, University of Washington doctoral dissertation, 282 p.

9. Helmke, P., 1971, Rare earth elements in the Steens Mountain basalts: Madison, Wisconsin, University of Wisconsin doctoral dissertation, p.

10. Fryberger, J. S., 1959, The geology of Steens Mountain, Oregon: Eugene, Oregon, University of Oregon Masters thesis, 65 p.

11. Wilkerson, W. L., 1958, The geology of a portion of the southern Steens Mountains, Oregon: Eugene, Oregon, University of Oregon Masters thesis, 89 p.

12. Cleary, J. C., 1976, Geothermal investigations of the Alvord Valley southeast Oregon: Missoula, Montana, University of Montana Master thesis, 71 p.

13. Harrold, J. L., 1973, Geology of the north-central Pueblo Mountains, Harney County, Oregon: Corvallis, Oregon, Oregon State University Masters thesis, 135 p.

14. Avent, J. C., 1965, Cenozoic stratigraphy and structure of Pueblo Mountains region, Oregon-Nevada: Seattle, Washington, University of Washington Doctoral dissertation, 119 p.

15. Rowe, W. A., 1971, Geology of the central Pueblo Mountains (Triassic-Recent), Harney County, Oregon: Corvallis, Oregon, Oregon State University Master thesis, 96 p.

16. Tower, D. B., 1972, Geology of the central Pueblo Mountains (Triassic-Recent), Harney County, Oregon: Corvallis, Oregon, Oregon State University Masters thesis, 96 p.

17. Carlton, R. W., 1969, The structure and stratigraphy of a portion of the Trout Creek Mountains, Harney County, Oregon: Corvallis, Oregon, Oregon State University Masters thesis, 116 p.

18. Minor, S. A., 1986, Stratigraphy and structure of the western Trout Creek and northern Bilk Creek Mountains, Harney County, Oregon, and Humboldt County, Nevada: Boulder, Colorado, University of Colorado Masters thesis, 177 p.

superconductors such as Nb, Ta, Zr, etc., and specialty clays presently being mined in the McDermitt calderas (J. Rytuba, personal communication).

Exploration for buried mineral deposits and calderas within Cenozoic volcanic rocks would also be an area of research within the Adel quadrangle. The use of geochemical anomalies, pathfinder elements, mineral deposit halos and the mobility of elements within young volcanic rocks would all be areas of interest. The geophysical studies associated with the search for "blind" mineral deposits and calderas within volcanic rocks would involve methods that can search beneath the surface, such as aerial and ground magnetics, gravity, and electrical measurements; and the surface measuring techniques of radioactivity and landsat imagery to detect surface expression of buried mineralization. Thé present methods used in the exploration for ore deposits, and the understanding of ore deposit genesis and alteration within young volcanic rocks would be greatly enhanced if these studies were persued within the Adel quadrangle.

Another important product of an Adel CUSMAP study would be the development of new, and the enhancement of existing deposit and grade-tonnage models. The development of new deposit and grade-tonnage models for non-metallic commodities present within the Adel quadrangle would be accomplished. This would significantly help resource analysts to quantify mineral resource assessments, both within the Adel quadrangle and elsewhere. Adding Adel mineral deposit information to currently existing models of commodities which occur in young volcanic rocks would increase their validity and the confidence with which they could be used.

Economic Benefits Expected

The economic benefits expected from a formal CUSMAP study conducted within the Adel quadrangle would influence private industry, the State of Oregon, and local academic institutions. Although these benefits may not be immediate nor result in guaranteed economic rewards, the long term affect of gaining a better understanding of the geologic environment and related mineral deposits would benefit the area immensely.

The State of Oregon is receptive to and anxious for the exploitation of its mineral resources, if it can be done in an environmentally sound fashion. The private minerals industry has invested money into exploration for new deposits within the Adel quadrangle, but with very little success. With the help of the types of products which would result from a CUSMAP study of the Adel quadrangle, mining companies could better define their target areas with respect to exploration and this could result in a new phase of exploration activity.

The State of Oregon would benefit from a formal CUSMAP study of the Adel quadrangle not only because of the possible increase to its tax base for the above stated reasons, but also through a better understanding of the geology and mineral deposits within the state. Oregon has a very active Department of Geology and Mineral Industries which would benefit from and be a benefit to a CUSMAP study.

The economic benefits of a CUSMAP study within the Adel quadrangle to academic institutions lies mainly in the additional funding which would be available to them through cooperative projects. There are many institutions which have worked in the area including: Oregon State University, University of Oregon, University of Washington, University of Montana, University of Colorado, and others.

GEOLOGY

Introduction

Topography and Setting

The Adel 1° x 2° quadrangle (lat. 42°00' N to 43°00' N by long. 118°00' W to 120°00' W) (plate 1-A and figure 1) covers a sparsely vegetated, semi-arid region of the northern Basin and Range physiographic province of southeastern Oregon. The region is characterized by several north-trending ranges, plateaus, and intervening basins. The highest and most prominent range in the region includes the Steens and Pueblo Mountains which trend north-northeast across the eastern part of the quadrangle. Elevations in the quadrangle range from 9,670 ft at the crest of Steens Mountain to 4,020 ft in Alvord Desert. The highest and lowest points in the quadrangle are less than 6 mi apart, separated by the impressive Steens Mountain scarp. Most of the quadrangle consists of upland ranges and plateaus ranging from 5,200 to 7,400 ft above sea level. The higher ranges and plateaus, as well as west facing slopes, support isolated groves of mountain aspen and juniper trees. The uplands are separated by four north-trending, trough shaped basins ranging from 4,100 to 4,500 ft above sea level. From west to east the basins include Warner Valley, Guano Valley, Catlow Valley, and Pueblo Valley. Small rivers and streams that drain the region, all part of internal drainage systems, are confined to the intervening ranges and basins. The westernmost basin contains several playa lakes while the eastern basins contain large playa deserts.

Access

Access into most parts of the quadrangle is generally poor or limited. State Highway 78 crosses the extreme northeast corner of the quadrangle (plate 1-A) and State Highway 140 crosses the southwestern part of the quadrangle. A third paved road, State Highway 205, enters the quadrangle from the north following the west side of Steens Mountain, terminating south of Frenchglen. Access to eastern and central parts of the quadrangle are by an improved gravel road that follows the north-trending Pueblo and Steens Valleys. The road branches to the west near Fields, crosses the Steens-Pueblo Range, and continues north along Catlow Valley to Frenchglen. The eastern branch follows Alvord Desert north through Steens Valley to State Highway 78. Limited access to the western part of the quadrangle is by an improved gravel road that follows the north-trending Warner Valley. The road passes through Adel, Plush, and the Hart Mountain National Game Refuge.

Base Materials

The entire Adel 1° x 2° quadrangle is available in finished 7.5 minute series topographic maps at a scale of 1:24,000.

Aerial photographes are available for the entire quadrangle through the U.S. Geological Survey EROS data center. They include low and high altitude black and white coverage at various scales, and high altitude color infrared photos at 1:64,000 scale. Direct geologic mapping on aerial photographes is practical in some areas because of sparse vegetation.

GEOLOGY

Previous Geologic Investigations

Previous geologic investigations of the Adel quadrangle are a reconnaissance geologic map by Walker and Repenning, published in 1965 (scale 1:250,000) and a number of unpublished theses (fig. 1). Between 1980 and 1983, the southeastern part of the quadrangle was mapped by the U.S. Geological Survey for caldera related studies (fig. 1). During the past 4 years, parts of the Adel quadrangle have been remapped by the U.S. Geological Survey for the purpose of mineral resource evaluation of wilderness lands (plate 1-B). About 30 percent of the quadrangle was remapped during these studies at a scale of 1:24,000.

Geologic Setting

The Adel 1° by 2° quadrangle is in the northern Basin and Range Province and exhibits many of the lithologic and structural features characteristic of the region. Dominant among the rocks exposed in canyon walls of fault-block mountains (horsts) are thick sequences of Cenozoic volcanic, volcaniclastic, and terrestrial sedimentary rocks; only in the Pueblo Mountains and in a small area in the western Trout Creek Mountains are older, pre-Cenozoic metamorphic and intrusive granitoid rocks exposed.

The maximum thickness of the Cenozoic section over most of the quadrangle is unknown, but is thought to be highly variable and in excess of 7,000 ft, perhaps locally totalling as much as 10,000 ft. This section consists of Oligocene tuffaceous sedimentary rocks, ash-flow tuffs, and rhyolite flows and domes 1,500 ft or more thick exposed on several major fault scarps bounding the Warner Valley graben and at the base of the Steens Mountain scarp west of Alvord Desert; in none of these areas is the base of the Cenozoic section exposed. At Steens Mountain these rocks have been identified as the Pike Creek Formation and Alvord Creek Formation (Fuller, 1931; Walker and Repenning, 1965). Stratigraphically above the Oligocene rocks is a sequence of basalt and andesite flows of lower and middle Miocene age that includes the Steens Mountain Volcanic (or Andesite) Series and the Steens Basalt (Fuller, 1931; Williams and Compton, 1953). The Steens Mountain Volcanic series has recently been renamed the Steens Mountain Volcanics (Minor and others, 1987). About 4,000 ft of Steens Basalt and 1,500 ft of Steens Mountain Volcanics are exposed on Steens Mountain scarp and over 2,000 ft of Steens Basalt is exposed on Poker Jim Ridge adjoining Warner Valley.

Ash-flow tuffs of middle Miocene age, partly the age equivalent of the Steens Basalt and partly younger, are extensively exposed in the Trout Creek Mountains and in areas along the southern border of the quadrangle east of Guano Valley. Measured sections of individual ash-flow tuffs range in thickness from a few tens of feet to as much as 600 ft. Several hundreds of feet of tuffaceous sedimentary rocks (plate 1-A); map unit Tts), of about the same middle Miocene age as the ash-flow tuffs, are exposed extensively west of Guano Valley, surrounding Beatys Butte and in several other parts of the quadrangle. The middle Miocene sedimentary rocks are overlain by late Miocene tuffaceous sedimentary rocks, ash-flow tuffs, and, locally, basalt flows all totaling 300 to 400 ft thick.

Major fault-block depressions (graben), such as Warner Valley and Pueblo Valley-Alvord Desert, contain late Pliocene and Quaternary sedimentary deposits of largely unknown thickness. Most of these poorly consolidated deposits relate to deposition in late Pleistocene (pluvial) lakes and to surfical, wind-blown, dune accumulations.

Stratigraphy

Mesozoic Rocks

The oldest rocks exposed in the Adel quadrangle are Mesozoic age metamorphic rocks and intrusions that form the eastern part of the Pueblo Mountains and southern parts of the Trout Creek Mountains (plate 1-A). Mesozoic rocks in the Pueblo Mountains include metamorphosed volcanic and intrusive rocks, and schist. Parts of the schist are intruded by stocks of quartz monzonite and quartz diorite (Roback and others, 1987). Mesozoic basement in the southern Trout Creek Mountains consists of quartzo-feldspathic schist and granitic intrusions (Minor, 1986). Mesozoic metamorphic and intrusive rocks in the Pueblo Mountains contain prospects for gold, silver, mercury, copper, lead, and zinc (Roback and others, 1987; Munts and Willet, 1987).

Pike Creek and Alvord Creek Formations

The Pike Creek and Alvord Creek Formations (Williams and Compton, 1953; Walker and Repenning, 1965) crop out along the eastern escarpment of the Steens and Pueblo Mountains, and form the oldest exposed Tertiary rocks in the eastern part of the quadrangle. The formations consist of late Oligocene and early Miocene sedimentary rocks, rhyolite and dacite flows, and rhyolite ash-flow tuffs. In the Pueblo Mountains, sedimentary rocks of the Pike Creek Formation lap onto pre-Tertiary metamorphic and intrusive basement rocks. The sedimentary rocks have a minimum thickness of 750 ft and contain prospects for gold, uranium, and mercury (Roback and others, 1987). Along the east escarpment of the Pueblo Mountains the formation crops out for a total of 5 to 6 mi, lapped to the north and west by younger basalt and andesite flows. Thirty miles north of the Pueblo Mountains, the Alvord and Pike Creek Formations reemerge along the base of the Steens Mountain escarpment (plate 1-A). Here, the sedimentary and volcanic rocks have a minimum thickness of 2,400 ft and have mineral potential for gold, uranium, mercury, zeolite mineral, and perlite resources (Minor and others, 1987).

Hart Mountain Volcanic and Sedimentary Rocks

Volcanic and tuffaceous sedimentary rocks of Oligocene or possibly older age exposed in the western part of the Adel quadrangle at Hart Mountain, were intruded by late Oligocene rhyolitic rocks, and partly buried by rhyolitic domal masses and related flows. The volcanic and sedimentary rocks are the oldest Tertiary rocks exposed in the western part of the quadrangle. Domal complexes of rhyolitic or rhyodacitic rocks that are approximately coeval with the silicic intrusions at Hart Mountain occur to the west of Hart Mountain at Coyote Hills and Rabbit Hills. Oligocene rocks at Hart Mountain were lapped, successively, by early to middle Miocene basalt flows correlative with the Steens Basalt, middle Miocene tuffaceous sedimentary rocks, and basalt flows of probable late Miocene age (plate 1-A; map unit Tb). The northeast and east base of the mountain is lapped by the distal ends of late Miocene ash-flow tuffs erupted from calderas outside of the Adel quadrangle. At the time the reconnaissance map of the Adel quadrangle (Walker and Repenning, 1965) was prepared, no precise evidence of the age of the rocks in either the rhyolitic domal complexes or the older wall rocks was available; subsequent K/Ar dating of selected rocks from silicic domal complexes indicates an age range of about 25- to 29-Ma (Noble and others, 1974; Fiebelkorn and others, 1983). These ages, however, do not adequately date the volcanic and tuffaceous sedimentary wallrocks that were intruded and partly buried by the late Oligocene rhyolitic rocks.

On the west face of Hart Mountain gently dipping moderately to well-lithified commonly altered tuffs, tuffaceous sedimentary rocks, and andesite flows and flow breccias are invaded and lapped by flows and domes of peralkaline soda rhyolite or pantellerite (Walker, 1961; Noble and others, 1974). A large 5-mi-long domal mass of chemically similar rock occurs on Hart Mountain, in the vicinity of Warner Peak, and eastward for about 5 mi. The pantelleritic rocks differ from type pantellerite, exposed on the island of Pantelleria, by being somewhat more silicic, slightly higher in Al_2O_3, and lower in K_2O + Na_2O, total Fe, and TiO_2. Ash and pumice fragments in selected beds of tuffaceous wallrock are pervasively altered to zeolites, mostly clinoptilolite, mordenite, and lesser phillipsite, and in other beds is altered to mixed-layer montmorillonite (bentonitic) clay (Walker and Swanson, 1968).

A large and complex Basin and Range horst located east of Warner Lakes (plate 1-A) includes Hart Mountain. Initial development of the horst appears to have taken place in late Miocene time, after the late Miocene basalt flows were emplaced, and probably prior to the eruption of the late Miocene ash-flow tuffs. By analogy with other nearby areas in the northern Basin and Range, displacements on faults bounding the horst apparently continued into Pliocene and possibly into Pleistocene time.

Domal Complexes of Coyote and Rabbit Hills

Silicic domal complexes in the Coyote and Rabbit Hills (west-central part of plate 1-B) are about the same age as the silicic complex at Hart Mountain, but, based on limited thin section petrography only, they appear to be somewhat less peralkaline in their chemistry. One small hypabyssal intrusion of porphyritic quartz monzonite is present in the silicic domal complex at Coyote Hills, and is considered to be a precursor to or comagmatic with associated rhyolitic volcanic rocks (Thomas, 1981). One might speculate that all these essentially coeval rhyolitic domal complexes at Hart Mountain and Coyote and Rabbit Hills are related to a larger, throughgoing, mostly buried volcanic collapse structure, the central part of which has been down-dropped in the north-northeast-trending graben of Warner Valley. Only additional investigations can provide data to assist in resolving this enigma.

Associated with the silicic volcanism at Coyote Hills was a period of hydrothermal activity which deposited minor quantities of precious and base metals in quartz-pyrite veinlets and as disseminations (Thomas, 1981). At various times, these mineralized areas were prospected for gold and mercury, but the only reported production is of a few flasks of mercury presumably extracted in the early 1940's.

Steens Basalt

Most of southeastern Oregon, and parts of southwestern Idaho and northern Nevada are underlain by Steens Basalt (Mankinnen and others, 1987). Baksi and

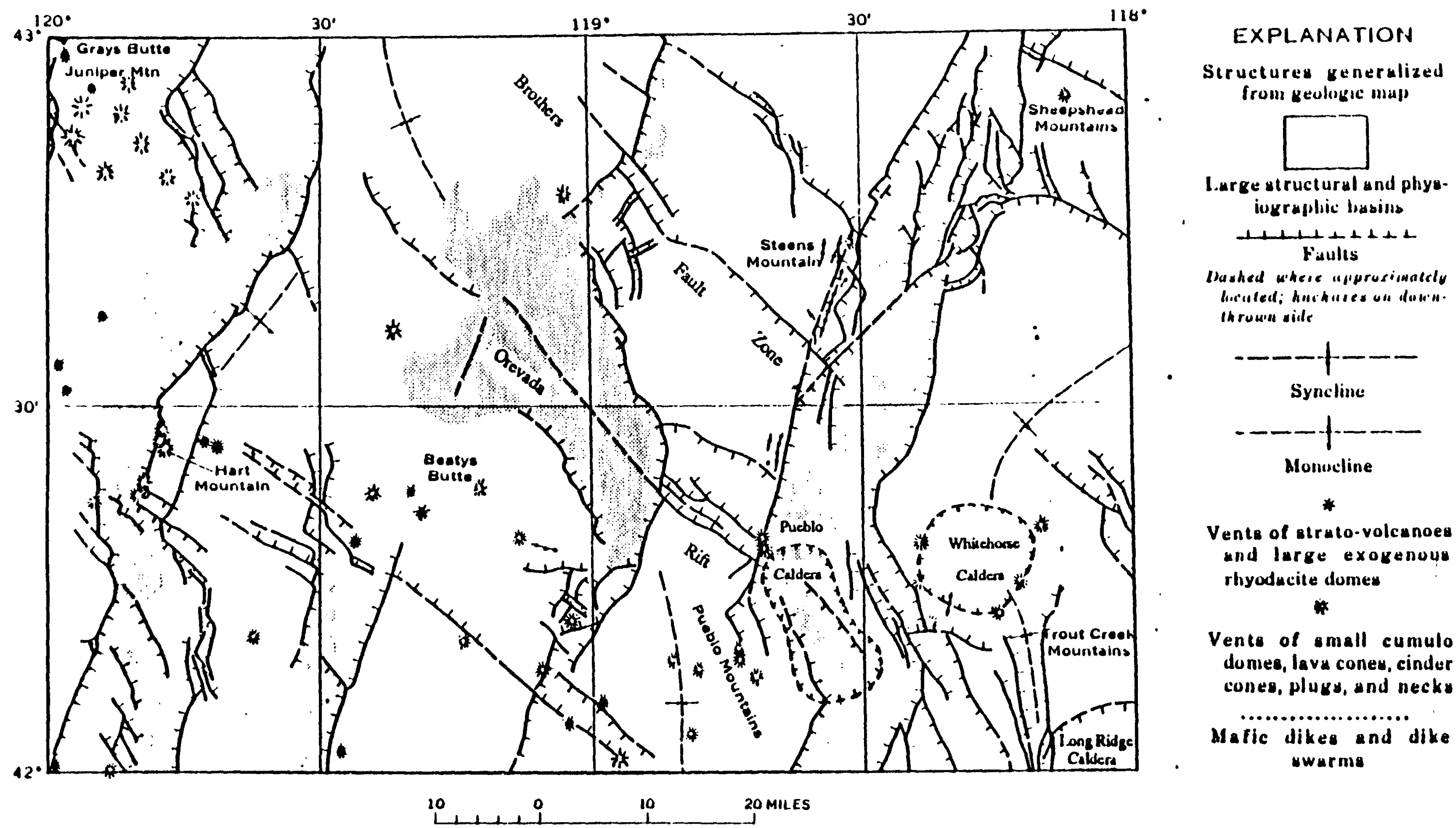


Figure 2- Tectonic sketch map of the Adel quadrangle, Oregon

others (1967) dated the Steens Basalt at 15.5 Ma. On the basis of stratigraphic relationships in the McDermitt volcanic field the Steens Basalt is considered to be older than 16.1 Ma (Rytuba and others, 1984). The Steens Basalt described by Fuller (1931) and by Piper and others (1939) consists of a chemically homogeneous sequence of thin basalt flows that average 20 ft thick. The thickest exposed section of Steens Basalt is at Steens Mountain where it reaches a maximum thickness of 4,300 ft. At Steens Mountain several large dikes consisting of Steens Basalt (150 ft wide-by-3 mi long) intrude, cross-cut, and merge into the flows (Minor and others, 1987). The dikes were probably the feeders for much of the Steens flood basalt.

A gravity survey of the Steens Mountain area indicates a 15 mi circular gravity low centered over the eastern part of the range. The circular form of the gravity low may represent a buried caldera below the Steens Basalt (Vander Meulen and others, 1988b). Rhyolite and dacite ash-flow tuffs and domes that form part of the Pike Creek Formation along the east scarp of Steens Mountain, may be associated with this proposed caldera.

Andesite Flows

Much of the Steens Basalt south and east of Steens Mountain is conformably overlain by andesite flows. The andesite unit varies from platey and flow foliated to vesicular and nonfoliated. In the eastern part of the quadrangle, the combined thickness of andesite flows stratigraphically above the Steens Basalt are generally 200 to 600 ft thick. A sequence of andesite flows west of the Pueblo Mountains, along Catlow Rim is over 1,100 ft thick (Vander Meulen and others, 1988a). Andesite flows and associated andesite dikes located in the northern Pueblo Mountains, contain prospects for mercury and copper. During the 1950's, small mercury mines operated in this area.

In the Trout Creek Mountains, andesite flows overlying mafic flows (possible correlative with part of the Steens Basalt) are interstratified with rhyolite ash-flow tuffs erupted from the McDermitt caldera complex (Conrad, 1983). Conrad (1983) suggests that the extensive andesite flows as well as some of the basalt flows in the region originated from major volumes of lower crustal partial melts.

Caldera Complex

The Trout Creek Mountains, located in the southeastern part of the Adel quadrangle, are capped by four middle Miocene peralkaline rhyolite ash-flow tuffs. In the quadrangle, the ash-flow sheets cover about 4,002 square miles, and range from a few feet thick at their distal margins to hundreds of feet thick near their source. The rhyolite tuffs are associated with four calderas that make up part of the McDermitt caldera complex.

The tuff of Oregon Canyon, dated by K/Ar methods at 16.1±0.2 Ma (Rytuba and McKee, 1984), is the oldest and most extensive of the four ash-flow tuffs. The tuff conformably overlies, and in some areas is interstratified with the andesite flows. The tuff of Oregon Canyon erupted from the Washburn caldera located 2 mi east of the quadrangle. Three additional tuffs erupted from calderas located in the southeastern part of the Adel quadrangle. The tuff of Trout Creek Mountains, dated at 15.9±0.3 Ma (Rytuba and McKee, 1984), resulted from the collapse of the Pueblo caldera (fig. 2). The margin of the Pueblo caldera is best exposed along the east escarpment of the Pueblo Mountains (plate 1-A) where it forms a broad embayment in the range front. Mercury mines, prospects, and silicified zones are located along this part of the caldera margin. Deposition of gold, silver, copper, zinc, molybdenum, mercury, and uranium are attributed to hydrothermal systems associated with the Pueblo caldera.

The tuff of Long Ridge, dated by K/Ar methods at 15.6±0.5 Ma (Rytuba and McKee, 1984), erupted from the Long Ridge caldera (fig. 2), part of the McDermitt caldera complex that occupies the extreme southeast corner of the quadrangle. Deposits of uranium and mercury occur along and adjacent to the ring fracture system of the Long Ridge and Washburn calderas (Rytuba, 1981). The largest producing mercury mines in the western hemisphere are located along the margin of these two calderas.

The youngest ash-flow tuff of the McDermitt caldera complex is the tuff of Whitehorse Creek, dated by K/Ar methods at 15.0±0.3 Ma (Rytuba and McKee, 1984). The tuff of Whitehorse Creek resulted from the collapse of the Whitehorse caldera, which forms part of a broad basin north of the Trout Creek Mountains (fig. 2). Alteration occurs around the margin of the Whitehorse caldera indicating past hydrothermal activity (Rytuba and others, 1981).

Domal Complexes of Beatys Butte, and Hawks and Lone Mountains

Silicic domal complexes at Beatys Butte and Hawks Mountain (or Valley) and Lone Mountain, in the central and south-central part of the quadrangle, are Miocene in age and have been dated by K/Ar methods at 10.6±0.5 and 13.9±0.2 Ma (McKee and others, 1976; Fiebelkorn and others, 1983), respectively. The domal complex at Beatys Butte represents the older end of an age progression in silicic volcanism that is uniformly younger to the west-northwest toward the Cascade Range (MacLeod and others, 1976).

Analysis of two rock samples from Beatys Butte indicate the presence of both alkali rhyolite and rhyodacite. Analysis of one rock sample from Hawks Mountain indicates that at least part of this domal complex is composed of alkali rhyolite.

Ash-Flow Tuff and Sedimentary Rocks (Western)

Much of the northern part of the Adel quadrangle west of Steens Mountain crest is underlain by late Miocene ash-flow tuff and interstratified and underlying tuffaceous sedimentary rocks, both of which thin and lap out on gently tilted (less than 15°) Steens Basalt. On the back (west) slope of Steens Mountain, both north and south of Frenchglen, erosion has stripped much of the tuff and tuffaceous sedimentary rocks down to the more resistant mafic flows leaving numerous isolated patches of less resistant volcaniclastic rocks. In areas west of Frenchglen and north of Catlow Valley the ash-flow tuff layers cover much of the surface; distal ends of the ashflows occur around the margins of Catlow Valley and extend to the Hart Mountain area and to bluffs northwest of Bluejoint Lake. The ash-flow tuff layers, that include the Devine Canyon Ash-flow Tuff, dated by K/Ar methods at about 9.2 Ma, and the Rattlesnake Ash-flow Tuff, dated at about 6.4 Ma, erupted from buried calderas in the Harney Basin, about 40 mi north of Frenchglen (Walker, 1979). The ash-flow tuffs are peraluminous rhyolite and in most rock classifications would be considered soda rhyolite or alkali rhyolite.

Along the walls of Kegs Springs Valley (plate 1-B), northwest of Frenchglen, a Barstovian (currently considered middle Miocene) vertebrate fauna occurs in tuffaceous sedimentary rocks exposed beneath the ash-flow tuff layers and above the andesite flows capping the Steens Basalt. The Barstovian age assignment indicates these tuffaceous sedimentary rocks are correlative with the middle Miocene Mascall Formation of north-central Oregon.

Caldera-fill Sedimentary Rocks

Three caldera depressions in the southeastern part of the Adel quadrangle (plate 1-A) are filled with thick accumulations of sedimentary rock and pyroclastic deposits. The sedimentary rocks are correlative with part of the Trout Creek Formation of Smith (1926) and Fuller (1931).

In the Whitehorse caldera, the Trout Creek Formation has a total thickness of about 600 ft. The U.S. Department of Energy drilled a 740 ft core within the southwest part of the caldera to test the uranium potential of the caldera-fill deposits. Radiometric logging of the drill hole showed no anomalous zones (Rytuba and others, 1981). The upper 120 ft of the intracaldera deposits are unaltered and consist primarily of diatomaceous earth (Rytuba and others, 1981). The lower 110 ft of the intracaldera volcanic and sedimentary rocks are altered to zeolites and potassium feldspar.

Caldera-fill sedimentary rocks within the Pueblo caldera crop out along the eastern Pueblo Mountains. The upper part of the caldera-fill sequence consists of weakly consolidated sandstone and conglomerate. The lower part of the sequence consists of thin beds of diatomaceous earth interstratified with tuffaceous sedimentary rocks and thin pyroclastic flows. Caldera-fill sedimentary rocks in the Pueblo caldera have an estimated total thickness of 3,200 ft (Rytuba and McKee, 1984).

Caldera-fill sedimentary rocks within the Long Ridge caldera have been altered to zeolites and potassium feldspar by hydrothermal and diagenetic processes (Rytuba and Glanzman, 1979). Because the depression created by caldera collapse remained closed; elements that are highly soluble were released during the alteration process and concentrated in the caldera-fill sedimentary rocks (Rytuba, 1981). Uranium is concentrated in organic and pyritic zones of the sedimentary rocks. Lithium deposits contained in the caldera-fill sedimentary rocks form one of the largest known lithium resources in the world (Rytuba, 1981). Presently, the lithium resources are not economic. Most of the mercury deposits in the McDermitt caldera complex are hosted in the caldera-fill sedimentary rocks, and specialty clays are being mined.

Structure

Two major northwest-striking deep-seated fault zones cross the Adel quadrangle. The fault zones, which show evidence of right lateral displacement (Lawrence, 1976), form part of the northern boundary of the Basin and Range physiographic province. Right lateral displacement along the fault zones suggests a more stable block north of the shearing with progressively greater extension and westward opening south of the shearing.

The older of these linear structures is the Orevada rift (fig. 2) (Eugene-Denio fault zone) which extends from central Oregon to northwest Nevada.

Rytuba and Conrad (1981) suggest that the 125-mi-long northwest-striking Orevada rift developed in response to basin and range tectonism. The rift marks the northernmost outcrops of Mesozoic rocks in southeastern Oregon (Rytuba and McKee, 1984). The oldest rocks that fill the rifted basin are a 24 Ma ash-flow tuff (Noble and others, 1970) and 21.3 Ma lavas of the Steens Mountain Volcanics (Minor and others, 1987). The Brothers fault zone, the youngest of the two shear zones, extends 180 mi across central Oregon from the Steens Mountain escarpment to the Cascade Range. The northwest-striking fault zone is located north of, and subparallel to, the Orevada rift (fig. 2). South of Steens Mountain, tectonism associated with the Brothers fault zone displaces 15.5- to 16.1-Ma Steens Basalt; here; the basalt flows are warped into a large northwest-trending faulted monocline (Walker, 1969).

Timing of basin and range faulting in the Adel quadrangle is partly controlled by the widespread distrubution of 15- to 16-Ma ash-flow sheets of the McDermitt volcanic field. The age of these voluminous sheets places a maximum age on the basin and range block faulting, which now dominates the topography of the quadrangle (Rytuba and McKee, 1984). Block faulting in the Pueblo-Steens and Catlow Valleys is further limited by the 9.2 Ma Devine Canyon Ash-flow Tuff, and in the Warner Valley by the 6.4 Ma Rattlesnake Ash-flow Tuff (Walker, 1979; Rytuba and McKee, 1984). These widespread tuff sheets, which erupted from calderas in the Harney Basin 40 mi north of the quadrangle, occur in ranges that bound the downfaulted valleys.

Faults bounding the valleys generally follow two major trends, N. 60° W. and N. 20° E. (fig. 2). Faults that strike N. 60° W are probably related to the major shear zones that cross southeastern Oregon. Block faults that strike N. 20° E. likely developed in response to regional NW-SE extension. North-northwest-trending faults in the Pueblo and Trout Creek Mountains are probably related to a more complex tectonic regime similar to that of northern Nevada. Several caldera ring structures as well as exposures of the Mesozoic basement have complicated the tectonic regime in the southeastern part of the Adel quadrangle. Discovery of extensive precious metal deposits adjacent to north-northwest-trending fault zones in northern Nevada, such as the Sleeper gold deposit, has stimulated exploration in parts of the ajoining Adel quadrangle.

EXPLORATION GEOCHEMISTRY

Introduction

Many thousands of samples have been collected for geochemical purposes from the Adel quadrangle. Several thousand of these have been analyzed for a wide variety of elements. The diversity of people and philosophies involved in this effort has lead to an equal diversity in sample types and analytical schemes. The end result is that no single data base can be constructed to unify the efforts of the various groups. Rather, it is necessary to consider each of the geochemical studies as a separate entity. Interpretations of these various parts do yield a generally coherent pattern for the entire quadrangle.

Two principle sources of geochemical information have been identified. These are the extensive suite of samples from the NURE program, covering the entire quadrangle and consisting of five separate sample types, and the more detailed but less uniform suite of samples collected for evaluation of Wilderness Study Areas scattered across the quadrangle. Each of these various sources of information is considered separately. In general, the most useful data set is that for soils from the NURE program. Information extracted from the soils data can be augmented by interpretation of the data from the Wilderness Study Areas. The remaining data is of little value.

NURE Soils

The NURE data set for "soils" provides the most uniform geographic distribution of data for the quadrangle. Whether they are "soils" as indicated by the data file or "sediments" as indicated by Averett (1984, Table C-1, p. C-2) is of little consequence to interpretation for the purposes of this report, so long as the sample type is uniform. The major difference between "soils" and "sediments" is in the area of influence reflected by a given sample. Since there is a separate data set within the NURE data file for the Adel quadrangle with data for "stream sediments," it seems likely that the large data set called "soils" is, in fact, "soils," and the individual samples represent a restricted area of influence. The uniformity of the sampling technique is a matter of faith. In the semiarid environment of this quadrangle, surficial materials, either soil or stream sediment, may contain a significant proportion of aeolian material. The aeolian material may be transported great distances and constitutes a foreign "contaminant" in the samples. The wind-transported material is thoroughly mixed and of uniform composition. Thus, it is a diluent rather than a "contaminant." The apparent internal consistency of the data suggests a uniform, representative set of samples, and the wide range of the data and reasonably sharp definition of the anomalies suggest that aeolian dilution is not a problem.

The data file contains 2,483 rows (samples). Less than half of these (1,230) have analytical data. The samples that were not analyzed have a suffix "s" on the field numbers, and comparison of the longitude and latitude for adjacent samples, one analyzed and one not analyzed, indicates that the samples not analyzed were duplicate samples collected a short distance from the analyzed samples. The useable data set contains 1,230 samples. Analyses are reported to be by plasma emission spectroscopy (Arendt et al., 1979).

Analytical data are presented for 31 elements (table 1). Three of these are severely truncated at the limit of analytical sensitivity--silver, hafnium, and molybdenum--and for these, little more can be done than search for the enriched areas. For the remainder, there are a sufficient number of valid observations and the ranges are great enough to allow evaluation of interelement relations. The means in table 1 are calculated for the valid observations only, thus are true means only for those elements with 1,230 valid observations. For the other elements, the mean presented is above the true mean. For silver, hafnium, and molybdenum, the mean presented is of little consequence. For boron, lead, and thorium, minimum possible means are 11, 4.5, and 3.4, respectively, so the means presented in the table are probably 30 to 50 percent too high. For the remaining elements, the mean presented is a good value.

Table 1. Summary of analytical data for 31 elements in 1,230 samples of "soil" from the Adel quadrangle, Oregon

[Data in ppm unless specified otherwise]

Element	Minumum	Maximum	Geometric mean	Number of valid observations	Number of "less than" values
Ag	2	4	2.1	28	1,202
Al (%)	4	11.25	7.9	1,230	--
B	10	380	19	1,008	222
Ba	78	1,550	562	1,230	--
Be	1	5	1.5	1,220	10
Ca (%)	0.68	6.9	2.3	1,230	--
Ce	1.5	207	21	1,229	1
Co	4	42	13	1,225	5
Cr	4	462	40	1,230	--
Cu	11	488	40	1,230	--
Fe (%)	1.5	9.4	4.0	1,230	--
Hf	15	35	19	123	1,107
K (%)	0.32	2.9	1.1	1,230	--
La	7	123	21	1,230	--
Li	8	280	20	1,230	--
Mg (%)	0.24	3.3	0.77	1,230	--
Mn	268	2,800	840	1,230	--
Mo	4	15	5	31	1,199
Na (%)	.6	3.25	1.7	1,230	--
Nb	4	49	12	1,129	1
Ni	3	198	22	1,230	--
P	198	7,760	627	1,230	--
Pb	10	93	17	652	578
Sc	4	26	11	1,230	--
Sr	75	650	338	1,230	--
Th	2	28	5.6	880	350
Ti	1,150	17,000	5,860	1,230	--
V	12	490	115	1,230	--
Y	7	77	21	1,230	--
Zn	43	260	84	1,230	--
Zr	48	610	130	1,230	--

The range of values reported for most of the elements is an order of magnitude or more. This range is in excess of that expected from sampling and analytical variation, thus, indicating a broad range of chemical characteristics in the soils. Variation of this magnitude could be expected from variations in parent materials to the soils, either chemical variation among the various bedrock lithologies or variation in the surficial chemical processes. Both of these appear to have provided major control on the chemical composition of the "soils" from the Adel quadrangle.

Within a data set reflecting this many variables, this number of samples, and this large an area, there is usually a large amount of redundant information. This redundancy results from the similar chemical behavior of groups of elements in the natural environment. Though this redundancy is useful in validating interpretations--two types of information yielding the same conclusion are better than one--it leads to a large amount of clutter in the presentation of an interpretation if not properly addressed. Fortunately, a variety of statistical methods are available for ordering and grouping data of this sort to reduce the redundancy while maintaining the advantage of the redundancy.

The most obvious case of chemical redundancy in this data set is the determination of both hafnium and zirconium. The chemical similarities of these two elements in nature are so great that Goldschmidt (1958, p. 422-426), for example, usually gives abundances for these elements as Zr + Hf. Because only 10 percent of the samples contain detectable hafnium, we were tempted to delete hafnium on the basis of redundancy and incomplete data. However, the samples containing detectable hafnium contain 70 to 370 ppm zirconium, about mid-range for the zirconium in the whole data set, and the mean zirconium content of the hafnium-rich samples is 139 ppm, not significantly different from the 130 ppm mean for the whole data set. That is, the hafnium-rich samples are not zirconium rich. Furthermore, the correlation coefficient for hafnium and zirconium in the hafnium-rich samples is -0.018. The two elements appear to be unrelated! We suspect the hafnium analyses and are removing the element from further consideration on a basis of analytical uncertainty.

The matrix of correlation coefficients (table 2) provides a first-pass method of identifying elements that exhibit parallel behavior. A cursory scan of the correlation coefficients is sufficient to identify at least two groups of elements that are mutually associated. In the vanadium column, for example, there are high positive correlations with calcium, cobalt, chromium, copper, iron, magnesium, nickel, scandium, and titanium. In the zirconium column, there are high positive correlations with lanthanum, niobium, and yttrium. Furthermore, there are moderately high negative correlations between these two suites of elements.

Factor analysis provides a method of analyzing the correlation matrix for multi-element suites of the type just described. Using a variety of factor models and projections, we believe that there are four legitimate factors and some noise exhibited in the data set. The oblique projection of the five-factor model, illustrated in figure 3 by the correlation of the variables with the factor scores, most elegantly displays our interpretation. Factor I is identified by high positive correlations with a suite of elements commonly enriched in mafic igneous rocks and moderate negative

Table 2. Correlation matrix for 1,230 samples and 28 variables in soils from the Adel quadrangle, Oregon. Silver, hafnium, and molybdenum excluded because of inadequate analytical sensitivity

[Values recorded as less than the lower limit of sensitivity for B, Be, Ce, Co, Nb, Pb, and Th have been arbitrarily replaced by values of 5, 0.5, 7, 2, 2, 5, and 1 ppm, respectively. The number of replaced values (in parentheses) are: B (222), Be (10), Ce (1), Co (5), Nb (1), Pb (578), and Th (350)]

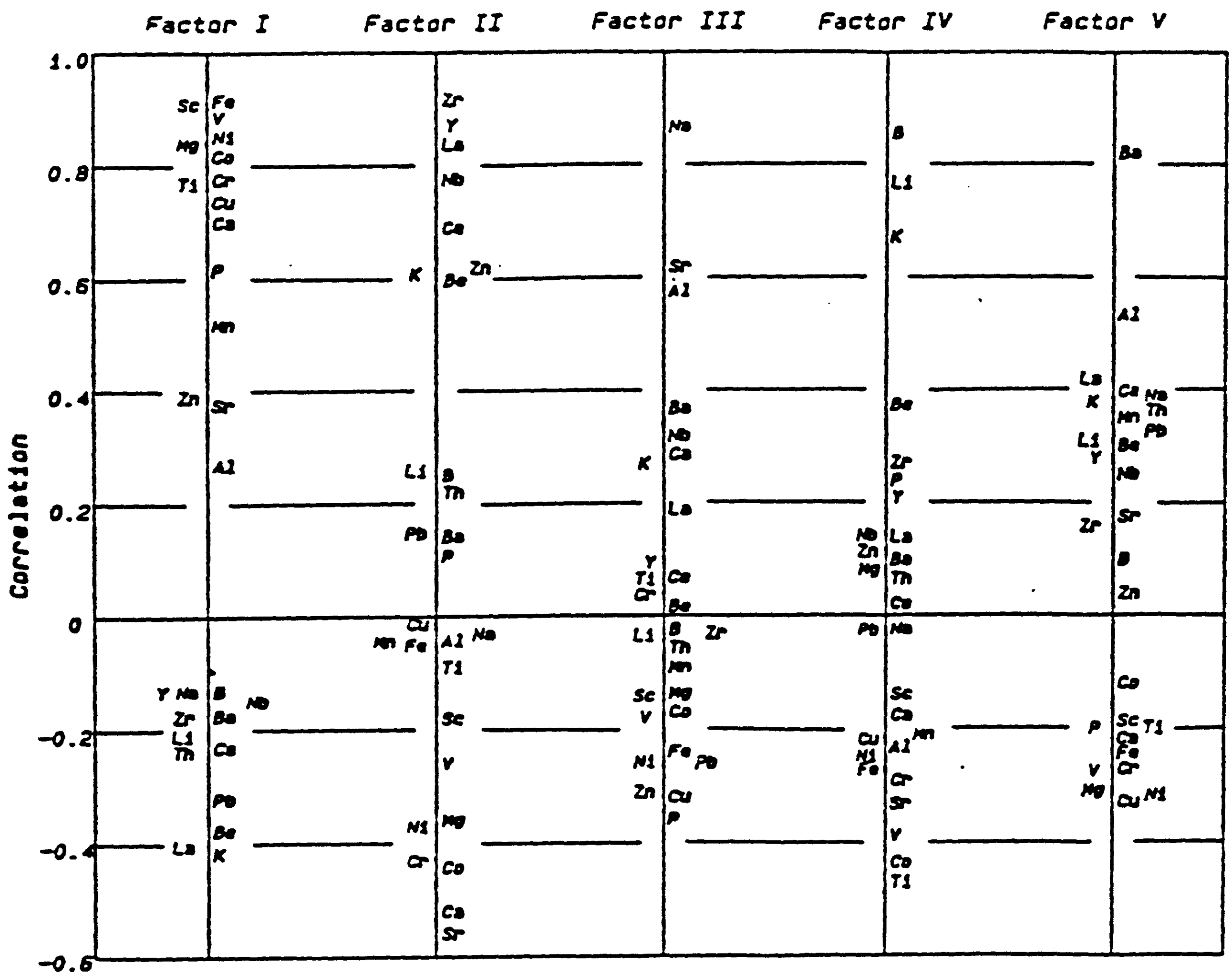
Al	B	Ba	Be	Ca	Ce	Co	Cr	Cu	Fe	K	La	Li	Mg	Mn	Na	Nb	Ni	P	Pb	Sc	Sr	Th	Ti	V	Y	Zn	Zr	
1.00	-.25	.39	-.04	.23	.05	.28	.26	.09	.23	-.04	.10	-.04	.05	.27	.39	.14	.19	-.07	-.19	.33	.48	-.03	.29	.23	.19	.03	.00	Al
	1.00	.03	.25	-.11	.11	-.32	-.23	-.19	-.25	.47	.20	.57	.06	-.15	-.03	.16	-.19	.13	.05	-.15	-.25	.15	-.38	-.31	.17	.05	.23	B
		1.00	.21	-.23	.22	-.18	-.31	-.25	-.15	.32	.30	.19	-.30	.20	.25	.17	-.36	-.03	.14	-.15	.14	.09	-.09	-.21	.21	.09	.15	Ba
			1.00	-.51	.40	-.47	-.43	-.26	-.30	.53	.49	.34	-.37	-.11	.01	.44	-.42	-.11	.22	-.29	-.42	.21	-.38	-.43	.52	.19	.51	Be
				1.00	-.39	.62	.76	.39	.53	-.42	-.53	-.36	.78	.23	.25	-.22	.63	.29	-.36	.63	.77	-.20	.57	.69	-.38	-.13	-.48	Ca
					1.00	-.23	-.30	-.07	-.14	.38	.83	.14	-.32	.06	.08	.55	-.30	-.09	.36	-.25	-.26	.30	-.11	-.22	.62	.28	.56	Ce
						1.00	.70	.60	.74	-.65	-.47	-.34	.64	.58	-.17	-.31	.82	.34	-.23	.70	.46	-.18	.66	.79	-.32	.08	-.37	Co
							1.00	.52	.62	-.52	-.48	-.29	.75	.29	.04	-.22	.83	.21	-.27	.74	.51	-.22	.61	.76	-.33	.03	-.43	Cr
								1.00	.70	-.34	-.22	-.18	.51	.26	-.18	-.17	.66	.47	-.13	.63	.14	-.22	.62	.70	.00	.46	-.04	Cu
									1.00	-.40	-.30	-.28	.71	.49	-.21	-.06	.73	.57	-.26	.85	.23	-.20	.84	.89	-.05	.47	-.03	Fe
										1.00	.53	.52	-.31	-.21	.31	.47	-.55	-.03	.17	-.40	-.35	.21	-.41	-.49	.48	.21	.54	K
											1.00	.24	-.53	-.09	.11	.72	-.50	-.18	.24	-.38	-.36	.35	-.20	-.39	.78	.31	.74	La
												1.00	-.11	-.14	-.04	.08	-.23	-.04	.11	-.22	-.31	.10	-.39	-.36	.20	.10	.25	Li
													1.00	.30	-.14	-.26	.78	.52	-.26	.78	.39	-.20	.49	.70	-.31	.13	-.34	Mg
														1.00	-.03	.06	.41	.27	-.08	.41	.14	-.02	.34	.38	.05	.32	-.01	Mn
															1.00	.25	-.22	-.30	-.07	-.16	.50	-.03	.07	-.05	.01	-.18	-.05	Na
																1.00	-.29	-.04	.04	-.15	-.20	.21	.01	-.19	.67	.39	.72	Nb
																	1.00	.39	-.24	.78	.30	-.20	.55	.74	-.27	.15	-.33	Ni
																		1.00	-.17	.57	-.03	-.13	.35	.41	.08	.43	.09	P
																			1.00	-.29	-.24	.31	-.29	-.28	.10	.10	.10	Pb
																				1.00	.30	-.19	.67	.79	-.06	.31	-.18	Sc
																					1.00	-.16	.44	.45	-.37	-.32	-.52	Sr
																						1.00	-.21	-.22	.18	.03	.20	Th
																							1.00	.91	-.09	.34	-.09	Ti
																								1.00	-.22	.28	-.25	V
																									1.00	.49	.80	Y
																										1.00	.54	Zn
																											1.00	Zr

correlations with a suite of elements commonly enriched in felsic igneous rocks. Factor II is identified by high positive correlations with a suite of elements commonly enriched in siliceous igneous rocks and moderate negative correlations with the suite of elements commonly enriched in mafic igneous rocks and with calcium and strontium. The absence of a correlation with sodium and the negative correlation with calcium and strontium are evidence that the parent materials for the soils rich in the elements of factor II are not "normal" plagioclase-rich rocks but are likely more evolved granites or rhyolites. Factor III is identified most strongly by a high positive correlation with sodium and less strong positive correlations with strontium and aluminum. Factor III is present and of similar composition in all models examined, from 4 to 10 factors, and could be predicted from the binary correlation coefficients for sodium and aluminum (table 2). It must be a legitimate characteristic of the data, but, unlike the first two factors, the element assemblage is not readily identified with a common lithology. The geographic distribution of high and low factor III scores (not illustrated here) is essentially random. We suspect that this factor reflects some systematic noise in the data, most likely an artifact of sampling, preparation, or analytical techniques. Erratically distributed but systematic variations in processes of soil formation or preservation may be possible to explain this factor. Factor IV is identified by high positive correlations with boron, lithium, and potassium, all common associates in salt accumulations. The absence of correlation for sodium with factor IV and its dominance in factor III lend some credence to the conclusion that the sodium factor represents systematic noise. Factor V, identified by high positive correlation with barium and a lesser correlation with aluminum on figure 3, is an unstable factor. Progressive factor models are generated by segmenting this factor. We consider factor V to be the non-systematic noise factor, a conclusion strengthened by the fact that the barium frequency distribution is dominated by an aberrantly low value suspected to be a transcription error. Thus, the data set can be simplified to three lithologically controlled components and noise.

The factor scores for the three factors of interest (numbers I, II, and IV) have a mean of zero and a standard deviation of one. The factor score for a given factor in a given sample is, therefore, the deviation of that sample from a sample of mean composition measured in units of standard deviation. The ranges of factor scores are remarkably large: -3.5 to 3 for factor I, -3 to 5.5 for factor II, and -3 to 5.5 for factor IV. For plotting, we have broken these frequency distributions into five classes at -2, -1, 1, and 2. The dots identify sample localities in the main body of the data between -1 and 1. Small and large circles identify sample localities with abnormally low and extremely low scores, respectively. Small and large triangles identify sample localities with abnormally high and extremely high scores, respectively. Thus, we are highlighting the extremes for each factor. Although both the positive and negative extremes are shown, it is the positive extremes that show the best patterns for all three factors.

Samples with high positive values for the factor I scores form a linear array extending the full width of the quadrangle along the east-facing scarp of the Pueblo Mountains and Steens Mountain (plate 1-C). The high values spread eastward onto the western part of the Pueblo and Alvord Valleys, presumably reflecting alluvial dispersion from the scarp. Relatively few

Figure 3. Composition of an oblique projection of a five-factor R-mode model for soils from the Adel quadrangle, Oregon. The composition is given by the correlation of the variables with factor scores for each of the factors.



high values are seen on the western side of the range, most notably in the vicinity of the high point of Steens Mountain. A smaller cluster of high scores for factor I are along the Fish Creek Rim north of Adel. The source of the extreme values for the factor we would associate with mafic rocks is evidently one or several units within the sequence of basalts and andesites that comprise the Pueblo Mountains and Steens Mountain. No particular economic significance is attached to these rocks per se. The great range of values for individual elements associated with this factor, and the high values associated with the mafic rocks in the Steens Mountain area could, however, mask significant anomalies for several elements of interest, most notably copper and zinc.

Samples with high positive values for the factor II scores form two prominent clusters in the northern and western parts of the quadrangle (plate 2-A). The larger of these clusters extends northward from the north end of Catlow Valley to the vicinity of Keg Springs Valley. The smaller cluster extends northeastward from the scarp west of Hart Mountain to include the mountain east of Warner Peak. This second cluster of extreme values is the easier of the two to explain. It coincides with the prominent, peralkaline volcanic center exposed in this area (Noble et al., 1974, and Walker, 1981), confirming our suspicion that the assemblage of elements is derived from siliceous igneous rocks. The larger anomaly to the north is also in an area of siliceous volcanic rocks, tuffs, and tuffaceous sediments. However, the extreme values are much more restricted in areal distribution than are tuffaceous rocks. Evidently, the geochemical assemblage is derived from some more evolved rocks with a more restricted range than is characteristic of the entire assemblage of tuffaceous rocks. Anomalous concentrations of these elements are associated with both intrusive porphyries and rhyolites elsewhere in the western U.S., in Nevada, Utah, Colorado, and Arizona. These rocks host deposits of molybdenum, tungsten, tin, beryllium, and similar elements. Anomalous concentrations of tin were found in heavy-mineral concentrates from the Orejana Canyon Wilderness Study Area (King, H.D., oral communication) just to the west of the northern cluster of extreme values for factor II. Thus, from these preliminary geochemical evaluations, it would seem probable that there is potential for this granitophile suite of elements in the quadrangle.

Samples with high positive values for the factor IV scores form two curvilinear arrays and an isolated cluster (plate 2-B). The western curvilinear array is coincident with the alluviated, lake, and salar-filled valley extending north from Coleman Lake to Bluejoint Lake. The eastern curvilinear array is coincident with the alluvium- and salt-lake-filled valley that includes the Pueblo Valley and the Alvord Desert. The isolated cluster of extreme values is in the southeast corner of the quadrangle and is coincident with the moat sediments inside of a caldera-bounding ring fracture. The assemblage of elements is identified with salt deposits, and the areal distribution suggests resource potential in both of the long, closed valleys. The sparse high values for factor IV in the Catlow Valley indicate a low potential in that area. High values for the factor score seen around the southern edge of the large, closed basin that includes Coyote Lake suggest some potential, but the absence of samples from this basin precludes more than a suggestion for additional work. A second, and related, possible association for this assemblage is in the deposits from hot springs. Thermal springs are common in the eastern valley and an association of this type may be appropriate to the cluster of extreme values in the southeast corner of the quadrangle.

Metallic Elements

Five of the metallic elements display patterns of distribution that transcend the major lithologic controls outlined above. To discern these patterns, it is necessary to consider each of these elements separately; (plate 2-C).

Silver and molybdenum were detected in too few of the samples to allow an analysis of their frequency distributions or valid comparisons of the distribution of these elements relative to the other elements. We have arbitrarily assumed that any detectable value for these elements is anomalous. For silver, only three values, 2, 3, and 4 ppm, are reported in 24, 3, and 1 samples, respectively. Values at the limit of detection are more suspect than those above the limit of detection so, for display, values of 2 ppm are shown by a small triangle, whereas those above 2 ppm are shown with a larger triangle (plate 2-C). All of the large triangles and most of the small triangles are clustered in the southeastern part of the quadrangle. The remaining small triangles are scattered as isolated spots or perhaps in a smaller cluster in the northwest corner of the quadrangle. For molybdenum, 31 samples contain detectable quantities, 16 of these at the 4 ppm limit of sensitivity. We have chosen to display only the 15 samples with molybdenum in the range of 5 to 15 ppm (the squares on plate 2-C). The majority of the molybdenum-rich samples are clustered in the southeastern part of the quadrangle coincident with the silver-rich area. Four of the molybdenum-rich localities are scattered northward from the cluster in the southeast, along the Pueblo Valley, and three are in the central and western part of the quadrangle adjacent to silicic volcanic centers.

Lead was detected in 53 percent of the samples in the range of 10 to 100 ppm. This is an adequate proportion of the data and sufficient range to allow comparison of the lead distribution to that of the other elements. Lead does not have a high correlation with any of the other elements (table 2), and it is not a prominent component of any of the factors of the favored five-factor model (figure 3). In expanded models from R-mode factor analysis, lead appears as a unique, single-element factor. Lead is behaving as an independent variable not strongly related to the major lithologic controls on the geochemistry exhibited by most of the other elements. We have chosen to define as anomalous values in the upper 5 percent of the frequency distribution, though the absolute values at the threshold are not high--30 ppm. This range of anomalous values is divided into a weakly anomalous group of samples with 30 to 40 ppm of lead and a strongly anomalous group of samples with more than 40 ppm of lead. These are illustrated by small and large circles, respectively, on plate 2-C. Two clusters of lead-rich samples are apparent--one in the southeast part of the quadrangle coincident with the silver- and molybdenum-rich area, and one in the south-central part of the quadrangle. There are remarkably few, isolated lead-rich samples. The only two of these that are in the strongly anomalous category are in the anomaly previously defined on the basis of extreme values for the factor II scores coincident with the silicic volcanic center in the vicinity of Hart Mountain.

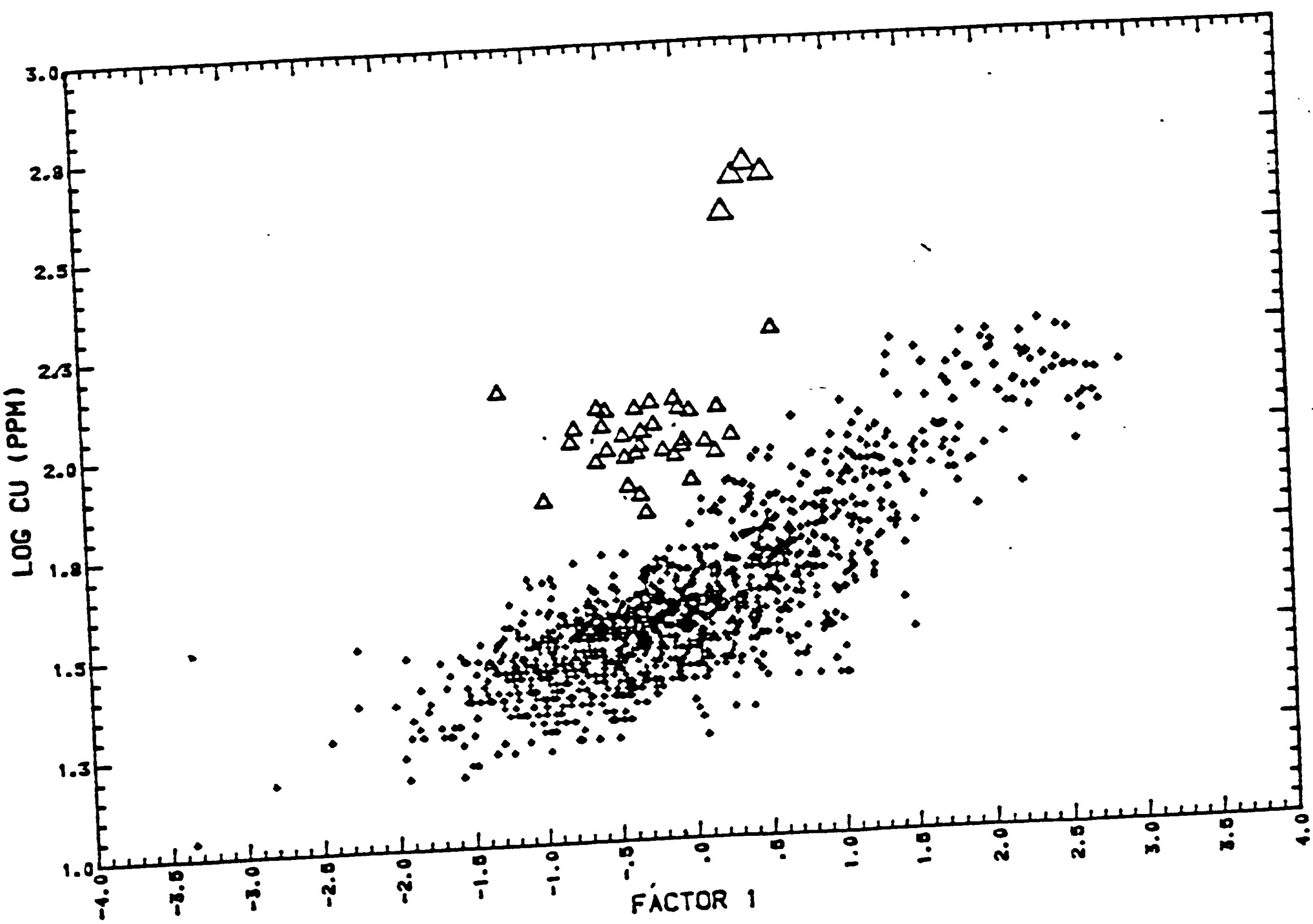
Most of the variation in copper can be attributed to lithologic control (figure 3), particularly to the association of elements in factor I that reflects the mafic component of the samples. Mafic-rich soils are copper rich, and mafic-poor soils are copper poor. The correlation of copper with factor I is displayed graphically in figure 4. The small plus symbols of this figure define the regression that is the correlation. The range of copper values we would attribute solely to lithologic variation spans more than an order of magnitude, from 10 to 200 ppm. The total range of copper values is only 1.5 orders of magnitude, extending up to 500 ppm. However, viewed in the context of the major lithologic-controlled regression, there are two clusters of samples above and to the left of the regression that contain more copper than would be predicted from the factor I scores. The four samples with 400 to 500 ppm copper, the large triangles in the upper part of the diagram, are clearly anomalous. The cloud of small triangles at about 100 ppm copper and a factor score near zero is also anomalous, but only with respect to the major regression. We will define this cloud of samples as the normalized anomalous samples.

The distribution of samples anomalous for copper, the diamonds on plate 2-C, defines a diffuse, northwest-trending, copper-rich province in the north-central part of the quadrangle. The four clearly anomalous localities form a tighter cluster within the copper-rich province. This tighter cluster is in the area of structural complexity between Frenchglen and Solomon Canyon.

The interelement relationships for zinc are even more complex than those of copper. All of the samples have detectable zinc in the range 43 to 260 ppm, and 20 percent of the samples contain 100 ppm or more. A large part of this range can again be attributed to zinc held in rock-forming minerals. The interelement relations for zinc, figure 3, indicate an association with factor I, mafic-rich soils, and with factor II, high-silica igneous rocks. Zinc substitutes readily for iron in both silicate and oxide minerals, and most of the lithology-controlled zinc is held in these minerals. Thus, iron-rich rocks should be more zinc-rich than iron-poor rocks. From these considerations it follows that high zinc values associated with high factor I scores likely reflect "rock zinc." High zinc values not associated with high factor I scores can be considered anomalous.

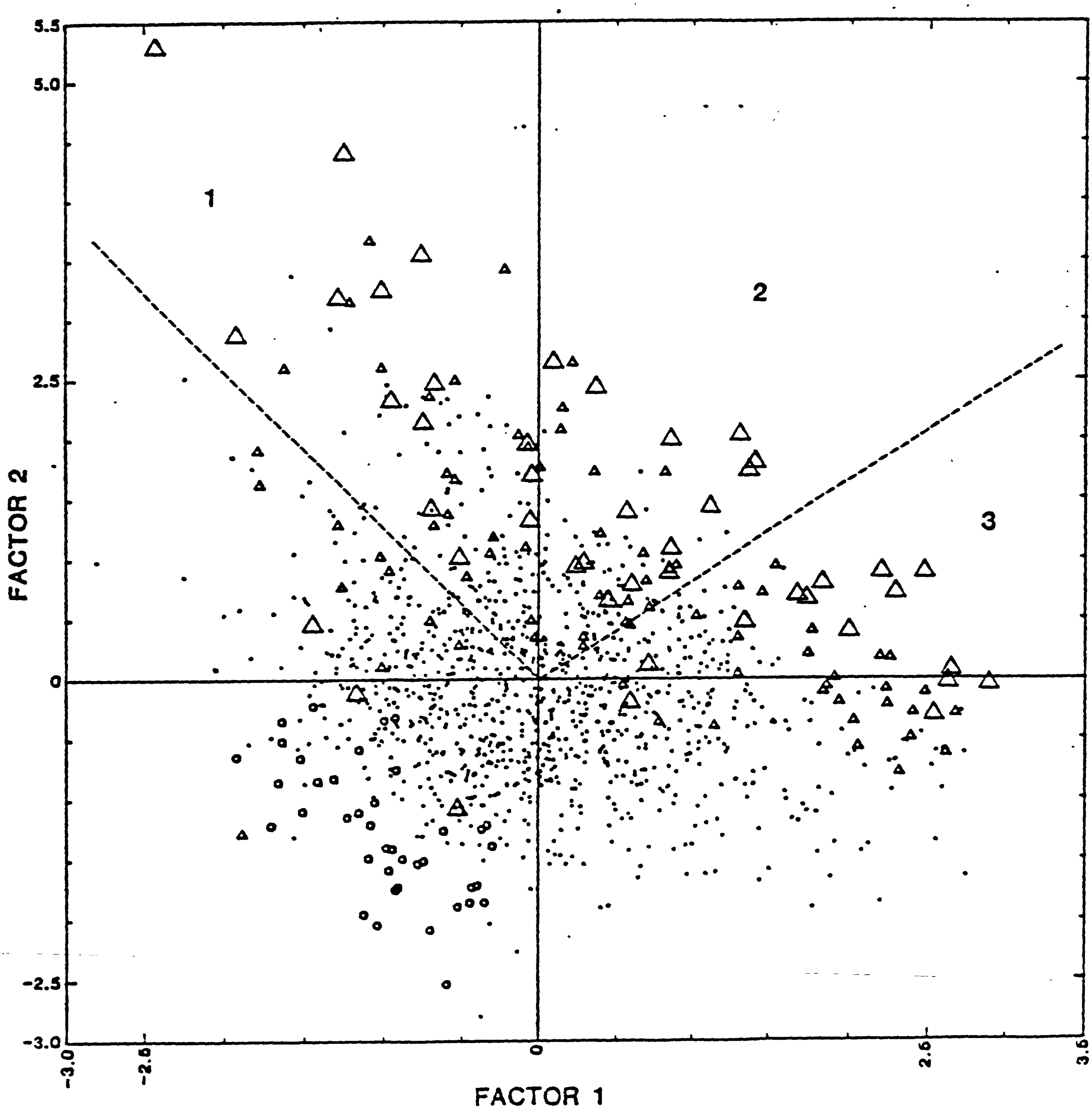
The zinc content of the soils is mapped in relation to the factor I and factor II scores on figure 5. Low values for zinc cluster in the lower left part of the diagram where both of these factor scores are low. High values for zinc generally cluster in the upper right parts of the diagram where either or both of these factor scores are high. It is this tendency that provides for the association of zinc with the two factors (figure 3). Three of the zinc-rich samples are clearly anomalous, coinciding with low scores for both factors. We have arbitrarily divided the zinc-rich samples in the north and east quadrants of the diagram into three groups: (1) samples with factor scores of 1 or more for factor I and less than 0 for factor II (2) samples with factor scores of 0.5 or more for factor I and positive scores above and to the left (closer to the factor I axis) of an arbitrary diagonal bisecting the northeast quadrant and (3) samples with factor scores below this diagonal for factor I but positive scores above 0.5 for factor II. The third of these groups is for samples associated with high values of factor I in which high zinc is to be expected on lithologic grounds. The first of

Figure 4. Relationship of copper to factor I scores for 1,230 soils from the Adel quadrangle, Oregon. The small plus symbols define a regression of increasing copper with increasing factor score, interpreted to be "normal" variation with lithology. The large triangles have much more copper than predicted by the regression and are anomalous. The small triangles have an excess of copper over that expected from the regression and are defined as normalized anomalous.



SOILS

Figure 5. The distribution of zinc in relation to factor I and factor II scores for 1,230 soils from the Adel quadrangle, Oregon. Circles contain less than 60 ppm Zn, dots contain 60 to 110 ppm, small triangles contain 110 to 130 ppm, and large triangles contain more than 130 ppm Zn. Large triangles to the left of the zero factor I score are considered anomalous. Large triangles in the field designated as 2 may be anomalous.



these groups is for samples with high values of factor II, not associated with factor I, where high zinc values are not expected on lithologic grounds. This first group is anomalous. The second group is intermediate in characteristics and can be considered marginally anomalous.

The anomalous localities for zinc are plotted as hexagons on plate 2-C. A few fall in the cluster of silver-, lead-, and molybdenum-rich samples in the southeast part of the quadrangle. Another group falls in the cluster of lead-rich samples in the south-central part of the quadrangle. The largest cluster of zinc-rich samples, all with high factor II scores, coincides with the silicic volcanic center northeast of Hart Mountain, and two of the zinc-rich samples are in the cluster of extreme values for factor II in the north-central part of the quadrangle. Most of the zinc-rich samples in the intermediate group (group 2, above) are along Steens Mountain and these may reflect the mafic nature of the country rocks. However, four of the intermediate group of zinc-rich samples coincide precisely with the four copper-rich samples south of Frenchglen.

The anomalous localities for these five elements have been plotted together on plate 2-C to emphasize the overlap of the anomalies. Four distinctive anomalous areas are evident and several of the more scattered anomalous localities add to the anomalous areas defined on a basis of the factor scores. The most prominent of these anomalous areas lies outside of the ring-fracture zone in the southeast corner of the quadrangle in the structural complex that underlies the Trout Creek Mountains and Pueblo Mountain. This area is characterized by anomalous silver, lead, molybdenum, and locally, zinc. The second anomalous area is in the structurally complex terrane to the west of Hawks Mountain. It is characterized by anomalous lead and zinc. The third anomalous area coincides with the silicic volcanic center northeast of Hart Mountain that was identified on the basis of extreme values for the factor II scores. This area is identified here by anomalous zinc and locally anomalous lead, copper, and silver. The fourth anomalous area is centered on the structural knot south of Frenchglen but is within a larger anomalous area that seems to coincide with a zone of northwest-trending faults. The larger area is identified with weakly anomalous copper, the center with strongly anomalous copper and with zinc. The scattering of anomalous values for molybdenum along the Pueblo Valley is in an area previously identified as anomalous on the basis of factor IV scores, and the pair of anomalous values for zinc in the northern part of the quadrangle is in an area previously identified as anomalous on the basis of factor II scores.

Summary, NURE Soils

Both the interelement relations and the individual metallic elements are combined on plate 2-D to identify those areas of greatest potential based on the NURE data for soils. The B-Li-K anomalies in the Warner Valley on the west side of the quadrangle, in the small basin northeast of Mickey Springs, and in the caldera sediments in the southeast corner of the quadrangle are derived directly from the factor IV scores. The anomaly in the Pueblo Valley and Alvord Desert is augmented by the presence of anomalous molybdenum at several of the localities. The extension of this anomaly into the large basin that includes Coyote Lake is tentative because of the paucity of samples in that area. The two anomalies reflecting the complex assemblage of granitophile elements, identified on the plate with Zr-Y-La-Nb, are augmented by scattered localities anomalous for zinc in the northern anomaly and a strong anomaly for zinc in the anomaly northeast of Hart Mountain. The Ag-Pb-Mo anomalies in the southeastern part of the quadrangle have scattered anomalous values for zinc. The separation of two anomalies in this area reflects the topographic interruption by the Pueblo Valley. They may be parts of a single, larger metalliferous province. The Pb-Zn anomaly in the south-central part of the quadrangle is directly from the consideration of the metallic elements, and the Cu-Zn anomaly in the north-central part of the quadrangle is the core of the larger copper-rich province in that area.

This is the most comprehensive interpretation that can be made for available data from the entire quadrangle. It is a generalization emphasizing the clustering of anomalous characteristics and localities. The scale of the data base is such that individual anomalous localities or scattered anomalous localities for a single element may signify additional potential--for example, the scattered, low-level, silver-rich localities in the northwest corner of the quadrangle. Furthermore, the data set is not comprehensive in terms of the elements determined. Notably, most of the suite of elements associated with epithermal deposits is lacking, including gold, mercury, uranium, arsenic, and antimony. An initial step of further evaluation of this quadrangle should include consideration of a reanalysis of the samples for the epithermal suite of elements.

NURE Water Data

The NURE data set for waters, both well and spring waters, provides a second geochemical media with fairly uniform coverage of the quadrangle. This data set is fraught with internal problems and should be used with care. As was true for the soils, samples were evidently collected in duplicate and a broad range of elements was determined in only one sample of the pair. Four additional elements, Br, Cl, F, and U, were determined in only a few of the second samples of the pair. Lack of knowledge of how or why samples were selected for these additional determinations and the sparsity of the data have prompted us to simplify the data set by eliminating all of the duplicate samples. This left a data set consisting of 142 spring waters and 44 well waters, all analyzed for 27 components.

The well waters and the spring waters have similar ranges and similar means. There is no evidence for bias resulting from either natural or artificial (drilling, plumbing, etc.) differences between the two sample types. They were lumped into a single data set of 186 samples. The data set was further reduced by eliminating alkalinity, better measured by the composition of the water, and yttrium, detected in only a few samples. The pH has been retained as an independent measure of a chemical component of the waters however, the total lack of correlation between pH and any of the chemically determined elements leads us to suspect the measurements.

The ranges and means for the remaining data (table 3) seem reasonable for waters. The correlation matrix (table 4) yields unexpectedly high values for some element pairs (Mg/Ca is the maximum at 0.95) and an absence of correlation of some elements with any of the others (for example, Co, Li, Mo, Ni, and Zr). R-mode factor analysis yields a strong and stable factor

Table 3. Summary statistics for 25 variables in 186 waters from springs and wells in the Adel quadrangle, Oregon

[All values for the elements in ppb except as noted. Mean calculated for valid observations only.]

Variable	Minumum	Maximum	Geometric mean	Number of valid observations
pH	6.2	9.7	7.6	186
Al	17	97,000	156	115
B	4	640	31	73
Ba	3	270	25	156
Be	1	5	3	163
Ca (ppm)	0.1	96	9.7	164
Co	2	380	13	130
Cr	4	2,700	31	166
Cu	2	161	6.4	159
Fe	10	26,000	260	172
K (ppm)	0.3	20	3.5	185
Li	2	1,300	59	102
Mg (ppm)	0.1	49	4.6	162
Mn	2	1,100	16	126
Mo	4	1,400	56	130
Na (ppm)	0.4	230	9.7	163
Ni	5	25,000	32	127
P	40	32,000	270	93
Sc	17	50	27	154
Si (ppm)	0.3	38	6.4	161
Sr	2	580	69	156
Ti	2	33,000	32	82
V	12	69	25	156
Zn	5	4,000	36	167
Zr	2	72	5.4	97

Table 4. Correlation coefficients among 25 variables in 186 samples of water from springs and wells in the Adel quadrangles, Oregon

pH	Al	B	Ba	Be	Ca	Co	Cr	Cu	Fe	K	Li	Mg	Mn	Mo	Na	Ni	P	Sc	Si	Sr	Ti	V	Zn	Zr	
1.00	-.06	.00	-.02	.00	-.05	.07	.06	.03	.00	-.06	.00	-.07	.00	-.02	.01	.02	.02	.02	-.11	-.08	.04	.00	.06	.01	pH
	1.00	.17	.38	.25	.42	-.08	.15	.21	.29	.04	.06	.43	.21	-.08	.32	.06	-.14	.29	.41	.42	.06	.11	.30	-.12	Al
		1.00	.35	.22	.42	-.03	.13	.17	.12	.29	.11	.36	.35	.03	.50	.02	.04	.13	.44	.35	.13	.32	.27	.03	B
			1.00	.64	.73	-.07	.49	.52	.60	.33	.02	.77	.44	.08	.42	.07	.10	.55	.69	.81	.40	.53	.56	.05	Ba
				1.00	.78	-.10	.67	.46	.44	.05	.05	.78	.28	.16	.43	.05	-.08	.78	.77	.75	.28	.83	.57	.14	Be
					1.00	-.05	.51	.44	.37	.13	.08	.95	.39	.09	.56	.14	-.11	.69	.89	.88	.20	.61	.64	.00	Ca
						1.00	.00	-.01	-.09	.06	-.08	-.05	.03	-.04	.02	.00	.04	-.04	-.10	-.02	-.03	-.05	-.06	.03	Co
							1.00	.49	.46	.14	.00	.56	.24	.09	.24	.03	-.04	.48	.51	.45	.33	.61	.38	.17	Cr
								1.00	.58	.22	-.13	.50	.35	.05	.17	-.07	.20	.30	.42	.42	.45	.42	.49	.07	Cu
									1.00	.20	-.09	.41	.31	.08	.15	-.08	.09	.44	.50	.42	.60	.28	.36	.10	Fe
										1.00	-.07	.18	.17	.10	.31	-.02	.24	.03	.19	.18	.24	.12	.15	.14	K
											1.00	.07	.12	.20	.13	.10	-.15	.08	.05	.06	-.22	.03	.08	.00	Li
												1.00	.42	.10	.50	.12	-.07	.68	.81	.90	.23	.64	.66	.02	Mg
													1.00	-.09	.29	.01	.19	.28	.37	.44	.17	.25	.29	.08	Mn
														1.00	.11	.00	-.08	.12	.07	.10	.04	.17	.06	.06	Mo
															1.00	.11	-.06	.35	.55	.48	-.04	.37	.36	.02	Na
																1.00	-.08	.17	.04	.12	-.12	.03	.03	.05	Ni
																	1.00	-.18	-.06	-.07	.36	.10	.04	.07	P
																		1.00	.66	.71	.19	.50	.50	.21	Sc
																			1.00	.78	.31	.58	.56	.04	Si
																				1.00	.22	.59	.59	.05	Sr
																					1.00	.27	.14	.18	Ti
																						1.00	.45	.15	V
																							1.00	-.10	Zn
																								1.00	Zr

I, which includes the elements with high correlation coefficients. Beyond factor I, in models with up to 10 factors, the factors are unstable and not easily explained--most are unique factors for a single element. This prompted us to examine factor I in more detail.

A histogram of the factor I scores, prepared as a precursor to plotting the scores, yields an unlikely frequency distribution (figure 6). The distribution displays a pronounced negative skewness and is decidedly bimodal. There are two distinct populations. Well and spring waters are about evenly distributed between the two populations. The limit of analytical sensitivity in the lower mode is about half of that for the upper mode for many of the elements. The samples in the lower mode are consecutive samples and form a single block of data in the data file. The geographic distribution of samples in the lower mode forms a continuous band of samples crossing the mid-section of the quadrangle from west to east, irrespective of geology or topography. It seems clear to us that the difference between these two populations reflects some change in the analytical protocol. We do not know what that change is, but it dominates the chemical data, and it separates the geographic distribution into small groups of samples that are not representative of the quadrangle as a whole.

We have chosen, therefore, to abandon the water data as unusable. Braver souls, with more time to burn, might be able to glean some information from the larger, higher valued population of the data set, but uncertainties about the value of this information make the attempt undesirable at this time.

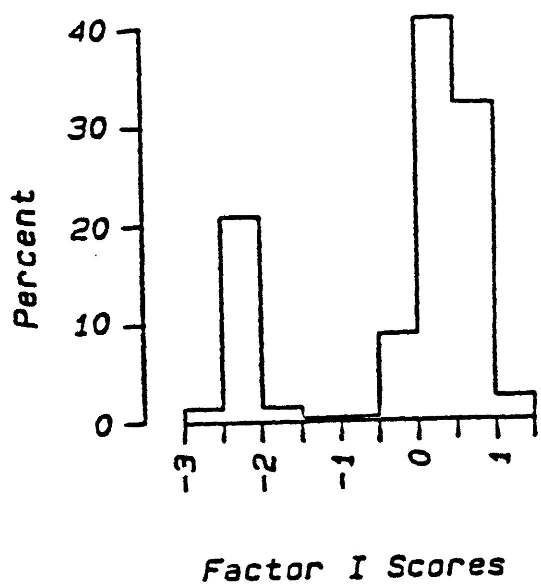
NURE Stream Sediments and Talus

There are eight samples identified as stream sediment and seven samples identified as talus in the NURE data base that have adequate chemical data to be of use. These are widely scattered across the quadrangle. Uncertainties concerning the nature of these samples and why they were collected where they were, coupled with the small number of scattered sample localities, severely limit the usefulness of the data. However, it should be noted that one of the samples of stream sediment collected at the eastern base of Steens Mountain, near the mouth of Little Alvord Creek, is anomalous for Zn and Pb. A nearby sample of talus is anomalous for zinc. The two samples of talus from the Coyote Hills, along the western edge of the quadrangle, are anomalous for Ce and La and one of those is also anomalous for Ag, Mo, and P. A single sample of talus collected along Highway 205 north of Frenchglen is anomalous for Cu and P. The fact that one-third of these samples are anomalous in some way leads us to suspect that they were intentionally selected to reflect some unusual circumstance.

Wilderness Study Area Data

There are 21 small Wilderness Study Areas scattered across the quadrangle (plate 1-B) for which geochemical data is, or will be, available. These have been variously lumped for reporting purposes and only the currently available reports can be cited here because the final grouping of the study areas has not been determined. The study areas fall into three broad groups based on the people responsible for geochemical data. Data for the centered part of the quadrangle, including the study areas on and

Figure 6. Frequency distribution of factor I scores for 186 spring and well waters from the Adel quadrangle, Oregon. The complete separation of the data into two populations, one element rich and the other element poor, is attributed to a change in the analytical protocol. This separation overrides all attempts to interpret the data further.



adjacent to Steens Mountain and the Pueblo Mountains, are only available through the work of the State of Oregon Department of Geology and Mineral Industries (Gray et al., 1983) and of Barringer Resources, Inc. (Bukofski et al., 1984) who performed the work under contract for the Bureau of Land Management. The first of these reports gives data for stream sediments and an interpretation of the data that is fairly straightforward. The second report presents data for heavy-mineral concentrates, is difficult to interpret, and is of little direct value to this preassessment. Interpretive reports on these study areas prepared by the U.S. Geological Survey (Minor et al., 1987; Roback et al., 1987) provide the most useful source of information.

The Wilderness Study Areas to the east of Steens Mountain and the Pueblo Mountains have been sampled by R. L. Turner of the U.S. Geological Survey. Some of these areas are also represented in the State and Barringer reports cited above, and additional data are available from the Bureau of Land Management (Rimal et al., 1986). Interpretive reports for these areas are available in manuscript form.

The Wilderness Study Areas to the west of Steens Mountain and the Pueblo Mountains have been sampled by H. D. King of the U.S. Geological Survey. At the time of this writing (March, 1988) the analytical work for these areas was not completed. Sufficient information is available, however, to identify most of the anomalous areas.

Each of these participants in the evaluation of the Wilderness Study Areas has used different sampling and analytical methods. Although the data for these studies is at a scale more suited to resource evaluation, in many instances including a more pertinent suite of elemental determinations, rather than the NURE data, the wilderness data is not suitable for merging into a single data set for the quadrangle. For purposes of the preassessment, I have chosen to extract pertinent parts of the interpretations of the mineral resource potential of the Wilderness Study Areas as presented in the various reports or as described verbally by Turner and King. Future work in the quadrangle, if focused on specific areas that include these study areas, could make use of the data itself.

The location of the Wilderness Study Areas is given on plate 1-B and the geochemical anomalies uncovered during the evaluation of these areas as described above is given in table 5. These data add significantly to the geochemical understanding of the eastern part of the quadrangle where, at least in the limited area of these studies, one or more of the suite of elements commonly associated in epithermal mineral deposits (Ag, Au, As, Sb, Hg, U) is frequently present in anomalous concentrations. In these areas and elsewhere in the quadrangles, the data from the Wilderness Study Areas support the interpretation of the soils from the NURE data base.

GEOPHYSICS

Introduction

Gravity and magnetic data help to analyze the sub-structure in the Adel Quadrangle, part of the northern Basin and Range Province in the western United States. The Basin and Range structure consists of a system of normal faults in

Table 5.--Geochemical anomalies in Wilderness Study Areas in the Adel quadrangle, Oregon

[Data based on published accounts (Gray et al., 1983, Bukofski et al., 1984; Rimal et al., 1986; Minor et al., 1987; and Roback et al., 1987; Conrad et al., 1988; Minor et al., 1988; Sherrod et al., 1988; Vander Meulen et al., 1988a; Vander Meulen et al., 1988b; and Vander Meulen et al., 1988c) and verbal accounts by R. L. Turner and H. D. King of the U.S. Geological Survey]

Wilderness study area	Anomalous elements	Comments
Sheepshead Mtns and Wildcat Canyon	As, Hg, Ag, Au	Most of the anomalous samples are in the vicinity of the boundary between the two study areas
East Alvord	Sb, Hg, As	Anomalous samples are along the valley edge in the northwestern part of the study area and extends at least as far north as Mickey Springs
High Steens	Hg, U, As, Mo	Anomalous samples are along and east of the eastern boundary of the study area at the base of eastern scarp of Steens Mountain
Disaster Peak, Oregon Canyon, Fifteenmile Creek, and Willow Creek	As, Hg, Sb, Ag	Anomalous samples are scattered throughout the area between the caldera in the southeastern corner of the quadrangle and the caldera north of the Trout Creek Mountains
Pueblo Mountains	Au, Ag, Sb, As, Hg, U, Mo, Cu, Pb, Zn	Anomalous samples are most common along the eastern edge and to the east of the study area in the terrane between Pueblo Mountain and Pueblo Valley
Hawk Mountain	Bi, Au	Anomalous samples are generally in the northwestern part of the study area west of Hawk Mountain
Spaulding	Ba, Ag, Bi, Pb, Zn	A single anomalous sample along the southeastern side of the study area
Rincon	Ag	A single anomalous sample in the northern part of the study area
Orejana Canyon	Sn	Anomalous samples are in the northern part of the study area

which movement has resulted in downdropped grabens that form valleys and basins and uplifted sections that form mountain ranges, horsts and tilted monoclines. The color-shaded topographic relief map (plate 5) presents the Basin and Range structures in the form of north-trending features such as the Warner graben, Hart Mountain and the Poker Jim Ridge, the Catlow Valley, and the Pueblo and the Steens Mountain and the Pueblo Valley and Alvord Desert. Strato volcanoes, small domes, vents and calderas pre-date the Basin and Range structure.

GRAVITY

Gravity Coverage

The gravity data presented here in a complete Bouguer gravity contour color map (plate 6) and a clear gravity contour and station map (plate 3-A) are derived from gravity data of Plouff, 1987, and A. Griscom, written communication, and data from the Department of Defense. The data were reduced at a density of 2.67 g/cm3 and contoured at a 5 mGal interval. These data represent a compilation of numerous surveys, of which the accuracy and method of reduction are in many cases unknown. Some of the isolated anomalies (i.e., one station anomalies) of plates 3-A and 6 may be artifacts of the data reduction procedure and may not represent true density variations.

Gravity Anomalies

The Bouguer gravity map mostly reflects regional gravity anomalies, partially because of sparse station coverage. Small-scale (amplitude and wavelength) anomalies, such as those that might be associated with individual mineral deposits, cannot be resolved with the current data set.

The large gravity low that covers much of the southern part of the map area is probably due to isostatic compensation of the regionally high terrain (Eaton and others, 1978). The gravity low over the northern part of the Steens Mountain may be caused by sediments and/or volcaniclastic rock that fill a very large caldera (Vander Meulen, 1988A). The gravity low on the east side of the Pueblo and Steens Mountains may be related to great thicknesses of tuffs and sediments that fill the Pueblo Valley and underlie the Alvord Desert (Roback and others, 1987). A local gravity low occurs over the Whitehorse Caldera that is related to the low density sediments and volcaniclastic rocks that fill the caldera. A gravity low also occurs over the southern Warner Valley that is apparently related to the low density rocks that fill the valley. Other lows on the map do not have enough stations to define them to allow interpretation.

A gravity high over the Pueblo Mountains and southern Steens Mountains interrupts the regional low. The source of the high may be the core of these mountains which is composed of rocks older and denser than those in the northern Steens Mountains (Griscom, 1975). A gravity high occurs over the southern rim of the Whitehorse Caldera and is associated with high-iron andesite flows (Conrad, 1983). The rest of the map shows a regional gravity high poorly defined by station coverage. Steep gravity gradients delineate the faults that bound the east and west sides of the upthrown Pueblo and southern Steens Mountains.

MAGNETICS

Magnetic Coverage

The aeromagnetic survey (plates 3-B and 7) used in this assessment was flown in an east-west direction with 2 mile line spacing at 9000 ft barometric elevation. It was compiled by Scintrex Mineral Surveys, Inc. (U.S. Geological Survey, 1972a).

Magnetic Anomalies

The Adel area is covered by volcanic rocks that can have high remanence and susceptibility which can cause magnetic anomalies. The Steens basalt, has both normal and reversely magnetized flows that can cause large positive and negative magnetic anomalies (Mankinen and others, 1985).

Positive magnetic anomalies are often associated with normally magnetized terrain. Topographic features such as Hawk Mountain, Antelope Butte and Beatty Butte have positive magnetic anomalies associated with them. Positive aeromagnetic highs reflecting normally magnetized Steens basalt are centered over the Pueblo Mountains (Mankinen and others, 1985) and Kiger Creek on the north edge of the map (Minor and others, 1987).

On the southeast corner of the map is a circular magnetic high with a magnetic low in the center. This is the Whitehorse caldera (Rytuba and McKee, 1984). The low is related to lake sediments; the circular high is caused by the high topography composed of high-iron andesite (Conrad, 1983).

The other positive magnetic anomalies on the map are not clearly related to topography or to the mapped geology. The circular magnetic high near Hart Mountain may be caused by a buried normally magnetized volcano. The low in the center, northeast of Hart Mtn., may be caused by caldera fill and/or by a rhyolite dome. A buried volcano with either a sediment filled crater or a rhyolite dome in the center may also cause the circular magnetic high with low center observed in the Steens Mountains northwest of the Alvord Desert. The magnetic high near Cox Butte may also be related to a buried volcano.

Magnetic lows on the map are caused primarily by reversely magnetized flows, rhyolite domes with low magnetic intensity and caldera fill. The magnetic lows on the east and west side of the Pueblo Mountains coincide with the reversely magnetized parts of the Steens basalts (Roback and others, 1987) as do the lows that surround the Kiger Creek high (Minor and others, 1987). Two circular magnetic lows on the west side of the Adel map are associated with the rhyolite domes and intrusions that compose the Coyote and Rabbit Hills.

Not all of the mapped calderas in the area have simple magnetic signatures. The Pueblo Caldera (Rytuba and McKee, 1984), has a postive anomaly only associated with its western flank, which is Pueblo Mountain. The rest of the caldera lies in the Pueblo Valley and is associated with a magnetic low, probably related to a combination of caldera-fill and valley-fill sediments (Roback and others, 1987).

Steep magnetic gradients on the east and west sides of the Pueblo and Steens Mountains, like the gravity data, delineate faults.

A detailed aeromagnetic survey (U.S. Geological Survey, 1985) was flown with lines spaced at 1/2 mile and at altitudes about 100 ft above the mean terrain over the Pueblo Mountains. The resulting magnetic map is dominated by a pair of north-elongated magnetic highs and lows. The magnetic low on the western part of the map is probably related to the reversely magnetized sections of Steens basalts (Mankinen and others, 1985). Local magnetic highs within the central magnetic high are related to exposed sections of normally magnetized Steens basalt, which is older than the reversed section (Roback and others, 1987).

North-trending magnetic contours along the eastern flank of the Pueblo Mountains are partly deflected to the west along the margin of the Pueblo caldera. The buried margin of the caldera is further delineated by a ground magnetic survey (Rytuba and McKee, 1984) that shows a zone of low magnetization along the caldera ring fracture. The magnetic low may have been formed by the hydrothermal alteration of iron oxide (Roback and others, 1987). In general, the intense magnetic anomalies associated with the Steens basalt mask other local anomalies that may be relevant to evaluation of mineral resource potential.

Gamma-Ray Spectrometry

Data Coverage

Existing gamma-ray radioactivity data for the Adel quadrangle consists primarily of a NURE aerial survey of the entire quadrangle (Department of Energy, 1980). These data were acquired along 3-mi spaced east-west and 12-mi spaced north-south flight lines at 400 ft above ground level. The 3- and 12-mi line spacing represents about 6% coverage of the quadrangle, because an aerial gamma-ray system at 400-ft above ground level effectively detects terrestrial gamma radiation from a swath 800-ft wide along flight line. Other aerial gamma-ray data for the quadrangle consist of a detailed (1/3-mi spaced east-west flight lines) survey of the McDermitt calderas (U.S. Geological Survey, 1982). These data are mostly in Nevada, include only the southeast corner of the Adel quadrangle, and were not used in this report.

Summary of Existing Knowledge

NURE aerial gamma-ray data for the Adel quadrangle have been compiled into a database for the CUSMAP program. These data represent the near surface (<50 cm) distribution of the natural radioelements potassium (K), uranium (U), and thorium (Th)[1]. The gamma-ray data have been gridded with a cell-size of 3.089 km to allow preparation of contour and color composite maps.

Plates 3-C, 3-D, and 4-A are, respectively, the U, K, and Th black-and-white contour maps of the Adel quadrangle at scale 1:250,000. Mesozoic and Cenozoic bedrock of igneous (volcanic, hypabyssal, and plutonic) and volcaniclastic origin, and continental sedimentary rocks, dominates in the quadrangle and the radioelement data readily discriminates the more radioactive more silicic

[1]The e for equivalent prefix for uranium and thorium, often used with gamma-ray derived measurements to denote the possibility of disequilibrium in the respective decay series, is not used in this report.

(rhyolites, rhyodacites, dacites) rocks from the less radioactive less silicic (andesites, basalts) rocks. The south-central part of the quadrangle includes the largest and most prominent area of higher concentrations, as values of 3 to 5 ppm U, 2 to 3% K, and 8 to 18 ppm Th are associated with rhyolitic and dacitic tuffs and flows of Miocene age and rhyodacitic intrusions and flows of Tertiary and Quaternary age. This area extends from Lone Mountain west to but not including Guano Valley, and includes some outcrops of tuffaceous sedimentary rocks of Pliocene age, which in other areas are not as radioactive. The variable concentrations of this volcaniclastic unit could directly reflect the relative proportions of more silicic detritus. Another sizeable area of relatively higher concentrations is in the southeast corner, includes part of the Trout Creek Mountains and the northwest part of the McDermitt calderas, where values of 3 to 4 ppm U, 2.5 to 3% K, and 10 to 14 ppm Th relate to source rocks similar to those in the south-central part of the quadrangle, rhyolitic and dacitic tuffs and flows of Miocene age. Exterior to this area to the west and north, lower values of 2 to 3 ppm U, 2 to 2.5% K, and 6 to 10 ppm Th reflect Miocene andesite flows and other less silicic rocks. The specific contours 3 ppm U, 2.5% K, and 10 ppm Th define the relative high-low relationship. Neither the small part of the McDermitt calderas in the quadrangle nor the Pueblo or Whitehorse calderas have expression in the radioelement data.

Other areas of relatively higher concentrations include a small but prominent feature at the south side of the quadrangle, where distinctly higher K of 3.5% and moderate Th of 6 to 10 ppm defines the Mesozoic metamorphic and intrusive rocks of Pueblo Mountain and vicinity. This feature has 1.5 to 2 ppm U and is adjacent to the southwest corner of the Pueblo caldera, whose existence has been determined from geologic and other geophysical data. Bedrock at Pueblo Mountain and vicinity are known to contain abundant mica which could explain the elevated K concentrations. A prominent area of higher radioactivity occurs just west of Guano Lake and Guano Valley, where isolated values of 3 to 5 ppm U, 2% K, and 8 to 14 ppm Th occur where bedrock is mostly mapped as less silicic Pliocene tuffaceous sedimentary rocks and olivine basalt flows. The radioelement data, especially the U and Th, suggest the presence of more silicic, possibly rhyolitic, rocks. East of Guano Lake, in the east side of Guano Valley, similar radioelement lithologies could explain the area of 3 ppm U and 8 to 10 ppm Th where bedrock is again mapped as Pliocene tuffaceous sedimentary rocks. At Warner Peak and to the east, relatively higher values of 2 ppm U, 2 to 3% K, and 8 to 10 ppm Th are associated with silicic flows and intrusions of Tertiary and Quaternary age. This feature is primarily of K and Th, and reflects the radioelement lithology of peralkaline soda rhyolite or pantellerite (Walker, 1961; Noble and others, 1974). At the west-central side of the quadrangle, several small areas of 2 ppm U, 2 to 2.5% K, and 6 ppm eTh reflect the silicic intrusions of Rabbitt Hills and Coyote Hills, which are approximately coeval with the Warner Peak (Hart Mountain) complex. The radioelement data show that Rabbitt Hills-Coyote Hills rocks contain less K and Th relative to Warner Peak (Hart Mountain) rocks.

Sizeable areas of relatively low concentrations in the quadrangle reflect the occurrence of less silicic volcanic rocks (primarily basalts and some andesites) and volcaniclastic rocks containing less silicic detritus. One area is in the east-central and northeast part of the quadrangle, where values of 0.5 to 2 ppm U, 1 to 2% K, and 2 to 8 ppm Th occur. This area extends from Catlow Rim and its northern extension on the west past Steens Mountain on the east to include the lowlands east of the mountain front. Bedrock is generally basalt flows of Miocene age with alluvium and other surficial materials occurring in lowlands. The area narrows to the south to include parts of the Pueblo Mountains where bedrock continues to be Miocene basalt. This feature continues eastward to include the northeast part of the quadrangle and the Sheepshead Mountains, where relatively lower concentrations of 1.5 to 2 ppm U, 1 to 2% K, and 4 to 8 ppm Th reflect the presence of less radioactive source rocks, usually Miocene basalt and andesite and Quaternary basalt. The other sizeable area of primarily lower concentrations is in the west-central and southwest parts of the quadrangle, where values of 0.5 to 2 ppm U, 0.5 to 2%K, and 2 to 6 ppm Th reflect abundant basalt flows of Miocene and Pliocene age and other low concentration source materials, including Quaternary alluvium and water in the graben valley that contains Warner Lakes. Relatively moderate concentrations occur in a large area that includes the northwest part of the quadrangle and extends into Catlow Valley in the central part. Values of 1 to 3 ppm U, 1 to 2.5% K, and 4 to 6 ppm Th occur where source rocks are Pliocene tuffaceous sedimentary rocks in the northwest and Tertiary and Quaternary sedimentary deposits in Catlow Valley.

Mineral resource studies done in the Adel quadrangle include those of the High Steens and Little Blitzen Gorge areas (Minor and others, 1987), and the Pueblo Mountains area (Roback and others, 1987), and included examination of NURE aerial gamma-ray data. In the High Steens and Little Blitzen study, uranium measurements derived from NURE data are part of a data set used to suggest uranium mineralization in part of the study area (Minor and others, 1987, p. 11). The gamma-ray data, however, were suspect because of abrupt changes in survey altitude (Minor and others, 1987, p. A9). The data of the current report have been properly compensated (normalized) for altitude variations, and 2 areas of relative U anomalies, each 1.5 to 2 ppm, occur at the east side of Steens Mountain, in and adjacent to the study area. The northern anomaly occurs from Willow Creek north along the east front of Steens Mountain out of the study area, and correlates with an area of low mineral resource potential including uranium (Minor and others, 1987, p. A4). The southern anomaly is west of Alvord Desert and includes Pike and Indian Creeks, and correlates with an area of high mineral resource potential including uranium (Minor and others, 1987, p. A4, A11). These areas of "anomalous" U are anomalous only in terms of their comparison with adjacent areas, and not in terms of the absolute concentrations. The area of the southern anomaly also correlates with occurrences of limonitic material derived from Landsat imagery (plate 12) and a relative high in K concentrations (plate 3-C); these coincident features suggest the occurrence of hydrothermal alteration. In the Pueblo Mountains study area, the previously mentioned distinctive K (3.5%) and moderate Th (6 to 10 ppm) concentrations that include Pueblo Mountain are associated with Mesozoic metamorphic and intrusive rocks, and occur at the east side of the study area, west of the Pueblo caldera. The distinctive or anomalous K could reflect normal lithologies of the source rocks or the effect of hydrothermal alteration.

Plates 8 through 11 are color composite radioelement maps of the Adel quadrangle at scale 1:250,000. These maps use the color composite technique (Duval, 1983) of simultaneously depicting three parameters on the same map using the primary colors of red, green, and blue. Plate 8 is the elements color composite map where U is red, K is green, and Th is blue. Combined highs are light or white and combined lows are dark or black. Areas where non-primary colors are dominant indicate mixing of the radioelements in relative proportions.

Color composite maps have qualitative relevance only and should not be considered in a quantitative manner. This technique is used to simultaneously portray each radioelement and its ratios thereby highlighting the distribution of the radioelement relative to the other two radioelements. Plate 9 shows U in red and the ratios U:K as green and U:Th as blue; plate 10 shows K as red and the ratios K:U as green and K:Th as blue; plate 11 shows Th as red and the ratios Th:K as green and Th:U as blue.

The color composite technique affords a method of extracting nuances in radioelement distribution from the Adel data, and is an excellent complement to contoured radioelement data. An example of a feature not apparent in the contoured data is on the elements composite (plate 8), where a linear feature of lighter colors extends north-east from Guano Valley to the west side of and north of Beaty's Butte, paralleling the trend of the fault system that controls the east side of Guano Valley, suggesting that the fault system extends to the northeast. East of the proposed extension and including Beaty's Butte, the K composite (plate 10) shows a distinct lighter color, denoting the preponderance of K relative to U and Th. In this area, the elements composite (plate 8) is green, again indicating the preponderance of K, and the U and Th composites (plates 9, 11) have indistinct patterns. Also, the linear feature on each CCM is different in color compared to the Guano Lake-Guano Valley area, suggesting a different radioelement lithology for the linear relative to the Guano Lake-Guano Valley area. Rock types crossed by the linear include a variety of Tertiary and Quaternary volcanic and volcaniclastic rocks and those in the area of the K feature include Tertiary and Quaternary rhyodacitic flows and domes and basaltic and andesitic strato-volcanic rocks. The K feature could reflect the presence of the rhyodacitic rocks, but the lack of U and Th expression is not characteristic of silicic rocks. Other features related to subtle changes in radioelement concentration can be seen in the color composite maps, especially characteristic colors that suggest similar radioelement lithologies for the areas of those colors. Examples include the violet of the elements CCM (plate 8) in the eastern part of the Catlow Valley, the yellow of the U CCM (plate 9) in the south-central and occasionally in the eastern part of the quadrangle, the pink of the K CCM (plate 10) in western Catlow Valley and the northwestern part of the quadrangle, and the light yellow of the Th CCM (plate 11) at Warner Peak and occasionally in the southeast part of the quadrangle.

Problem Areas

Available aerial gamma-ray data for the Adel quadrangle (U.S. Department of Energy, 1982) are of satisfactory quality as surveying technology has not changed significantly since the late 1970's. However, the coarse flight line spacing confines their use to application in reconnaissance geologic mapping and on occasion in mineral exploration.

Landsat MSS and Thematic Mapper

Data Coverage

The U.S. Geological Survey, Branch of Geophysics maintains a library of Landsat satellite digital tape data, and complete coverage of the Adel quadrangle, for multispectral scanner (MSS), is available in this library. Three scenes of MSS are required to provide full coverage of the quadrangle. For this investigation, Landsat MSS data for three scenes were registered to a

UTM grid and digitally mosaiced to provide a 1:250,000-scale image base for plotting and comparing other types of digital data (plate 13) and for the preparation of a map showing the regional distribution of limonitic materials in the Adel quadrangle (plate 12). The regional limonite map (plate 12) was prepared to identify areas that might be associated with hydrothermal alteration. Vegetation cover was included on the limonite map (plate 12) to indicate areas that could not be assessed for limonite due to the masking of vegetation. A computer-enhanced color-infrared composite plate (plate 13) (1:250,000) was prepared for reference use in pre-assessment team discussions and regional structural interpretations.

Summary of Existing Knowledge

Landsat MSS imagery data were used to prepare a map (plate 12) of the regional distribution of limonitic materials in the Adel quadrangle that might help target areas of potential hydrothermal alteration. Limonite detection was based on the steep positive slope of the spectral reflectance of iron oxide minerals in the visible part of the spectrum due to strong absorption in the ultraviolet region. The single band MSS data were calibrated to percent reflectance (Robinove, 1982) and an image of the ratio of the green band (band 4) to the red band (band 5) was used as a measure of slope of the reflectance curves. The pixels containing limonite were defined by low 4/5 ratios (i.e., steep positive slope) less than 0.88. The limonite map (plate 12) was filtered with a 9 x 9 box filter to eliminate scattered isolated limonite pixels and to enhance concentrations of limonitic pixels.

Areas of limonitic material in the Adel quadrangle (plate 12) commonly occur in the graben valley that includes Warner Lakes, in Catlow Valley, in the lowland north of Frenchglen, and in Pueblo Valley and other lowland areas east of the Pueblo Mountains and Steens Mountain. Occurrences outside of lowland areas include the area of the relative U and K anomalies west of Alvord Desert, west and southwest (at the north rim of the Pueblo caldera) of Alvord Lake, sporadically in the Pueblo Mountains and in other small areas in the western part of the quadrangle. A notable feature is the cluster of limonite occurrences in the southeastern part of the quadrangle east of the Pueblo Mountains and the adjacent lowlands, which includes the Whitehorse caldera (plate 1-A). The paucity of limonite occurences in the quadrangle could reflect the common presence of wind-lain detritus and soils at the surface of the ground.

Problem Areas

Parts of the Adel quadrangle have enough vegetation cover to dominate the spectral response of the Landsat MSS system (plate 12), and limonite distribution cannot be directly determined using the MSS data for these areas. More detailed analysis of the alluvial material derived from these areas, using Landsat Thematic Mapper (TM) data, may provide clues to the possibility of potential alteration that is masked by vegetation. TM data, because of its greater spatial resolution, will allow the spectral character of the ground to be evaluated for limonite characteristics in areas of modest vegetation density.

MINERAL RESOURCES

Introduction

The confidence with which a mineral resource appraisal can be made is dependent upon the quality and quantity of information used as input into the resource assessment. Therefore, products of mineral resource assessments are a product of the "times" in which they are made and become more finely tuned as the quality and quantity of the information used as input gets better and/or increases. As has been shown in previous sections, the level of knowledge with respect to the geology, geochemistry, and geophysics could be greatly enhanced with additional data collection and analysis. Neither the quality nor quantity of information as it presently exists is sufficient to do an adequate resource assessment. But enough information does exist to conduct a preliminary resource assessment in order to document shortcomings within the data with respect to the types of ore deposits under consideration and to recommend future types of studies.

The Adel 1 X 2 degree quadrangle lies in the southeast corner of Oregon and is within the northern extension of the Basin and Range Province. Mineral deposits within the Adel quadrangle are typical of those deposits which occur in relatively young Cenozoic volcanic rocks of the Basin and Range Province. The structure of the area is characterized by north-trending fault-block mountains and basins of internal drainage. The mountains within the Adel quadrangle are either horsts with intervening grabens, or tilted fault blocks. At the base of the Steens Mountain-Pueblo Mountains fault block scarp are exposures of pre-Cenozoic metamorphic rocks, which occur in the south-central part of the quadrangle. These are the oldest rocks exposed and are host to epithermal mineral deposits. In addition to mountainous fault-bounded blocks and extensive Cenozoic volcanic rocks are the intermountain grabens or sedimentary basins which exhibit internal drainage patterns. These late Quaternary and Pliocene deposits exhibit characteristics of the types of host rocks which are being eroded in the watershed areas and have resulted in the presence of saline deposits.

Although the mineral production from Oregon has been diverse because of the varied geology in the physiographic provinces (Baldwin, 1976), documented mineral production from the Adel quadrangle which lies in the northern Basin and Range province has been more restricted. A large disseminated gold deposit, the Sleeper deposit, has been discovered in the Basin and Range province to the south in Nevada. Established mining districts within the Adel quadrangle are the Opalite mining district, the Steens-Pueblo mining district and an informal Coyote Hills mining district. The Opalite mining district occurs in the southeast corner of Adel quadrangle and is part of the McDermitt caldera complex. Over 12,000 flasks of mercury have been produced from the Opalite district and it is by far the most significant deposit discovered thus far within the Adel quadrangle. However, there has been production much larger than this from mines just outside of the Adel quadrangle and associated with the McDermitt caldera complex. Uranium and lithium deposits are also associated with the McDermitt caldera complex with specialty clays currently being mined. The Steens-Pueblo mining district occurs along the eastern edge of the Steens Mountain and Pueblo Mountain fault-bounded block. Documented mineral production includes mercury (Ross, 1942; Brooks, 1963), gold (Brooks, 1963), and zeolites. However, anomalous geochemical signatures and permissive geological environments also allow for potentially economic deposits of silver, copper, molybdenum, lead, tin, uranium and zinc. Among the potential nonmetallic commodities are bentonite, diatomite, perlite, zeolites, arsenic, lithium, thorium, boron, and other salines. These commodities will be discussed within the framework of mineral deposit models and permissive environments in another section.

Within this study, the mineral resource assessment of the Adel 1 X 2 degree quadrangle will consist of three steps. The first step is to identify the mineral deposit model types which could be present in the area based on what is known about the geology, geophysics and geochemistry of the area. The second step is to delineate areas which are considered to be permissible for each of the deposit types, again based on the geology, geochemistry, and geophysics of the area. The third step is to estimate the number of deposits which could occur in each of the permissible areas for each of the deposit types. The first step which lists the known and unknown but permissible deposit types for the Adel quadrangle is shown in table 6. The second step which delineates the areas most favorable for each of the deposit types is shown on plate 4-B and in figure 7. The third step which estimates the number of undiscovered deposits within the favorable areas is not attempted in this study. Due to the time frame involved and limited geologic information available, a credible estimate of the numbers of deposits which might occur could not be accomplished.

Mineral Deposit Types

One of the methods used in estimating the resource potential within designated areas of interest is through the use of mineral deposit models. Mineral deposit models are descriptive in nature, characterizing the relevent structure and rock types within the deposit. Grade-tonnage models document the grades and tonnages associated with similar deposits. Mineral deposit models and grade-tonnage models have been evolving for many years from very general and qualitative descriptions to very specific and quantitative critera as more and more knowledge is gathered about each deposit type. A comprehensive list and description of many of the deposit types used in this study is given in Cox and Singer, 1986.

The known and unknown mineral deposit models thought to be permissible within the Adel quadrangle are shown in table 6. Model number refers to models described in Cox and Singer, 1986. Deposit types without model numbers are not described in Cox and Singer. The known presence of a deposit type within the Adel quadrangle is indicated with either a Y(yes) or N(No), respectively. Models shown with a "Y" have known mineral deposit occurrences. Models shown with an "N" have no known mineral deposit occurrences within the Adel quadrangle, but are geologically permissive. The "Level of Assessment" shown in table 6 indicates to what level the assessment was carried within this study, whether or not grade-tonnage models exist, and how confident the delineated permissive tract. Tracts, as shown in table 6, are keyed to plate 4-B and figure 7. These tracts show where the mineral deposits are likely to occur and what the most likely host lithology is to be.

Table 6.--Some permissible mineral deposit types by tract.

Model number	Deposit type	Present	Level of assessment	Tract
	Tuff	Y	3	
	Oil & Gas Resources	N	4	
23	Basaltic Cu	N	4	
	Basalt	Y	3	
	Sand and Gravel	Y	3	
	Geothermal Resources	N	3	
	Precious Opal	Y	4	
	Clay(bentonite)	Y	3	
	Zeolites	Y	3	
	Halite	Y	4	
30c	Sandstone U	N	4	basins
25d	Sado Epithermal Veins	N	3	I
27d	Simple Sb Deposits	Y	2	I
25e	Epithermal Quartz-Alunite Au	N	4	I
25f	Volcanogenic U	Y	2	I
36a	Low-Sulfide Au-Quartz Veins			I
25a	Hot-Spring Au-Ag	Y	2	I
27e	Disseminated Sb Deposits	N	4	I
27a	Hot-Spring Hg	Y	2	I
39a	Placer Au-Pge	Y	2	I
37b	Gold on Flat Faults	N	4	I
	Diatomaceous Earth	Y	3	I
25g	Epithermal Mn	N	4	I
	Lithium Clay	Y	3	I
22c	Polymetallic Veins	N	4	I
25c	Comstock Epithermal Veins	Y	4	I
27b	Almaden Hg	Y	2	I
	Saline Deposits	Y	3	II
22a	Volcanic-Hosted Cu-As-Sb	N	4	III
17	Porphyry Cu	N	4	III
19a	Polymetallic Replacement Dep.	N	4	III
15b	Sn Veins	N	4	III
20a	Porphyry Sn	N	4	III
21a	Porphyry Cu-Mo	N	4	III
16	Climax Mo	N	4	III
15c	Sn Greisen Deposits	N	4	III
20b	Sn-Polymetallic Veins	N	4	III
15a	W Veins	N	4	III
21b	Porphyry Mo, Low-F	N	4	III
20c	Porphyry Cu-Au	N	4	III
22b	Au-Ag-Te Veins	N	4	IV

Table 6.--Some permissible mineral deposit types by tract--continued.

Model number	Deposit type	Present	Level of assessment	Tract
25h	Rhyolite-Hosted Sn	N	4	IVa
39e	Alluvial Placer Sn	N	4	IVa
	Perlite	Y	3	P
	Plagioclase Sunstones	Y	3	V
	Obsidian	Y	3	VI

Model numbers refer to Cox and Singer (1986).

Presence of a deposit type either yes(Y) or no(N)

Level of Assessment:

1 expected number of undiscovered deposits has been estimated
2 permissive environment; grade-tonnage models exist
3 permissive environment; no grade-tonnage models exist
4 probable permissive environment

Tracts delineated on tract map (see plate 21 or figure 7.)

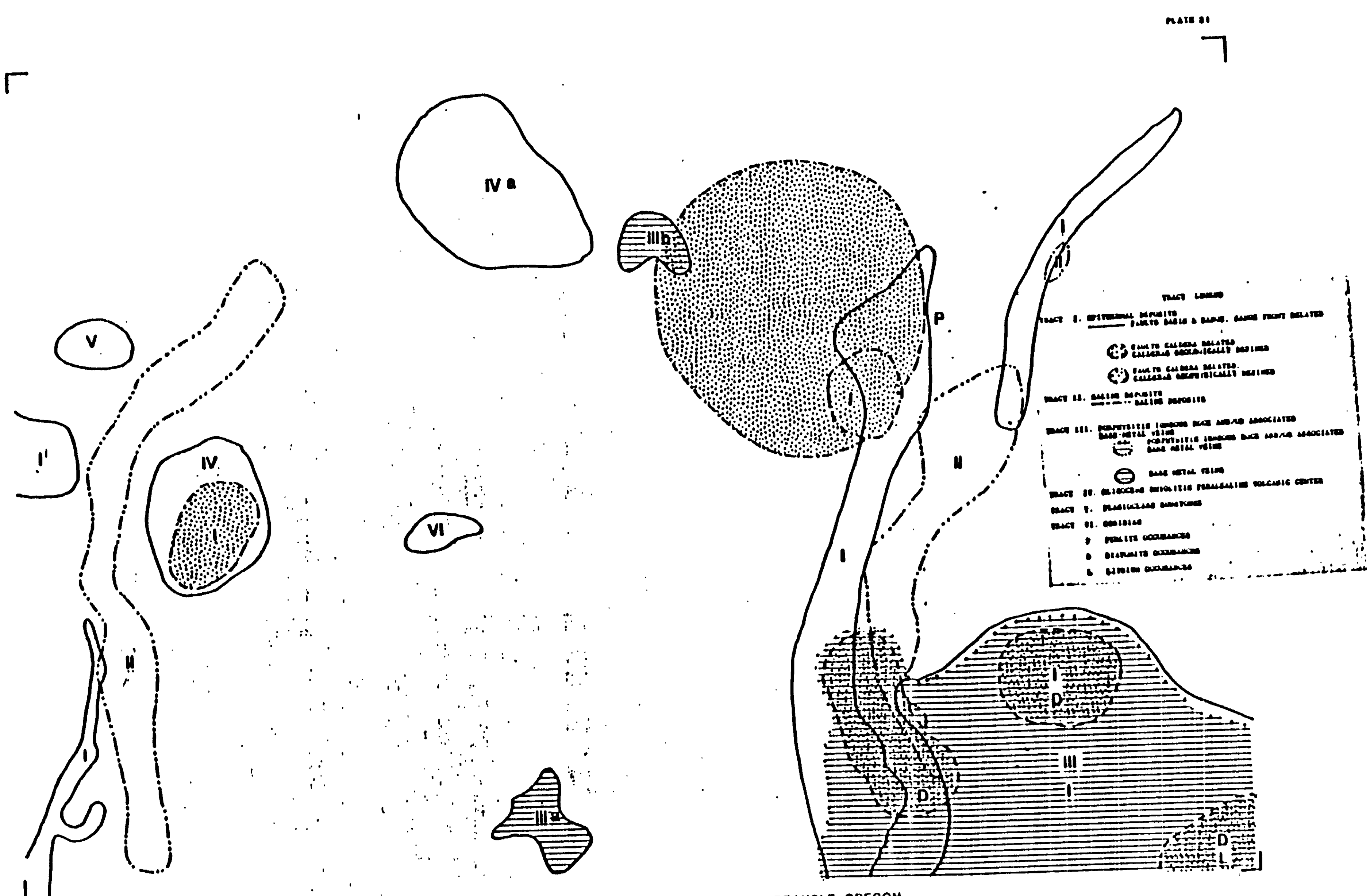


Figure 7.-- MINERAL RESOURCES TRACT MAP FOR THE ADEL QUADRANGLE, OREGON.

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Mineral Occurrence Compilation

The mines and prospects plotted for the Adel quadrangle are displayed on plate 4-C. Sources of information for these localities include: the Mineral Resource Data System (MRDS) of the U.S. Geological Survey; Mining Districts and Mineral Deposits of the Basin and Range Province of Oregon by Robin Bradley (1982); Mineral Resources of the Pueblo Mountains Wilderness Study Area, Harney County, Oregon, and Humboldt County, Nevada by Robert Roback, and others (1987); and Mineral Resources of the High Steens and Little Blitzen Gorge Wilderness Study Areas, Harney County, Oregon by S. Minor and D. Plouff (1987). No attempt was made to access the U.S. Bureau of Mines Minerals Availibility System (MAS) or Mineral Information Library (MILS) due to time constraints. However, inquiry of these data bases is highly recommended for a formal CUSMAP mineral resource assessment.

Commodities which are displayed on the Mines and Prospects plate 4-C include mercury, uranium, gold, saline, and perlite deposits. Mineral prospect localities which appear in Roback and others, 1987, have no commodity associated with each prospect, and are therefore plotted as "unknown". As can be seen in plate 4-C, most mines and prospects are concentrated along the Steens Mountains and the Pueblo Mountains. This is a function of both initial exploration being concentrated on the edges of exposed metamorphic lithologies and along fault-bounded blocks, and followup studies being concentrated in those same areas. It must also be remembered that localities are mostly for prospects of these assigned commodities; therefore, these localities indicate only what was sought and not necessarily what was found or present. Mercury is the most widespread of the commodities shown with respect to spatial distribution. Mercury occurs in the Steens-Pueblo mountain area and sporatically throughout the quadrangle. Uranium prospects are more limited with only one occurrence of uranium being outside of the Steens-Pueblo Mountains area. Gold localities, which represent both placer and lode type claims, are all located within the Steens-Pueblo Mountains. Saline deposits are located in basins with internal drainage, and the perlite deposit shows an area of marginally economic reserves (Minor, 1987). Additionally, there are specialty clays being mined by several companies in the Long Ridge caldera (J. Rytuba, personal communication) which are not shown on plate 4-C.

A listing of all the mines and prospects plotted on plate 4-C can be found in Appendix 1. The information contained within Appendix 1 includes: the area of interest, mine name, commodities present, a brief description of deposit characteristics, and latitude and longitude in decimal degrees. This appendix is partitioned according to the source of the data, and then by area within each source. The labeling of each point at the scale displayed of 1:250,000 on plate 4-C would be very cluttered and would lead to much confusion. If the reader is interested in seeing the spatial distribution of the labeled mines and prospects within a specific area and at a much smaller scale, it is recommended that they go to that specific reference as outlined in Appendix 1.

Mineral Resource Potential

The mineral resource potential as defined for the Adel 1 X 2 degree quadrangle is based upon information and inferences drawn from the geology, geochemistry, and geophysics of the area. The geology helps to delineate areas of favorable lithologies or host rocks, and also helps to interpret the structural configuration both in the surface and subsurface. The geochemistry helps to isolate areas which exhibit anamolous values for either target elements or pathfinder elements. This information can be used to either constrain areas as to their potential mineral resources, or to expand areas depending on the size of the area of influence for the sample. The geophysics helps to examine physical property variations which relate to the distribution of rock types in the subsurface, and to observe anomalies in the surface geology using remote sensing and radioactivity measurements.

Tracts were delineated for the Adel quadrangle using the types of information as described in the preceeding paragraph. These tract characteristics are summarized in table 7, are shown on plate 4-B and in figure 7, and will be explained more fully below.

Tract I

Tract I delineates the favorable areas for the occurrence of epithermal system deposits. Epithermal deposits are by definition shallow or near-surface occurrences, but depending upon the depth and host lithology, deposits can be in the form of sinter, silica cap, replacement ore, breccia and stockwork bonanza ore, clast cemented ore, and base metal ore (Hollister, 1985). The information used in delineating these areas were the known occurrence of prospects or mines which are epithermal; the presence of a fracture system which is either caldera related or basin and range, range-front fault related; the presence of contemporary hot springs; and geochemically anomalous silver, lead, molybdenum, and zinc. However, not all of these characteristics are necessary to define Tract I areas. A summary of the characteristics used to define each Tract I area can be found in table 7 and the deposit types associated with Tract I can be found in table 6.

Most of the past mineral production and the potential for additional new mineral deposits for the Adel quadrangle lies within the Tract I areas. The basin and range faults, and the range-front faults provide conduits for metalliferous hydrothermal solutions. Veins associated with basin and range faults, and range-front faults may contain gold and silver. Caldera-related faults also allow for the movement of hydrothermal fluids from depth. Calderas are known to exist within the southeastern part of the Adel quadrangle based on geologic evidence, and there is an indication of buried calderas in the central and western part of the quadrangle based on geophysical data. Within the McDermitt caldera complex, fluids have remobilized the mercury, uranium, and lithium from adjoining rhyolites and reconcentrated it into higher grade deposits. Other metals which are associated with caldera-complexes within the Adel quadrangle include gold, copper, zinc, mercury, uranium, molybdenum, and silver.

Tract II

Tract II delineates the favorable areas for the occurrence of saline deposits. Saline deposits within the Adel quadrangle result from the accumulation of water from surface flow and its evaporation from basins with internal drainage systems. This results in the gradual deposition of soluble materials which are brought into the basins. In addition to the evaporation process which accumulates deposits at the surface, saline deposits may also

Table 7.--Descriptive characteristics and criteria used for tract delineation of deposit types within the Adel quadrangle, Oregon.

Tract

I. Epithermal deposits - based on the presence of:

1. mines and prospects
2. fractures
   a. caldera related
   b. basin & range, range-front faults
3. hot springs
4. geochemical evidence for epithermal suite
5. limonite alteration
6. silicious volcanic rocks

II. Saline deposits - based on the presence of:

1. closed basins
2. source rocks of silicious rhyolite
3. permeable sediments
4. thermal water
5. geochemically anomalous saline elements
6. production and prospects

III. Porphyritic igneous rock and/or base metal veins - based on the presence of:

1. porphyry present in Pueblo Mountains
2. drill hole intersection of molybdenum vein in porphyritic rock
3. includes all older rock in Pueblo Mountains
4. includes all rock underlying Pueblo caldera
5. includes area anomalous in silver,lead, molybdenum, occasionally zinc

IIIa. Hawks Mountain - based on the presence of:

1. anomalous values for zinc, lead, and bismuth
2. faults
3. presence of gold flakes

IIIb. Frenchglen Area - based on the presence of:

1. intersection of several major fault zones (Brothers fault zone)
2. hot springs just to the north
3. geochemically anomalous values for copper and zinc

Table 7.--Descriptive characteristics and criteria used for tract delineation of deposit types within the Adel quadrangle, Oregon--Continued

Tract

IV. Oligocene rhyolitic peralkaline volcanic center - based on the presence of:

1. intrusive & extrusive rocks
2. proposed caldera based on aeromagnetic low in ring of highs
3. anomalous zirconium, REE, niobium, zinc
4. relative high in potassium,thorium relative low in uranium with respect to Adel quadrangle

IVa. Keg Springs Valley - Buckhorn Canyon area - based on the presence of:

1. same geochemically anomalous elements as IV
2. moderately faulted
3. late Miocene ash-flow tuff(Devine Canyon and Rattlesnake) rests on Miocene sediments which overlies Steens basalt
4. relatively higher in uranium,potassium; relatively lower in thorium with respect to Adel quadrangle
5. cassiterite in heavy mineral concentrates from Orejana Canyon

V. Plagioclase sunstones - based on the presence of:

1. known occurrences

VI. Obsidian - based on the presence of:

1. known occurrences

D. Diatomaceous Earth - based on the presence of:

1. known occurrences
2. caldera moat sediments or lacustrine sediments

P. Perlite - based on the presence of:

1. Pike Creek formation
2. glassy margins of felsic flows and domes
3. known marginal reserve of 400,000 short tons at Cinder Cone Claims

L. Lithium - based on the presence of:

1. caldera moat sediments and lacustrine sediments

form at depth due to diagenitic processes or remain in solution as brine. The information used in delineating these areas were the presence of closed basins; source rocks of siliceous volcanics; permeable sediments; the presence of thermal waters; and geochemically anamolous values for elements associated with saline deposits such as boron, lithium, potassium, and occasionally molybdenum. The characteristics used to define these Tract II areas are summarized in table 7. Mineral production from saline deposits within the Adel quadrangle has reportedly come only from Alvord Lake/Borax Lake (Bradley, 1982). Chemical precipitation from hot spring systems is the primary source for borate deposits (J. Rytuba, personal communication). There is currently no production occurring from tract II types of deposits within the Adel quadrangle.

Tract III

Tract III delineates the permissible areas for the occurrence of porphyritic igneous rock and/or related base metal veins. Porphyritic igneous rock exhibits a bimodal distribution of crystal sizes. The information used in delineating these Tract III areas were the known occurrence of porphyritic igneous rock in the Pueblo Mountains; the drill-hole intersection of porphyritic igneous rock with molybdenum veins at depth within the McDermitt caldera complex; includes all older rock in the Pueblo Mountains; includes all rock underlying the Pueblo caldera; and includes areas anomalous in NURE soil samples for silver, lead, molybdenum, and occasionally zinc. Because most of the Tract III areas for porphyritic igneous rock lie below the present erosional surface and can only be inferred from the type of data now available, all characteristics are not present for all the areas. It must be remembered that these delineated areas are for the presence of porphyritic igneous rock and for the presence of base metal veins which could accompany these porphyritic rocks. Since in most cases we are dealing with "blind" deposits which cannot be observed at the surface, the evidence for their existence is more tentative and more subjective than the deposit types we would expect to find at the surface. The summary characteristics for all delineated areas for Tract III deposits can be found in table 7.

Tract IV

Tract IV delineates an area which has been explored very little and is in the Hart Mountain-Warner Peak area of the Adel quadrangle. Tract IV is an Oligocene peralkaline rhyolitic volcanic center that exhibits an aeromagnetic low in a ring of high values (plates 3-C, 7); has anomalous zirconium, Rare Earth Elements, niobium, and zinc (plates 2-A, 2-C); is relatively high in potassium and thorium; and relatively low in uranium (plates 9, 10, 11). However, the tract IV trace elements of zirconium, Rare Earth Elements, niobium, and zinc are highly enriched in peralkaline magmas and may only reflect the original magmatic concentrations (J. Rytuba, personal communication).

Tract IVa occurs in the Keg Springs Valley-Buck Horn Canyon area where the late Miocene Devine Canyon ash-flow tuff rests on Miocene sediments. This in turn overlies the thick Steens basalt. The area is moderately faulted; has relatively high uranium and potassium values; and has relatively low thorium values (plates 9, 10, 11). Cassiterite has been reported in the heavy mineral concentrates from Orejana Canyon which lies immediately to the west. The geochemistry indicates that the elements which are anomalous in the Hart Mountain-Warner Peak area (Tract IV) are also anomalous in the Keg Springs Valley-Buckhorn Valley area (Tract IVa). This geochemical signature indicates potentially similar types of magmatic rocks and mineral deposits. The mineral deposit types can be found in table 6.

Tract V

Tract V delineates a favorable area for the occurrence of plagioclase sunstones. Although of little known economic importance, these sunstones are of value to mineral and gem collectors and consist of large phenocrysts of feldspar. This tract was delineated because of a known occurrence.

Tract VI

Tract VI delineates a favorable area for the occurrence of obsidian. This tract was delineated by outlining an area of known occurrence.

Geothermal Energy Resources

The delineation of tracts for permissive areas with respect to geothermal resources is based upon the presence of known hot springs, sedimentary basins, and high surface heat flow. Surface or near surface water temperatures range up to 99°C and several underground aquifer temperatures have been calculated by chemical geothermometer methods at up to about 200°C (Mariner and others, 1974).

The Federal Government has designated two large areas in the Adel quadrangle as Known Geothermal Resources Areas (KGRA's). One is located in southwestern Warner Valley and another in northern Pueblo (or Alvord) Valley; KGRA's are outlined in figure 1.

There is a very low potential for utilization of thermal waters within the Adel quadrangle because of the very low population density and the current use of thermal waters appear to be restricted to individual ranch needs. A potential for high-temperature geothermal resources has been found in the Mickey Hot Springs Known Geothermal Resource Area where the Mickey basin has potential to generate 160 megawatts of electricty from geothermal steam (BLM, 1985, p. 65). There is also a high favorability for geothermal resources in the Alvord Valley Known Geothermal Resource Area (Brown and Peterson, 1980) and the Pueblo Mountains (Gray et al., 1983).

Other Potential Mineral Resources

It was not possible to confidently delineate favorable tracts for some commodities. The reason for this could be that they are either ubiquitous, poorly defined, or of very low unit value. These commodities include oil and gas resources, and industrial minerals such as diatomaceous earth, perlite, and zeolites.

Oil and gas resources within the Adel quadrangle have been a source of speculation, with much of the quadrangle subject to leasing in the past. However, drilling and exploration for oil and gas has been unsuccessful thus far, and extremely limited. There are no surficial tar or oil seeps, black shales, or other evidence of hydrocarbon source beds exposed at the surface and it is highly speculative that they exist at depth. However, the presence of lignite in Eocene and Oligocene beds and the trace of natural gas in drill holes that have penetrated the Neogene strata provide positive shows (Fouch, 1983).

Resources of diatomaceous earth within the Adel quadrangle are based on the presence of known occurrences in caldera moat sediments and sedimentary basin fill. However, grades and tonnages of known occurrences have been too low for economical recovery and/or production. Evaluation of diatomite in the White Horse caldera (fig. 2) by several mining companies has been extensive and a large resource has been delineated, although only marginally economic at this time (J. Rytuba, personal communication).

Perlite resources within the Adel quadrangle have not been well defined to date. Perlite is known to occur in the glassy margins of felsic flows and domes, which occur throughout the quadrangle. A known marginal reserve of 400,000 short tons of perlite occurs at the Cinder Cone claims within the Pike Creek formation (USGS Bull. 1740-A).

Zeolites are found in tuff and volcanic sedimentary rocks within the Adel quadrangle. However, they have not been found of sufficent size and high enough grade to justify production. Zeolite beds and K-feldspar beds are of adequate grade to be of economic significance in the McDermitt caldera. They are presently being evaluated and will probably be of economic significance (J. Rytuba, personal communication).

RECOMMENDATIONS

Introduction

A large amount of information already exists on the geology, geochemistry, geophysics, and mineral resources for the Adel quadrangle. However, the type of information collected is difficult to apply to the problems associated with trying to assess the mineral resources of the Adel quadrangle. In many cases, the relevant information which would be of great importance when assessing mineral resources was not analyzed, observed or even looked for when the data was being collected. However, much of this information is still helpful and informative, even if in a circumstantial sense.

This section makes specific suggestions as to where and what kind of additional work needs to be done within the Adel quadrangle; explains why this information is important to the mineral resource assessment; these and other issues will be addressed by discipline below. It must be remembered, however, that these recommendations are subject to changes, additions, and deletions as more knowledge is gained about the Adel quadrangle and as technologies and knowledge of mineral deposits improve.

Recommendations By Discipline

The analysis of geologic information to evaluate resource potential is a multi-disciplinary activity which is dependent on input from many fields of geology. Due to this interdependency and the interrelation between specialties within the geologic community, when evidence or information is lacking to solve a problem, it can be identified through any of a number of geologic specialties. This will be the case within the Adel quadrangle when geology, geochemistry, and geophysics select the same areas for further evaluation, but for vastly different reasons. Also of importance, however, is when each of these geologic specialties select an area of further evaluation which is unique to their own discipline within the Adel quadrangle and the area has not been identified as needing further investigation by the other disciplines. It is these unique areas which provided the most focus for discussion within the group and between the scientists.

A tract map delineating areas for further study within the Adel quadrangle is shown on plate 4-D. This plate was the final product produced by the Adel preassessment team after several months of individual investigations and several days of meetings of the group. These areas are general in nature and the boundary lines were not meant to be rigorous. Plate 4-D will be referred to throughout the rest of this section.

Geology

Hart Mountain-Coyote Hills Area

Several nearby areas in the western part of the Adel quadrangle at Hart Mountain and in the Coyote and Rabbit Hills deserve additional study based on the presence of silicic domal and intrusive complexes, geochemical and geophysical anomalies, and, in the Coyote Hills, known precious and base metal deposits. Critical areas are covered by Warner Peak, Hart Lake, and Rabbit Hills, SW, 7.5' quadrangles; the southern half of the Rabbit Hills, NW, 7.5' quadrangle; and parts of the Flagstaff Lake and Campbell Lake, 7.5' quadrangles (see plate 4-D; 1:250,000 overlay of recommended studies). All areas are sufficiently closely grouped that a single project (or investigation) is recommended. The study should include geologic mapping at a scale of 1:24,000, and detailed geophysical and geochemical studies to determine 1) whether these silicic complexes are related to a major through-going structure (caldera?), the central part of which has been downdropped by the Warner Valley graben, 2) whether the aeromagnetic anomaly centered on Hart Mountain and the silicic complex adjacent on the east reflects a buried caldera or simply a silicic domal complex, or both, 3) whether a large plutonic mass underlies all these essentially coeval silicic complexes, 4) whether large, low-grade disseminated deposits of precious and/or base metals are permissible at depth, and 5) whether there is a significant potential for metallic or non-metallic resources within the area covered by these quadrangles.

Pueblo-Steens Mountain Range-Front

Part of the range-front between the Pueblo Mountains and Steens Mountain requires additional investigations based on the presence of known base and precious metals in the Pueblo Mountains south of the area, and the potential for precious metals along the Steens Mountain escarpment north of this proposed area. Critical areas are covered by the Fields, and V Lake 7.5' quadrangles. The investigation requires detailed geologic mapping at a scale of 1:24,000, and detailed geochemical and geophysical studies to determine 1) depth of the Pike Creek Formation which commonly hosts much of the mineralization in the Pueblo and Steens Mountains, 2) location of the major range-front fault-zones and buried range-front fault-zones, 3) the existence of pathfinder elements for precious metals, 4) whether the potential for precious metal deposits exist along the range-front fault-zones, buried fault zones, or in the underlying formations.

Geochemistry

Existing data and samples would seem to preclude the need to resample the entire quadrangle, though the regional data based on NURE soils have significant drawbacks. Recapturing these samples for reanalysis and reprocessing could provide sufficient information to allow subsequent field-phase work to be more focused. Two options are possible for an initial phase of a CUSMAP appraisal of the quadrangle: 1) the NURE soils should be analyzed for the suite of elements characteristic of epithermal deposits, particularly for Au, Ag, Hg, U, As, and Sb, and 2) heavy-mineral concentrates could be prepared from the NURE soils; particularly useful would be the duplicate set of samples if they have not been ground. These concentrates would provide much needed information on mineralogy, particularly in the areas of siliceous volcanic rocks, as well as chemical data with greater contrast. These additional, regional data should help to refine the areas of resource potential and should help to focus the follow-up studies.

A field phase is needed initially to validate the anomalies apparent in the existing data as well as those that may be found during the work recommended above. This phase should be designed to provide sufficient information on the nature of incorporation of the elements in the anomaly to allow for efficient planning of more comprehensive follow-up study. The base-metal anomalies near Hawks Mountain and Frenchglen and the expected anomalies in the Coyote Hills (weakly reflected in the NURE soils and talus) need special attention during this validation phase.

Follow-up studies of the various areas of interest should constitute the major part of an expanded program to assess the mineral resource potential of the quadrangle. The approach to each of these areas should be tailored to the problems posed in those areas. In the absence of adequate orientation surveys, it is premature to define what these approaches should be. It is even premature to constrain the limits of the areas of interest, as expanded, or additional areas may result from the recommendations made above and some areas may be dropped as a result of the validation phase of the investigation. It is only possible at this time to identify some areas that should be considered and to suggest some approaches to be tried. Five general, topical studies can be anticipated from the data available.

1. Base metals and the suite of elements commonly associated with epithermal deposits are anomalous in a large area of the southeastern part of the quadrangle. The anomalies are best known from the evaluations of the Wilderness Study Areas in the Pueblo Mountains and the eastern part of the Trout Creek Mountains. It can be expected that a large effort has been expended in this area by a variety of exploration companies. Present evidence suggests that the main mass of the Trout Creek Mountains is as

prospective as the Wilderness Study Areas. In this area, neither the sample types nor the analytical procedures used is suited to the problem. Suggested methods might include nonmagnetic heavy-mineral concentrates to search for minerals like cinnabar, arsenopyrite, and stibnite; partial dissolution techniques to enhance the contrast for base metals; and ultra-sensitive analytical procedures on the fine-grained fraction of soils or sediments to search for gold.

2. The epithermal suite of elements is sporadically known north of the Trout Creek Mountains along the flanks of the Alvord Valley and extending northeastward into the Sheepshead Mountains from the distribution of prospects and a few evaluations of Wilderness Study Areas. Hot springs are spatially associated with these anomalies. The continuity of the anomaly should be established. Suggested methods might include nonmagnetic heavy-mineral concentrates to search for the epithermal minerals, ultra-sensitive analyses of fine soils and sediments for gold, and analyses of waters and precipitates in and around the hot springs to evaluate the association of the anomalies and the thermal waters.

3. The base-metal anomalies in the vicinity of Hawks Mountain and south of Frenchglen are presently somewhat enigmatic. The Hawks Mountain anomaly has survived validation in the Wilderness Study Area where the assemblage would suggest that nonmagnetic heavy-mineral concentrates might enhance contrast for Bi, Au, and possible Pb, whereas partial dissolution techniques might be useful for Zn and Pb. If the anomaly south of Frenchglen survives validation, partial dissolution techniques might be appropriate for follow-up.

4. The assemblage of elements anomalous in the vicinity of Hart Mountain and in the north-central part of the quadrangle is appropriate to, and evidently associated with, siliceous volcanic rocks. The northern anomaly can be tenuously validated on the presence of tin, as cassiterite, in nonmagnetic heavy-mineral concentrates from the nearby Orejana Canyon Wilderness Study Area. A dilemma posed by these anomalies is why there are not similar anomalies in the Coyote Hills, where there are similar rocks and prospects, or near Beatys Butte, where the volcanic center is more prominently exposed. It would seem appropriate to include all four areas in follow-up studies--Coyote Hills, Hart Mountain, Beatys Butte, and the north-central anomaly. The suite of elements is mostly contained in chemically and mechanically resistant minerals. With the exception of possible Be in beryl, these minerals have high specific gravities, but they also have a broad range of magnetic properties. The most appropriate approach would seem to be heavy-mineral concentrates, although both the paramagnetic and the nonmagnetic fractions should be considered. Initially, stream sediments would be appropriate, though the attempt should be made to isolate bedrock sources as soon as possible.

5. The anomalies along the Warner Valley, the Pueblo Valley, and the Alvord Valley suggest the presence of saline deposits. These could either be saline minerals, like those prospected in the Alvord Valley, or in the form of brines. Although some additional information at the surface would be valuable for validation purposes, the most needed information is in the third dimension. Well and spring waters offer the most easily available sample media, and this effort could be coordinated with the recommendations

in number 2 mentioned above. It might be productive to seek out any cores or cuttings from drill holes in these basins. Additional geophysics and/or drill information would require additional geochemical effort.

Geophysics

Gravity

In order to provide gravity data that will be useful in understanding the upper crustal structure, especially the location and composition of buried intrusions, calderas and volcanoes, the overall station density must be improved in the Adel quadrangle. We recommend the gravity data sets be expanded to 1 station per 2.5 to 5 km. Work is now underway to improve the station coverage in the northeast portion of the quadrangle (Griscom, personal communication, 1988). The gravity data can then provide important information about major structures that lie close to the surface and about contrast in lithology.

Particular areas for detailed gravity station coverage are over the inferred buried volcanoes and calderas delineated by the magnetic data (plate 4-B). The gravity data might be able to help narrow the possibilities for the depth and composition of these features.

Another target for detailed gravity coverage is over the area marked IVa (plate 4-B). Better gravity data might be able to determine whether a pluton that could be the source of the Devine Canyon tuff (Walker, 1979) underlies the area.

Magnetics

The two-mile line spaced data are adequate for preliminary assessment, but is not adequate for detailed assessment when compared to the detail of geologic mapping. Even more detailed surveys than the one done over the Pueblo Mountains may need to done in order to locate areas of hydrothermal alteration that may be associated with mineralization.

More detailed (1/4 mile spaced, 400 ft. above ground) surveys could be flown over specific areas of interest like the Hart Mountain area, the proposed caldera in the Steens Mountains, and the Whitehorse Caldera. If even greater detail is required a ground magnetometer survey could be done.

Gamma-Ray Spectrometry

Data Needs

At this time, further aerial gamma-ray surveying is not recommended because this preassessment disclosed only a few geologic targets with significant radioelement characterization. These targets can be field-checked relatively inexpensively by a geophysicist using a quantitatively-calibrated portable gamma-ray spectrometer and working with a geologist competent in volcanic geology and associated mineral deposits. This work can be done early in the formal CUSMAP study and help determine whether contract aerial gamma-ray data should be obtained. The preassessment study demonstrates that the volcanic geology of the Adel quadrangle provides variations in radioelement concentrations readily measured by aerial surveying and easily applied in geologic mapping. Should additional magnetic or new electromagnetic aerial surveying be done, the feasibility of doing simultaneous aerial gamma-ray spectrometry measurements should be investigated.

Landsat MSS and Thematic Mapper

Data Needs

Preliminary spectral studies using Landsat MSS data have shown that a number of areas contain ferric iron oxides and possibly indicate areas of hydrothermal alteration exposed at the surface. The use of Landsat Thematic Mapper data, with its higher spatial resolution and additional spectral bands, would allow these areas to be characterized in greater detail, both spatially and by mineral content. Landsat Thematic Mapper data will also provide better data for conducting regional structural and tectonic studies in support of mineral resource assessment. The analysis of Landsat Thematic Mapper data is recommended for the early stages of CUSMAP investigations.

Areas of previously recognized hydrothermal alteration discovered during CUSMAP studies or areas of known, but inadequately characterized, alteration in the study area could apply airborne imaging spectrometer data to facilitate the timely definition of alteration types and zonal patterns needed for detailed mineral resource assessment.

Modern side-looking airborne radar imagery, if available, should be analyzed to detect new structural or tectonic relationships in the study area that may contribute to the understanding of the structural control of mineral deposits in the region and help constrain mineral resource potential evaluations.

The partially completed linear features map of the Adel quadrangle mapped from Landsat MSS data must be completed before the data can be analyzed for regional fracture patterns and lineaments.

Mineral Resources

Tasks needed to refine the mineral resource estimates include: compile and document the occurrence of all mines and prospects within and adjacent to the Adel quadrangle; characterize these mines and prospects into mineral deposit models; describe tracts or areas which are delineated by these deposit types and relate these tracts to the geology, geochemistry, and geophysics; estimate the number of deposits which are undiscovered but could occur.

Compiling and documenting the occurrence of all mines and prospects within the Adel quadrangle is achieved by accessing all known databases which contains this information: the U.S. Geological Survey's Mineral Resource Data Base, and the U.S. Bureau of Mines' Mines Overlay System and Mineral Information Library System. The MRDS system was accessed for this preassessment and found to have incomplete records. The USBM files were not accessed due to time constraints. However, it appears that a great deal of editing and verification of information contained within these databases will be necessary.

The examination of all known mines and prospects will be necessary to determine exactly what kinds of deposits are present. Currently, the USGS is ascribing deposits to models which are described in USGS Bulletin 1693, Mineral Deposit Models. This attempts to provide a commonality to all mineral resource assessments which occur now and in the future. This is a critical step to the resource assessment and can be very time consuming when adequate descriptions for the deposits are not readily available.

Within the Adel quadrangle and throughout the State of Oregon, the nonmetallic commodities are important to the mineral production within the state. Unfortunately, there are no grade-tonnage models for these commodities. Therefore, if the Adel quadrangle is to be assessed properly, grade-tonnage models should be developed for the nonmetallics.

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APPENDIX 1.—Mines and prospects within the Adel 1 x 2 degree quadrangle grouped by source document. These localities are plotted on Plate 4-C.

Bradley, Robin, 1982, Mining districts and mineral deposits of the Basin and Range Province of Oregon: U.S. Geological Survey Open-File Report 82-58, 14 p.

MINE NAME	COMMODITIES	DESCRIPTION	LATITUDE	LONGITUDE
HARNEY COUNTY				
ISOLATED DEPOSITS AND OCCURRENCES				
ALVORD LAKE	BORAX, NA	SALINE DEPOSIT	42.38333	118.60000
BORAX LAKE	BORATES	SALINE DEPOSIT		
EILEEN	HG	—	42.29917	118.71194
LOBO #3	U, HG	—	42.56667	118.60000
LUCKEY BOY	HG	—	42.32639	118.28167
MCLEAN'S COPPER	HG	—	42.20250	118.66917
MILE HIGH	HG	—	42.09861	118.62778
NO. 6, MARY D	U	DISSEMINATED	42.56667	118.55000
OLD FAITHFUL NO. 1	HG	—	42.29889	118.69250
OLD HOPEFUL AND NEW	HG	VEINLETS	42.57333	118.55639
PUEBLO MINING CO.	HG	—	42.11306	118.62806
RED HILL	HG, CU	HYDROTHERMAL	42.19417	118.68694
SOUTH O'KEEFE	HG	—	42.21556	118.56889
YELLOW JACKET	HG	—	42.29861	118.67333
—	U	—	42.40000	118.83333
—	CU, U, HG	VEIN	42.10000	118.60000
—	U	FRACTURE FILLING	42.57361	118.53750
—	U, CU	—	42.10000	118.64583
—	U, HG	—	42.60278	118.53750
—	U, HG	VEIN	42.10000	118.60000
—	U, HG	VEIN	42.11250	118.62778
—	U	—	42.18611	119.28889
STEENS-PUEBLO DISTRICT				
ALEX-LADD	U	SILICIFIED & FE SATINED FAULT	42.57361	118.53750
ALEXANDER	HG	FRACTURE COATING, SEAMS	42.56278	118.55167
APACHE	HG, CU	VEIN	42.11361	118.63500
ARIZONA GROUP	HG, CU, MN, AU	—	42.12806	118.65028
BLAIR GROUP	HG, BA, CU	VEIN/SHEAR ZONE	42.29917	118.71194
BLUE BULL	HG, CU, AS	SHEAR ZONE	42.17194	118.66722
CASH GROUP	HG, CU	HYDROTHERMAL	42.15833	118.66778
DOUBLE LICK	HG, CU	FRACTURE COATING	42.01333	118.66778
ELDORADO GROUP	HG, CU	VEIN/SHEAR ZONE	42.34417	118.67167
FARNHAM(WONDER ROCK)	AG, HG, AU	VEIN	42.10583	118.62778
FISHER GROUP	HG, BA, CU	VEIN/SHEAR ZONE	42.37778	118.65444
HARMONY AND SURPRISE GROUP	HG, CU	—	42.21500	118.68750
JACK POT	HG	DISSEMINATED	42.55889	118.55667
LAST CHANCE	HG	SHEAR ZONE	42.55889	118.55667
LUCKY STAR GROUP	HG, CU, BA	SHEAR ZONE	42.32250	118.67583
LUCKY STRIKE	HG, AU	FRACTURE COATING	42.29667	118.69056
MONGUL	HG, BA, CU	VEINLETS	42.29917	118.70389

NELLIE B	HG	"PAINT"	42.29889	118.69250
O'KEEFE	HG, CU, BA	FRACTURE COATING	42.31722	118.71694
PIKE	HG	VEINLETS	42.55889	118.55667
PIKE CREEK CARNOTITE	U, HG	HYDROTHERMAL	42.58889	118.54306
POT HOLE	HG	FRACTURE COATING	42.55889	118.53694
PUEBLO GROUP	HG, AU, CU, AG	VEIN/SHEAR ZONE	42.10417	118.62778
RABBIT HOLE	HG, CU, BA	HYDROTHERMAL	42.20250	118.66917
RED HILL	HG	FRACTURE COATING	42.29833	118.67139
RED KING	HG, CU	HYDROTHERMAL	42.20306	118.68722
RHOADS	HG, BA	DISSEMINATED, FRACTURE COATING	42.58806	118.55639
RHOADS PROSPECT	U, MN	SECONDARY ENRICHMENT	42.60417	118.54389
SPRING CREEK	HG, CU	REEF/SHEAR ZONE	42.18611	118.55250
STEENS MTN.(STEPHANSON & BRADLEY)	HG	FRACTURE COATING	42.57361	118.55000
STEWART	HG	VEINLET	42.55528	118.55222
TIMBERBEAST	U, MO	SECONDARY ENRICHMENT	42.60000	118.54333
UPPER PIKE	U	VOLCANIC, SECONDARY ENRICHMENT	42.59250	118.56556

LAKE COUNTY

ISOLATED DEPOSITS AND OCCURRENCES

ADEL	HG	SALINE DEPOSIT	42.18139	119.88500
HART MOUNTIAN	HG	—	42.44361	119.77611
LOST CABIN (COYOTE HILL) DISTRICT				
GRAY(WINDY HOLLOW)	HG	DISSEMINATED	42.53389	119.98139
OPALITE (MCDERMITT) DISTRICT				
OPALITE	HG, U, LI	FRACTURE FILLING	42.05528	118.02500

Minor, Scott A., and Plouff, Donald, 1987, Mineral Resources of the High Steens and Little Blitzen Gorge Wilderness Study Areas, Harney County, Oregon: U.S. Geological Survey Bulletin 1740-A, 21 p.

CINDER CONE NOS. 1-6	PERLITE	RHYOLITE & BIO-DACITE FLOW	42.65025	118.54875
KNIGHT HAWK NO. 1 CLAIM	URANIUM	FE & MN OXIDE STAINS	42.64938	118.54038
(CLAIM NO. 6)				
(RHOADS PROSPECT)				
ALVORD URANIUM CAVE CLAIMS	URANIUM	FE & MN OXIDE STAINED	42.64763	118.53125
HORSE HEAVEN MINE	MERCURY	CINNABAR COATINGS IN FAULT	42.62750	118.55000
RED ROCK NO. 6 CLAIM	MERCURY	CINNABAR DISSEM. IN QTZ. VEINS	42.62663	118.54125
WESTON MINE	MERCURY	CINNABAR DISSEM. & COATINGS	42.61875	118.55250
(JUNIPER MERCURY MINE)				
STEENS NOS. 1-74 CLAIMS	URANIUM	FE OXIDE STAINED, KAOLINIZED	42.63013	118.55625
AILE ROUGE [SIC] NO. 1 CLAIM	MERCURY	FE STAINING ALONG NW FAULT	42.61350	118.54875
SUNSHINE NO. 3 CLAIM	MERCURY	SILICIFIED,FE STAINED VEINLETS	42.62575	118.55000
(RED ROCK NO. 6 CLAIM)				
BIG INDIAN MINE	PLACER GOLD	GRAVEL VENEER,BIG INDIAN CR.	42.68438	118.61875
BUCKHORN MINE	PLACER GOLD	PLACER, BIG INDIAN CREEK	42.68438	118.60875
DAISY CLAIMS	GOLD	CINDER & SCORACEOUS ANDESITE	42.71938	118.52625
GOLD CROWN CLAIM	PLACER GOLD	ALLUVIUM	42.68000	118.59000
GOLD QUEEN CLAIM	PLACER GOLD	POINT BAR DEPOSIT	42.68525	118.59625
HEAD LIGHT MINE	PLACER GOLD	GRAVEL BAR	42.68438	118.60625
HOMESTRETCH LODE	PLACER GOLD	POINT BAR DEPOSIT	42.67125	118.63625
JACK POT CLAIM	PLACER GOLD	POINT BAR DEPOSIT	42.68525	118.60375

LADY WASHINGTON CLAIM	PLACER GOLD	GRAVEL DEPOSIT	42.68438 118.59375
MINERS DREAM LODE	GOLD	FE STAINED FRACTURE ZONE	42.67125 118.61625
OLE OLSON LODE	GOLD	TUFF	42.67388 118.62375
SNOWBIRD CLAIM	PLACER GOLD	ALLUVIUM	42.64413 118.59375
WEST END CLAIM	PLACER GOLD	ALLUVIUM	42.68613 118.62375

Roback, Robert C., Vander Meulen, Dean B., King, Harley D., Plouff, Donald, 1987, Mineral Resources of the Pueblo Mountains Wilderness Study Area, Harney County, Oregon, and Humboldt County, Nevada: U.S. Geological Survey Bulletin 1740-B, 30 p.

BLACK DOG GROUP		QUARTZ VEINS	42.15694 118.75972
B AND H CLAIM		MALACHITE-RICH QTZ VEIN	42.18750 118.72917
RED OXIDE GROUP		QUARTZ AMYGDALOIDS	42.18333 118.72083
BLACK BEAUTY PROSPECT		CHLORITIC ALTERATION	42.15000 118.71250
RAVEN PROSPECT		LIMONITE ON FRACTURES	42.14583 118.71861
KING COAL PROSPECT		VITROPHYRIC IGNIMBRITE UNITS	42.15000 118.70417
FREEMAN DORSEY PROSPECT		SURFICIAL IRON OXIDE	42.13889 118.70833
STAR PROSPECT		PROPYLITIC ALTERATION	42.14028 118.70000
STUMBLEBUM PROSPECT		QUARTZ FLOAT	42.13611 118.68333
STAR OF THE WEST PROSPECT		QUARTZ VEINS	42.14167 118.67083
GLOW 1 AND 2 PROSPECT		LIMONITE, SILICIFICATION	42.14722 118.66250
CHUKAR GROUP		SILICIFIED FAULT ZONE	42.17917 118.66806
VICTOR GROUP		PYRITE,CINNABAR,LIMONITE VEIN	42.20972 118.67917
WHITE HOUSE PLACER		ALLUVIAL FANS, PEDIMENT	42.15139 118.61667
QUAIL PROSPECT		SILICIFIED ZONE	42.14722 118.65833
IRENES GROUP		LIMONITE, QUARTZ VEINS	42.13472 118.65833
LONE STAR MINE		LIMONITE, QUARTZ VEINS	42.12500 118.66250
KING COPPER PROSPECT		CHALCOPYRITE-BEARING QUARTZ	42.12500 118.65000
WHALE PROSPECT		SERICITE AND CLAY ALTERATION	42.12361 118.64444
BIG BAD JOHN-WILLIES GROUPS		SILICIFICATION,SERICITE ALTERA	42.12083 118.64583
UNNAMED PROSPECT		CHLORITE,QUARTZ VEIN	42.11806 118.65000
GRACE MINE		CHLORITE,EPIDOTE,CLAY ALTER.	42.11667 118.62500
BLUE BIRD PROSPECT	GOLD PLACER	ALLUVIUM	42.11528 118.64167
UNNAMED PROSPECT		CHLORITIC,ARGILLIC ALTER.	42.11250 118.62917
ACE GROUP		QUARTZ,SERICITE,CLAY,CHLORITE	42.10556 118.64167
MOHAWK CLAIMS		ALTERED ZONE	42.10278 118.63333
SHAMROCK PROSPECT		BRECCIATED SHEAR ZONE	42.10833 118.62222
ROBERT SMITH PROSPECT		LIMONITE AND QUARTZ VEINLETS	42.10694 118.63194
UNNAMED PROSPECT		SILICIFIED BRECCIA	42.10694 118.62639
CLIMAX PROSPECT		PYRITE-BEARING QTZ VEINS	42.10000 118.62500
UNNAMED PROSPECT		BRECCIATED QUARTZ VEIN	42.09583 118.63889
PUEBLO CLAIM		SILICIFIED,ALTERED RHYOLITE	42.08056 118.65139
BONANAZA CLAIM		HYDROTHERMALLY ALTERED ZONES	42.07500 118.65000
ETHEL MAY PROSPECT		QUARTZ VEIN FLOAT	42.08611 118.63750
LUCKY DANE CLAIMS		QUARTZ VEIN FLOAT	42.08472 118.63333
COLONY CREEK PROSPECT		SILICIFIED ZONE	42.07778 118.64722
VIQUEEN PROSPECT		MINOR LIMONITE	42.07778 118.63056
MAMMOTH NO. 1 PROSPECT		LIMONITIC QUARTZ VEIN	42.07778 118.62917
COYOTE ROB PROSPECT		LIMONITIC QUARTZ VEIN	42.08056 118.62639
MONOLITH PROSPECT		QUARTZ VEINLETS, MALACHITE	42.07778 118.62639
COYOTE ROY PROSPECT		SILICIFIED ZONE	42.07500 118.62917
KEYSTONE PROSPECT		LIMONITIC QUARTZ	42.07222 118.63056
LONE CLAIM PROSPECT		QUARTZ VEIN	42.06250 118.62500

VIKING CLAIM		QUARTZ VEIN, SPECULAR HEMATITE	42.07500	118.63750
PUEBLO PROSPECT		MALACHITE-COATED CALCITE	42.08194	118.67361
UNNAMED PROSPECT		CHALCEDONY FRAGMENTS	42.07639	118.66944
F & G CLAIMS		IRON OXIDE STAINS	42.06250	118.67361
WHITE ELEPHANT CLAIM		PHYLLITIC GREENSTONE	42.05833	118.67083
GOLDEN NO 1 CLAIM		MINUTE FELDSPAR PHENOCRYSTS	42.05417	118.66528
BLUE JAY CLAIM		SILICIFIED ANDESITE	42.05278	118.66250
VAN HORN CLAIM		SILICEOUS FRACTURE ZONE	42.05556	118.65833
TWO FRIENDS CLAIM		HYDROTHERMALLY ALTERED ZONES	42.05417	118.65000
PEARL MINE		ALTERED BRECCIA ZONES	42.05556	118.64722
UNNAMED PROSPECT		QUARTZ, LIMONITE-FILLED FRACTU	42.03056	118.66250
MISSOURI GROUP	GOLD PLACER	CREEK GRAVEL	42.03056	118.66667
DENIO BASIN GROUP		ALTERED BASALT	42.02361	118.68056
UNNAMED PROSPECT		LIMONITIC QUARTZ FRACTURES	42.02083	118.67500
GRAY EAGLE PROSPECT		LIMONITE,CLAY ALTERATION	42.01250	118.68056
UNNAMED PROSPECT		CLAY,SERICITE ALTERATION	42.00833	118.67083
UNNAMED PROSPECT		QUARTZ VEINS, ALTERATION	42.00417	118.65556
SULFIDE GROUP		QUARTZ VEIN CUTS SCHIST	42.01667	118.65417
UNNAMED PROSPECT		QUARTZ VEINS WITH AZURITE	42.03611	118.61944
UNNAMED PROSPECT		ALTERATION WITH MALACHITE	42.02917	118.62222