UNITED STATES DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

RESOURCE ASSESSMENT OF THE BUREAU OF LAND MANAGEMENT'S WINNEMUCCA DISTRICT AND SURPRISE RESOURCE AREA, NORTHWEST NEVADA AND NORTHEAST CALIFORNIA

An Interim Project Status Report

by

Jeff L. Doebrich [1], George V. Albino [2], Charles E. Barker [3], Wendell A. Duffield [4], Victor C. Dunn [5], Willam F. Hanna [6], Joseph P. McFarlan [7], Dawn J. McGuire [8], Michael S. Miller [9], Stephen G. Peters [1], Donald Plouff [10], Gary L. Raines [1], Don L. Sawatzky[1], and Gregory T. Spanski [11]

United States Geological Survey Open-File Report 94-712

1994

[1]USGS, MS 176, Reno Field Office, Mackay School of Mines, University of Nevada, Reno, NV 89557-0047

[2]U.S. Geological Survey, Unit 62101, APO AE 09811-2101

[3]USGS, MS 971, Box 25046, Denver Federal Center, Denver, CO 80225-0046

[4]USGS, Bldg. 3, 2255 North Gemini Dr., Flagstaff, AZ 86001-1698

[5]Bureau of Land Management, 705 E. 4th St., Winnemucca, NV 89445

[6]USGS, National Center, MS 927, 12201 Sunrise Valley Dr., Reston, VA 22092-0001

[7]Bureau of Land Management, P.O. Box 460, Cedarville, CA 96104

[8]USGS, MS 973, Box 25046, Denver Federal Center, Denver, CO 80225-0046

[9]Western Field Operations Center, U.S. Bureau of Mines, E. 360 Third Ave., Spokane, WA 99202

[10]USGS, MS 989, Bldg. 2, 345 Middlefield Road, Menlo Park, CA 94025-3591

[11]USGS, MS 937, Box 25046, Denver Federal Center, Denver, CO 80225-0046

EXECUTIVE SUMMARY

The U.S. Geological Survey (USGS), in cooperation with the U.S. Bureau of Mines (USBM), is conducting a resource assessment of the Bureau of Land Management's (BLM) Winnemucca District and Surprise Resource Area, an area covering 13.5 million acres in northwest Nevada and northeast California. This resource assessment will assist the BLM in meeting inventory and evaluation, resource-management planning, and other management requirements of the Federal Land Policy and Management Act of 1976 (FLPMA). Land management issues that could impact or could be impacted by resource development in the project area include the presence of threatened and endangered species (for example, the Lahontan Cutthroat trout, raptor habitats, and the Desert Dace fish), the withdrawal of public lands from mineral entry (for example, the proposed 1.2 million acre High Rock/Black Rock National Conservation Area), and the impact of mine dewatering on drainage basin groundwater resources (for example, the Humboldt River drainage basin).

Primary objectives of this assessment include 1) identifying areas in which significant deposits of mineral, oil and gas, and geothermal resources may be present, and 2) providing probabilistic estimates of the number of undiscovered mineral deposits and the quantity of metal contained in those undiscovered deposits. The latter information will be used by the BLM, after economic analysis by the USBM, in their construction of Reasonable and Foreseeable Development scenarios as part of their Resource Management Plan for the District/Resource Area or for other planning units such as drainage basins or identified ecosytems.

The assessment is being conducted in two stages. The compilation and synthesis of existing data pertinent to conducting a resource assessment (stage I) has resulted in the identification of data and (or) knowledge deficiencies that are guiding stage II field studies. This report describes stage I accomplishments, documents data and knowledge deficiencies identified during stage I compilations, outlines stage II work plans, and presents preliminary interpretations of data. Though it is unrealistic that all identified data and knowledge deficiencies will be addressed in the time frame of this project, this will serve as a record for those who follow to address in future assessments.

An assessment for non-fuel mineral resources is being conducted both qualitatively and quantitatively. This includes metallic mineral resources, industrial rock and mineral resources, and sand and gravel resources. Qualitative assessment consists of preparation of mineral potential tract maps that outline the likelihood of occurrence of specific mineral deposits types at three levels of potential (low/permissive, moderate/favorable, high/prospective). Preliminary 1:250,000 scale working copies of mineral potential tract maps have been prepared for the project area. Stage II activities include field studies to define geologic and structural features controlling mineral deposit distributions and examinations of poorly characterized or controversial mineral occurrences to ensure proper deposit classification. A quantitative assessment for metallic mineral resources (and some industrial mineral resources) will result in a probabilistic estimation of the number of undiscovered mineral deposits (by deposit type) and the quantity of metal contained in them.

An assessment for fuel resources includes assessments for geothermal and oil and gas resources. Several recently constructed geothermal power plants are within and very near the project area. The Great Basin is currently the principal domestic target area for commercial exploration and this assessment will aid in identifying new sites with potential to generate electricity. Geothermal resources appropriate for non-electric applications also are fairly abundant in the project area, and some of these resources are already developed (e.g., alfalfa drying at Gerlach, onion drying at Nightingale). The USGS has completed three national geothermal-resource assessments during the past two decades. The general methodology and much of the data base used for those assessments will be employed for the project area. Stage I activities have included working with personnel of the Nevada Bureau of Mines and Geology who are currently reassessing geothermal resources for the entire state. Stage II studies, and future assessments, should focus on improving our understanding of subsurface hydrology, both locally and regionally. Oil and gas assessment of the project area is being conducted as part of the 1995 National Petroleum Assessment. Stage I activities have included compilation of all existing data on known hydrocarbon plays in the area and the identification and description of speculative or conceptual oil and gas plays. Conceptual plays are of three types: 1) Permian-Triassic source rocks, 2) Cretaceous source rocks , and 3) Neogene source rocks. Stage II studies and any future oil and gas assessment in the WSRA project area should include: 1) documentation of the origin of and natural gases by isotopic analysis; 2) determination of the extent of Triassic source rocks in west central Nevada; and, 3) better documentation of depth of fill, potential traps, and areal extent of source rocks in the Late Cenozoic basins.

Supporting data bases are a critical component of any assessment, without which the assessments could not be conducted. Because the BLM is working toward automation of resource management planning, all spatial data pertinent to conducting a resource assessment of the project area are being compiled and archived in digital form in an Arc/Info GIS. Supporting data bases include geology, geochemistry, geophysyics, hydrothermal alteration, and mineral locality data (MRDS, MILS, etc.). Stage I activities have resulted in preliminary interpretations of existing supporting data and are presented here. Stage II activities include 1) examination of important geologic and structural features that influence the distribution of resources, 2) compilation and interpretation of new geochemical data from the reanalysis of NURE samples and incorporation of this new information into the mineral resource assessment, 3) classification of hydrothermally alterered areas identified by color-ratio composite Landsat Thematic Mapper imagery, and 4) examination of mineral localities for which deposit type classification are unknown or uncertain.

INTRODUCTION

The U.S. Geological Survey (USGS) is a party to joint interagency Memorandum of Understandings (MOUs) with the Bureau of Land Management (BLM) and the U.S. Bureau of Mines (USBM) to coordinate resource assessments and evaluations of BLM administered lands. Resource assessments of BLM Resource Areas (RAs), that are conducted by the USGS under these MOUs, assist the BLM in meeting inventory and evaluation, resource-management planning, and other management requirements of the Federal Land Policy and Management Act of 1976 (FLPMA).

Location of Project Area and Land Management Issues

The project area is composed of three contiguous BLM RAs, totalling 13.5 million acres, in northwest Nevada and northeast California (figs. 1, 2). The Sonoma-Gerlach and Paradise-Denio RAs in northwest Nevada together comprise the BLM's Winnemucca District. The Surprise RA is located in extreme northwest Nevada and northeast California and is part of the BLM's Susanville District, which is administered by the BLM's California state office. Henceforth, the project area will be referred to as the Winnemucca-Surprise Resource Assessment (WSRA) project area.

There are several land management issues that could impact or could be impacted by resource development in the project area. These include the presence of threatened and endangered species, the withdrawal of public lands from mineral entry, and the impact of mine dewatering on drainage basin groundwater resources. The Lahontan Cutthroat trout (primarily in the Paradise-Denio RA), raptor habitats (primarily in the Surprise RA), and the Desert Dace fish (Soldier Meadows area, Surprise RA) are examples of species and habitats in the project area that are listed as threatened or endangered by the U.S. Fish and Wildlife Service. The 1.2 million acre High Rock/Black Rock National Conservation Area (NCA) (fig. 2) is part of the historic Applegate-Lassen Emigrant Trail that branched off the Humboldt River near Rye Patch Reservoir and continued across the Black Rock Desert through High Rock Canyon (fig. 2). The High Rock NCA is being proposed for withdrawl from mineral entry (a 20 year administrative withdrawal) to protect the historic and scenic value of the area. The discovery and development of large gold deposits in north-central and northeast Nevada over the past decade has created concern about the impact of mine dewatering on groundwater resources in this region. The Humboldt River drainage basin, which extends into the southeast part of the project area is currently the focus of impact studies by the USGS, the BLM, and the USBM.

Objectives

The principal goals of this project are to provide other federal agencies, particularly the BLM, with 1) maps (with interpretive text) showing geology, geophysics, geochemistry, hydrothermal alteration, and most importantly, the location of tracts in which significant deposits of mineral, oil and gas, and geothermal resources may be present in the three BLM Resource Areas (Sonoma-Gerlach, Paradise-Denio, and Surprise), and 2) probabilistic estimates of the number of undiscovered mineral deposits and the quantity of metal contained in those undiscovered deposits. The latter information will be used by the BLM, after economic analysis by the U.S. Bureau of Mines (USBM), in their construction of Reasonable and Foreseeable Development scenarios as part of their Resource Management Plan (RMP) for the Resource Areas or possibly an RMP for drainage basins or identified ecosytems in the study area.

We will gain additional insight into factors that control the distribution of mineral, oil and gas, and geothermal resources in the region through topical studies of regional geology, geophysics, geochemistry, hydrothermal alteration, and more detailed studies of mineral deposits.

Strategy

The assessment project is being conducted in two stages, following the guidelines for mineral-resource studies of public lands (appendix 1). Stage I activities have involved the gathering and compilation of all existing data pertinent to conducting a resource assessment of the project area and the preparation of GIS-compatible digital data bases. Selected multidisciplinary interpretations using existing data have been made, and include a preliminary qualitative assessment (mineral potential tract maps) for metallic mineral deposits. Stage I activities have resulted in the identification of both data and knowledge deficiencies that will help focus stage II studies. This report summarizes accomplishments to date, presents preliminary interpretations of data, and outlines strategy for stage II activities.

Stage II will emphasize field-based studies of high-priority items identified during stage I data compilation and synthesis. These studies will aid in refining resource potential tract boundaries and resource deposit models. Stage II will conclude with the release of a resource assessment report that will include the results of qualitative assessments (tract maps showing resource potential) for all resources and a quantitative assessment (estimation of numbers of undiscovered deposits and the quantity of metal contained in them) for metallic and industrial mineral resources, as well as all supporting data. The assessments will be published at 1:500,000 scale.

Previous Assessments and Concurrent Projects

Previous resource assessments of all or parts of the area have included resource potential surveys of wilderness study areas (table 1, fig. 2), a mineral resource assessment of the Reno 1° by 2° quadrangle (John and others, 1993) which covered the project area south of latitude 40°N, and a statewide mineral assessment of Nevada (Cox and others, 1989, 1991; Blakely and Jachens, 1991; Ludington and others, 1994). The USBM recently completed a resource inventory for the proposed High Rock/Black Rock NCA (Miller, 1993), a 1.2 million acre area located in the western part of the project area (fig. 2). Mineral inventories of the Winnemucca District (Bonham and others, 1985) and the Nevada part of the Surprise Resource Area (Garside and Davis, 1992) were conducted by the Nevada Bureau of Mines and Geology.

The USBM is concurrently conducting a mineral land assessment (MLA) of the project area. This work is largely analytical and inventorial in nature and concentrated around areas of significant impact, including areas of critical environmental concern (ACECs), proposed national conservation areas (NCAs), wilderness study areas (WSAs), Nevada State and United States wildlife refuges, and populated area. Areas of development interest (ADIs) will be classified as having high, moderate, or low significance. Socioeconomic and(or) potential supply analyses will be conducted by the USBM using USGS probabilistic ore-deposit estimates.

Aknowledgments

Several USGS personnel, though not officially attached to the project, are contributing their time and expertise to various aspects of the project and are listed as consultants to the project in appendix 2. In particular, Tom Nash, Ted Theodore, and David John are acknowledged for their participation in a preliminary quantitative assessment for metallic mineral resources of the project area and for their field investigations in the High Rock/Black Rock NCA. Harley King assisted in the collection of new stream sediment samples in the project area and is currently compiling analytical data from the reanalysis of NURE samples. Kathy Connors has been instrumental in the preparation of maps and figures from the project GIS data bases.

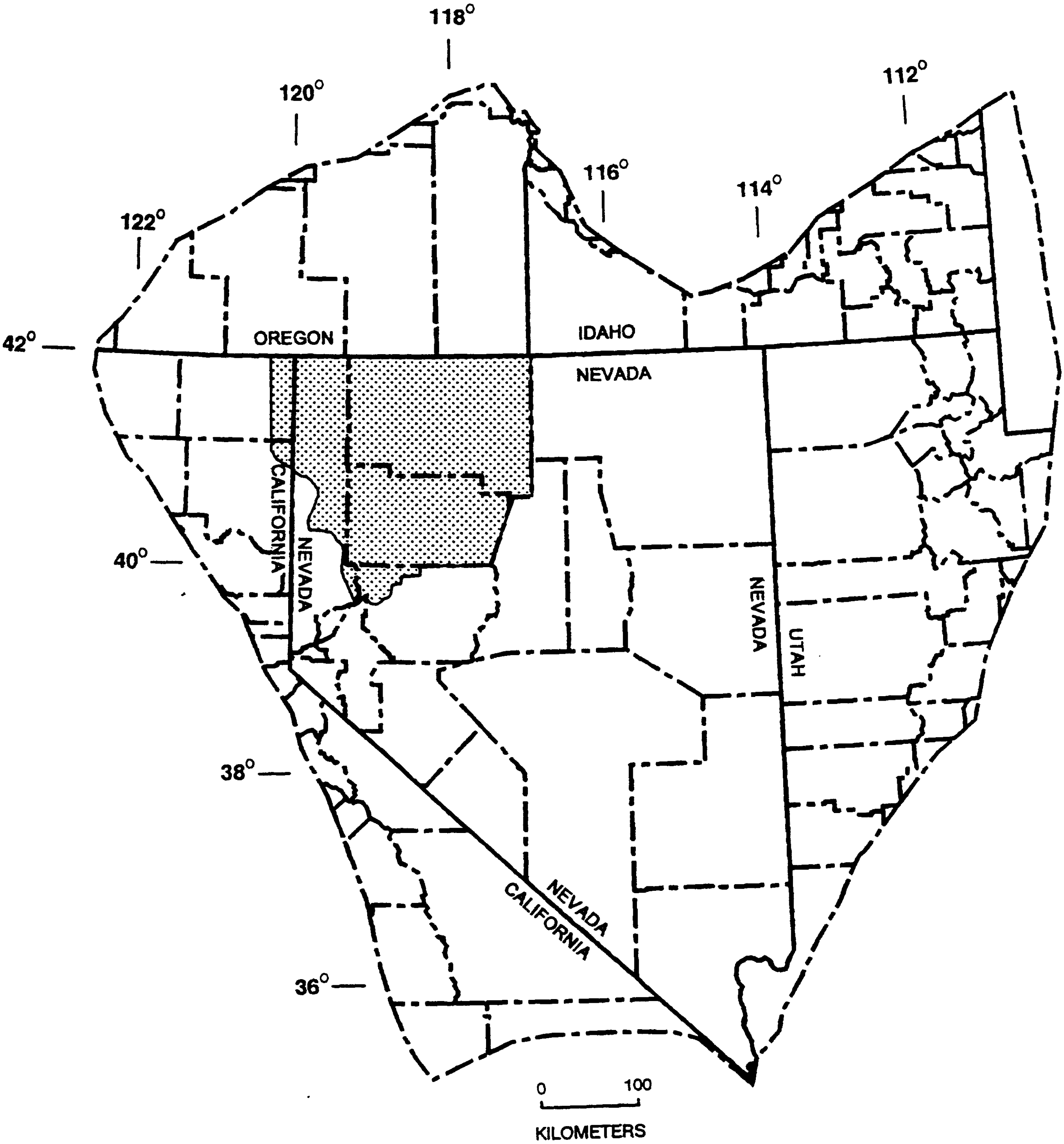

Figure 1. Map of Great Basin showing state and county boundaries and location of Winnemucca-Surprise Resource Assessment project area (stippled).

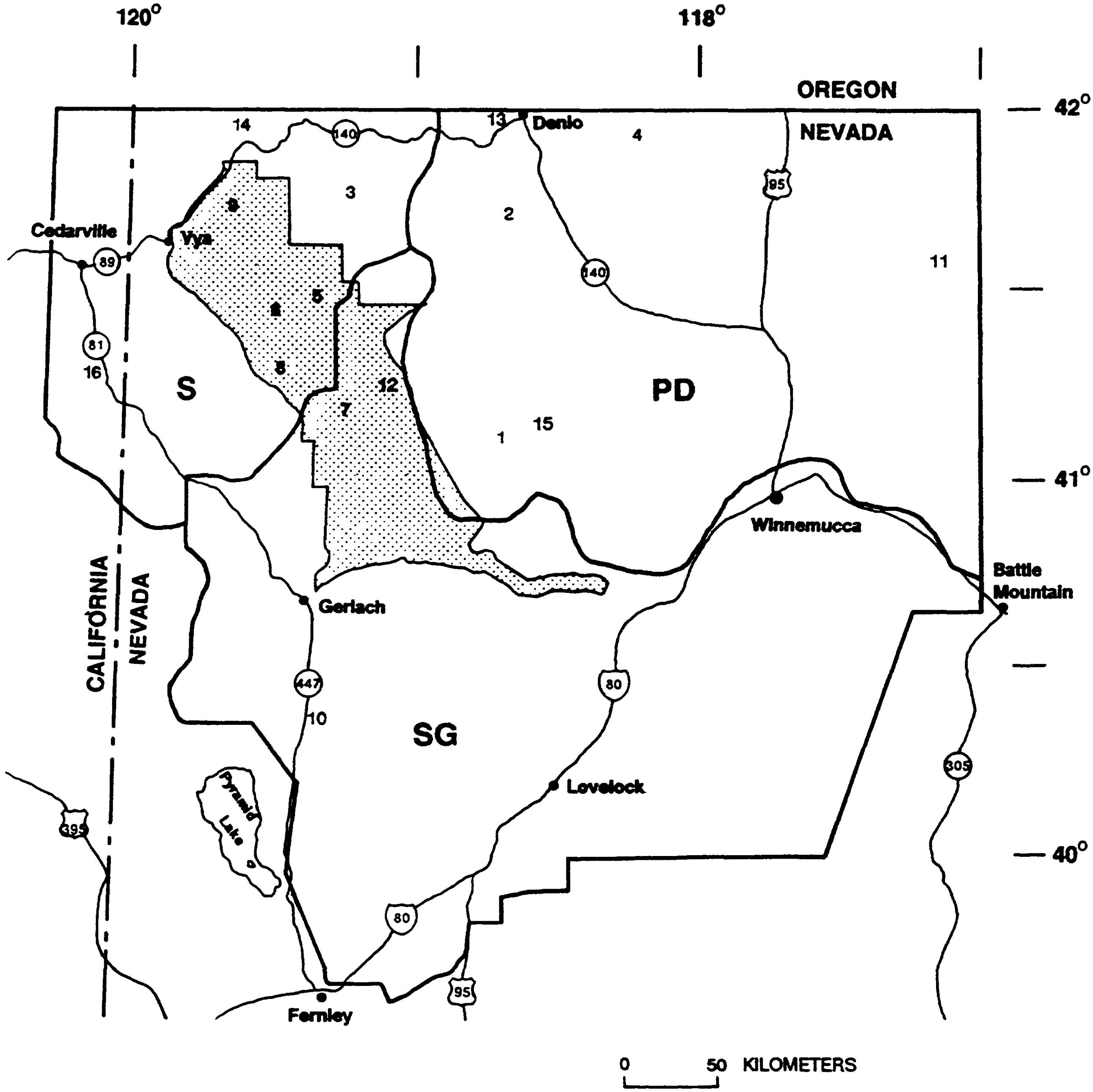

Figure 2. Map of project area. Stippled area is proposed High Rock/Black Rock National Conservation Area. Numbers refer to Wilderness Study Areas listed in table 1. Heavy lines are BLM Resource Area (RA) boundaries. S - Surprise RA, PD - Paradise-Denio RA, SG - Sonoma-Gerlach RA.

Table 1. Wilderness and other areas in the WSRA project area for which resource surveys were conducted by the USGS and USBM. For locations see figure 2.

NAME OF WILDERNESS STUDY AREA[1]	IDENTIFIED RESOURCES	RESOURCE POTENTIAL[2]	REFERENCES
1. Black Rock Desert	none	**M:** gold, silver, mercury, lithium; **L:** oil & gas	Olson, 1985; Calzia and others, 1987
2. Blue Lakes	none	**L:** gold, silver, antimony, copper, lead, mercury, molybdenum, zinc, uranium	Willet, 1986; Bergquist and others, 1987
3. Charles Sheldon Antelope Range and National Antelope Refuge	opal, ornamental stone, uranium	Probable: copper, gold, lead, mercury, silver, uranium, zinc	Cathrall and Tuchek, 1984; Cathrall and others, 1985
4. Disaster Peak	none	**H:** gold; **L:** gold, silver, mercury, uranium	Leszcykowski, 1987; Minor and others, 1988
5. East Fork High Rock Canyon	none	**M:** gold, silver, mercury, zeolites **L:** geothermal	Schmauch, 1986; Ach and others, 1987
6. High Rock Canyon	none	**H:** zeolites; **M:** gold, silver, mercury; **L:** uranium, lithium, geothermal, oil & gas	Scott, 1987; Turrin and others, 1988
7. High Rock Lake	geothermal	**L:** mercury, uranium, gold, geothermal	Neumann and Close, 1985; Noble and others, 1987
8. Little High Rock Canyon	none	**M:** gold, silver; **L:** gold, silver, uranium, pozzolan, perlite, geothermal	Keith and others, 1987; Peters and others, 1987
9. Massacre Rim	none	**M:** gold, silver, mercury, uranium	Causey, 1987; Bergquist and others, 1988b

10. Mount Limbo	none	**M:** gold, silver **L:** gold, silver, geothermal	Keith and others, 1986; Rumsey, 1986
11. North Fork Little Humboldt River	none	**L:** mercury	Leszcykowski, 1985; Peterson and others, 1986
12. Pahute Peak	none	**H:** gold, silver, geothermal; **M:** gold, silver, copper, lead, zinc, molybdenum, tungsten; **L:** mercury, uranium	Olson, 1986; Noble and others, 1987
13. Pueblo Mountains	gold, copper, molybdenum, zeolites, diatomite, geothermal, sand, gravel, stone	**H:** silver, mercury; **M:** gold, silver, mercury, copper, molybdenum; **L:** silver, zinc, mercury, molybdenum, copper, lead, zeolites, diatomite, oil & gas, geothermal	Munts, and Willett, 1987; Roback and others, 1987
14. Sheldon Contiguous	none	**L:** mercury, gold, silver, natural gas	Cathrall and others, 1984; Tuchek and others, 1984; Esparza, 1986; Bergquist and others, 1988a
15. South Jackson Mountains	none	**M:** gold, silver, copper, lead, zinc, iron; **L:** oil & gas, geothermal	Hamilton, 1987; Sorenson and others, 1987
16. South Warner, CA	calcite	**L:** geothermal	Duffield and Weldin, 1976

[1] Numbers refer to areas shown on figure 2.

[2] as defined in Taylor and Stevens (1983); L - low, M - moderate, H - high.

Table 2. Project timetable showing schedules for specific activities and important target dates.

	4/93	10/93	4/94	10/94	9/95	10/95	4/96
Stage I Assessment for Metallic Mineral Resources and Oil & Gas							
Stage II Studies for Metallic Mineral Resources and Oil & Gas							
Stage I Assessment for Geothermal Resources							
Stage II Studies for Geothermal Resources							
Stage I Assessment for Industrial Rocks and Minerals and Sand and Gravel							
Stage II Studies for Industrial Rocks and Minerals and Sand and Gravel							
Project Review and Preliminary Quantitative Assessment for Mineral Resources			X				
Final Quantitative Assessment for Mineral Resources					X		
Submittal of Final Product into Peer Technical Review						X	
Release of Final Product as Open-File Report							X

ACCOMPLISHMENTS AND WORK PLANS

The Winnemucca-Surprise Resource Assessment (WSRA) project commenced in April 1993 and is scheduled to be completed in April 1996. Stage I activities have been conducted during the first year of the project and stage II studies are being conducted over the final two years of the project. A timeline chart illustrating the schedule for specific activities is presented in table 2.

The compilation and synthesis of existing data pertinent to conducting a resource assessment (stage I) has resulted in the identification of data and(or) knowledge deficiencies that will guide stage II field studies. Presented below is a short description of stage I accomplishments and documentation of data and knowledge deficiencies. Though it is unrealistic that all deficiencies will be addressed in the time frame of this project, this will serve as a record for those who follow to address in the future assessments; resource assessments are and should be dynamic.

Assessment for Metallic Mineral Resources

A wide variety of metallic mineral deposit types occur throughout the project area. The most common and historically most economically important metallic commodities produced from the area include gold, silver, and tungsten. Presently, gold accounts for most mining in the project area, with annual production of more than one million ounces of gold. Gold is produced mainly from 1) sediment-hosted (Carlin-type), 2) hot-spring and vein-type gold-silver deposits, and 3) distal disseminated Ag-Au deposits (appendix 3). Some additional gold and silver production is derived from a variety of less important mineral deposit types. Discoveries of new mineral deposits made since 1985 have included some of the largest deposits in the WSRA area (for example, deposits at the Twin Creeks, Marigold, and Lone Tree mines) and has encouraged exploration throughout the region.

An assessment for metallic mineral resources is being conducted both qualitatively and quantitatively. Qualitative assessment consists of preparation of mineral potential tract maps that outline the likelihood of occurrence of specific mineral deposits types at four levels of potential (no/nonpermissive, low/permissive, moderate/favorable, high/prospective). These are defined as follows:

> *Non-permissive* - This is equivalent to No mineral resource potential (Taylor and Stevens, 1983). There is only an infinitesimal chance of a given deposit type present. This ranking can be depth-dependent, where a 1 km depth limit determines all areas where alluvium or other lithologic types exceeds 1 km cover for a deposit model type.
>
> *Permissive* - This ranking is equivalent mineral to Low mineral potential (Taylor and Stevens, 1983) and is applied to areas where no geological feature prohibits the presence of a given deposit model type, but where there is no or scant positive indication that mineralizing processes were operative within the tract, so there is a low likelihood of a deposit existing. In many cases this classification is given to large areas or the entire resource area, where cover is less than 1 km. This classification also covers areas where

levels of uncertainty may be very high and is therefore sometimes equivalent to the "Unknown" classification.

Favorable - This classification is similar to **M**oderate mineral potential (Taylor and Stevens, 1983) and favorable tracts are a sub-set of permissive tracts. This ranking applies to tracts where evidence of a mineralizing process for deposit model types is known or can be extrapolated into adjacent covered (but <1 km) or poorly documented areas. These tracts are considered to have a significant likelihood of hosting one or more deposits and are equivalent to 'mineral belts', or tracts defined by geological features, or alignments, or grouping of mineral occurrences. Evidence of a mineralizing process includes more than deposits themselves, such as genetically related deposit model types, areas of hydrothermal alteration, or geophysical or geochemical anomalies.

Prospective - This classification is equivalent to **H**igh mineral potential (Taylor and Stevens, 1983) in areas and is a sub-set of favorable tracts. The probability of discovering deposits in these tracts is high. They are small tracts where strong indications of mineralizing processes are documented, and in most cases have a history of mineral production.

Mineral deposit types that are known or suspected to exist in the project area, and for which preliminary mineral potential tract maps have been prepared, are listed in table 3. Descriptive models for all pertinent mineral deposit types, outlining defining characteristics, are presented in appendix 3. Preliminary 1:250,000 scale working copies of mineral potential tract maps have been prepared for the project area. Figures 3, 4, and 5 are page-size examples of mineral potential tract maps for Carlin-type gold deposits, low-sulfide Au-Ag quartz vein deposits, and hot-spring and epithermal Au-Ag deposits, respectively.

A quantitative assessment for metallic mineral resources (and some industrial mineral resources) in the project area will follow the methodology outlined in Singer (1993). This will result in a probabilistic estimation of the number of undiscovered mineral deposits (by deposit type) and the quantity of metal contained in such undiscovered deposits. A separate quantitative assessment for mineral resources in the High Rock/Black Rock NCA (fig. 2) may be conducted should such an assessment be required before completion of the project. Field work was conducted in the NCA during June 1994 in prepartion for an assessment.

Stage II includes field studies to define stratigraphic units or structural features controlling mineral deposit distributions and examinations of poorly characterized or controversial mineral occurrences to ensure proper deposit classification. Geochronologic, petrographic, and geochemical studies will be used to verify field observations when necessary.

Data and knowledge deficiencies that need to be addressed in order to conduct a more accurate mineral resource assessment of the area include:

> Characterization of mesothermal polymetallic vein (a variety of low-sulfide gold-quartz veins) deposits and belts. How do they differ from the published descriptive

Table 3. Metallic mineral deposit types known or suspected to exist in the WSRA project area. For descriptive models see appendix 3.

Porphyry copper-gold deposits
Porphyry copper-molybdenum deposits

Porphyry copper, skarn-related deposits
Copper skarn deposits
Iron skarn deposits
Volcanic-hosted magnetite deposits
Polymetallic vein deposits
Polymetallic replacement deposits
Zinc-lead skarn
Replacement manganese deposits
Gold skarn deposits
Distal disseminated silver-gold deposits

Climax molybdenum deposits
Porphyry molybdenum, low-fluorine deposits
Tungsten skarn deposits
Tungsten vein deposits

Epithermal gold-silver deposits
Hot-spring gold-silver deposits
Hot-spring mercury deposits
Hot-spring manganese deposits

Sediment-hosted (Carlin-type) gold deposits
Low sulfide gold-quartz vein deposits

Kuroko massive sulfide deposits
Besshi massive sulfide deposits
Cyprus massive sulfide deposits
Franciscan-type volcanogenic manganese deposits
Exhalative sedimentary lead-zinc deposits

Volcanogenic uranium deposits
Sediment-hosted uranium deposits

Gold placer deposits

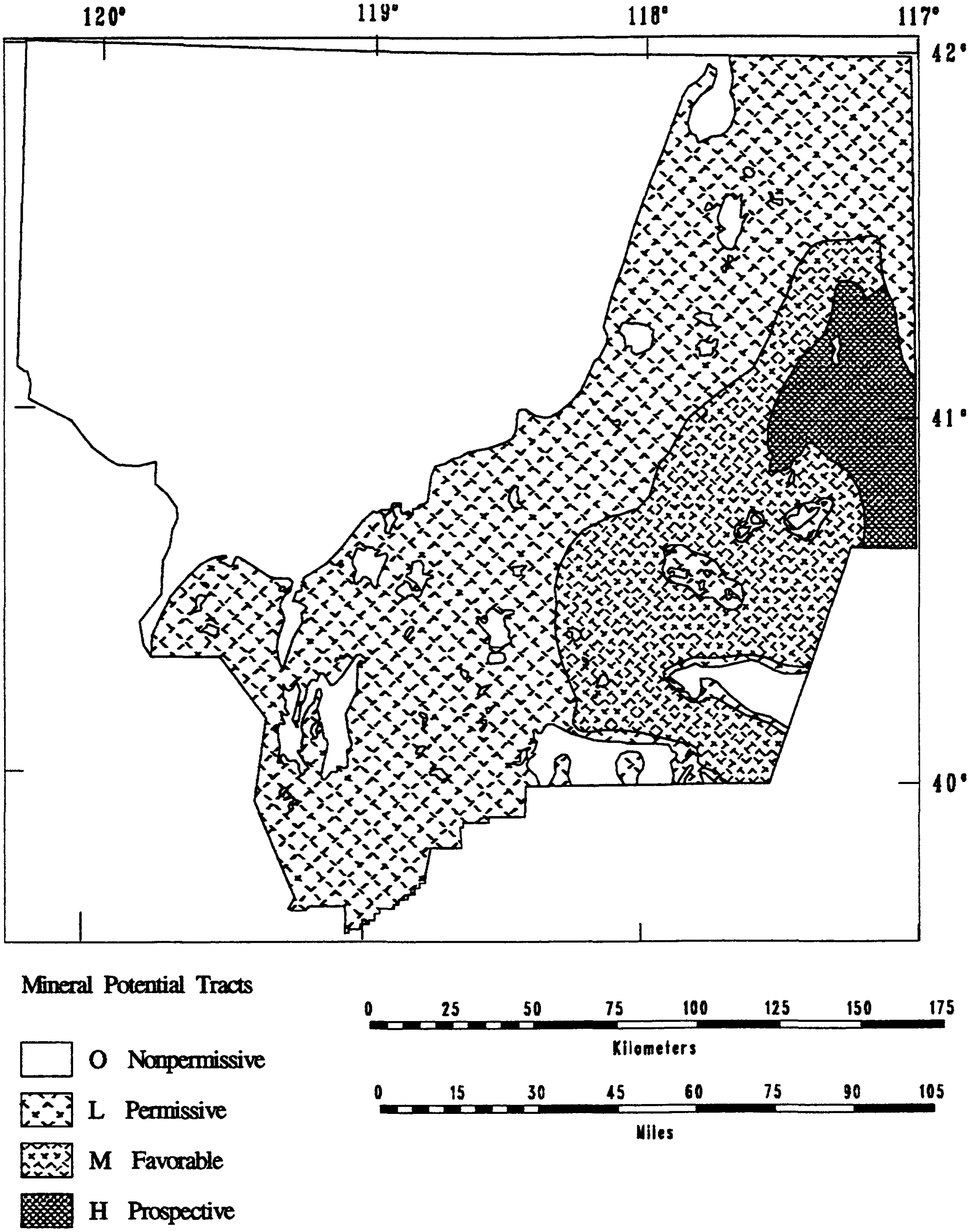

Figure 3. Mineral potential tract map for Carlin-type gold deposits, WSRA project area. See appendix 3 for descriptive model.

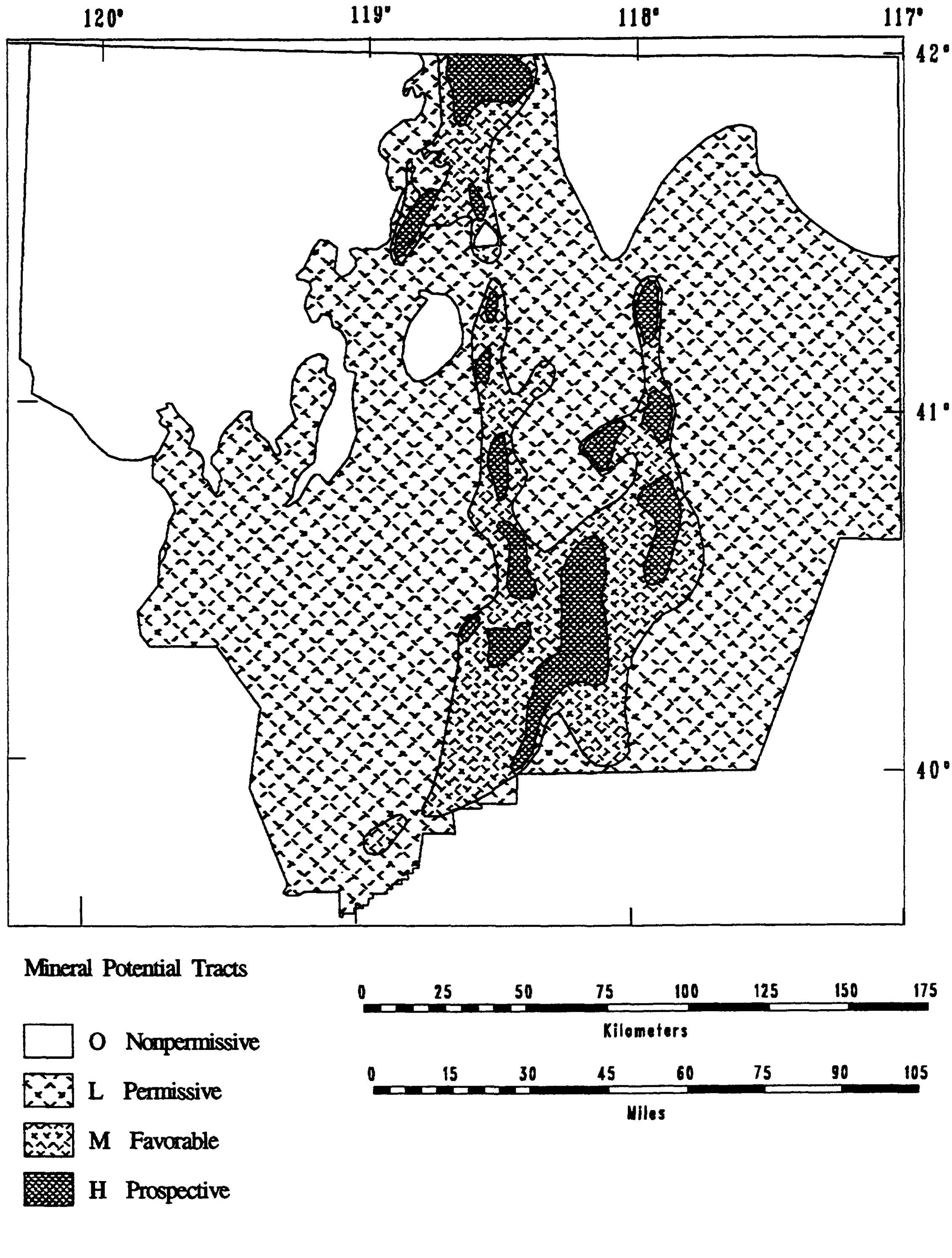

Figure 4. Mineral potential tract map for low-sulfide gold-silver quartz vein deposits, WSRA project area. See appendix 3 for descriptive model.

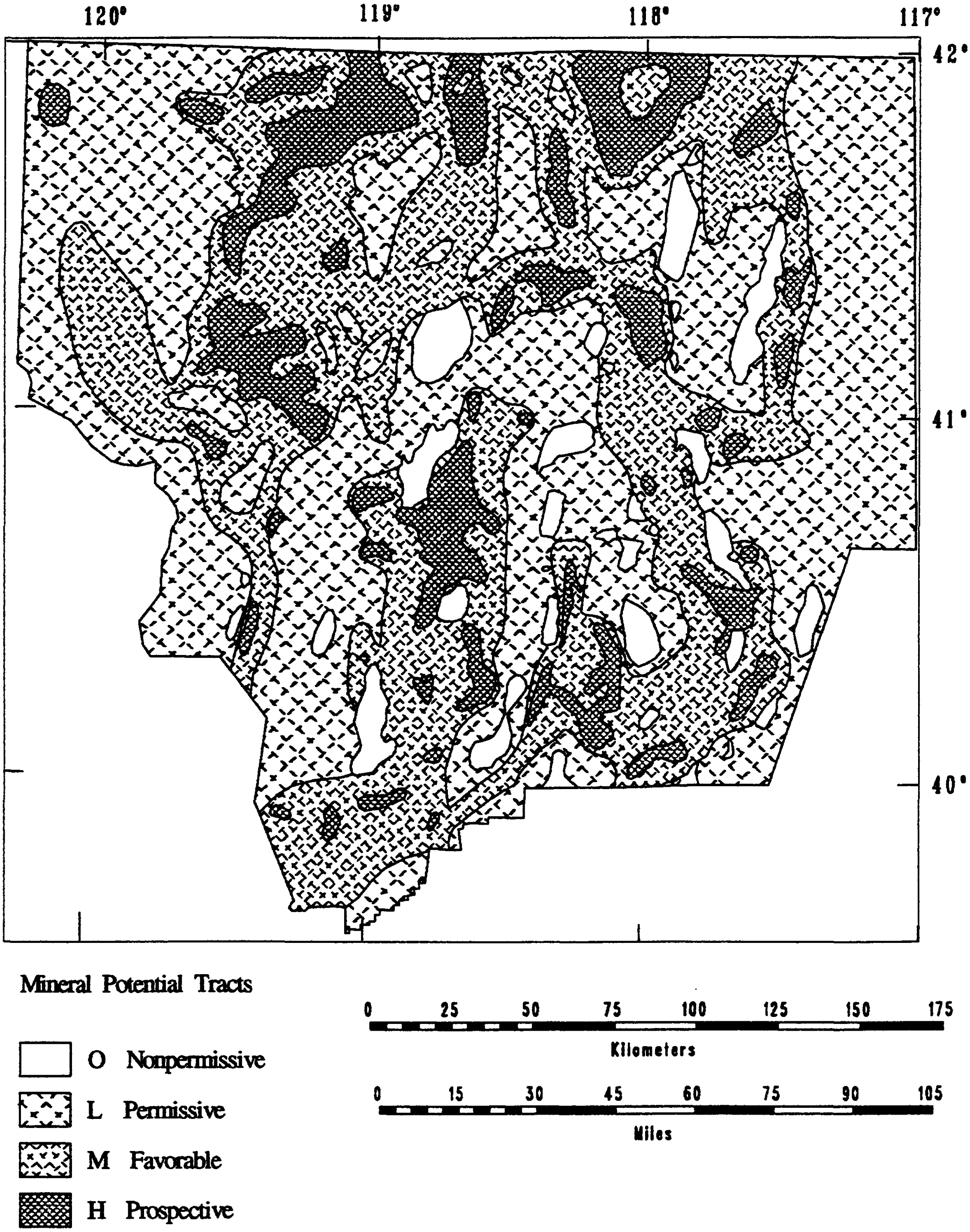

Figure 5. Mineral potential tract map for hot-spring and epithermal gold-silver deposits, WSRA project area. See appendix 3 for descriptive model.

model? What tectonothermal event are they related to?

> Tertiary stratigraphy in the Jessup-Sulphur region. Documentation of stratigraphic successions and regional stratigraphic correlations are needed to better understand timing of hot-spring and epithermal Au-Ag mineralizing events and thus identify prospective stratigraphic intervals.

> What surficial or other features delineate the northwest end of the northwest-trending Battle Mountain-Eureka mineral belt, which transects the northeast part of the project area? Can these or other features be used to extend the trend to the northwest?

> What, if any, correspondence exists between regional geophysical data and ore deposits? Features that need better understanding are probably crustal ones. There needs to be more modelling of geophysical data and a comparison of modelling with available isotopic data.

> Tertiary volcanic stratigraphy in the Osgood Mountains area. This is needed to understand the magmatic history of the area, help unravel extensional history, and provide constraints on the relative ages and amounts of movement. For example, aeromagnetic signatures of basaltic andesite indicate that some were formed during a period of reversal in the Earth's field and some were not; thus what are now lumped together as one unit clearly represent at least two units of different age.

> Interpretation of bedrock geology in Neogene basins. Geologic extrapolation and geophysical modeling and data interpretation (e.g., shallow magnetic source data) need to be applied to basin areas to aid in delineating mineral resource potential of basin areas. Other remote sensing techniques must be developed and applied to basin areas.

> Definition and delineation of tectonic domains. How are individual tectonic domains defined in terms of geologic, structural, geochemical, and geophysical characteristics? What is the nature of tectonic domain boundaries? What correlation exists between tectonic domains or domain boundaries and the distribution of different types of mineral deposits?

Assessment for Non-Metallic Mineral Resources

Assessment for non-metallic mineral resources will include a qualitative assessment (preparation of mineral potential tract maps) for industrial rocks and mineral commodities and sand and gravel resources in the project area and a probabalistic estimate of undiscoverd deposits (quantitative assessment) for deposits types or commodities for which adequate descriptive and grade/quality and tonnage models exist. This activity began in April 1994 (table 2). Few descriptive and grade/quality and tonnage models currently exist for these commodities. Those that do are presented in Orris and Bliss (1989, 1991). The USGS is actively involved in developing additional models for industrial rock and mineral commodities for use in mineral resource assessments.

The USGS Mineral Resources Data System (MRDS) and USBM Mineral Inventory Location System (MILS) data bases show that about 16 non-metallic commodities have been reported in the WSRA project area. Industrial rock and mineral commodities known and suspected to exist in the project area are listed in table 4. Geologic occurrence models will be developed from synthesis of the computer data and from available literature and data files at the Nevada Bureau of Mines and Geology. Tract maps of permissive areas for each commodity are being prepared based on occurrence models.

Selected location and desciptive fields in the MRDS data base have been imported into an ARC/INFO data base for the project area. Information on host lithology has been added to this information by combining or intersecting localities with the Nevada Geology Map digital data base. This information is being synthesized to help define geologic occurrence models and ultimately predict the locations of specific commodities. Additional, more general occurrence information will be added from literature and commodities experts. Occurrence maps are being produced for commodities showing locations and host lithologies of non-metallic mineral sites. These maps will be first-cuts at mineral potential tract maps for non-metallic commodities. Figures 6 shows the distribution of all industrial rock and mineral localities in the WSRA project area and figure 7 shows the distribution of selected industrial mineral commodities.

An assessment for sand and gravel resources will be qualitative, outlining areas of sand and gravel potential and classifying areas based on principles outlined by Bliss (1993, 1994). Locations of sand and gravel quarries and pits in the project area are shown in figure 8 and are concentrated along major transportation corridors (see fig. 2).

Assessment for Geothermal Resources

Geothermal energy is the thermal energy of the Earth, and thus geothermal resource assessment is the estimation of what fraction of the Earth's heat might be extracted economically at some reasonable future time. Though relatively intangible compared to such "hard" resources as minerals and petroleum, geothermal energy can be thought of as representing many deposits over a broad spectrum of tonnage (volume) and grade (base temperature). For example, a large-volume, high-temperature, hydrothermal-convection system is a very desirable resource economically, whereas a small-volume, low-temperature aquifer is of far less economic value even though it may be a developable resource. The only geothermal environment that can be considered a resource, in the restricted sense of this word noted above, is a high-temperature hydrothermal system.

The USGS has completed three national geothermal-resource assessments during the past two decades (White and Williams, 1975; Muffler, 1979; Reed, 1983). The general methodology and much of the data base used for those assessments will be employed to assess the geothermal resources of the WSRA project area.

Agencies of state governments, especially in the western United States, have also assessed their geothermal resources. The Nevada Bureau of Mines and Geology (NBMG) is currently reassessing geothermal resources for the entire state, as part of a Department of Energy supported program. The NBMG is willing to share information and the timing is such that the

Table 4. Industrial rock and mineral commodities known or suspected to exist in the WSRA project area.

Diatomite
Barite
Perlite
Gypsum
Zeolite
Sulphur
Pumice
Clays
Gemstones
Semi-precious Stone
Beryl
Lithium
Limestone
Ornamental/Facing Stone
Phosphate ?
Borates ?
Potash
Dumorterite
Wollastonite
Silica

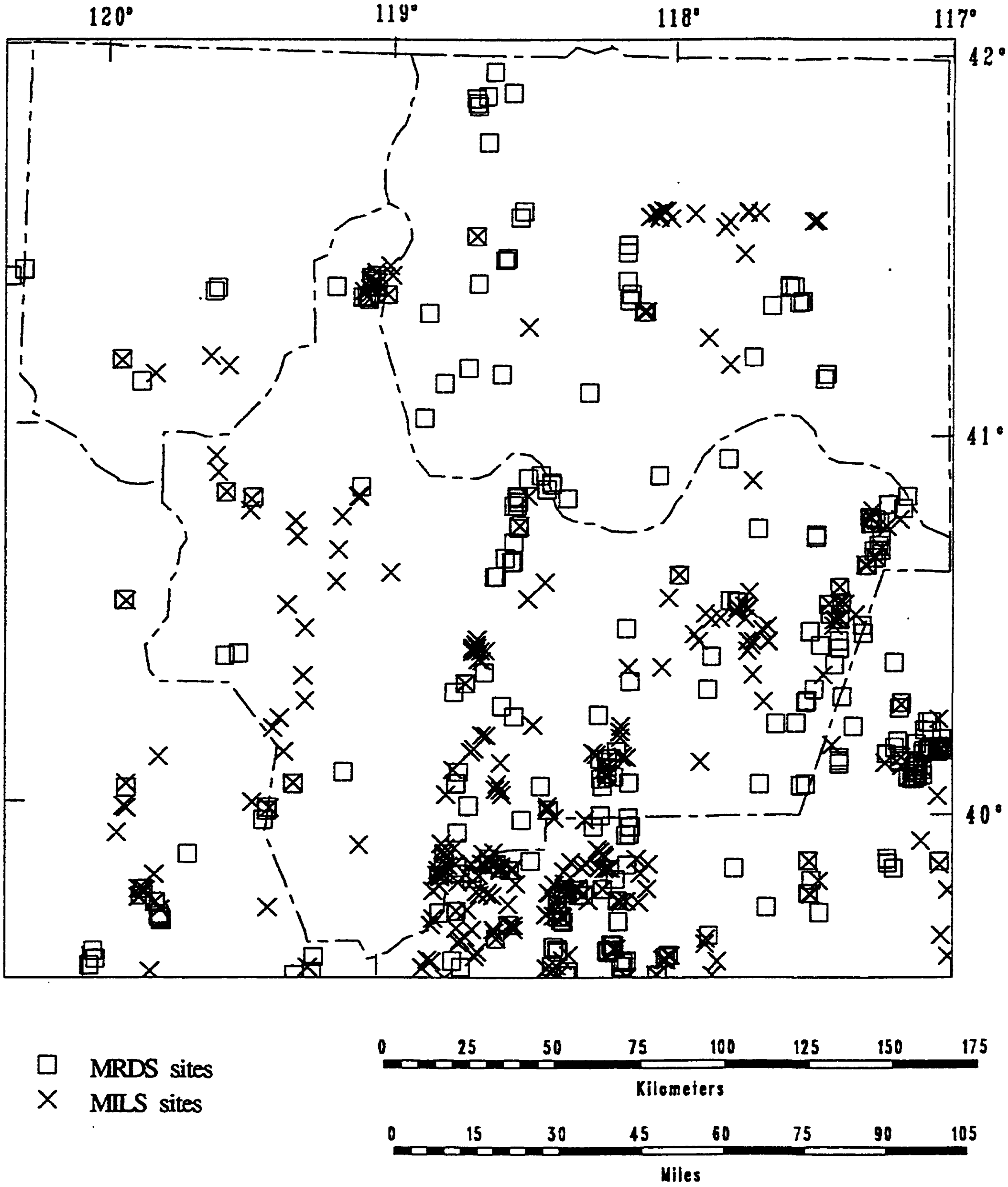

Figure 6. Distribution of all industrial mineral sites in the WSRA project area reported in the MRDS and MILS data bases.

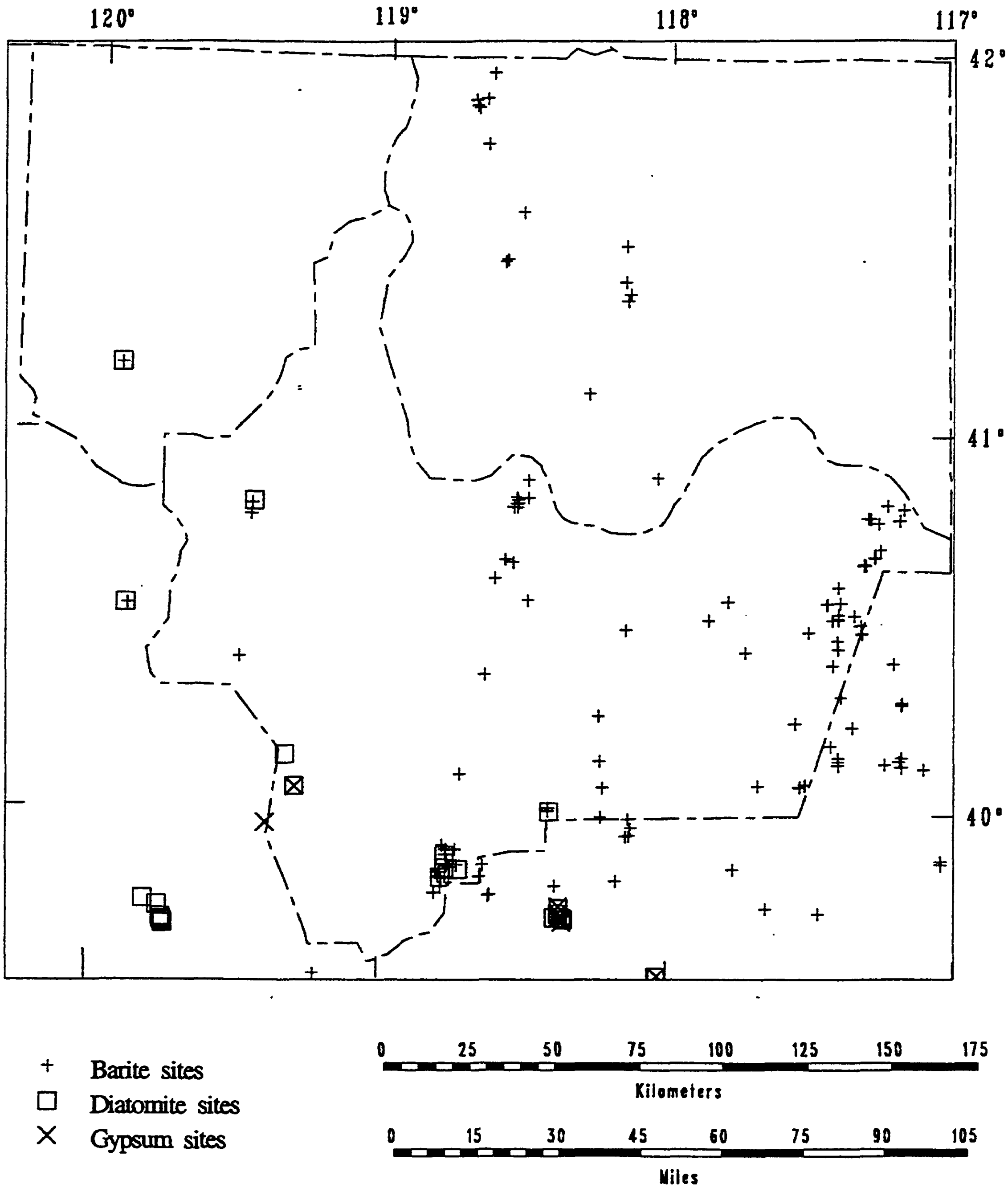

Figure 7. Distribution of sites reported in MRDS and MILS in the WSRA project area for the economically important commodities barite, diatomite, and gypsum.

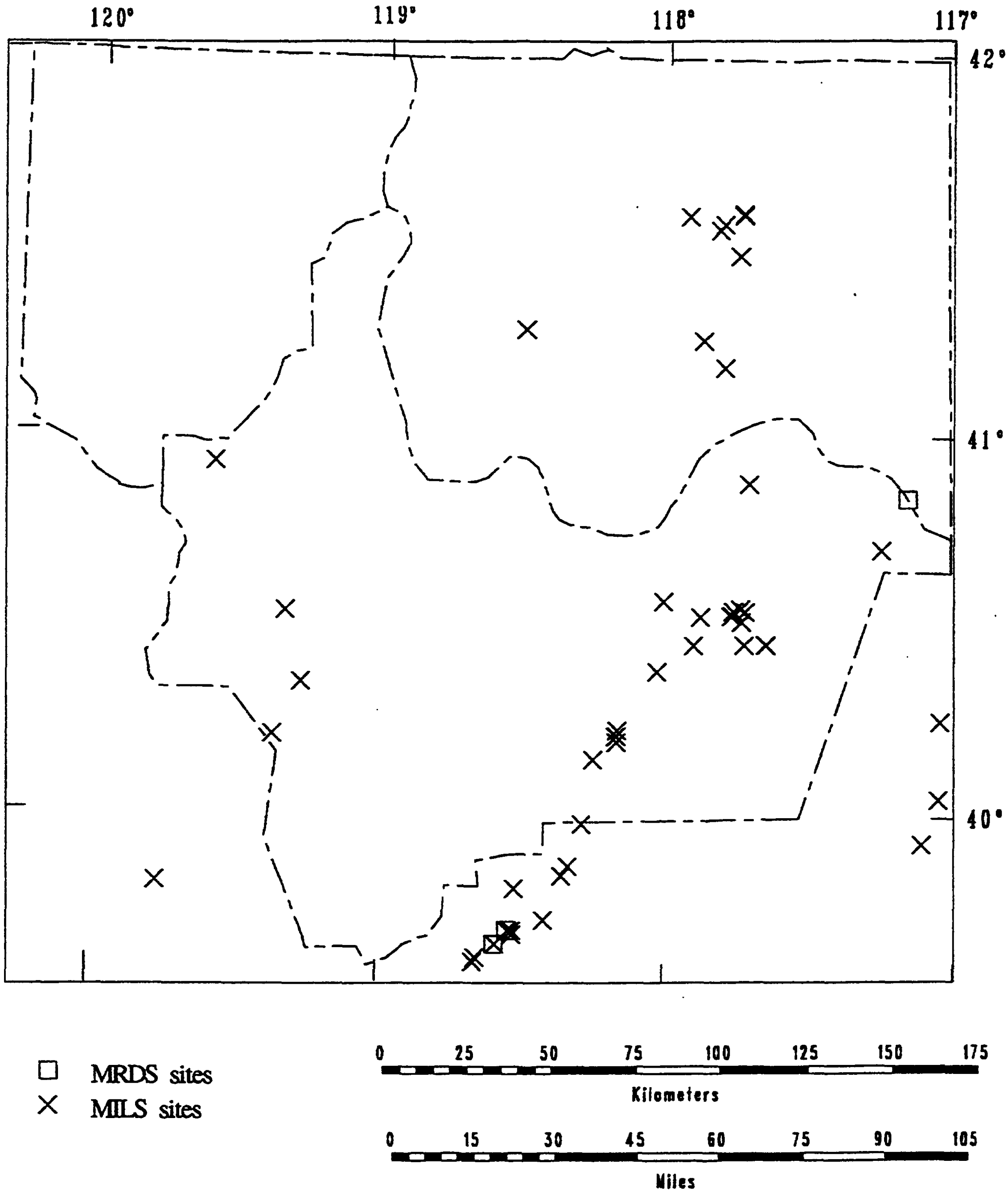

Figure 8. Distribution of sites of sand and gravel quarries and pits reported in MRDS and MILS in the WSRA project area.

updated Nevada data base will be available for our use in cataloging the location and temperature of each known hydrothermal system in the WSRA project area. The data will be in a format that permits direct import into the USGS GIS system being used for the overall resource study.

Geothermal resources presently of greatest economic value are those capable of being developed to generate electricity, and most geothermal resources of electrical-grade are directly associated with geologically young, if not active, volcanism. Nevada and extreme northeastern California have no active volcanoes and few (if any) young enough to represent the surface expression of a crustal magma heat source for a geothermal system. Nonetheless, the entire Great Basin is characterized by high heat flow, another primary indicator of geothermal-resource potential. In fact, all of the project area has heat flow greater than the world crustal average (about 40 milliwatts per square meter: mW/m2), and much of the project area has heat flow three-or-more-times the world average (fig. 9). Several recently constructed geothermal power plants are within and very near the project area. The Great Basin is currently the principal domestic target area for commercial exploration to try to identify new sites with potential to generate electricity. Geothermal resources appropriate for non-electric applications also are fairly abundant in the project area, and some of these resources are already developed (e.g., alfalfa drying at Gerlach, onion drying at Nightingale).

To conduct a more accurate assessment for geothermal resources in the project area, stage II studies, and future assessments, should focus on improving our understanding of subsurface hydrology, both locally and regionally. For example, many hydrothermal systems of resource caliber may exist within basin-fill sediments and permeable fault zones, but are hidden because of the arid climate and generally great depth to the water table.

Assessment for Oil and Gas Resources

Oil and gas assessment of the project area is being conducted as part of the 1995 National Petroleum Assessment. Stage I activities have included compilation of all existing data on known hydrocarbon plays in the area (province 18, Western Great Basin) and the identification and description of speculative oil and gas plays. Oil and gas source rocks and samples from an oil seep have been collected and analyzed.

The conceptual plays defined in the WSRA project area (fig. 10) are based on the presence of source rocks with demonstrated hydrocarbon potential. Triassic carbonate source rocks have oil potential in portions of the Stillwater, Clan Alpine and Augusta Mountains of west central Nevada. Jurassic(?) to Cretaceous lacustrine rocks have source rock potential in the Black Rock Desert and Jackson Range of Nevada. Cenozoic source rocks are found throughout the Winnemucca-Surprise Area but usually have reached only marginal thermal maturity except in areas of high heat flow. These Cenozoic, mostly Neogene, source rocks are present in almost all Basin-and-Range type basins. The Cenozoic source rocks can contain algal organic-matter in lacustrine marls and humic coals or coaly rocks. Oil and gas generation occurred during high heat flow in the Neogene. Numerous gas shows are found in most Cenozoic basins of the Winnemucca-Surprise Area (Brady, 1984). The gas shows are thought to be largely biogenic in the shallow subsurface but deeper gas shows are likely thermogenic in origin. A few oil shows and seeps are documented in the north and central portions of the Winnemucca-Surprise Area (Garside et al., 1988; Schalla et al., 1994). The oil shows in Cenozoic rocks are typically and

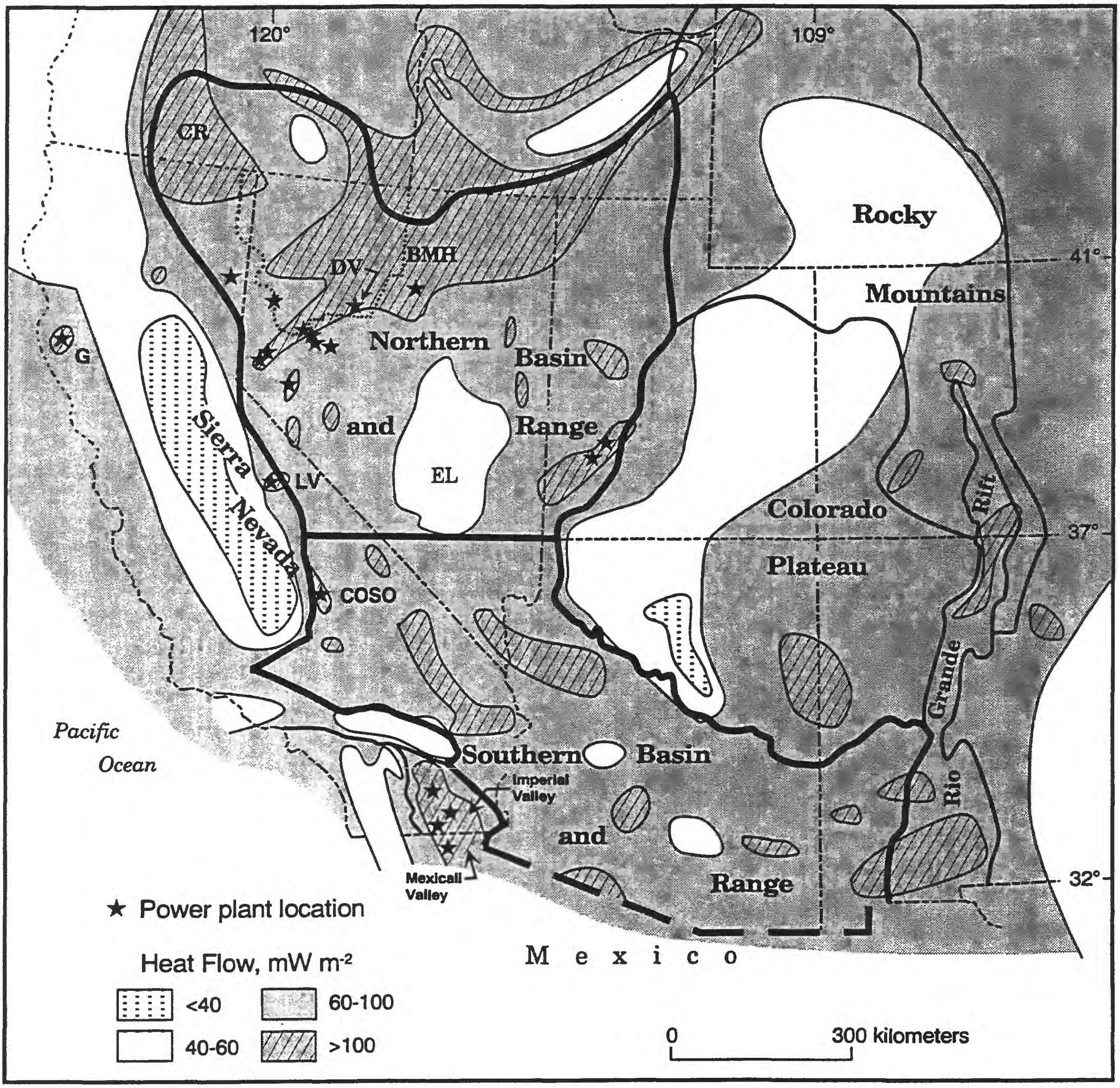

Figure 9. Heat flow, in milliwatts per square meter (mW m^{-2}), for the western United States. Note that the entire project area (see fig. 1) is well above the world average of about 60 mW m^{-2}. Dotted line is approximate boundary of WSRA project area. BMH - Battle Mountain High, EL - Ely Low (area of low heat flow), CR - Cascade Range, DV - Dixie Valley, G - the Geysers, LV - Long Valley, COSO - COSO geothermal area.

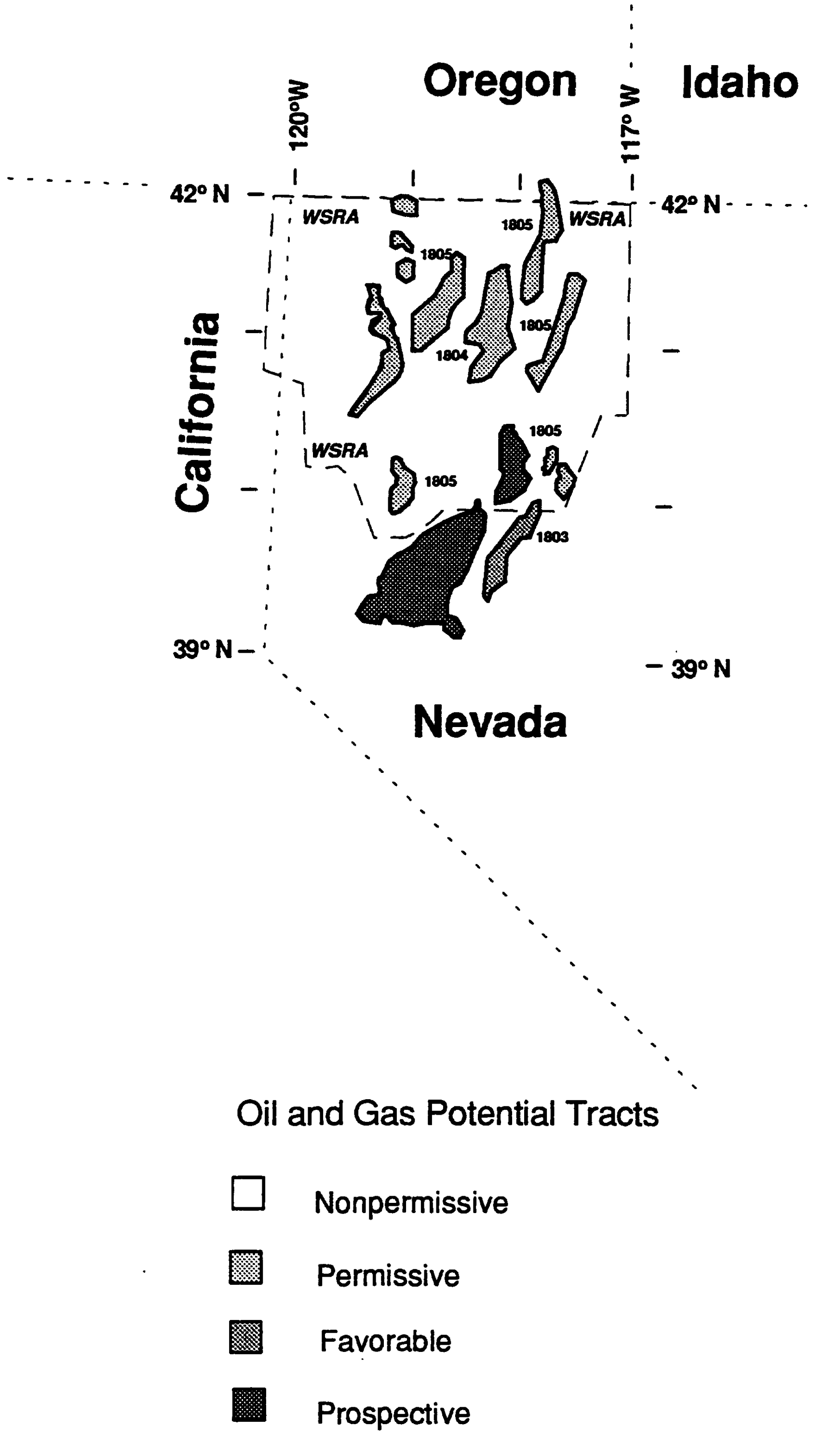

Figure 10. Oil and gas potential tract map for the WSRA project area and vicinity. Conceptual plays are defined as follows: 1803 - areas with Permian and Triassic source rocks; 1804 - areas with Cretaceous source rocks; 1805 - area with Tertiary source rocks.

perhaps genetically related to contact or hydrothermal metamorphism. All of the major plays have been tested by drilling but no commercial production has been established in the Winnemucca-Surprise area. The major traps and reservoir rocks are thought to be formed by: 1) folding and fault truncation related to Mesozoic thrusts of Paleozoic and Mesozoic carbonate and clastic rocks; 2) fault truncation at the basin margins of reservoirs formed by fracture enhanced permeability in Paleozoic and Mesozoic carbonate and clastic rocks or interbedded Cenozoic lacustrine, fluvial and alluvial rocks; 3) sand bodies or pockets of primary or secondary porosity encased in low permeability volcanigenic or lacustrine sediments; and 4) fractured tuffs and volcanic flows.

Conceptual Play Definition Technique

The technique to define the conceptual play boundaries in the Neogene basins was to use a series of overlays that: 1) outline areas of Tertiary-Quaternary fill in basins (usually grabens) from the Nevada 1:500,000 geologic map; 2) use gravity data (Jachens and Moring, 1990 or other gravity data) to reduce the play area to where the Tertiary fill is deep (>1-2 km or so; based on the conclusions of Barker and Peterson, 1991) ; and 3) extend the play into shallower portions of the basin or where hydrocarbon shows or seeps are known (Brady, 1984; Garside and others, 1988; Schalla et al., 1994; unpublished reports).

Permian-Triassic source rocks, northwest Nevada -- A conceptual play based on deep burial and effective sealing of Permian-Triassic source rocks in Basin and Range type basins and horsts in Nevada (1803, fig. 10). Play based on speculation that on some fault blocks the Permian-Triassic rocks may have petroleum generation potential that was preserved until now when they are deeply buried and heated by burial, hydrothermal and contact metamorphism. Reservoir formations include Permian to Triassic sandstones and limestones and overlying basin-margin alluvial fans and fractured volcanic rocks. Traps are formed by drag folds and(or) truncation related to imbricate thrust sheets in the Fencemaker and Willow Creek thrust systems and by fault truncation within the Neogene basins or at their margins. Traps may also be formed by fault-bounded subblocks within the horsts that form the ranges in the area. Seals are mudrocks and(or) faults. It is also possible that fractured source rocks may form reservoirs. Source rocks are marine Permian to Triassic shales containing oil-prone organic matter in west central Nevada. Preservation of source rock potential is spotty. Conodont alteration index mapping by Harris et al (1980), vitrinite reflectance measurements (McDaniels, 1982) and Rock-Eval analyses (Barker et al., 1994) shows most of the Triassic of the western Great Basin is overmature. Organic geochemistry suggests the Triassic source rocks in west central Nevada have a high TOC and hydrogen content. The ranges, rather than the basins, where there may have been a lower degree of contact, geothermal, or low-grade regional metamorphism, may represent areas where Neogene oil generation and preservation has occurred. Fossils from the Augusta and Clan Alpine Mountains contain live oil. No wells test the oil potential of the ranges in this play. Neogene generation is considered important as any earlier hydrocarbon generation from these rocks is presumed lost due to the ongoing disruption of traps by extensional tectonics or igneous intrusions and contact metamorphism. Wells drilled into the basins next to the Augusta and Clan Alpine ranges encountered overmature rocks and gas shows but no production (Garside et al., 1988; Barker et al., 1994). A 1993 mineral exploration well in Buena Vista Valley near Kyle

Hot Springs, west central Nevada, produced an oil show that is apparently generated from Cenozoic lacustrine rocks and reservoired in fractured Triassic sedimentary rocks (Schalla et al., 1994). Active geothermal systems are present near all of these wells and throughout the area and may be the cause of the local maturation of the source rocks.

Cretaceous source rocks, NW Nevada -- A conceptual play based on Neogene to present deep burial of Cretaceous source rocks in NW Nevada Neogene basins (1804, fig. 10). This play considers any Neogene basins with deep valley fill to be conceptually prospective (based on conclusions of Barker and Peterson, 1990). Reservoir formations include lacustrine beds laterally interbedded with marginal alluvial fans or sandstones interbedded with the Cretaceous lacustrine beds and fractured Tertiary volcanic rocks. Trapping mechanisms are fault truncation of reservoir rocks, mudstone draped lenticular sandstones and Neogene lacustrine beds laterally interbedded with marginal alluvial fans-- (overlying seal= continental evaporites, mudstones, altered volcanic tuffs or flows, lateral seal= fault truncation). Cretaceous source rocks are locally mature and have produced oil and gas shows but no discoveries. Thermal maturation may also occur by heating of source rocks by geothermal convection, shallow intrusions, fluid flow up basin faults especially near the graben boundaries. The source rocks in this play may be mature to overmature in high heat flow and geothermal areas.

Neogene source rocks, NW Nevada -- A conceptual play based on deep Neogene to Recent burial of Late Cenozoic source rocks in NW Nevada Neogene basins (1805, fig. 10). This play considers any Cenozoic basins with deep valley fill to be conceptually prospective (based on conclusions of Barker and Peterson, 1991). Reservoir formations include lacustrine beds laterally interbedded with marginal alluvial fans and fractured Tertiary volcanic rocks. Trapping mechanisms are fault truncation of reservoir rocks; mudstone draped lenticular sandstones and Neogene lacustrine beds laterally interbedded with marginal alluvial fans-- (overlying seal= continental evaporites, lateral seal= fault truncation). Tertiary source rocks are apparently locally mature and have produced oil and gas shows but no discoveries. Tertiary to Recent lacustrine rocks are immature when encountered at shallow depth in non-geothermal wells Barker et al., 1994). Thermal maturation may also occur by heating of source rocks by geothermal convection, shallow intrusions, fluid flow up basin faults especially near the graben boundaries. The source rocks in this play may be mature to overmature in high heat flow and geothermal areas.

Recommendations

Stage II studies and any future oil and gas assessment in the WSRA project area should include: 1) documentation of the origin of natural gases by isotopic analyses; 2) determination of the extent of Triassic source rocks in west central Nevada; and, 3) better documentation of depth of fill, potential traps, and areal extent of source rocks in the Late Cenozoic basins.

Supporting Databases

Digital Data Bases

The BLM is working toward automation of resource management planning and thus is in

Table 5. Digital databases archived on CDROM Great Basin Geoscience Data Base (Raines and others, in press).

Base Maps
Administrative boundaries
BLM Resource Areas
BLM administered land
Great Basin Outline
Geographic names
Public boundaries
Roads
Streams
Topo contours
Water bodies

Public Land System
California
Idaho
Nevada
Oregon

Geology
Great Basin lithology
Great Basin faults
Great Basin legend
Nevada geology
NV legend
Oregon geology
Oregon faults
Oregon legend
Faults from states
Cenozoic faults

Geophysics
Aeromagnetics
Bouguer gravity
Basement gravity anomally
Extent of plutons
Pluton legend
Shallow magnetic sources
Depth to basement
NURE radiometrics
- uranium
- thorium
- potassium

Geochemistry
NURE - mix
NURE - oes
NURE - naa
NURE - springs

Mineral Resource Sites
MRDS sites
BLM permits

Thematic
Pluvial lakes
Lithotectonic terranes
Extension terranes 0-6 ma
Extension terranes 6-17 ma
Extension terranes 17-34 ma
Extension terranes 34-43 ma
Cinder cones 0-6 ma
Cinder cones 6-17 ma
Cinder cones 17-34 ma
Calderas 6-17 ma
Calderas 17-34 ma
Calderas 34-43 ma
Radiometric ages
Linear features
Limonite

Grids
Shaded relief
Aeromagnetics
Bouguer gravity
Basement gravity anomally
Depth to basement
Nure radiometrics
- uraniam
- thorium
- potassium

Limonite
Western US topography

need of digital products from resource assessment projects. Much of the existing spatial data used in the mineral resource assessment of the project area is now in digital form in an Arc/Info GIS; that which is not will be added to the digital data base inventory during the course of the project. Many of the digital data bases used in the assessment project are included on a Great Basin Geoscience Data Base CDROM (Raines and others, in press). A listing of all data bases included on the CDROM is presented in table 5.

Geology

As the final published assessment will be at 1:500,000 scale, geology, derived initially from the Nevada and California state maps, will be used as a foundation for assessment work. Much of the information on the Nevada state map was derived from 1:250,000-scale county geologic maps. Since the publication of both state maps, selected areas have been remapped at larger scales and, in some cases, changes even at 1:500,000 are warranted (e.g. Whitebread, 1994). These changes will be incorporated into the final geologic base map released with the resource assessment. Furthermore, any changes in the existing geologic base that is warranted by additional geologic mapping or geochronologic studies conducted as part of the assessment will be made if such changes can be incorporated at 1:500,000 scale.

Generalized geology of the project area is shown in figure 11 and the geologic history of the area, and its relation to resource development, is depicted in figures 12, 13, and 14. Paleozoic rocks crop out mainly in the east part of the project area and consist of Cambrian and Ordovician parautochthonous and autochthonous miogeoclinal rocks, Cambrian and Ordovician allochthonous slope and basinal rocks of the Roberts Mountains allochthon(Silberling and roberts, 1962; Hotz and Willden, 1964; Roberts, 1964; Erickson and Marsh, 1974f,g; Madrid, 1987), Mississippian to Permian autochthonous overlap assemblage rocks (for example, the Antler sequence) (Roberts, 1964; Saller and Dickinson, 1982), and Mississippian to Permian allochthonous slope, basinal and turbiditic rocks of the Golconda allochthon (Havallah sequence) (Silberling and Roberts, 1962; Roberts and Thomasson, 1964; Stewart and others, 1977, 1986; Murchey, 1990) (fig. 12). Minor mafic plutonism within the allochthonous assemblages was associated with basaltic seafloor volcanism. Emplacement of the Roberts Mountains and Golconda allochthons occurred during the Antler orogeny (Late Devonian to Early Mississippian) and Sonoma Orogeny (Late Permian to Early Triassic), respectively (Roberts and others, 1958; Silberling and Roberts, 1962; Roberts, 1964; Gabrielse and others, 1982) (fig. 12). Mineral deposits formed during the Paleozoic were largely related to seafloor hydrothermal processes that produced relatively minor volcanogenic deposits of base metals, manganese, and barite (e.g., Snyder, 1978; Rye and others, 1984)

Mesozoic rocks are most abundant in the southwest, central, and northeast parts of the project area and are divided into two primary lithotectonic terranes, the Jungo and Jackson/Black Rock terranes (Silberling and Speed, 1981; Silberling and others, 1987, 1992) (figs. 11, 13) Rocks of the Jungo terrane consist of a Triassic autochthonous shelf and platform sequence (Koipato volcanics, Star Peak and Auld Lang Syne Groups) (Silberling and Roberts, 1962; Silberling and Wallace, 1969; Burke and Silberling, 1973; Nichols and Silberling, 1977) and a Late Triassic allochthonous basinal sequence of the Fencemaker allochthon (so-called mudpile rocks) (Elison and Speed, 1988; Oldow and others, 1986,1990; Heck, 1991). Rocks of the

Jackson/Black Rock terrane consist of Late Triassic to Early Cretaceous magmatic arc-related volcanic and sedimentary rocks (Stewart, in press; Silberling and others, 1987, 1992). Mesozoic plutonism was most prevalent during the period 105-70 Ma, during which granodioritic and monzogranitic stocks related to the Sierra Nevada batholith were emplaced (Evernden and Kistler, 1970; Silberman and McKee, 1971; Smith and others, 1971; John and others, 1993, 1994) (fig. 13). Plutonism also occurred in the Middle and Late Jurassic. The emplacement of the Fencemaker allochthon during the Jurassic and formation of north-trending shear zones in the Late Cretaceous represent two important Mesozoic tectonic events that occurred in the project area (Oldow, 1984; Oldow and others, 1986). Resource development during the Mesozoic was largely related to tectonic and plutonic events (fig. 13). Cretaceous plutonism resulted in porphyry and porphyry-related deposits of molybdenum, tungsten and copper (for example, Buckingham; Theodore and others, 1992). Late Cretaceous shear zones host low-sulfide Au-Ag quartz veins. The age of Carlin-type gold deposits remains uncertain though evidence suggests they formed either in the Middle to Late Jurassic (S.G. Peters, unpub. data) and (or) during the early Cretaceous (Arehart and others, 1993). Favorable petroleum source rocks were deposited in the Triassic and heat for hydrocarbon generation was produced throughout the Mesozoic during accretionary and plutonic events .

Cenozoic rocks are found primarily in the northwest and northern margins of the project area (fig. 11). These rocks consist of Oligocene to early Miocene calc-alkaline magmatic-arc-related volcanic rocks of the interior andesite-rhyolite assemblage (McKee, 1971; Noble, 1972; Cox and others, 1991), middle Miocene to Pleistocene subalkaline to peralkaline extension-related volcanic rocks of the bimodal basalt-rhyolite assemblage (Noble, and others, 1970; McKee and Noble, 1986; Rytuba and McKee, 1984; Noble, 1988; Cox and others, 1991), and late Miocene to Holocene lacustrine sedimentary rocks (fig. 14). Tertiary plutonism was most prevalent during the latest Eocene and Oligocene and associated with volcanic rocks of the interior andesite-rhyolite assemblage (McKee and Silberman, 1970; Cox and others, 1991). Extensional tectonics and block faulting dominated during the Tertiary. Northeast-southwest extension in the middle Miocene created the Northern Nevada Rift (Stewart and others, 1975; Zoback and Thompson, 1978; Zoback and others, 1994). At about 9 Ma extension direction changed to Northwest-southeast and resulted in the formation of the Midas Trough (fig. 11) and related structures (Zoback and Thonpson, 1978; Wallace, 1991). This extension has continued to the present and has been responsible for the present-day Basin and Range horst and graben structures. Resource development during the Tertiary was largely related to plutonism during the late Eocene and Oligocene and high regional heat flow during Miocene to Holocene extensional tectonism (fig. 14). Large deposits of copper, gold, and silver, related-to late Eocene to early Oligocene plutonism, have been and continue to be mined in the Battle Mountain area (Roberts and Arnold, 1965; Theodore and Blake, 1975, 1978; Wotruba and others, 1988; Theodore and others, 1990). The change from calc-alkaline intermediate volcanism in the Oligocene to early Miocene to subalkaline and peralkaline bimodal volcanism in the middle Miocene is mimicked by a corresponding change in the type of epithermal gold-silver deposits produced; subvolcanic quartz-adularia-type (Comstock-type) deposits are associated with the former whereas higher-level hot-spring and sub-hot-spring type deposits are associated with the latter (Noble and others, 1988; Cox and others, 1991). Neogene block faulting resulted in burial of Triassic petroleum source rocks and hydrocarbon generation. Elevated regional heat flow created by Neogene

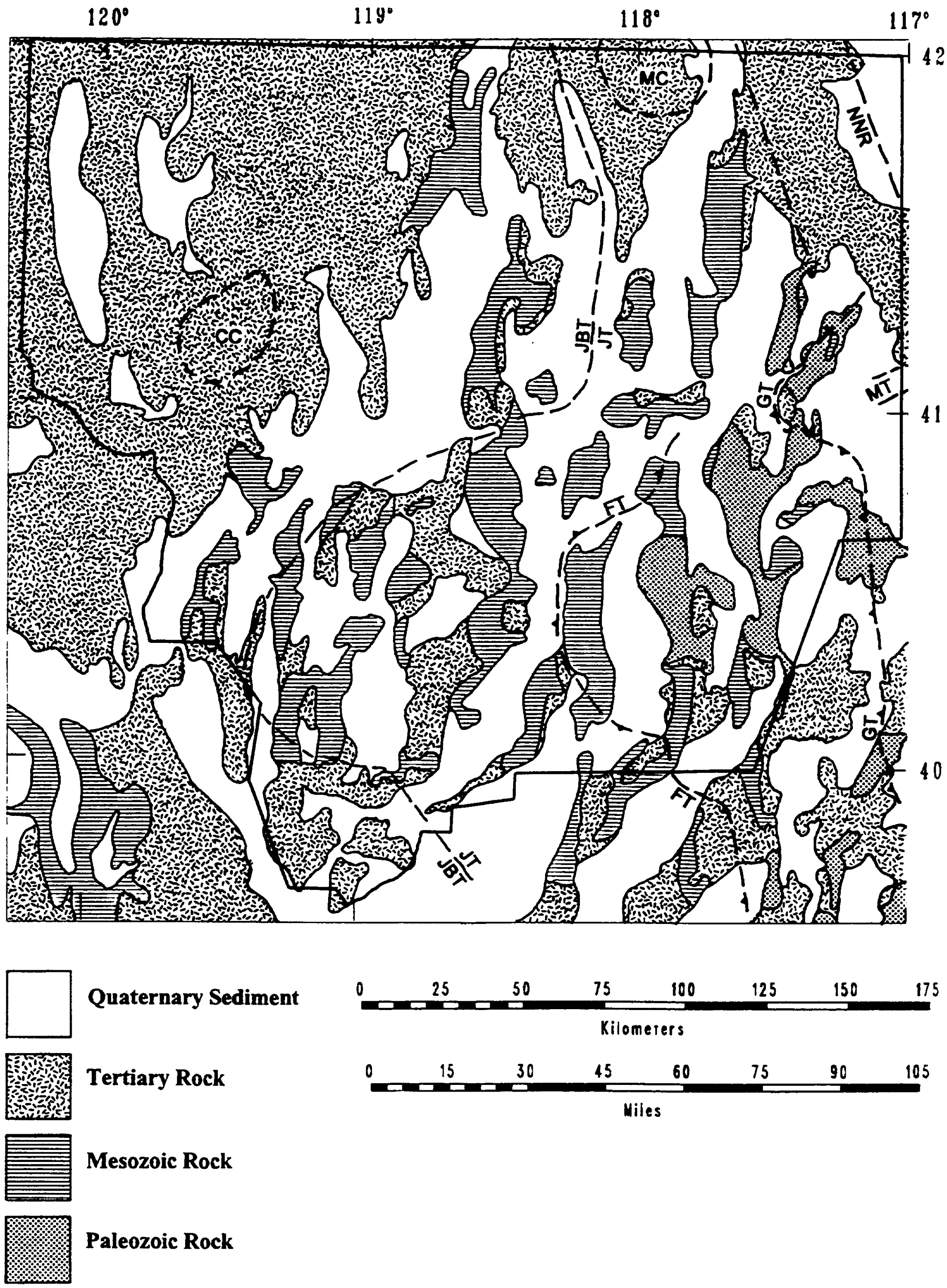

Figure 11. Generalized geologic map of the WSRA project area and vicinity. Geology generalized from Stewart and Carlson (1978). Solid thick line is approximate boundary of WSRA project area. Dashed thick lines are the approximate locations of geologic and structural features referred to in the text. GT - Golconda thrust; FT - Fencemaker thrust; JT - Jungo terrane; JBT - Jackson/Black Rock terrane; CC - Cottonwood Canyon volcanic complex; MC - McDermitt caldera complex; NNR - Northern Nevada rift; MT - Midas trough.

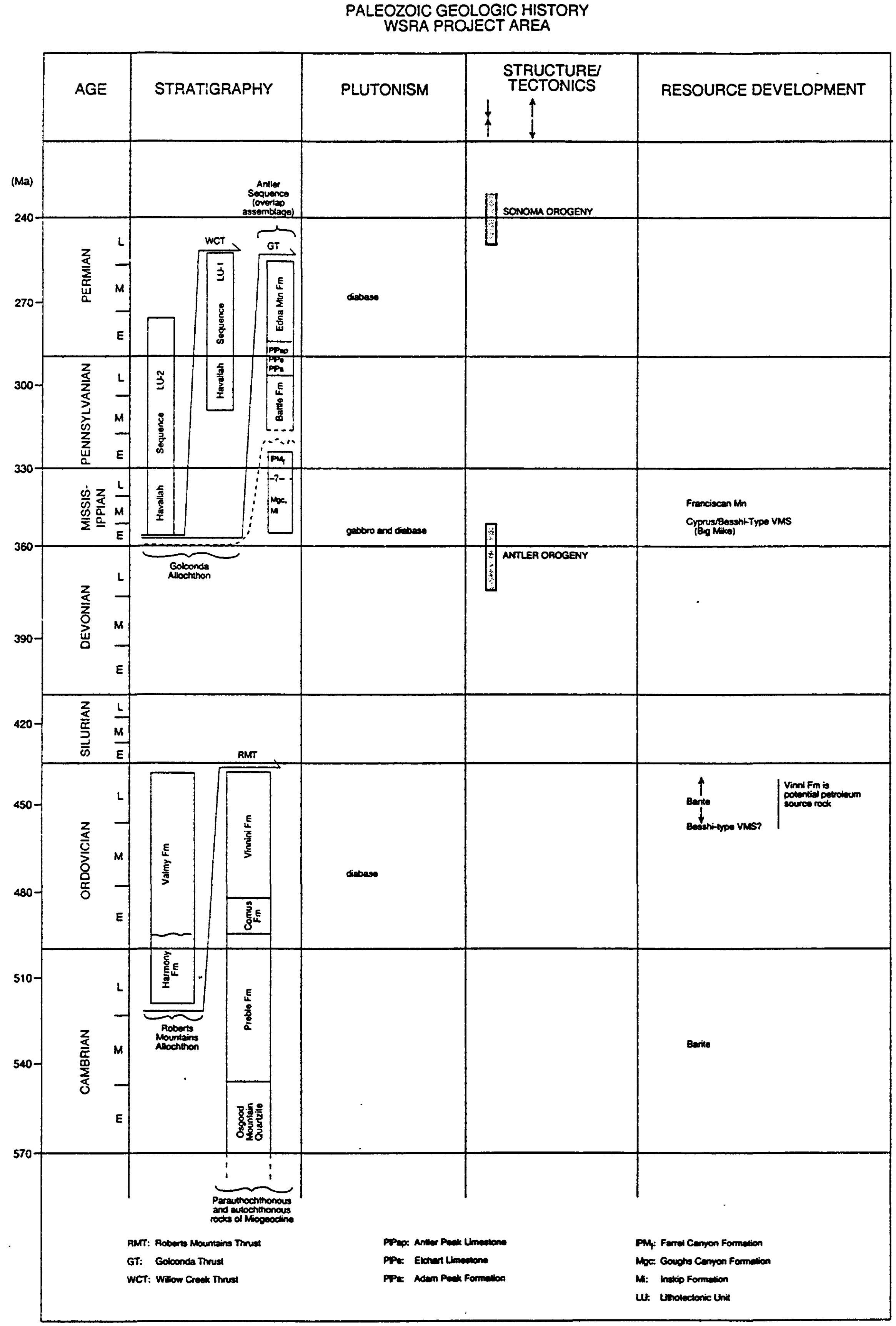

Figure 12. Chart summarizing Paleozoic geology and resource development for the WSRA project area.

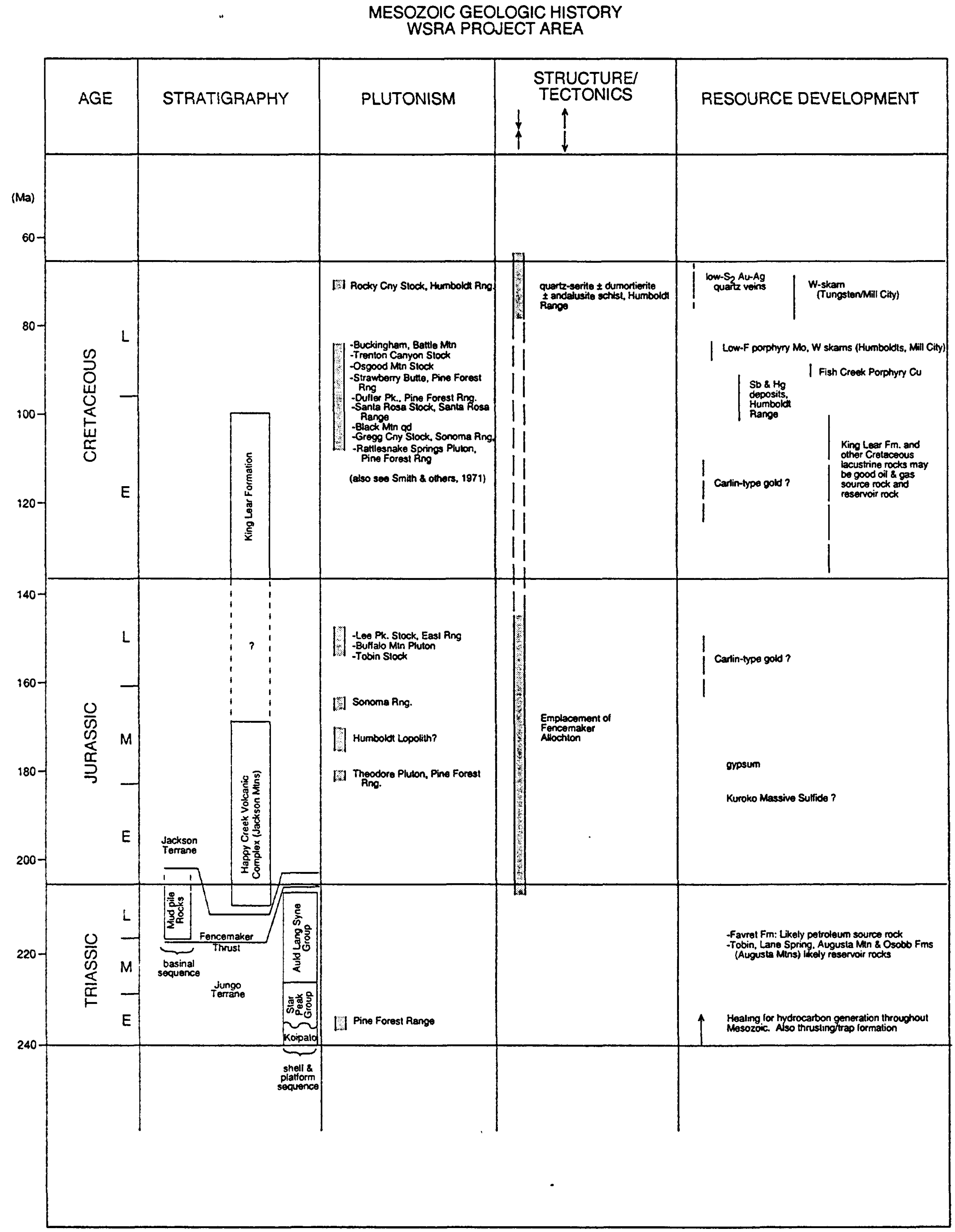

Figure 13. Chart summarizing Mesozoic geology and resource development for the WSRA project area.

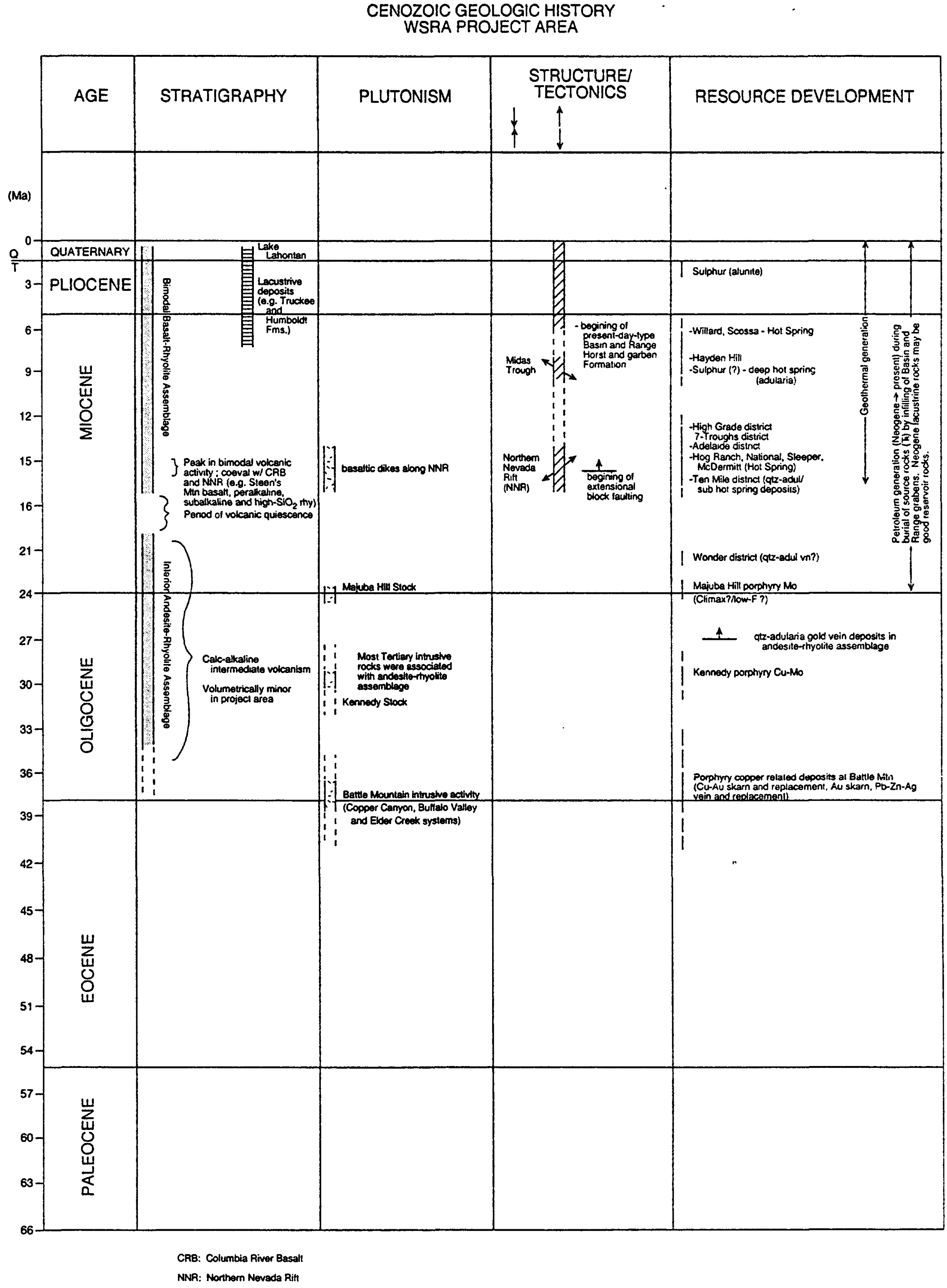

Figure 14. Chart summarizing Cenozoic geology and resource development for the WSRA project area.

extensional tectonics has also resulted in geothermal resource generation to the present day.

Geochemistry

Available Geochemical Data

Geochemical data are available from the following sources: the National Geochemical Data Base of the U.S. Geological Survey; the Bureau of Land Management's geochemical evaluation of the Winnemucca District, which was conducted by Barringer Resources (Barringer Resources, 1982); the Nevada State mineral inventory of the Winnemucca District (Bonham and others, 1985); and studies of mine sites in the Winnemucca-Surprise Resource Area, conducted by the U.S. Bureau of Mines during the early 1990's (Miller, 1993). The USGS National Geochemical Data Base includes useful regional stream-sediment geochemical data from the NURE HSSR (National Uranium Resource Evaluation Hydrogeochemical and Stream Sediment Reconnaissance) program of 1976-1980, and rock and stream-sediment data from the National Wilderness Program (1965 to present) and from numerous smaller mineral-resource assements and geologic and geochemical studies with data in RASS (Rock Analysis Storage System), within the National Geochemical Data Base. Figure 15 illustrates sources of available geochemical data for the project area. The U.S. Geological Survey has recently completed the reanalysis of approximately 3,500 NURE stream-sediment samples from the project area by using multi-element inductively coupled plasma (ICP) and low-level (parts per billion) gold analytical techniques (AAS). This new data will be used to refine mineral potential tract boundaries and focus activities for stage II (and future) follow-up studies.

NURE Geochemical Data

Regional geochemical sampling was done during the NURE program, when samples of stream sediment, soil, and water were collected in 1976-1979 from five of the six 1:250,000-scale quadrangles in the Winnemucca-Surprise Resource Area (Bennett, 1980; Grimes, 1982; Puchlik, 1978; Qualheim, 1979; Thayer and Cook, 1980). Samples were not collected in the Alturas quadrangle, California. Geochemical data from stream-sediment and soil samples are discussed here. Elements were analyzed by different DOE (Department of Energy) -contracted laboratories in sediment of different size fractions in the five quadrangles: Winnemucca and Lovelock (Lawrence Livermore Laboratory, 500-1000 μm), and Reno, McDermitt, and Vya (Savannah River and Oak Ridge, <149 μm). The difference in size fractions and in laboratory methods created differences in the structure of the geochemical data, such as differences in means and ranges of values. Samples were collected primarily for uranium analyses at about 1 site per18 km^2 (about 1,000 samples per 1:250,000-scale quadrangle), but not all samples were analyzed for elements other than uranium.

Because of interference during analyses, elements in the NURE data generally have multiple lower detection limits and, therefore, multiple qualified values. Some qualified values were higher than the minimum measured (unqualified) values. So, to preserve the measured values, the qualified values (N's) were replaced with the minimum unqualified value for each element before univariate statistical analysis and map plotting.

Elements were selected from the NURE database and plotted at 1:250,000. Geochemical interpretations for the various elements were based on single-element plots of the 75th, 90th,

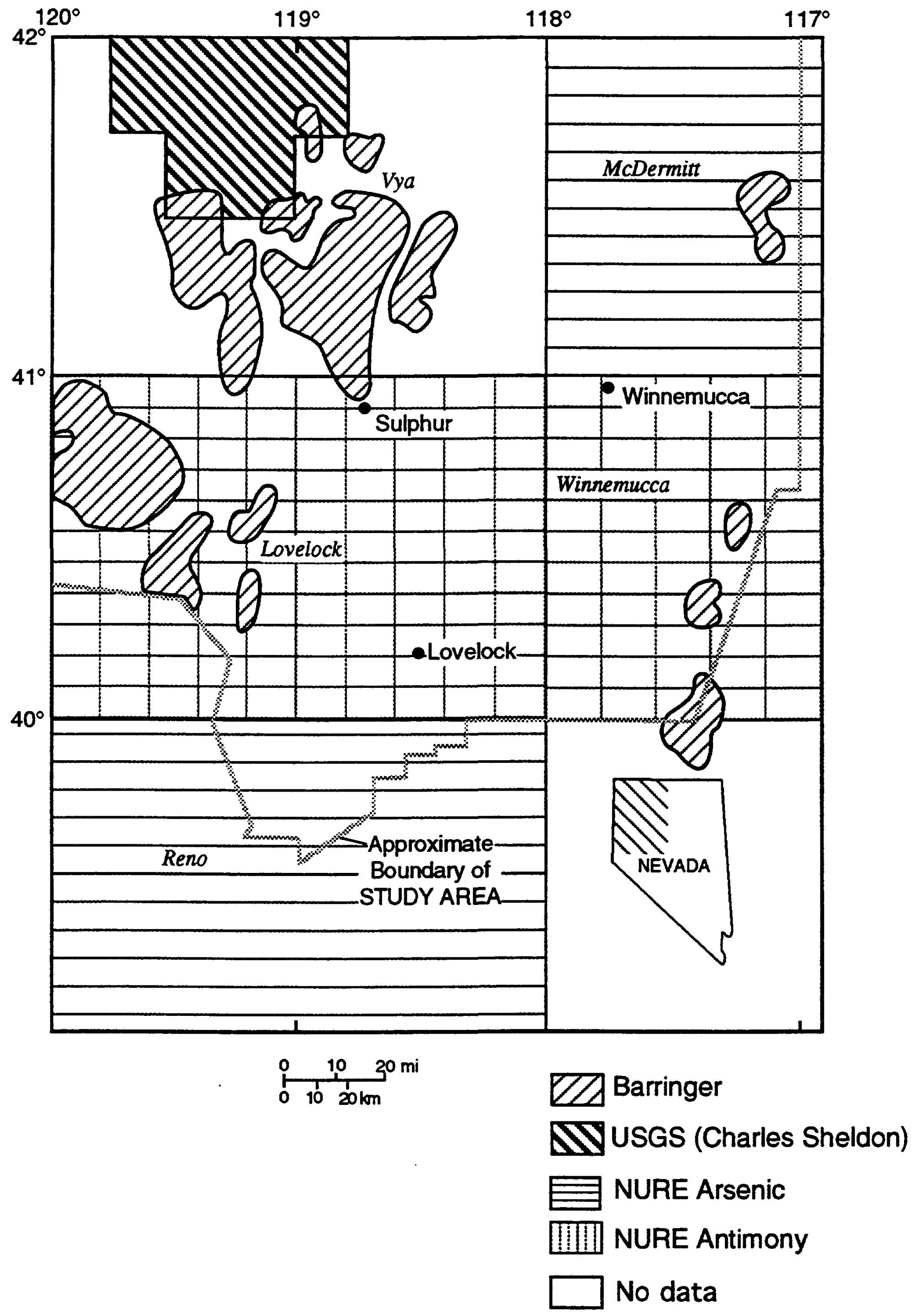

Figure 15. Map showing the boundary of the Nevada portion of the WSRA project area and the five 1° by 2° quadrangles containing NURE, Barringer, and RASS (USGS, Charles Sheldon) geochemical data.

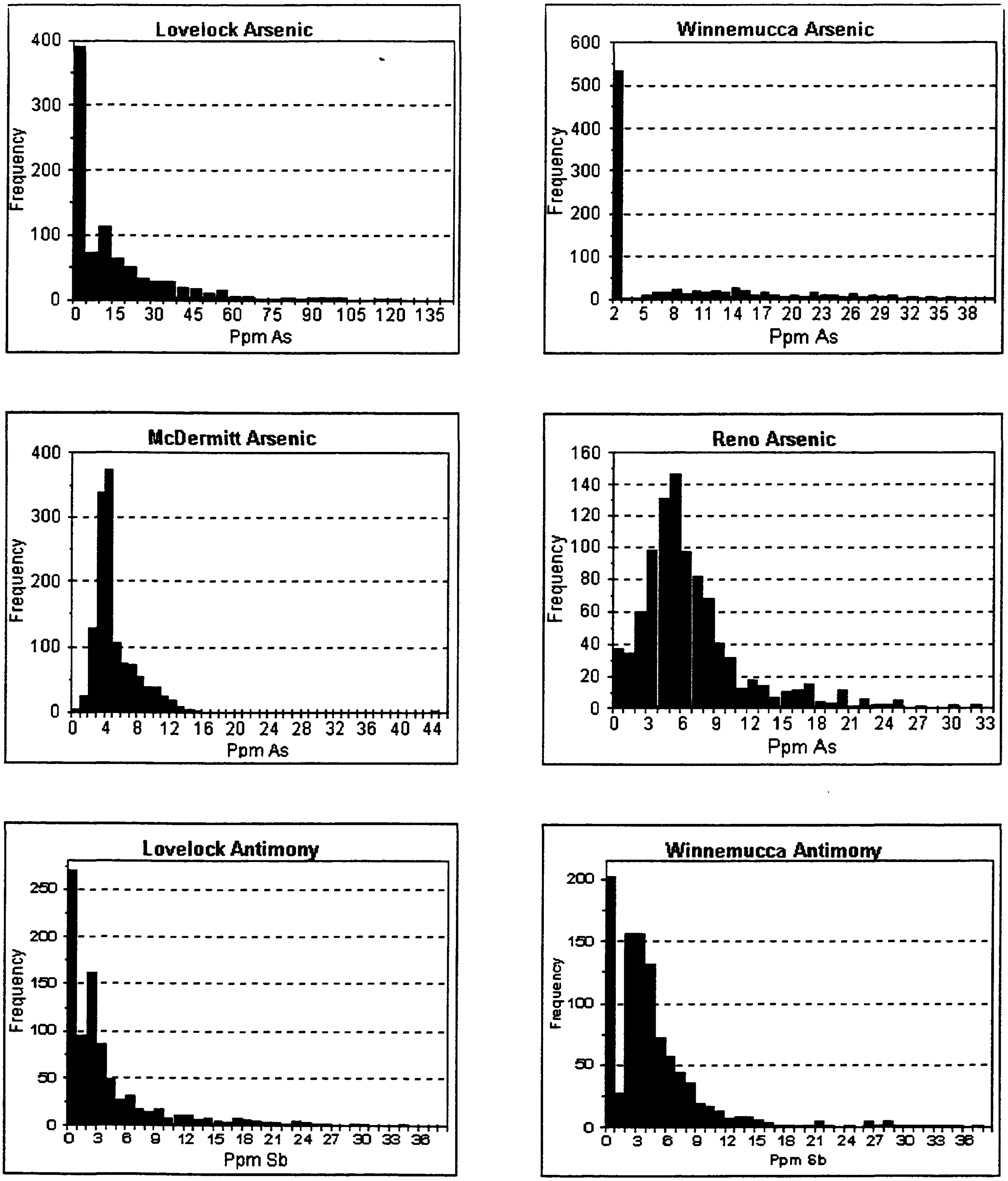

Figure 16. Histograms showing frequency distributions of NURE arsenic and antimony data by quadrangle for the WSRA project area.

Table 6. Univariate statistics for NURE arsenic and antimony data for stream sediment samples from the Nevada portion of the WSRA project area. Data is from neutron activation analyses. N= number of samples. All other values are in parts per million.

Quadrange	N	Minimum	Maximum	Geo. Mean	Geo. Dev.	75%	90%	95%	97.5%
Lovelock									
As	498	1.74	827	15.1	2.8	30.87	53.88	85.98	133.45
Sb	617	0.29	473.7	3.1	3.1	6.9	16.2	22.9	32.1
Winnemucca									
As	489	2.15	587.3	20.19	2.4	32.19	62.67	102.3	153.45
Sb	819	0.47	1,800	3.96	2.6	6.38	12.3	25.46	35.47
McDermitt									
As	1373	1	44	4.12	1.68	6	9	10	12
Reno									
As	953	1	50	5.5	1.96	8	13	17	22

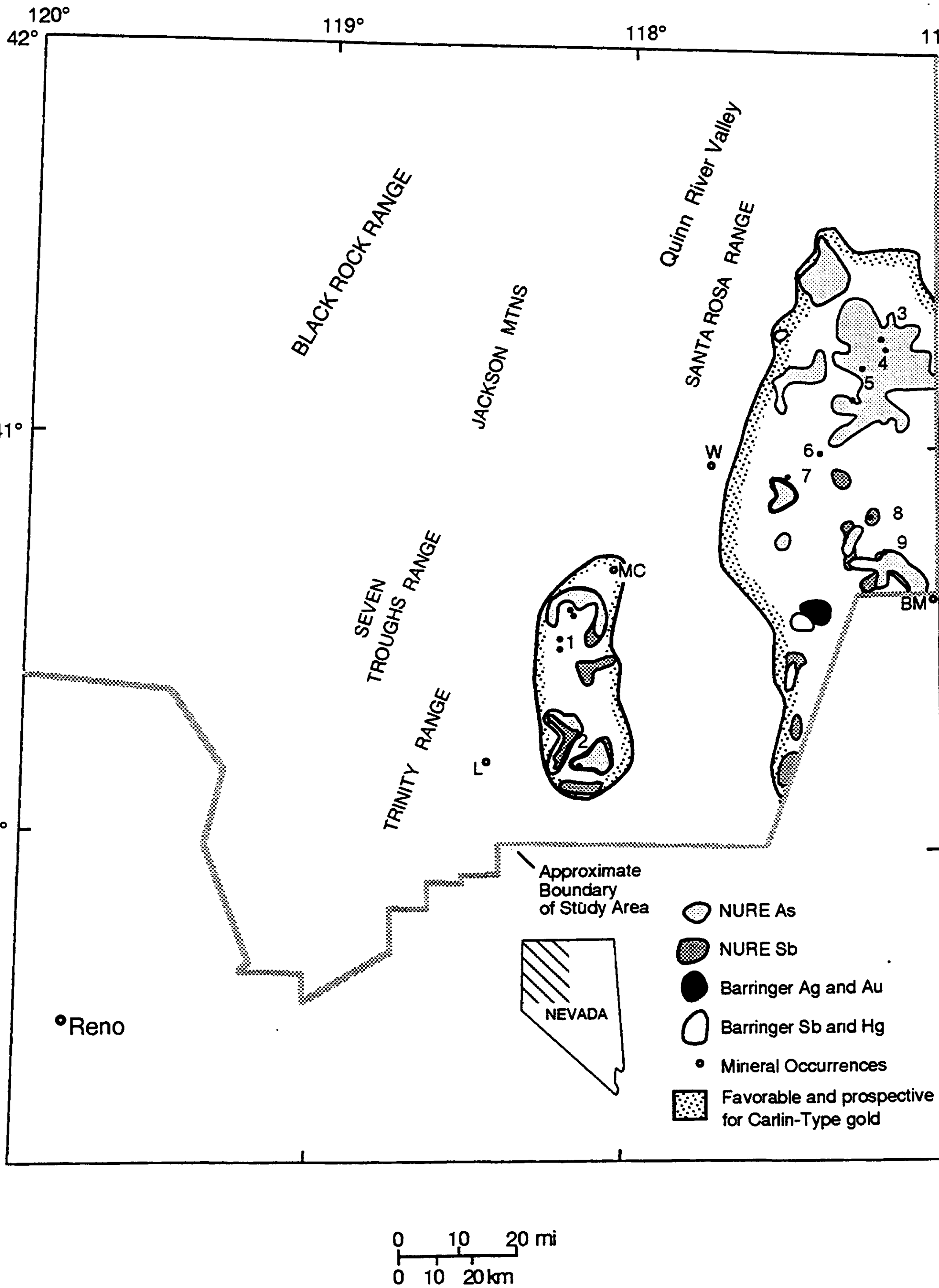

Figure 17. Areas containing anomalous concentrations of As, Sb, Ag, Au, and Hg in sediment within tracts that are favorable and prospective for Carlin-type sediment-hosted gold deposits. Mineral deposits: 1, Standard; 2, Relief Canyon; 3, Twin Creeks; 4, Getchell; 5, Pinson and Mag; 6, Preble; 7, Kramer Hill; 8, Lone Tree; and 9, Marigold. Towns: L, Lovelock; MC, Mill City; W, Winnemucca; BM, Battle Mountain. QRV, Quinn River Valley. Geochemical data are from the National Geochemical Data Base of the USGS and from Barringer Resources (1982).

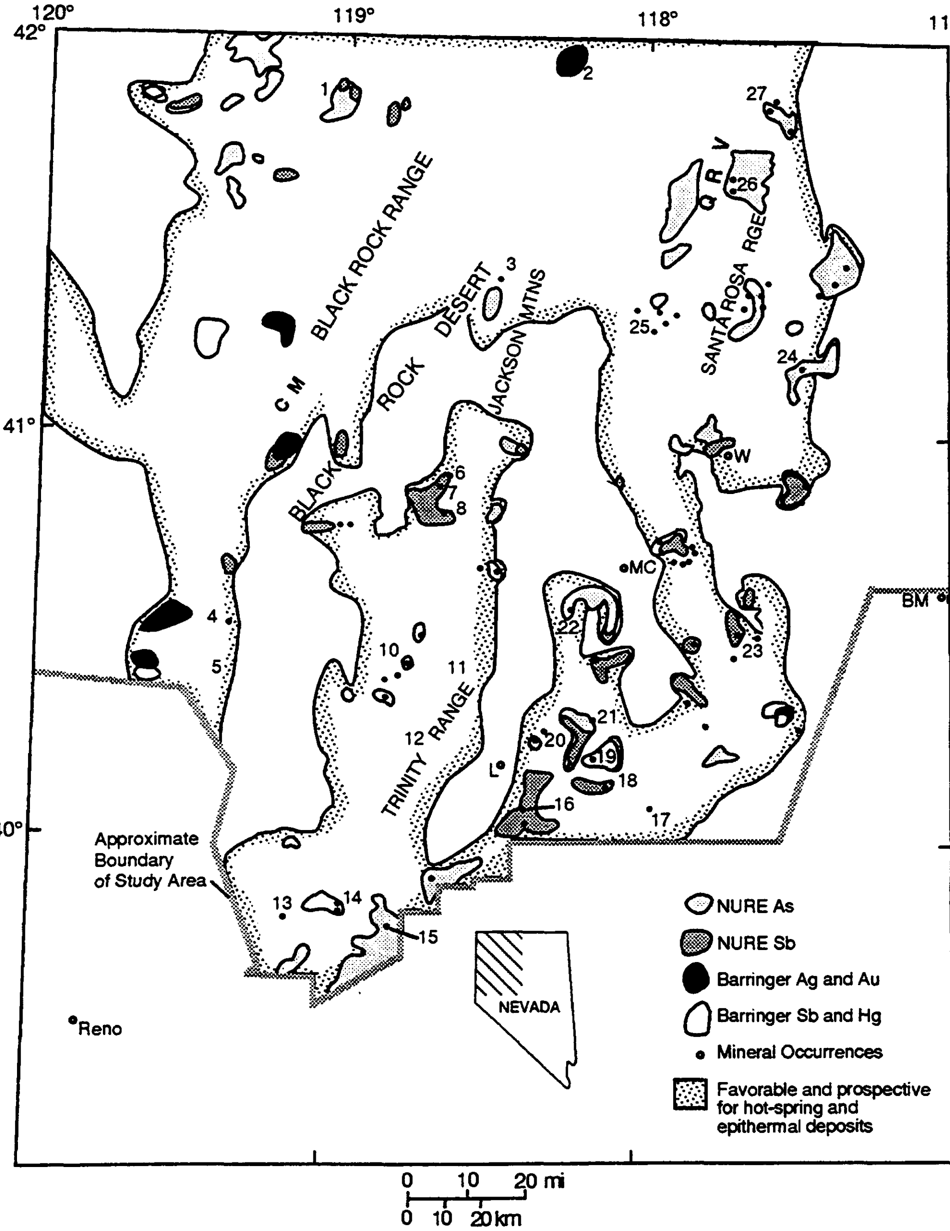

Figure 18. Areas containing anomalous concentrations of As, Sb, Ag, Au, and Hg in sediment within tracts that are favorable and prospective for hot-spring and epithermal deposits. Mineral deposits, localities, and districts: 1, Virgin Valley opal district; 2, opalite;, 3, North Jackson Mountain;, Hooker; 5, Wind Mountain; 6 Lewis-Crofoot; 7, Sulphur; 8, Rosebud; 9, Majuba Hill; 10 Seven Troughs; 11, Trinity; 12, Velvet; 13, Truckee; 14, Desert; 15, Lake; 16, Willard; 17, Table Mountain; 18, Antelope Springs; 19, Relief Canyon; 20, Muttleberry; 21, Rochester; 22 Florida Canyon; 23, Goldbanks; 24, Dutch Flats; 25, Sleeper; 26, Rebel Creek; and 27, National. Towns: L, Lovelock; MC, Mill City; W, Winnemucca; BM, Battle Mountain. Other labeled areas: CM, Calico Mountains; QRV, Quinn River Valley. Geochemical data are from the National Geochemical Data Base of the USGS (data from the NURE program and from Cathrall and others, 1978, combined on the figure as NURE As and NURE Sb) and from Barringer Resources (1982).

95th, and 97.5th percentiles and on log and arithmetic probability plots. Areas outlined on the percentile plots generally enclose sample localities enriched above the 90th percentile, but some areas may include samples above the 75th percentile as well. Geochemical maps based on log-probability plots were generated for a few elements by visual identification of inflection points on log probability plots and subsequent computer-generated extrapolations of an upper few percent of the population to pinpoint the areas of greatest element enrichment.

A number of the elements show some correspondance with mining districts: As, Sb, U, U/Th, Li, K, Ag, Cu, Pb, and Zn. Of these elements, As and Sb were particularly useful in delineating mineralization.

Arsenic and Antimony

Geochemical data from NURE stream-sediment samples show enrichments in As and/or Sb, which correlate with known mineralization and delineate less-explored areas where undiscoverd mineral deposits might exist. Arsenic is present in a variety of minerals in some of the different types of mineral deposits in the project area. These minerals include arsenopyrite and arsenian pyrite, and the arsenic sulfides orpiment and realgar. Antimony-bearing minerals include stibnite, tetrahedrite, and lead-antimony and arsenic-antimony sulfosalts.

Geochemical interpretations for arsenic and antimony were based on quadrangle by quadrangle study of single-element percentile maps (75th, 90th, 95th, and 97.5th percentiles) and log probability maps. The data were plotted and interpreted separately by quadrangle because of the differences in analytical procedures mentioned previously. For example, there are differences in geometric means for As: 20 ppm and 15 ppm for the coarser size fractions analyzed in the Winnemucca and Lovelock quadrangles, and 5.5 ppm and 4 ppm for the finer size fractions analyzed in the Reno and McDermitt quadrangles, respectively (fig. 16, table 5).

To illustrate their value, maps of the highest As and Sb concentrations can be compared with maps showing areas that are favorable and prospective for Carlin-type sediment-hosted gold deposits (figs. 17) and hot-spring and epihermal deposits (fig. 18). Many areas of known, Carlin-type gold mineralization are delineated in single-element geochemical maps of both arsenic- and antimony-enriched stream sediments. Percentile maps of As show enrichments along and south of the Getchell trend from the Chimney Creek and Rabbit Creek (Twin Creeks) mines to the Marigold mine (with corresponding Sb enrichments where Sb was analyzed). Enrichments of As and Sb also occur in the Humboldt Range, southward from the Imlay district to the Antelope Springs district, within another area that is favorable for sediment-hosted gold deposits. Geochemical maps based on log-probability plots of As and Sb show enrichments in areas that are the same as, but much more restricted than, the percentile-based maps. The probability maps were generated by visual identification of inflection points on log probability plots of As and Sb, to visually identify and separate geochemical populations, and subsequent computer-generated extrapolations of the upper 1-3 percent of the population. These maps pinpoint the most significant element enrichments within the upper 25 percent of the data.

Geophysics

Data sources

Regional geophysical data primarily consists of aerial gamma-ray, gravity, and magnetic data. Aerial gamma-ray data will be obtained from reports published as part of the National Uranium Resource Evaluation (NURE) program. A set of gravity data was obtained from data points in ASCII format available in computer files of the U.S. Geological Survey. A set of gridded magnetic data in binary format was obtained from computer files of the U.S. Geological Survey.

Aerial gamma-ray data

Hill (1991) listed aerial gamma-ray data published in analog format. Gamma-ray and aeromagnetic data for the entire study area are contained in reports by Aero Service Corporation (1981a, b) and GeoLife, Inc. (1978a, b; 1979a, b, c, d) along profiles spaced at intervals of about 4.8 km (3 mi). These data will be supplemented by gridded data in computer files of the U.S. Geological Survey and by data from surveys flown near Getchell, Nevada (TerraSense, Inc., 1989) and near McDermitt, Nevada, (McConnell and others, 1990).

Gravity data

An initial set of gravity data covering the study area and a band of at least 11 km (7 mi) outside the study area was obtained from Saltus (1988b) in Nevada, C.R. Roberts (written commun., 1990; Snyder and others, 1982) in California, and Plouff (1987, 1994). Data subsets collected in the early 1950's --with inherently doubtful gravity meter calibrations, elevation sources, and ties to local base stations--and data copied from previous data were deleted. Redundant data points and data points plotted on maps at scales of 1:24,000 in California with doubtful locations were deleted. Bouguer gravity anomalies that disagreed with the latitudes, elevations, values of observed gravity, and terrain corrections of data points were corrected. Data points with elevations that differed from linearly interpolated digital terrain elevations by greater than 150 m (500 ft), and data points with Bouguer gravity anomalies that conspicuously disagreed with nearby values were deleted, to obtain a preliminary data set of 7,320 data points (fig. 19).

Inasmuch as different computer programs and different terrain models were used to calculate the gravity effect of isostatic compensation, values of isostatic compensation were re-calculated for all data points by using data from Kdrki and others (1961) and an unpublished modification of a computer program written by Jachens and Roberts (1981) (fig. 20). Gravity maps in the study area were published by Chapman and Bishop (1968), Erwin (1974), Oliver and others (1975), Erwin and Berg (1977), Erwin and Bittleston (1977), Erwin and others (1985), Wagini (1986), Saltus (1988a, c), and Plouff (1992).

To the extent that is practical, further deletion of redundant and erroneous gravity data and correction of mis-located data will be done by analyzing data plotted on topographic maps published at scales of 1:24,000. Field ties by the authors and redundant data will be analyzed to evaluate errors and to improve the accuracy of datum shifts of observed gravity applied by previous compilers (Snyder and others, 1982; National Geophysical Data Center, 1984; Saltus, 1988b) to values of observed gravity from original sources (Peterson and Dansereau, 1975; Crewdson, 1976; Peterson and Hassemer, 1977; Plouff, 1976; Plouff and others, 1976; Robbins and others, 1976; Chapman and others, 1977; Peterson and Hoover, 1977; Plouff, 1977a, b;

Peterson and Kaufman, 1978a, b, c; Schaefer and Maurer, 1980; Erwin, 1982; Wagini, 1985; Glen and others, 1987; Sikora, 1991). Digital gravity terrain corrections (Godson and Plouff, 1988), which were based on topography digitized at a scale of 1:250,000 in Nevada and a hand-digitized topographic model in California (Robbins and others, 1973), will be evaluated for their effect on data accuracy and will be corrected, to the extent that is practical, by hand calculations (Hammer, 1939; Swick, 1942; and Campbell, 1980, for example) or may be improved by developing a computer program (for example, Cogbill, 1990) to utilize available topographic data digitized at a spacing of 30 m (98 ft). A total of 258 gravity stations collected by the authors in 1993 in an area of about 2,000 km^2 (800 mi^2) to the north and west of Winnemucca, Nevada (lat 41°58' N., long 117°44' W.) (fig. 19) will be merged with the data set. Data also will be supplemented by current data releases by the National Geophysical Data Center.

Maps showing loci of maximum gravity gradients and estimated basement depths will be prepared. Maps showing gravity gradients help to delineate the regional tectonic framework, faults, edges of calderas, and steeply dipping intrusive contacts, for example. Maps showing basement depths (Jachens and Moring, 1990) can be used to map the extent of pediments, to limit the extent of mineral exploration, and to delineate deep Cenozoic basins for petroleum and geothermal exploration. Modeling of possible sources of gravity anomalies will be done in selected areas.

Magnetic data

An initial set of gridded aeromagnetic data covering the study area and a band of at least 11 km (7 mi) outside the study area was obtained from Kucks and Hildenbrand (1987) for Nevada and unpublished data was obtained from C.R. Roberts (written commun., 1994) in California and adjacent parts of Oregon (fig. 21). These data include digital data or aeromagnetic maps published by Mabey (1964), the U.S. Geological Survey (1968a, b, c; 1970; 1972a, b; 1973a, b, c; 1981), Erickson and Marsh (1971a, b, c, d, e; 1973a, b, c; 1974a, b, c, d, e), Smith (1971), the Nevada Bureau of Mines and Geology (1974), Davis (1976), Zietz and others (1977), the California Division of Mines and Geology (1978), Kirchoff-Stein and Hildenbrand (1986), Hildenbrand and Kuchs (1988), Kirchoff-Stein (1988), Youngs (1988), and Chase and Mattison (1989). Data from the U.S. Geological Survey (1982b; 1985a, b, c) and McConnell and others (1990), which are not part of the initial data set but are available in digital format from the National Geophysical Data Center, will be digitally merged with the initial data set.

A map showing loci of maximum magnetic gradients (corrected for the inclination and declination of the magnetic vector) will be prepared. Maps showing magnetic gradients help to delineate faults, edges of calderas, and steeply dipping intrusive contacts (Grauch and others, 1988). Aeromagnetic profiles in analog format from the National Uranium Resource Evaluation program (Aero Service Corporation, 1981a, b; GeoLife, Inc., 1978a, b; 1979a, b, c, d) will be used to estimate the extent of and depth to shallow igneous sources concealed beneath sediments in valleys. Modeling of possible sources of magnetic anomalies will be done in selected areas.

Current state of geophysical interpretation

Guidelines for geophysical classification of a selected set of mineral deposit models were provided by Hoover and others (1992). Corbett (1991) summarized methods of geophysical exploration for precious metals in Nevada. Previous interpretations of geophysical data in the study area were made by Willden (1963), Smith (1968), Crewdson (1976), Isherwood and Mabey (1978), Cogbill (1979), Rytuba and others (1979), Willden (1979), Whelan (1980), Greene and Plouff (1981), Schaefer and Maurer (1983), Wright (1983), Plouff (1984, 1985, 1986, and 1992), Keith and others (1986, 1987), Peterson and others (1986), Ach and others (1987), Bergquist and others (1987; 1988a, b), Calzia and others (1987), Nobel and others (1987a, b), Roback and others (1987), Sorensen and others (1987), Grauch and others (1988), Minor and others (1988), Turrin and others (1988), Wallace and others (1988), Blakely and Jachens (1991), Grauch and Bankey (1991), Hoover and others (1991), Oliver and others (1991), Pitkin (1991), and Grauch and Hoover (1993).

Prominent gravity lows closely follow trends of basin-range valleys because thick sediments are less dense than basement rocks at the same elevation beneath adjacent mountains. Therefore, the distribution of upper crustal densities reflected by lines connecting gravity lows and highs (figs. 20 and 22) may depict basin-range deformation better than topography, which also reflects complexities of differential erosion and uplift, or mapped faults, which occur discontinuously and include faults of many ages. The northerly basin-range trend, which is interpreted as a manifestation of crustal stretching and consequent extension (strain), in most of the study area is absent within a broad gravity low in the northwest part of the study area (fig. 20). Plouff (1984) suggested that the gravity low of about 15 milligals reflects about a 2-km (1-mi) thickness of Cenozoic rocks to the west of the Pine Forest Range where denser Cenozoic rocks crop out. After applying an isostatic correction and extending the area of investigation to California and Oregon, Plouff (1985) speculated that a piecewise continuous peripheral gravity gradient (fig. 22) partly may reflect edges of an upper crustal plutonic source beneath the Cenozoic volcanic rocks and an inferred caldera (point A, fig. 22; Greene and Plouff, 1981). The topographic expression of the Black Rock Desert and three inferred alignments of magnetic highs and gradients are concentrically aligned to the southeast of the broad gravity low (fig. 22). Blakely and Jachens (1990, p. 19,445 and pl. 2) interpreted the gravity low as part of a structurally-bounded transverse segment of the Cascade arc, which includes upper crustal source rocks with low densities and extends nearly 400 km (250 mi) northeastward from Lassen Peak, California, to McDermitt, Nevada. Interpretation of seismic data (Callaway, 1978) by Lynn and others (1981) was used to postulate a depth of 6.2 km (3.9 mi) to the strongly reflective base of an inferred batholith beneath Trego, Nevada (fig. 22), which was assumed to be the same age as preCenozoic rocks exposed at the surface.

The "Oregon-Nevada lineament" (Stewart and others, 1975) or the "northern Nevada rift," which extends south-southeastward for at least 280 km (175 mi) from the study area, and two postulated sub- parallel rifts (fig. 22) are sharply delineated by magnetic highs (Blakely, 1988, pl. 1). Although magnetic highs and associated gravity highs and gradients that delineate the northern Nevada rift are narrow, geophysical modeling shows that igneous source rocks--probably exposed as 14- to 17-Ma basalt and andesite--extend deep into the crust in a dikelike form (Blakely, 1988). A transverse structure may be indicated to the west of lat 41 N., long 118 W., where gravity trends are truncated and the crest of a north-trending gravity high that reflects basin-range structure is deflected in the right lateral sense about 25 km (15 mi) between sub-parallel magnetic highs that reflect Miocene emplacement (fig. 22).

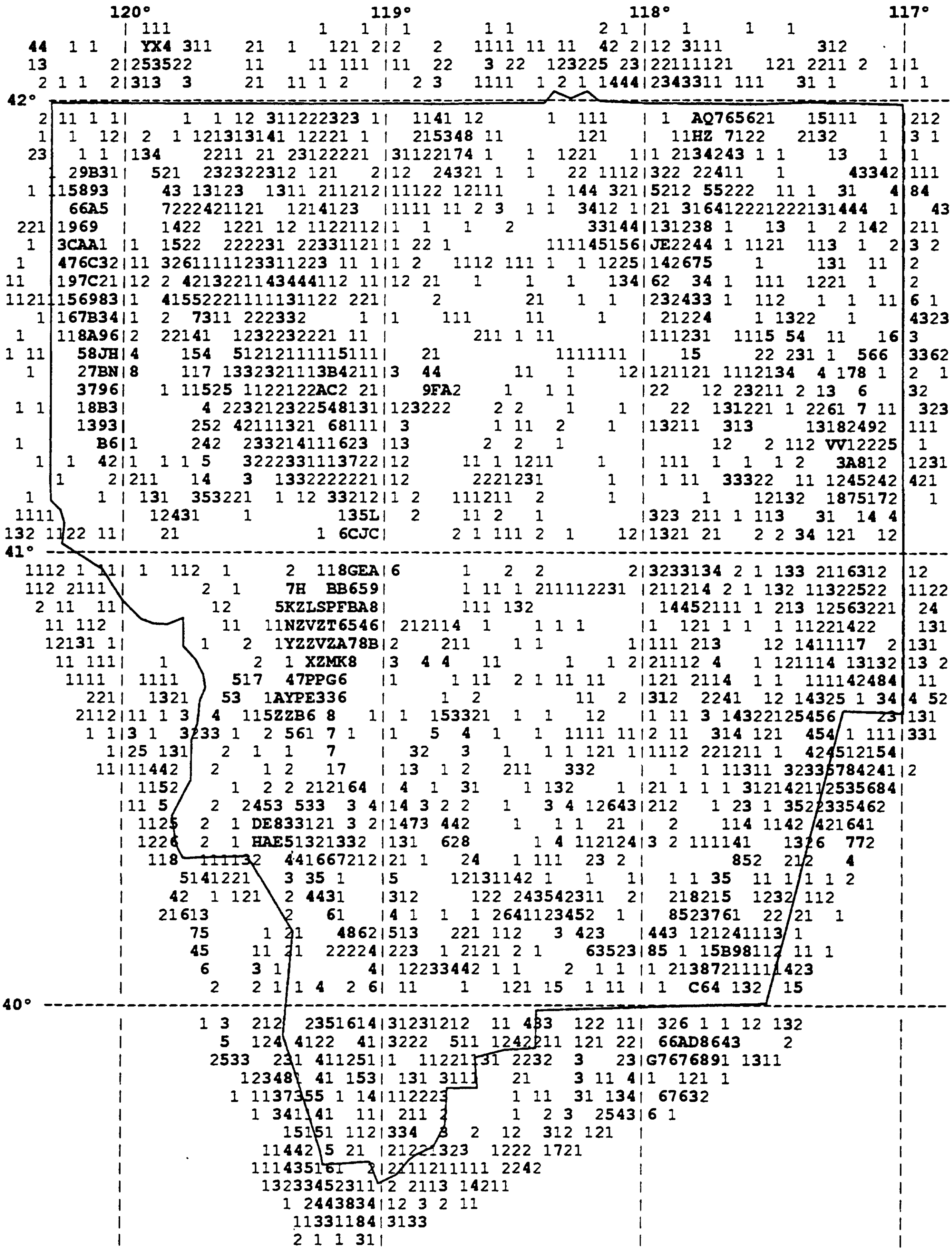

Figure 19. Map showing distribution of gravity data points in preliminary data set for WSRA project area. Numbers and letters indicate number of data points in 2.5-minute cells. Blank spaces indicate no data. A indicates 10 data points, the letters I and O are not used, Y indicates 31 data points, and Z indicated 32 or more data points. Solid line is approximate boundary of project area.

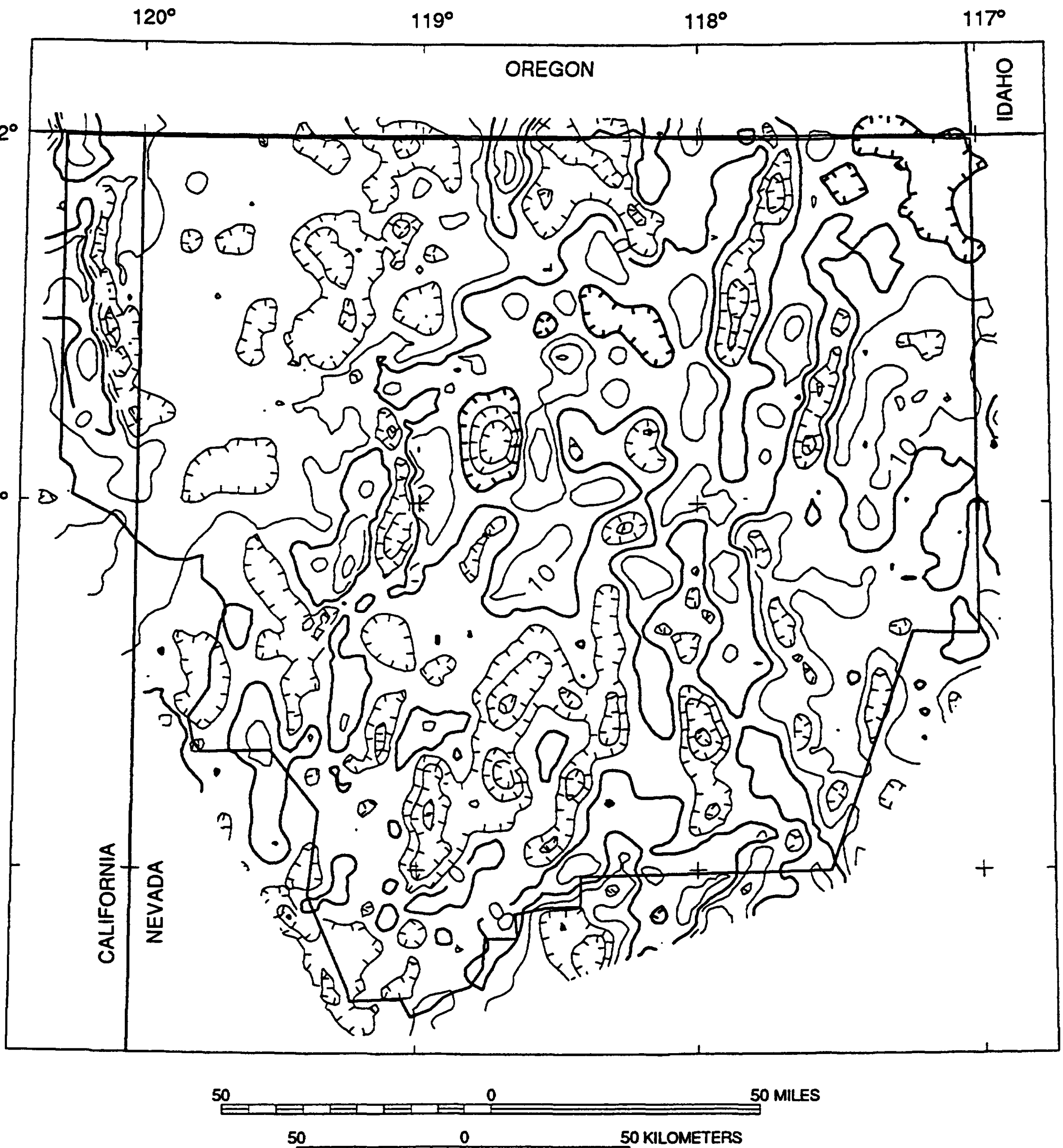

Figure 20. Isostatic residual gravity map of the WSRA project area. Contour interval is 10 milligals. Hachures indicate closed gravity lows. Outermost thick solid line represents approximate boundary of project area.

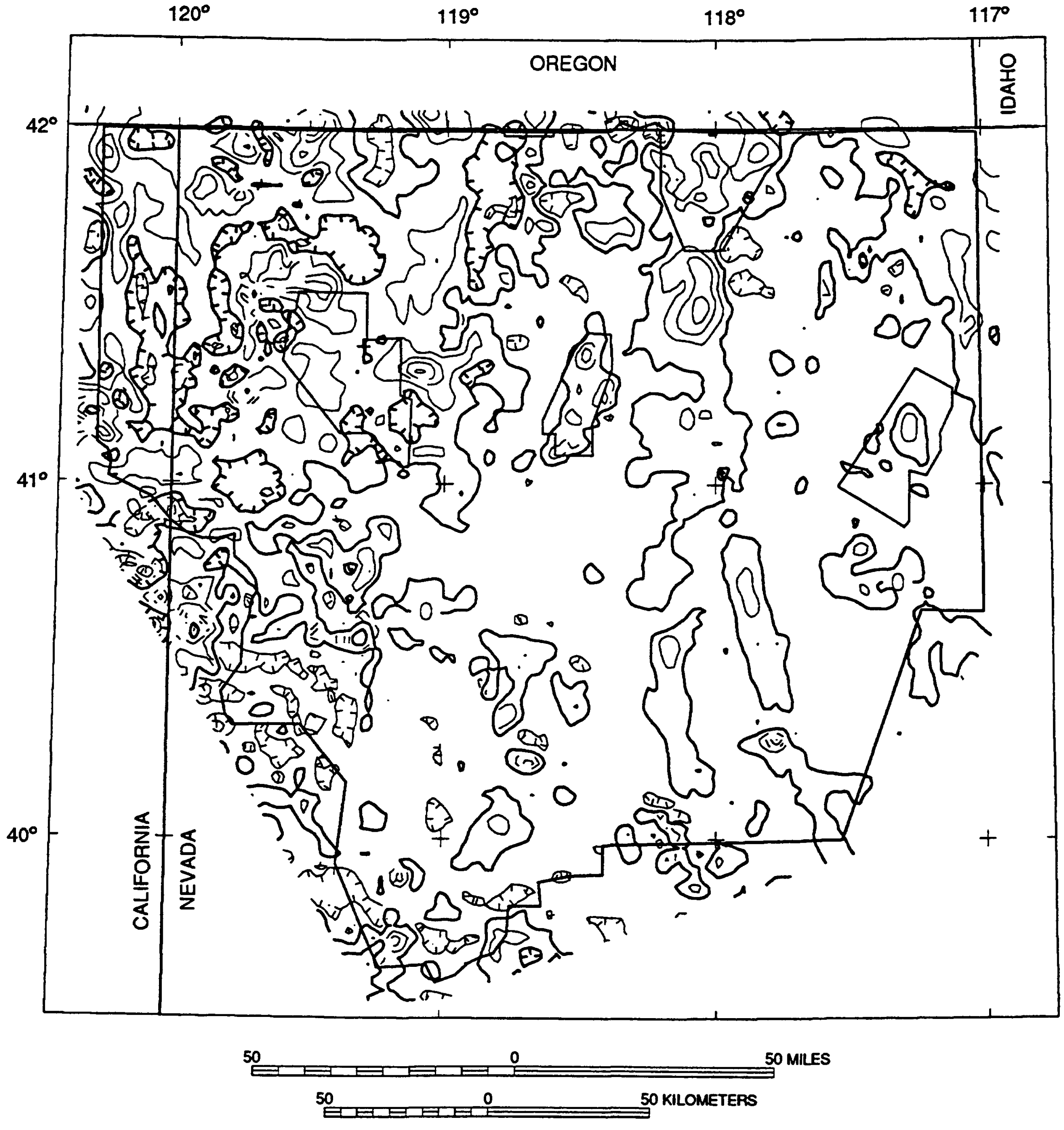

Figure 21. Aeromagnetic map of the WSRA project area. Contour interval is 200 nanoteslas. Hachures indicate closed magnetic lows. Outermost thick line is approximate boundary of project area. Polygons indicate locations of aeromagnetic surveys not included in this compilation.

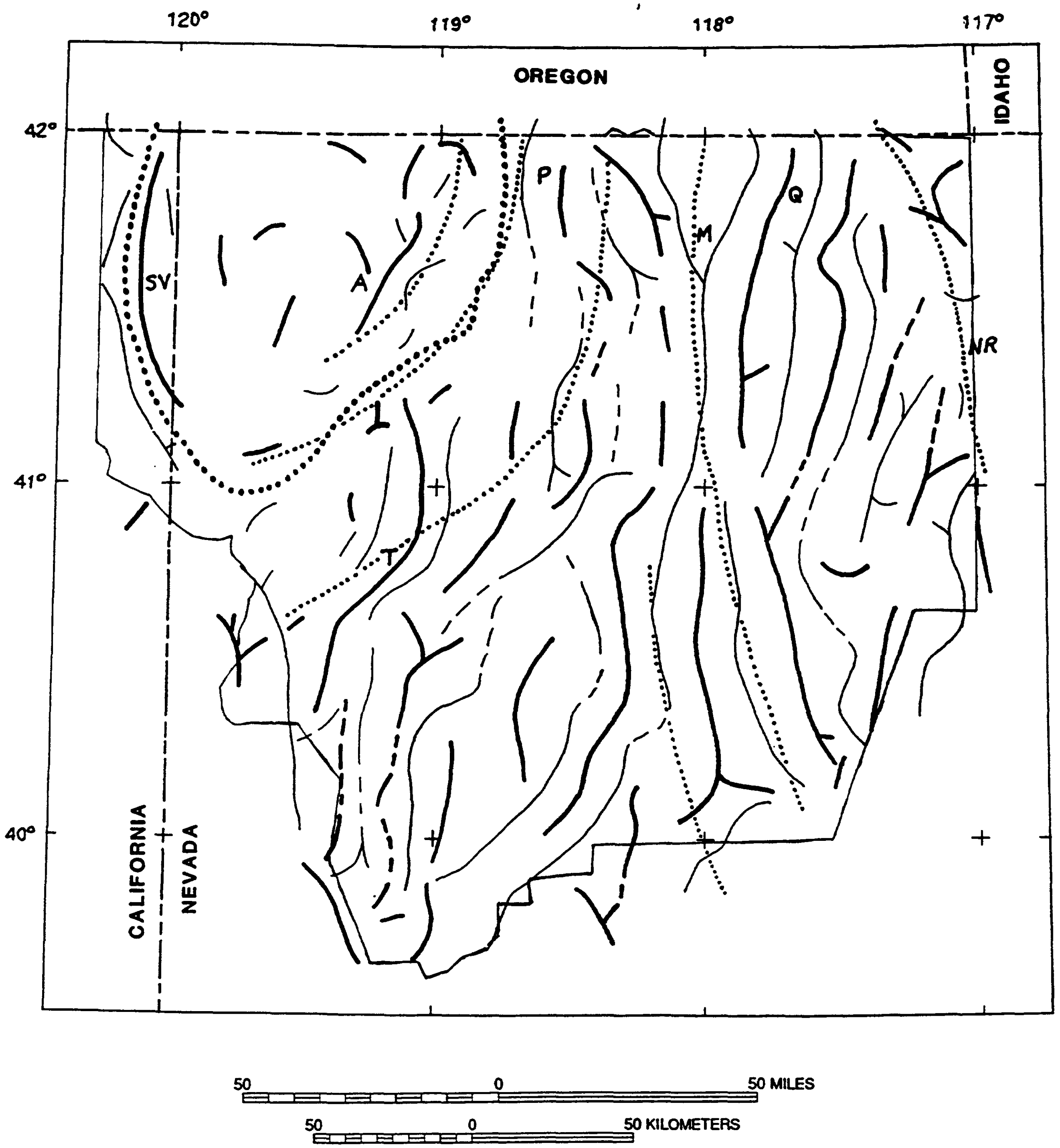

Figure 22. Tectonic framework of WSRA project area indicated by gravity and magnetic anomalies. Thick line segments indicate troughs of gravity lows. Thin line segments indicate crests of gravity highs. Thick dotted line in northwest part of area delineates gravity gradient that encloses area discussed in text. Thin dotted lines connect apparently aligned magnetic highs adjacent to prominent magnetic gradients. Continuous outer line is approximate boundary of project area. A - prominent gravity and magnetic lows in Charles Sheldon Wilderness Study Area; M - southernmost gravity low of McDermitt caldera complex; NR - northern Nevada rift; P - northeast end of Pine Forest Range and southwest end of Pueblo Valley; Q - gravity low in Quinn River Valley; SV - Surprise Valley; T - Trego, Nevada.

Rapid lithospheric extension and heat sources related to the presently observed Battle Mountain heat flow high (fig. 9), which covers a large part of the study area, have been attributed to intrusion of basalt as dikes or underplating at the base of the crust (Lachenbruch and Sass, 1978). Blackwell (1983, p. 82-83) emphasized that the composite source of anomalous heat flow primarily consists of intrusive magmas with basaltic compositions, and the role of consequent extension, which is viewed as a manifestation of underlying crustal stretching, is to provide space in which to transport and store magma and consequently heated fluids. Although extensive geophysical studies have been made since major geothermal exploration began in the mid-1970's in the study area (Callaway, 1978; Crewdson, 1978; Keller, Crewdson, and Daniels, 1978; Keller, Grose, and Crewdson, 1978; Kumamoto, 1978; Morris, 1978; Zeisloft and Keller, 1978; Goldstein and Paulsson, 1979; Benoit and Butler, 1983), upper crustal geophysical models clearly associated with the Battle Mountain heat flow high have not yet been developed.

Hydrothermal Alteration

Two sources of regional hydrothermal alteration data and information (interpretation of data) are being used to classify hydrothermally altered areas in the project area. Western Mining Corporation has provided the project with an interpreted alteration map of the northwest part of the project area, showing altered areas classified by alteration type. The BLM has processed Landsat Thematic mapper data for the project and provided color ratio composite imagery that are being used to classify hydrothermally altered areas for the entire project area. Field examinations are being conducted to field check and adequately interpret this new information and to qualify the previously interpreted data. This information will ultimayely be used to refine mineral potential tract boundaries.

Mineral Resource Data System (MRDS)

The USGS MRDS data base for the project area is one of several data bases that are being used to delineate mineral potential tracts. The data base will continually be cleaned and updated such that by the end of the assessment project it represents an accurate mineral resource inventory of the project area. Revision of the data base will emphasize deposit type classification and accurate location information. Some MRDS localities were classified by deposit type as part of the statewide Nevada mineral assessment (Cox and others, 1989, 1991). To date, more than 2000 localities have been preliminarily classified by deposit type. Stage II field studies will confirm deposit type classifications where it remains uncertain; an understanding of the distribution of deposit types is fundamental in conducting a mineral resource assessment.

Final Product

The final product is scheduled for release to the BLM as a USGS open-file report by April 1996 (table 2). A preliminary outline of the analog product with lists of tables, figures and plates is presented in appendix 4. All plates will be at 1:500,000 scale. It is anticipated that all spatial data relevant to the resource assessment, and used in compiling the plates, will be simultaneously released in digital form.

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APPENDIX 1

SUGGESTED GUIDELINES FOR MINERAL RESOURCE STUDIES OF PUBLIC LANDS

(as proposed by Branch-level panel of the Office of Mineral Resources)
(modified from 26 April 93 memo from Ron Worl to BWMR Management Team)

SUGGESTED GUIDELINES AND MINIMUM PRODUCTS FOR MINERAL-RESOURCE STUDIES OF PUBLIC LANDS

Introduction

This memo provides some guidelines for content and procedures for conducting mineral-resource assessments of public lands including Bureau of Land Management (BLM) Resource Areas and National Forests. It is not meant to be a detailed cookbook of how to undertake a mineral-resource assessment but merely to provide some general guidelines and a minimum set of items to be included in all mineral- resource assessment reports for these studies.

General Procedures

Mineral resource-assessments of public lands will be conducted in two stages. The first stage, to be completed during the first 6-12 months of the project, is a preliminary evaluation that results in a planning document which identifies priority areas and/or types of deposits that need additional study. The second stage is a field-based site-specific study of high-priority items identified during stage 1, a mineral resource-assessment, and writing of a formal mineral-resource assessment report. These stages are briefly described in the following paragraphs.

Stage 1. Stage 1 is a compilation of existing geologic, geophysical, geochemical, and mineral occurrence data at a scale of 1:250,000, if possible, or at 1:500,000, of an area larger than the target area for assessment. These compilations should build on data collections compiled as part of the 2-year National Assessment. Regional descriptive mineral deposit models and sets of diagnostic criteria for recognition of these deposit types should be developed. An important aspect of stage 1 studies is early meetings between the USGS project coordinator and counterparts in the land management agency and U. S. Bureau of Mines (BOM) to determine the needs and priorities of these agencies. Stage 1 studies should result in a planning document that can be released to the land management agency as an administrative report ~~or open-file report~~, if necessary. In this planning document, parts of the study area and/or types of mineral deposits that need additional study should be identified and prioritized. These high priority items for additional study should be a combination of items identified by USGS studies and needs expressed by the other agencies.

The information gathered in stage 1 studies will be presented to the land management agency and BOM personnel at a meeting to be held in the study area. Field trips should be included in this meeting. High priority items for stage 2 studies should also be presented at this time. In some cases, the preliminary report may be sufficient to address client needs and no stage 2 studies may be necessary except for writing the formal report. The best time for these meetings should be at the beginning of the stage 2 field seasons.

Stage 2. Stage 2 consists of field-based studies of high-priority items identified during stage 1, the mineral-resource assessment, and report writing. Priority study items and the mineral-resource assessment are only within the target area. Studies conducted during stage 2 may be larger scale (1:100,000 or larger) studies of parts of the study area and/or of specific deposit types. Additional geochemical and/or geophysical studies may not be part of these studies if they are deemed unnecessary at the end of stage 1. The formal mineral resource-assessment report should follow the general guidelines described in the next section.

Content of Mineral Resource-Assessment Reports

Mineral resource-assessments should be contained in a single stand-alone product that contains the following major elements. Additional sections and/or plates or maps may be included only if warranted.

1. Summaries. Two are required: (1) one page-bullet summary written for Congress or other land use decision makers, and (2) short (5-10 page) non-technical summary written for land use planners (e.g., non-scientific personnel of the land management agencies).

2. Introduction. Should include:
    a) statement of purpose and scope of study
    b) geographic information
    c) brief summary of past and present studies

3. Main text (written in technical terms for use by peers). Should include:
    a) geologic summary
    b) geochemical summary
    c) geophysical summary
    d) discussion of known mineral resources (past and present mining activity)
    e) discussion of mineral deposit occurrence models that are applicable to the study area (both worldwide models and models developed specifically for the study area). This discussion should include both known types of deposits and types of deposits that might exist within the study area. It should also contain lists of diagnostic criteria for each deposit type that can help non-economic geologists identify possible types of deposits present.
    f) evaluation of undiscovered mineral resources–this should be done by deposit type or by groups of genetically related deposit types and include a summary of the methodology used and definition of terms
    g) recommendations for future studies
    h) references

Figures and plates

1. Index map (page size)

2. Geologic and mineral resource assessment map(s) on topographic base. The type of geologic map and its scale will vary by study area, but in most cases the map should either be a simplified geologic map or a map based on lithologies or tectonostratigraphic terranes that are useful in defining/delineating permissive terranes. This map should be used as a base for mineral-resource assessment maps. A more detailed geologic map is not required in this report but can be published as a separate product in the standard USGS map series. The scale of the geologic map may differ from area to area, but the compilation and publication scales should not be any larger than the data warrant in the judgment of the geologists working on their compilation. Publication scale may vary depending on compilation scale and size of the area, but publication of numerous plates at large scales (e.g., 1:100,000 or larger) is discouraged. The mineral assessment should delineate permissive terranes for all major types or groups of genetically related deposits and, wherever possible, portray smaller areas ("tracts") that have higher potential or favorableness for undiscovered deposits. All known deposits should be included either in the permissive terranes or favorable areas. The number of mineral-resource maps required will differ from area to area, but combining several deposit types on single maps is encouraged as long as they are legible.

3. Geophysics maps. At a minimum, standard gravity and aeromagnetic maps should be included at either the scale of the geologic map or at a smaller scale if a) the data don't warrant more detailed

maps or b) the maps are simple enough to show at a smaller scale (e.g., page size). Other types of geophysical maps, such as radiometric, remote sensing, depth of bedrock, edge of magnetic anomalies, etc., can be included if they are available and are used in the mineral-resource assessment.

4. Geochemical map(s). These map(s) will differ from area to area depending on the availability of geochemical data and their usefulness in the mineral-resource assessment as judged by the geochemist(s) working on the project. At a minimum, some sort of sample location map and anomaly map(s) should be included. The scale of the map(s) will differ but should not be larger than the data warrant and page size maps are encouraged.

5. Mineral occurrence map. This map can be either a separate figure or plate, or if there are relatively few occurrences, it may be included on the geologic map. Mineral occurrences should include both MRDS records and any other known occurrences. Mineral occurrences should be distinguished by the deposit types that are discussed in the text. Mineral occurrences that are shown on the map and are not in MRDS should be added to MRDS, and MRDS records should be updated at the end of the project to include deposit type whenever possible.

General Suggestions

1. Length of report. Authors are urged to be concise and only include data and discussions that are pertinent to the mineral-resource assessment; scientific results of the study that are not directly applicable to mineral-resource assessment should be published elsewhere or concisely summarized. Although there should be no set limit to the length of a report, it is unlikely that any report need be longer than about 150 manuscript pages. The use of tables to summarize data that would otherwise require lengthy written descriptions is encouraged.

2. Scale. Scale is discussed above in several sections on maps and figures. No one scale is applicable to all projects, but the scale(s) must be determined on an individual basis with the most important limiting factor being the detail of the data. It is imperative that compilation and publication scales (which are not necessarily the same) must not exceed the viability of the data. Publication scale(s) is a tradeoff between the desires of the land management agency (typically they desire 1:100,000 or 1:125,000 scale maps), the data, and the realities of the USGS publication process (maximum size of plates, increased publication time with increased number of plates, etc.). In most cases, publication probably should be at 1:250,000 or 1:500,000 with the possibility of inset maps of critical areas at 1:100,000 or larger scales.

3. Digital products. Digital products are to be encouraged, but at the present time, given the limitations on existing resources (both personnel and hardware), it is unreasonable to make digital products mandatory.

4. Quantitative assessment. Quantitative assessments are undergoing external peer review. We await an OMR policy statement and guidelines following completion of this review.

5. Nonmetallic mineral-resources. The importance of nonmetallic mineral-resources is steadily increasing, and all resource assessments need to address these resources. Their importance will differ from area to area, and the project team needs to meet with personnel from the land management agency to help determine their relative importance within the study area. At a bare minimum, an inventory of known resources and brief discussion of types of nonmetallic resources and their importance should be included in the report.

6. Coal and oil and gas resources should be addressed if they are likely to be present in the study area. OMR has agreements with the Branches of Coal Geology and Oil and Gas to provide assessments of coal and oil and gas resources, respectively, within BLM RAs and National

Forests. The project coordinator should contact the OMR coordinator to find out the names of people in other offices assigned to study these resources.

7. Interaction with the land management agency and the BOM. These agencies should be involved in the projects from the beginning of the project, if in no other way than to determine their needs and desires. In particular, the BOM needs information about types of deposits that are in the study area at an early date. In some cases, the land management agency may have expertise in nonmetallic minerals or a metallic commodity and can be involved in the assessment and report writing. The project coordinartor should have a meeting at the beginning of the project with counterparts in the land management agency and the BOM and should make regular (at least semi-annual) contact with these agencies. It should be kept in mind that personnel of some land management agencies are transferred frequently (commonly yearly), and that in a 2-3 year project there may be several different people in these agencies that are responsible with interacting with the USGS who know nothing about what the USGS is doing. Also, while we should strive to serve the customer, our resources are limited and these agencies cannot dictate what the format and content of our studies and products are to be.

APPENDIX 2

LIST OF PARTICIPANTS
WINNEMUCCA-SURPRISE RESOURCE ASSESSMENT PROJECT
(as of October 1994)

Name	Tel./Fax/E-mail	Postal Address	Role
BLM			
Vic Dunn (BLM, Winnemucca)	(702) 623-1500 (702) 623-1503	Bureau of Land Management 705 E. 4th St. Winnemucca, NV 89445	Winnemucca District geologist
Joe McFarlan (BLM, Cedarville)	(916) 279-6101 (916) 279-2171	Bureau of Land Management P.O. Box 460 Cedarville, CA 96104	Surprise Resource Area geologist
USBM			
Mike Miller (USBM, Spokane)	(509) 353-2700 (509) 353-2661 miller@wfoclan.usbm.gov	Western Field Operations Center, U.S. Bureau of Mines, E. 360 Third Ave. Spokane, WA 99202	Coordinating USBM minerals inventory for project area
NBMG			
Steve Castor (NBMG, Reno)	(702) 784-1768 (702) 784-1709 scastor@nbmg.unr.edu	NBMG, MS 178 University of Nevada Reno, NV 89557	Consultant on industrial minerals
USGS			
Charles Barker (BPG, Denver)	(303) 236-5797 (303) 236-8822 barker@bpgsvr.cr.usgs.gov	USGS, MS 971 Box 25046, DFC Denver, CO 80225-0046	Oil and gas assessment
Kathy Connors (BWMR, Reno)	(702) 784-5803 (702) 784-5079 kathy@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557-0047	Consultant on GIS applications and Tertiary geology & economic geology
Jeff Doebrich (BWMR, Reno)	(702) 784-5789 (702) 784-5079 jeffd@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557-0047	Project coordinator, Paleozoic and Mesozoic geology, economic geology
Wendell Duffield (BVGP, Flagstaff)	(602) 556-7205 (602) 556-7169 wduffield@iflag2.wr.usgs.gov	USGS, Bldg. 3 2255 North Gemini Dr. Flagstaff, AZ 86001-1698	Geothermal resource assessment
Bill Hanna (BGP, Reston)	(703) 648-6362 (703) 648-4828 whanna@bgrdg1.er.usgs.gov	USGS, National Center MS 927 12201 Sunrise Valley Dr. Reston, VA 22092-0001	Regional geophysics, primarily for Paradise-Denio RA
David John (BWMR, Menlo Park)	(415) 329-5424 (415) 329-5490 djohn@mojave.wr.usgs.gov	USGS, MS 901, Bldg. 2 345 Middlefield Rd. Menlo Park, CA 94025-3591	Consultant on Tertiary volcanics, Mesozoic plotuns, and related mineralization
Harley King (BGC,Denver)	(303) 236-1852 (303) 236-3200	USGS, MS 966 Box 25046, DFC Denver, CO 80225-0046	Geochemistry
Dawn McGuire (BGRA, Golden)	(303) 273-8587 (303) 273-8600 dmcguire@helios.cr.usgs.gov	USGS, MS 966 Box 25046, DFC Denver, CO 80225-0046	Geochemistry, Paleozoic geology

Tom Nash (BGC, Denver)	(303) 236-5515 (303) 236-3200 tnash@helios.cr.usgs.gov	USGS, MS 973 Box 25046, DFC Denver, CO 80225-0046	Consultant on Tertiary geology/economic geology
Steve Peters (BWMR, Reno)	(702) 784-5574 (702) 784-5079 speters@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557-0047	Economic geology, preliminary qualitative assessment
Don Plouff (BGP, Menlo Park)	(415) 329-5312 (415) 329-5133 plouff@mojave.wr.usgs.gov	USGS, MS 989, Bldg. 2 345 Middlefield Rd. Menlo Park, CA 94025-3591	Regional geophysics, primarily for Sonoma-Gerlach RA
Gary Raines (BWMR, Reno)	(702) 784-5596 (702) 784-5079 graines@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557-0047	GIS coordination, remote sensing/regional alteration classification
Norm Silberling (BPS, Denver)	(303) 236-5660 (303) 236-5690	USGS, MS 919 Box 25046, DFC Denver, CO 80225-0046	Consultant on Mesozoic geology
Don Sawatzky (BWMR, Reno)	(702) 784-5379 (702) 784-5079 dons@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557- 0047	Industrial rock and mineral assessment
Greg Spanski (BORA, Denver)	(303) 236-5705 (303) 236-5448	USGS, MS 937 Box 25046, DFC Denver, CO 80225-0046	Facilitator for quantitative assessment
Ted Theodore (BWMR, Menlo Park)	(415) 329-5363 (415) 329-5940 theodore@mojave.wr.usgs.gov	USGS, MS 901, Bldg. 2 345 Middlefield Rd. Menlo Park, CA 94025-3591	Consultant on Paleozoic geology/general economic geology
Jim Yount (BWRG, Reno)	(702) 784-5565 (702) 784-5079 jyount@usgs.unr.edu	USGS, MS 176 Mackay School of Mines University of Nevada Reno, NV 89557- 0047	Consultant on sand and gravel assessment

APPENDIX 3

DESCRIPTIVE MODELS FOR METALLIC MINERAL DEPOSIT TYPES KNOWN AND SUSPECTED TO EXIST IN THE WINNEMUCCA-SURPRISE RESOURCE ASSESSMENT PROJECT AREA.

DESCRIPTIVE MODEL OF PORPHYRY Cu-Au DEPOSITS

(modified from Cox, 1986e; Albino, unpub. data)

APPROXIMATE SYNONYM   Diorite-type porphyry copper

DESCRIPTION Disseminated and stockwork Cu-Fe sulfides with Au in sub-volcanic intrusions

GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types   early gabbro/ quartz diorite, syn-mineral diorite porphyry, andesitic country rocks, locally marine carbonate and other sedimentary rocks. Granodiorite porphyry in the Battle Mountain district

Textures   early intrusions equigranular, later prominently porphyritic, host volcanics massive flows, flow breccias

Age Range   known examples early Mesozoic to Plio-Pleistocene, could be any age

Depositional Environment   within and adjacent to upper parts of syn-volcanic stocks

Tectonic Setting   above subduction zone, in calc-alkaline island arcs, in North America within accreted terranes

Associated Deposit Types Cu skarn, Au skarn, masssive pyrite-enargite replacements, polymetllic replacements

DEPOSIT DESCRIPTION

Mineralogy   Chalcopyrite, bornite, magnetite commonly abundant, native Au, PGE tellurides/arsenides

Texture/Structure   early disseminated Cu-Fe sulfides, dense stockwork quartz-sulfide veining

Alteration   early K-feldspar-Fe-Mg silicate (may be biotite, amphibole or pyroxene), anhydrite may be abundant, later intermediate argillic common, advanced argillic forms upper parts in some examples

Ore Controls   location proximal to late-stage, porphyritic, sub-volcanic intrusion

Weathering   variable depending on climate/physiography and development of acid alteration

Geochemical Signature   Cu, Au, Ag (Pt, Pd), Mo low in most

EXAMPLES

Worldwide:

Grasberg (INDS)
Panguna (PPNG)
Lepanto Far SE (PLPN)
Island Copper (CNBC)
Tanama (PTRC)

WSRA Project Area and Vicinity:

Copper Canyon, Battle Mountain district

DESCRIPTIVE MODEL OF PORPHYRY Cu-Mo DEPOSITS
(modified from Cox, 1986f; Albino, unpub data)

APPROXIMATE SYNONYM Arizona-type porphyry copper

DESCRIPTION Cu-Fe sulfides, commonly with molybdenite, in intense quartz stockworks in and adjacent to high level porphyritic intrusions

GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Type genetically associated with small stocks or dike sets of quartz-feldspar porphytic quartz monzonite, commonly larger bodies of more equigranular, less felsic intrusive rocks. Wallrocks locally dominated by intermediate-felsic volcanics, but more commonly pre-volcanic basement.

Textures strongly porphyritic, aphanitic stocks/dikes, early equigranular to seriate-porphyritic stocks

Age Range mainly Cretaceous and younger, but can be any age (few or no Precambrian examples). Examples in WSRA project are late Eocene to Oligocene.

Depositional Environment within and adjacent to high level felsic stocks, some of which form cores of stratovolcanoes

Tectonic Setting Andean-type continental margin arcs, may extend several thousand kilometers inboard of subduction zone

Associated Deposit Types Cu skarn, Au skarn, polymetallic replacement, distal-disseminated Au-Ag, polymetallic veins, Comstock-type veins

DEPOSIT DESCRIPTION

Mineralogy chalcopyrite-bornite and/or molybdenite zones central, surrounded by chalcopyrite-pyrite and pyrite zones; magnetite in some examples

Texture/Structure strongly developed quartz-sulfide stockwork, multiple veinlet sets, typically have some preferred orientation

Alteration central, early k-feldspar-biotite±anhydrite zone, peripheral propylitic zone. In most examples there is a well-developed phyllic (quartz-sericite-pyrite) overprint, concentrated at original potassic-propylitic boundary

Ore Controls location proximal to minealizing intrusion, limited control by favorable wallrock composition (mafic rocks, carbonate rocks)

Weathering Typically well-developed Fe-oxide stained 'leached' capping in examples with well-developed phyllic zones

Geochemical Signature Cu, Mo, Ag, Au extremely variable (may be associated with Bi, Te, PGE's), peripheral

Zn, Pb $\pm$ Ag-Au common

EXAMPLES

Worldwide:

Mineral Park (USAZ)
Bingham Canyon (USUT)
Yerington (USNV)
Valley Copper (CNBC)
Chuquicamta, (CILE)
Sierrita-Esperanza (USAZ)
Butte (USMT)

WSRA Project Area and Vicinity:

Kennedy district
Pyramid district

DESCRIPTIVE MODEL OF PORPHYRY Cu, SKARN-RELATED DEPOSITS
(modified from Cox, 1986b)

DESCRIPTION Chalcopyrite in stockwork veinlets in hydrothermally altered intrusives and in skarn with extensive retrograde alteration.

GENERAL REFERENCE Einaudi and others (1981), p. 341-354.

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks.

Textures Porphyry has microaplitic groundmass.

Age Range Mainly Mesozoic and Tertiary, but may be any age. Late Eocene to Oligocene in WSRA project area.

Depositional Environment Epizonal intrusion of granitic stocks into carbonate rocks. Intense fracturing.

Tectonic Setting(s) Andean-type volcanism and intrusion superimposed on older continental shelf carbonate terrane.

Associated Deposit Types copper skarn, gold skarn, replacement Pb-Zn-Ag.

DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite + magnetite in inner garnet pyroxene zone; bornite + chalcopyrite + sphalerite + tennantite in outer wollastonite zone. Scheelite and traces of molybdenite and galena may be present. Hematite or pyrrhotite may be predominant.

Texture/Structure Fine granular calc-silicates and quartz sulfide veinlets.

Alteration Potassic alteration in pluton is associated with andradite and diopside in calcareous rocks. Farther from contact are zones of wollastonite or tremolite with minor garnet, idocrase, and clinopyroxene (hedenbergitic). These grade outward to marble. Phyllic alteration in pluton is associated with retrograde actinolite, chlorite, and clay in skarn.

Ore Controls Intense stockwork veining in igneous and skarn rocks contains most of the copper minerals. Cu commonly accompanies retrograde alteration.

Weathering Cu carbonates, silicates, Fe-rich gossan.

Geochemical Signature Cu, Mo, Pb, Zn, Au, Ag, W, Bi, Sn, As, Sb.

EXAMPLES

Worldwide:

Ruth (Ely), USNV
Gaspe', CNQU
Christmas, USAZ
Silver Bell, USAZ

WSRA Project Area and Vicinity:
Copper Canyon, Battle Mountain district

DESCRIPTIVE MODEL OF Cu SKARN DEPOSITS
(modified from Cox and Theodore, 1986)

DESCRIPTION Chalcopyrite in calc-silicate contact metasomatic rocks

GENERAL REFERENCES Einaudi and Burt (1982), Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite to monzogranite intruding carbonate rocks or calcareous clastic rocks.

Textures Granitic texture, porphyry, granoblastic to hornfelsic in sedimentary rocks.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Miogeosynclinal sequences intruded by felsic plutons.

Tectonic Setting(s) Continental margin late orogenic magmatism.

Associated Deposit Types Porphyry Cu, zinc skarn, polymetallic replacement, Fe skarn.

DEPOSIT DESCRIPTION

Mineralogy Chalcopyrite + pyrite ± hematite ± magnetite ± bornite ± pyrrhotite. Also molybdenite, bismuthinite, sphalerite, galena, cosalite, arsenopyrite, enargite, tennantite, loellingite, cobaltite, and tetrahedrite may be present. Au and Ag may be important products.

Texture/Structure Coarse granoblastic with interstitial sulfides. Bladed pyroxenes are common.

Alteration Diopside + andradite center; wollastonite + tremolite outer zone; marble peripheral zone. Igneous rocks may be altered to epidote + pyroxene + garnet (endoskarn). Retrograde alteration to actinolite, chlorite, and clays may be present.

Ore Controls Irregular or tabular ore bodies in carbonate rocks and calcareous rocks near igneous contacts or in xenoliths in igneous stocks. Breccia pipe, cutting skarn at Victoria, is host for ore. Associated igneous rocks are commonly barren.

Weathering Cu carbonates, silicates, Fe-rich gossan. Calc-silicate minerals in stream pebbles are a good guide to covered deposits.

Geochemical Signature Rock analyses may show Cu-Au-Ag-rich inner zones grading outward to Au-Ag zones with high Au:Ag ratio and outer Pb-Zn-Ag zone. Co-As-Sb-Bi may form anomalies in some skarn deposits. Magnetic anomalies.

EXAMPLES

Worldwide:

Mason Valley, USNV
Victoria, USNV
Carr Fork, USUT

WSRA Project Area and Vicinity:

Copper Canyon, Battle Mountain district

DESCRIPTIVE MODEL OF Fe SKARN DEPOSITS
(modified from Cox, 1986d)

DESCRIPTION Magnetite in calc-silicate contact metasomatic rocks.

GENERAL REFERENCES Einaudi and Burt (1982), Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Gabbro, diorite, diabase, syenite, tonalite, granodiorite, granite, and coeval volcanic rocks. Limestone and calcareous sedimentary rocks.

Textures Granitic texture in intrusive rocks; granoblastic to hornfelsic textures in sedimentary rocks.

Age Range Mainly Mesozoic and Tertiary, but may be any age.

Depositional Environment Contacts of intrusion and carbonate rocks or calcareous clastic rocks.

Tectonic Setting(s) Miogeosynclinal sequences intruded by felsic to mafic plutons. Oceanic island arc, Andean volcanic arc, and rifted continental margin.

DEPOSIT DESCRIPTION

Mineralogy Magnetite ± chalcopyrite ± Co-pyrite ± pyrite ± pyrrhotite. Rarely cassiterite in Fe skarns in Sn-granite terranes.

Texture/Structure Granoblastic with interstitial ore minerals.

Alteration Diopside-hedenbergite + grossular-andradite + epidote. Late stage amphibole ± chlorite ± ilvaite.

Ore Controls Carbonate rocks, calcareous rocks, igneous contacts and fracture zones near contacts. Fe skarn ores can also form in gabbroic host rocks near felsic plutons.

Weathering Magnetite generally crops out or forms abundant float.

Geochemical and Geophysical Signature Fe, Cu, Co, Au, possibly Sn. Strong magnetic anomaly.

EXAMPLES

Worldwide:

Shinyama, JAPN
Cornwall, USPA
Iron Springs, USUT
Pumpkin Hollow, USNV

WSRA Project Area and Vicinity:

Jackson Mountains
Mineral Basin district
Copper Kettle district

DESCRIPTIVE MODEL OF VOLCANIC-HOSTED MAGNETITE
(modified from Cox, 1986i)

APPROXIMATE SYNONYM Porphyrite iron, Kiruna iron.

DESCRIPTION Massive concordant and discordant magnetite ore bodies in intermediate to alkalic volcanic rocks with actinolite or diopside alteration.

GEOLOGICAL ENVIRONMENT

Rock Types Andesitic to trachytic flows and subvolcanic intrusions, also at Kiruna, quartz porphyry, syenite porphyry, monzonite, and diorite.

Textures Porphyroaphanitic to fine- to medium-grained equigranular. Flows may be amygdaloidal.

Age Range Mesozoic to Holocene in circum-Pacific area. In Sweden and Missouri, 1,300-1,500 m.y.

Depositional Environment Continental volcanic rocks and clastic sediments intruded by subvolcanic intermediate plutons.

Tectonic Setting(s) Continental margin, subduction-related volcanic terrane. Especially with high-K volcanic rocks, possibly related to waning stages of volcanism.

Associated Deposit Types Sedimentary Fe in associated clastic rocks, apatite-magnetite deposits, hematite in quartz-sericite alteration, possible disseminated Au.

DEPOSIT DESCRIPTION

Mineralogy Magnetite + apatite. Rarely pyrite, chalcopyrite, chalcocite, and covellite. Ti is in sphene.

Texture/Structure Fine, granoblastic, skarn type textures.

Alteration Actinolite or diopside, andradite, biotite, quartz, albite, andesine, K-feldspar, sodic scapolite, epidote; carbonates, and locally, tourmaline, sphene, chlorite, barite, fluorite, kaolin, or sericite.

Ore Controls Magnetite in massive replacement, breccia filling and stockwork veins. Orebodies may be stratabound, concordant to intrusive contacts or in cross-cutting veins. Possibly related to cupolas of deeper plutons.

Geochemical and Geophysical Signature Fe, P, V, and minor Ba, F, Bi, Cu, Co; strong magnetic anomalies.

EXAMPLES

Worldwide:

Kirunavaara, Sweden
El Romeral, Chile
Middle-Lower Yangtze Valley

DESCRIPTIVE MODEL OF POLYMETALLIC VEINS
(modified from Cox, 1986g)

APPROXIMATE SYNONYM Felsic intrusion-associated Ag-Pb-Zn veins (Sangster, 1984).

DESCRIPTION Quartz-carbonate veins with Au and Ag associated with base metal sulfides related to hypabyssal intrusions in sedimentary and metamorphic terranes.

GEOLOGICAL ENVIRONMENT

Rock Types Calcalkaline to alkaline, diorite to granodiorite, monzonite to monzogranite in small intrusions and dike swarms in sedimentary and metamorphic rocks. Subvolcanic intrusions, necks, dikes, plugs of andesite to rhyolite composition.

Textures Fine- to medium-grained equigranular, and porphyroaphanitic.

Age Range Most are Mesozoic and Cenozoic, but may be any age.

Depositional Environment Near-surface fractures and breccias within thermal aureol of clusters of small intrusions. In some cases peripheral to porphyry systems.

Tectonic Setting(s) Continental margin and island arc volcanic-plutonic belts. Especially zones of local domal uplift.

Associated Deposit Types Porphyry Cu-Mo, porphyry Mo low-F, polymetallic replacement. Placer Au.

DEPOSIT DESCRIPTION

Mineralogy Native Au and electrum with pyrite + sphalerite ± chalcopyrite ± galena ± arsenopyrite ± tetrahedrite-tennantite ± Ag sulfosalts ± argentite ± hematite in veins of quartz + chlorite + calcite ± dolomite ± ankerite ± siderite ± rhodochrosite ± barite ± fluorite ± chalcedony ± adularia.

Texture/Structure Complex, multiphase veins with comb structure, crustification, and colloform textures. Textures may vary from vuggy to compact within mineralized system.

Alteration Generally wide propylitic zones and narrow sericitic and argillic zones. Silicification of carbonate rocks to form jasperoid.

Ore Controls Areas of high permeability: intrusive contacts, fault intersections, and breccia veins and pipes. Replacement ore bodies may form where structures intersect carbonate rocks.

Weathering Minor gossans and Mn-oxide stains. Zn and Pb carbonates and Pb sulfate. Abundant quartz chips in soil. Placer gold concentrations in soils and stream sediments. Supergene enrichment produces high-grade native and horn silver ores in veins where calcite is not abundant.

Geochemical Signature Zn, Cu, Pb, As, Au, Ag, Mn, Ba. Anomalies zoned from Cu-Au outward to Zn-Pb-Ag to Mn at periphery.

EXAMPLES

Worldwide:

St. Anthony (Mammoth), USAZ
Wallapai District, USAZ
Marysville District, USMT
Misima I., PPNG
Slocan District, CNBC

WSRA Project Area and Vicinity:

Gold Run district
Iron Hat district
Star district
Pyramid district

DESCRIPTIVE MODEL OF POLYMETALLIC REPLACEMENT DEPOSITS
(modified from Morris, 1986)

APPROXIMATE SYNONYM Manto deposits, many authors.

DESCRIPTION Hydrothermal, epigenetic, Ag, Pb, Zn, Cu minerals in massive lenses, pipes and veins in limestone, dolomite, or other soluble rock near igneous intrusions

GENERAL REFERENCE Jensen and Bateman (1981), p. 134-146.

GEOLOGICAL ENVIRONMENT

Rock Types Sedimentary rocks, chiefly limestone, dolomite, and shale, commonly overlain by volcanic rocks and intruded by porphyritic, calc-alkaline plutons.

Textures The textures of the replaced sedimentary rocks are not important; associated plutons typically are porphyritic.

Age Range Not important, but many are late Mesozoic to early Cenozoic.

Depositional Environment Carbonate host rocks that commonly occur in broad sedimentary basins, such as epicratonic miogeosynclines. Replacement by solutions emanating from volcanic centers and epizonal plutons. Calderas may be favorable.

Tectonic Setting(s) Most deposits occur in mobile belts that have undergone moderate deformation and have been intruded by small plutons.

Associated Deposit Types Base metal skarns, and porphyry copper deposits.

DEPOSIT DESCRIPTION

Mineralogy Zonal sequence outward: enargite + sphalerite + argentite + tetrahedrite + digenite ± chalcopyrite, rare bismuthinite; galena + sphalerite + argentite ± tetrahedrite ± proustite ± pyrargyrite, rare jamesonite, jordanite, bournonite, stephanite, and polybasite; outermost sphalerite + rhodochrosite. Widespread quartz, pyrite, marcasite, barite. Locally, rare gold, sylvanite, and calaverite.

Texture/Structure Ranges from massive to highly vuggy and porous.

Alteration Limestone wallrocks are dolomitized and silicified (to form jasperoid); shale and igneous rocks are chloritized and commonly are argillized; where syngenetic iron oxide minerals are present, rocks are pyritized. Jasperoid near ore is coarser grained and contains traces of barite and pyrite.

Ore Controls Tabular, podlike and pipelike ore bodies are localized by faults or vertical beds; ribbonlike or blanketlike ore bodies are localized by bedding-plane faults, by susceptible beds, or by preexisting solution channels, caverns, or cave rubble.

Weathering Commonly oxidized to ochreous masses containing cerrusite, anglesite, hemimorphite, and cerargyrite.

Geochemical Signature On a district-wide basis ore deposits commonly are zoned outward from a copper-rich central area through a wide lead-silver zone, to a zinc- and manganese-rich fringe. Locally Au, As, Sb, and Bi. Jasperoid related to ore can often be recognized by high Ba and trace Ag content.

EXAMPLES

Worldwide:	WSRA Project Area and Vicinity:
East Tintic district, USUT	Battle Mountain district
Eureka district, USNV	Gold Run district
Manto deposit, MXCO	Iron Hat district

DESCRIPTIVE MODEL OF Zn-Pb SKARN DEPOSITS
(modified from Cox, 1986c)

DESCRIPTION Sphalerite and galena in calc-silicate rocks.

GENERAL REFERENCES Einaudi and Burt (1982); Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Granodiorite to granite, diorite to syenite. Carbonate rocks, calcareous clastic rocks.

Textures Granitic to porphyritic; granoblastic to hornfelsic.

Age Range Mainly Mesozoic, but may be any age.

Depositional Environment Miogeoclinal sequences intruded by generally small bodies of igneous rock.

Tectonic Setting(s) Continental margin, late-orogenic magmatism.

Associated Deposit Types Copper skarn.

DEPOSIT DESCRIPTION

Mineralogy Sphalerite + galena ± pyrrhotite ± pyrite ± magnetite ± chalcopyrite ± bornite ± arsenopyrite ± scheelite ± bismuthinite ± stannite ± fluorite. Gold and silver do not form minerals.

Texture/Structure Granoblastic, sulfides massive to interstitial.

Alteration Mn-hedenbergite ± andradite ± grossular ± spessartine ± bustamite ± rhodonite. Late stage Mn-actinolite ± ilvaite ± chlorite ± dannemorite ± rhodochrosite.

Ore Controls Carbonate rocks especially at shale-limestone contacts. Deposit may be hundreds of meters from intrusive.

Weathering Gossan with strong Mn oxide stains.

Geochemical Signature Zn, Pb, Mn, Cu, Co, Au, Ag, As, W, Sn, F, possibly Be. Magnetic anomalies.

EXAMPLES

Worldwide:

Ban Ban, AUQU
Hanover-Fierro district, USNM

DESCRIPTIVE MODEL OF REPLACEMENT Mn

(modified from Mosier, 1986a)

DESCRIPTION Manganese oxide minerals occur in epigenetic veins or cavity fillings in limestone, dolomite, or marble, which may be associated with intrusive complexes.

GEOLOGICAL ENVIRONMENT

Rock Types Limestone, dolomite, marble, and associated sedimentary rocks; granite and granodiorite plutons.

Age Range Mainly Paleozoic to Tertiary, but may be any age.

Depositional Environment Miogeosynclinal sequences intruded by small plutons.

Tectonic Setting(s) Orogenic belts, late orogenic magmatism.

Associated Deposit Types Polymetallic vein, polymetallic replacement, skarn Cu, skarn Zn, porphyry copper.

DEPOSIT DESCRIPTION

Mineralogy Rhodochrosite ± rhodonite + calcite + quartz ± barite ± fluorite ± jasper ± manganocalcite ± pyrite ± chalcopyrite ± galena ± sphalerite.

Texture/Structure Tabular veins, irregular open space fillings, lenticular pods, pipes, chimneys.

Ore Controls Fracture permeability in carbonate rocks. May be near intrusive contact.

Weathering Mn oxide minerals: psilomelane, pyrolusite, and wad form in the weathered zone and make up the richest parts of most deposits. Limonite and kaolinite.

Geochemical Signature Mn, Fe, P, Cu, Ag, Au, Pb, Zn.

EXAMPLES

Worldwide:

Lake Valley, USNM
Philipsburg, USMT
Lammereck, ASTR

DESCRIPTIVE MODEL OF GOLD SKARNS
(modified from Theodore and others, 1991; Albino, unpub. data)

DESCRIPTION Gold in calc-silicate contact metasomatic rocks

GENERAL REFERENCE Meinert, 1989

GEOLOGICAL ENVIRONMENT

Rock Types Thin-bedded, impure carbonaceous limestone, contact with diorite to quartz monzonite.

Textures coarse-grained, granoblastic; porphyritic, oxidized sub-type may be heavily veined

Age Range Known examples are Early Jurassic to Tertiary, but may be any age

Depositional Environment Near contacts of shallow-level felsic to intermediate stocks

Tectonic Setting Andean-type continental arc

Associated Deposit Types Porphyry Cu-Au, Cu-Au skarns, polymetallic replacement, distal-disseminated Ag-Au, Au mantos

DEPOSIT DESCRIPTION

Mineralogy Gold/electrum, arsenopyrite, pyrrhotite, (pyrite), high-Fe sphalerite, chalcopyrite, magnetite, (hematite), native Bi, hedleyite, tetradymite, other tellurides.

Texture/Structure Massive coarse-grained skarn replacement of specific horizons, pods of coarse-grained heavy/massive sulfide common

Alteration Early K-spar-biotite common, endoskarn in pre-mineral intrusions. 1) Reduced sub-type - intermediate grandite garnets, hedenbergite, little retrograde; 2) Oxidized sub-type - andradite garnet, hedenbergitic pyroxene, epidote, Fe-oxides, abundant retrograde alteration (pyrite, hematite, epidote, amphibole, adularia, sericite, pyrite)

Ore Controls 1) Reduced sub-type - structure (fault or dike) distal to source intrusive, ore at or near marble line; 2) oxidized sub-type - stock contact and faults

Weathering Reduced sub-type will give little indication in terms of Fe staining, oxidized may be gossanous-weathering

Geochemical Signature Au, Ag, Cu, Zn, As, Bi, Te (W)

EXAMPLES

	Worldwide:	WSRA Project Area and Vicinity:
Reduced:	Nickel Plate (CNBC) Elkhorn (USMT)	Fortitude, Copper Canyon, Battle Mountain district
Oxidized:	Cable (USMT) Cooke City (USMT)	McCoy, Fish Creek Range

DESCRIPTIVE MODEL OF DISTAL-DISSEMINATED Ag-Au
(modified from Cox, 1992; Albino, unpub. data)

APPROXIMATE SYNONYM sediment-hosted Au-Ag (in part)

GENERAL REFERENCE Graybeal (1981); Noble and Alvarez ()

DESCRIPTION Disseminated Ag and Au in silicified and decarbonatized calcareous sediments

GEOLOGIC ENVIRONMENT

Rock Types limestone, impure limestone

Textures finely to coarsely recrystallized carbonate-rich rocks

Age Range known deposits Tertiary, may be any age

Depositional Environment peripheral to high-level felsic stocks

Tectonic Setting continental or oceanic magmatic arc

Associated Deposit Types porphyry Cu-Au, Cu-Au skarn, Au skarn, polymetallic replacement deposits

DEPOSIT DESCRIPTION

Mineralogy pyrite, galena, sphalerite, Pb and Ag sulfosalts

Texture/Structure pervasive fine-grained replacement, pods of coarsely recrystallized rock, sulfide fracture coatings

Alteration decalcification, jasperoidization, marbleization (Mn addition particularly), locally rhodochrosite replacement

Ore Controls faults linking mineralizing pluton and deposit, favorable calcareous strata, position peripheral to mineralized pluton

Weathering prominent silicified knobs, black Mn oxide staining

Geochemical Signature Ag, Au, Zn, Pb, Mn, (Bi, Te)

EXAMPLES

Worldwide:

Purisima Concepcion (PERU)
Bau (INDS)
Bald Mountain (USNV)
Golden Butte, USNV

WSRA Project Area and Vicinity:

Lone Tree/Stonehouse deposit
Marigold deposits
Cove, Fish Creeks Range

DESCRIPTIVE MODEL OF CLIMAX Mo DEPOSITS
(modified from Ludington, 1986)

APPROXIMATE SYNONYM Granite molybdenite (Mutschler and others, 1981).

DESCRIPTION Stockwork of quartz and molybdenite associated with fluorite in granite porphyry

GENERAL REFERENCE White and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Granite-rhyolite with >75 percent SiO2. Rb, Y, Nb are high, Ba, Sr, Zr low. Stocks with radial dikes; small breccias common.

Textures Porphyry with fine- to medium-grained aplitic groundmass.

Age Range Examples are mainly mid-Tertiary.

Depositional Environment Multistage hypabyssal intrusions.

Tectonic Setting(s) Mainly extensional zones in cratons. May be related to subduction, but found far from continental margins in areas of thick crust, and late in the cycles.

Associated Deposit Types Ag-base-metal veins, fluorspar deposits. On the basis of similar geochemistry of associated rhyolite magmas, rhyolite-hosted Sn deposits may be a surface expression. Porphyry tungsten deposits, as at Mount Pleasant, Canada, may be W-rich Climax systems.

DEPOSIT DESCRIPTION

Mineralogy Molybdenite + quartz ± fluorite ± K-feldspar ± pyrite ± wolframite ± cassiterite ± topaz.

Texture/Structure Predominantly in veinlets and fractures; minor disseminations.

Alteration Intense quartz and quartz + K-feldspar veining in ore zone. Upper phyllic and propylitic zones. Halo of rhodochrosite, rhodonite, spessartine garnet. Minor greisen veins below ore body.

Ore Controls Stockwork ore zone draped over small, <1 km2 stocks. Multiple phases of intrusion and mineralization are highly favorable.

Weathering Yellow ferrimolybdite stains.

Geochemical Signature Mo, Sn, W and Rb anomalies close above ore zones. Pb, Zn, F, and U anomalies in wall rocks up to a few kilometers distant. Cu anomaly external to Mount Emmons deposit. In panned concentrates, Sn, W, Mo, and F may be important.

EXAMPLES

Worldwide:
Redwell Basin, Winfield, Middle Mtn., Climax, Henderson, and Mt. Emmons, USCO
Pine Grove, USUT
Mount Hope, USNV
Big Ben, USMT

WSRA Project Area and Vicinity:
Majuba Hill (?)

DESCRIPTIVE MODEL OF PORPHYRY Mo, LOW-F
(modified from Theodore, 1986)

APPROXIMATE SYNONYM Calc-alkaline Mo stockwork (Westra and Keith, 1981).

DESCRIPTION Stockwork of quartz-molybdenite veinlets in felsic porphyry and in its nearby country rock.

GENERAL REFERENCE Westra and Keith (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite, granodiorite, and monzogranite.

Textures Porphyry, fine aplitic groundmass.

Age Range Mesozoic and Tertiary.

Depositional Environment Orogenic belt with calcalkaline intrusive rocks.

Tectonic Setting(s) Numerous faults.

Associated Deposit Types Porphyry Cu-Mo, Cu skarn, volcanic hosted Cu-As-Sb.

DEPOSIT DESCRIPTION

Mineralogy Molybdenite + pyrite + scheelite + chalcopyrite + argentian tetrahedrite. Quartz + K-feldspar + biotite + calcite + white mica and clays.

Texture/Structure Disseminated and in veinlets and fractures.

Alteration Potassic outward to propylitic. Phyllic and argillic overprint

Ore Controls Stockwork in felsic porphyry and in surrounding country rock.

Weathering Yellow ferrimolybdite after molybdenite. Secondary copper enrichment may form copper ores in some deposits.

Geochemical Signature Zoning outward and upward from Mo + Cu ± W to Cu + Au to Zn + Pb, + Au, + Ag. F may be present but in amounts less than 1,000 ppm.

EXAMPLES

Worldwide:

USSR deposits (Pavlova and Rundquist, 1980)

WSRA Project Area and Vicinity:

Buckingham, Copper Basin, Battle Mountain district

DESCRIPTIVE MODEL OF W SKARN DEPOSITS
(modified from Cox, 1986a)

DESCRIPTION Scheelite in calc-silicate contact metasomatic rocks.

GENERAL REFERENCE Einaudi and Burt (1982), Einaudi and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Tonalite, granodiorite, quartz monzonite; limestone.

Textures Granitic, granoblastic.

Age Range Mainly Mesozoic, but may be any age

Depositional Environment Contacts and roof pendants of batholith and thermal aureoles of apical zones of stocks that intrude carbonate rocks.

Tectonic Setting(s) Orogenic belts. Syn-late orogenic.

Associated Deposit Types Sn-W skarns, Zn skarns.

DEPOSIT DESCRIPTION

Mineralogy Scheelite ± molybdenite ± pyrrhotite ± sphalerite ± chalcopyrite ± bornite ± arsenopyrite ± pyrite ± magnetite ± traces of wolframite, fluorite, cassiterite, and native bismuth.

Alteration Diopside-hedenbergite + grossular-andradite. Late stage spessartine + almandine. Outer barren wollastonite zone. Inner zone of massive quartz may be present.

Ore Controls Carbonate rocks in thermal aureoles of intrusions.

Geochemical Signature W, Mo, Zn, Cu, Sn, Bi, Be, As.

EXAMPLES

Worldwide:

Pine Creek, USCA
MacTung, CNBC
Strawberry, USCA

WSRA Project Area and Vicinity:

Mill City
Potosi district (Osgood Mountains)

DESCRIPTIVE MODEL OF W VEINS
(modified from Cox and Bagby, 1986)

APPROXIMATE SYNONYM Quartz-wolframite veins (Kelly and Rye, 1979).

DESCRIPTION Wolframite, molybdenite, and minor base-metal sulfides in quartz veins

GEOLOGICAL ENVIRONMENT

Rock Types Monzogranite to granite stocks intruding sandstone, shale, and metamorphic equivalents.

Textures Phanerocrystalline igneous rocks, minor pegmatitic bodies, and porphyroaphanitic dikes.

Age Range Paleozoic to late Tertiary.

Depositional Environment Tensional fractures in epizonal granitic plutons and their wallrocks.

Tectonic Setting(s) Belts of granitic plutons derived from remelting of continental crust. Country rocks are metamorphosed to greenschist facies.

Associated Deposit Types Sn-W veins, pegmatites.

DEPOSIT DESCRIPTION

Mineralogy Wolframite, molybdenite, bismuthinite, pyrite, pyrrhotite, arsenopyrite, bornite, chalcopyrite, scheelite, cassiterite, beryl, fluorite; also at Pasto Bueno, tetrahedrite-tennantite, sphalerite, galena, and minor enargite.

Texture/Structure Massive quartz veins with minor vugs, parallel walls, local breccia.

Alteration Deepest zones, pervasive albitization; higher pervasive to vein-selvage pink K-feldspar replacement with minor disseminated REE minerals; upper zones, vein selvages of dark-gray muscovite or zinnwaldite (greisen). Chloritization. Widespread tourmaline alteration at Isla de Pinos.

Ore Controls Swarms of parallel veins cutting granitic rocks or sedimentary rocks near igneous contacts.

Weathering Wolframite persists in soils and stream sediments. Stolzite and tungstite may be weathering products.

Geochemical Signature W, Mo, Sn, Bi, As, Cu, Pb, Zn, Be, F.

EXAMPLES

Worldwide:

Pasto Bueno, PERU
Xihuashan, CINA
Isla de Pinos, CUBA
Hamme District, USNC
Round Mountain, USNV
Chicote Grande, BLVA

WSRA Project Area and Vicinity:

Rye Patch district (Humboldt Range)
Warm Springs district

DESCRIPTIVE MODEL OF COMSTOCK-CREEDE EPITHERMAL VEINS
(modified from Berger, 1986b; Albino, unpub. data)

APPROXIMATE SYNONYM Bonanza vein (in part)

DESCRIPTION gold and/or electrum with variable amounts of base metal sulfides in banded quartz veins, mainly in volcanic rocks

GENERAL REFERENCE Heald and others (1987), Bonham (1988)

GEOLOGICAL ENVIRONMENT

Rock Types differentiated andesite-dacite sequences, associated sub-volcanic intrusions

Textures volcanics are flows, flow breccias, laharic breccias, variably apahanitic to porphyritic, becoming more porphyritic with time, intrusive rocks typically porphyritic

Age Range North American examples mainly Oligocene and younger, can be any age

Depositional Environment in large andesitic stratovolcanoes, possibly associated with intrusive phases

Tectonic Setting continental or oceanic magmatic arc - main arc

Associated Deposit Types porphyry Cu, polymetallic replacements, Zn skarns, Ag-Pb mantos, polymetallic veins, lithocap Au-Ag, enargite-pyrite veins and replacements

DEPOSIT DESCRIPTION

Mineralogy Au or electrum, sphalerite, galena, chalcopyrite, tetrahedrite, Ag sulfosalts, vein hematite, chlorite fairly common, Mn carbonates (either Mn calcite of rhodochrosite) and/or rhodonite common, amythest common; barite locally present, true chalcedony and opal rare, very minor. Abundance of base metal sulfides-sulfosalts extremely variable (<.5% to >10%),may show vertical zoning in abundance, and in hematite/chlorite.

Texture/Structure early replacive silica, main stages characterized by open-space filling, well-developed comb and cockade structures, quartz commonly very coarsely crystalline, lamellar quartz after calcite fairly common, but typically is only locally present, is very coarse-grained, and occurs paragenetically late, hydrothermal breccias rare

Alteration regional 'low-grade' propylitization (chlorite-calcite-epidote-pyrite/hematite), restricted vein-related propylitic, dense rock with sericite, abundant pyrite, vein related sericite/illite-pyrite, locally with central zone of pervasive silicification±adularia. High in system get kaolinitic and locally alunite-bearing argillic alteration

Ore Controls pre-ore faults of moderate to large displacement, some related to caldera development, ore shoots typically have strong elevation control, influenced by irregularities in fault plane

Weathering illitic-argillic 'cap' may be seen as bleached, goethite-jarosite stained zone along fault, veins may be prominent, otherwise very subtle expression

Geochemical Signature — Au, Ag, Zn, Pb, Cu, As, Sb, Mn; may be strongly zones, with Au diminishing, and base metals incerasing at depth; Ag:Au typically >25:1, up to >1000:1, Ag:Au and Cu:Pb+Zn reflects composition of associated igneous rocks

EXAMPLES

Worldwide:

Creede, USCO
Comstock Lode, USNV
Tonopah, USNV
Mogollon, USNM
Misima, PPNG
Baguio, PLPN
Guanajuato, MXCO
Oatman, USAZ
Marysville, USMT
Gold Mountain, USUT
Camp Bird, USCO
Pajingo, AUQL
Waihi, NZLD
El Bronce, CILE
El Oro, MXCO

WSRA Project Area and Vicinity:

Desert District ?
Jessup district

DESCRIPTIVE MODEL OF EPITHERMAL QUARTZ-ALUNITE Au
(modified from Berger, 1986c)

APPROXIMATE SYNONYM Acid-sulfate, or enargite gold (Ashley, 1982).

DESCRIPTION Gold, pyrite, and enargite in vuggy veins and breccias in zones of high-alumina alteration related to felsic volcanism.

GENERAL REFERENCE Ashley (1982), Heald and others (1987), Bonham (1988)

GEOLOGICAL ENVIRONMENT

Rock Types Volcanic: dacite, quartz latite, rhyodacite, rhyolite. Hypabyssal intrusions or domes.

Textures Porphyritic.

Age Range Generally Tertiary, but can be any age.

Depositional Environment Within the volcanic edifice, ring fracture zones of calderas, or areas of igneous activity with sedimentary evaporites in basement.

Tectonic Setting(s) Through-going fracture systems: keystone graben structures, ring fracture zones, normal faults, fractures related to doming, joint sets.

Associated Deposit Types Porphyry copper, polymetallic replacement, volcanic hosted Cu-As-Sb. Pyrophyllite, hydrothermal clay, and alunite deposits.

DEPOSIT DESCRIPTION

Mineralogy Native gold + enargite + pyrite + silver-bearing sulfosalts ± chalcopyrite ± bornite ± precious-metal tellurides ± galena ± sphalerite ± huebnerite. May have hypogene oxidation phase with chalcocite + covellite ± luzonite with late-stage native sulfur.

Texture/Structure Veins, breccia pipes, pods, dikes; replacement veins often porous, and vuggy, with comb structure, and crustified banding.

Alteration Highest temperature assemblage: quartz + alunite + pyrophyllite may be early stage with pervasive alteration of host rock and veins of these minerals; this zone may contain corundum, diaspore, andalusite, or zunyite. Zoned around quartz-alunite is quartz + alunite + kaolinite + montmorillonite; pervasive propylitic alteration (chlorite + calcite) depends on extent of early alunitization. Ammonium-bearing clays may be present.

Ore Controls Through-going fractures, centers of intrusive activity. Upper and peripheral parts of porphyry copper systems.

Weathering Abundant yellow limonite, jarosite, goethite, white argillization with kaolinite, fine-grained white alunite veins, hematite.

Geochemical Signature Higher in system: Au + As + Cu; increasing base metals at depth. Also Te and (at El Indio) W.

EXAMPLES

Worldwide:

Goldfield, USNV
Kasuga mine, JAPN
El Indio, CILE
Summitville, USCO
Iwato, JAPN

DESCRIPTIVE MODEL OF HOT SPRING Au-Ag DEPOSITS
(modified from Berger, 1986a; Albino, unpub. data)

APPROXIMATE SYNONYM

DESCRIPTION Finely disseminated gold, electrum and minor sulfides in veinlets, breccia matrix, and primary porous horizons in volcanic and related sedimentary rocks

GENERAL REFERENCE Nelson (1988)

GEOLOGICAL ENVIRONMENT

Rock Types Rhyolite domes common, bimodal basalt/andesite-rhyolite, bulbous rhyolite dikes, alluvial clastic rocks, silica sinter

Textures Felsic volcanic rocks typically porphyritic, clastic rocks typically fairly well-sorted

Age Range Almost all documented examples Tertiary, mainly Miocene or younger. A few Paleozoic examples outside of North America

Depositional Environment Near or at paleosurface, commonly associated with development of local to widespread clastic basins and/or rhyolite dome fields, associated with steeply-dipping normal faults

Tectonic Setting Continental extensional zones, in extensional zones along major strike-slip faults, transtensional basins

Associated Deposit Types Rare, occasionally Ag-Sn-Mo-Bi bearing polymetallic veins

DEPOSIT DESCRIPTION

Mineralogy Opaque minerals typically very sparse, native Au or low-finenesss electrum and Ag selenides/sulfoselenides, pyrite as alteration of wall rocks, locally abundant stibnite, cinnabar in near surface, rarely native sulfur

Texture/Structure Veinlets and sinter typically finely banded, chalcedonic to opaline, randomly oriented, abundant open space typically preserved. Hydrothermal breccias common, may get hydothermal reuption craters. Adularia as overgrowths on detrital feldspars. Where argillized may get vuggy silica-alunite-clay zones

Alteration Variable, probably depending on position of paleo-water table. I) adularization with some silica addition up to paleosurface, with associated silica sinter, or; II) argillization (including kaolinitic or illitic clays) and leaching close to paleosurface, with adularization and silicification at depth. Peripheral smectitic clays, widespread propylitization uncommon.

Ore Controls Steep faults typically primary control, secondary controls include elevation and primary or tectonic permeability

Weathering — Silicified and/or adularized zones may form prominent topographic highs, colors typically subtle in centre of zone, peripheral reddening (hematite) in some examples, if argillization important may get large bleached areas (recessive weathering)

Geochemical Signature — Au, Ag, Sb, Hg, As, Se, Mo; Ag:Au <1 to ca. 100, but only very rarely >25. Base metals extremely low, Bi absent

EXAMPLES

Worldwide:

McLaughlin (USCA)
Buckhorn (USNV)
Hasbrouck Peak (USNV)
Grassy Mountain (USOR)
Milestone (USID)
McDonald Meadows (USMT)

WSRA Project Area and Vicinity:

Hog Ranch
Wind Mountain
Florida Canyon
Sulphur district
Sleeper, National district (sub-hot-spring deposits)

DESCRIPTIVE MODEL OF HOT-SPRING Hg
(modifified from Rytuba, 1986)

APPROXIMATE SYNONYMS Sulphur Bank type of White (1981) or sulfurous type of Bailey and Phoenix (1944).

DESCRIPTION Cinnabar and pyrite disseminated in siliceous sinter superjacent to graywacke, shale, andesite, and basalt flows and diabase dikes.

GEOLOGICAL ENVIRONMENT

Rock Types Siliceous sinter, andesite-basalt flows, diabase dikes, andesitic tuffs, and tuff breccia.

Age Range Tertiary.

Depositional Environment Near paleo ground-water table in areas of fossil hot-spring system.

Tectonic Setting(s) Continental margin rifting associated with small volume mafic to intermediate volcanism.

Associated Deposit Types Hot-spring Au.

DEPOSIT DESCRIPTION

Mineralogy Cinnabar + native Hg + minor marcasite.

Texture/Structure Disseminated and coatings on fractures in hot-spring sinter.

Alteration Above paleo ground-water table, kaolinite-alunite-Fe oxides, native sulfur; below paleo ground-water table, pyrite, zeolites, potassium feldspar, chlorite, and quartz. Opal deposited at the paleo water table.

Ore Controls Paleo ground-water table within hot-spring systems developed along high-angle faults.

Geochemical Signature Hg + As + Sb + Au.

EXAMPLES

Worldwide:

Sulfur Bank, USCA

WSRA Project Area and Vicinity:

Opalite district
Gold Banks district

DESCRIPTIVE MODEL OF EPITHERMAL Mn
(modified from Mosier, 1986b)

DESCRIPTION Manganese mineralization in epithermal veins filling faults and fractures in subaerial volcanic rocks.

GEOLOGICAL ENVIRONMENT

Rock Types Flows, tuffs, breccias, and agglomerates of rhyolitic, dacitic, andesitic or basaltic composition.

Age Range Tertiary.

Depositional Environment Volcanic centers.

Tectonic Setting(s) Through-going fracture systems.

Associated Deposit Types Epithermal gold-silver.

DEPOSIT DESCRIPTION

Mineralogy Rhodochrosite, manganocalcite, calcite, quartz, chalcedony, barite, zeolites.

Texture/Structure Veins, bunches, stringers, nodular masses, disseminations.

Alteration Kaolinitization.

Ore Controls Through-going faults and fractures; brecciated volcanic rocks.

Weathering Oxidization zone contains abundant manganese oxides, psilomelane, pyrolusite, braunite, wad, manganite, cryptomelane, hollandite, coronadite, and Fe oxides.

Geochemical Signature Mn, Fe, P(Pb, Ag, Au, Cu). At Talamantes W is important.

EXAMPLES

Worldwide:

Talamantes, MXCO
Gloryana, USNM
Sardegna, ITLY

DESCRIPTIVE MODEL OF CARLIN-TYPE Au DEPOSITS

(modified from Berger, 1986d; Albino, unpub. data)

APPROXIMATE SYNONYM Sediment-hosted epithermal gold

DESCRIPTION Au, commonly within crystal structure of disseminated pyrite, in variably silicified, argillized and decalcified sedimentary rocks

GENERAL REFERENCE Tooker (1985)

GEOLOGICAL ENVIRONMENT

Rock Types may be in virtually any rock type (calcareous or siliceous sedimentary rocks, skarn, mafic metavolcanics, felsic intrusive rocks) occurring within deposit area. Often favors calcareous siliciclastic units. Close spatial association in a number of areas with Mesozoic plutons; closely related Tertiary intrusive rocks uncommon, most are post-ore.

Textures many favorable hosts thin-bedded, flaggy mixed carbonate-siliciclastics. Mesozoic intrusive rocks porphyritic to equigranular - associated (Mesozoic) skarns coarse-grained. Tertiary intrusives glassy-porphyritic.

Age Range Favored interpretation of late Eocene-early Oligocene age - controversial.

Depositional Environment at moderate depths in linear belts in extensional environments near craton margin

Tectonic Setting controversial - favored interpretation is back-arc extensional zone.

Associated Deposit Types controversial, but favored interpretation is no genetically related deposit types known

DEPOSIT DESCRIPTION

Mineralogy Au-bearing arsenian pyrite, stibnite, realgar (orpiment), cinnabar, Tl-sulfides, rare Ag-Sb, Pb-Sb sulfosalts, sphalerite - total sulfide content from <1% to local essentially massive pyrite accumulations

Texture/Structure greatly variable depending largely on host rock nature - in calcareous rocks stratabound replacement common, local brecciation as a result of solution collapse; in non-reactive rocks mm-size stockwork veinlets to m-size vitreous quartz veins. Stratabound jasperoid commonly at unit contacts - brecciated texture common

Alteration decalcification of carbonate units, formation of secondary dolomite at intermediate stage, dolomite removed in intensely altered zones. Silification as jasperoidal replacement (jasperoids have characteristic reticulated textures in most examples) or subtle silica cementation. Some jasperoids are actually open-space. Breakdown of K-feldspar to illite(?) with kaolinite in most intensely altered, barite in veinlets and massive replacement with silica. Calcite veins commonly occur in hangingwall of mineralized zone, locally composite (early) jasperoidal silica-calcite veins.

Ore Controls — First order control appears to be location within geologically ill-defined 'trends' or regions. Second-order control is location along or adjacent to steeply-dipping (presumably deeply-penetrating) normal faults, generally parallel to strike of overall 'trend'. Local control is typically structural/stratigraphic (imbricate thrust zones generate major strata-parallel permeability) and/or elevation - mixing of deep-derived and surface-derived fluids may control Au precipitation, so hydrologic factors (i.e. boundary between two hydrologic regimes) may be important.

Weathering — In almost all cases of outcropping/subcropping mineralization get some prominent outcrops of hematitic jasperoid (may be Au-bearing, but typically sub-ore grade) - areas of decalcification (i.e. ore in most cases) typically recessive-weathering. Areas of gossanous Fe-staining developed in siliceous rocks where heavy sulfide veins (with some silica) are common. In some areas get yellow-green seconadry As-Sb minerals.

Geochemical Signature — Au, Ag (Ag:Au generally <1, in a few instances 2-5, may get early Ag-rich event), As, Sb, Hg (in highly variable amounts relative to Au; As and Hg anomalis usually larger than zone of Au enrichment. Tl highly anomalous in some examples, minor to absent in others. Te absent to X ppm - **Bi absent**. Base metals typically at background levels. Where pre-Tertiary base metal mineralization occurs nearby may get X00 ppm Cu or Pb. Anomalous Zn in some deposits, but may be related to syngenetic enrichment. Enrichment of Ni, Co, V, Mo in some deposits - Mn normally not enriched, may be depleted.

EXAMPLES

Worldwide:

- Carlin Trend, USNV
  - Rain
  - Gold Quarry-Maggie Creek
  - Carlin
  - Universal Gas
  - Bluestar
  - Genesis
  - North Star-Deep Star
  - Post-Betze
  - Purple Vein
  - Ren
  - Bootstrap-Capstone
  - Dee
  - Rossi (Au)
- Independence Range, USNV
  - Jerritt Canyon
  - Sammy Creek
  - Burns Basin
  - Wood Gulch-Dobie
  - New Deep
- Alligator Ridge, USNV
- Cortez Trend, USNV
  - Cortez
  - Horse Canyon
  - Gold Acres
  - Pipeline
  - Tonkin Springs
  - Gold Bar
  - Gold Pick etc.
- Eureka area, USNV
  - Windfall
  - Rustler
  - Ratto Canyon
- Oquirrh Mountains, USUT
  - Mercur
  - Barney's Canyon
  - Melco

WSRA Project Area and Vicinity:

- Osgood Mountains
  - Chimney Creek
  - Rabbit Creek
  - Getchell
  - Pinson
  - Preble
- Marigold deposits (?)

DESCRIPTIVE MODEL OF LOW SULFIDE Au-QUARTZ VEINS
(modified from Berger, 1986e; Albino, unpub. data)

APPROXIMATE SYNONYM Mother Lode-type

DESCRIPTION Au in quartz veins and carbonate-altered selvages associated with Fe-sulfides

GENERAL REFERENCE

GEOLOGICAL ENVIRONMENT

Rock Types ultramafic to felsic metavolcanics, immature clastic metasediments, oxide facies BIF, small gabbroic to trondhjemitic plugs and dikes, mainly metamorphosed under regional greenschist to lower amphibolite grade conditions.

Textures variably well-preserved primary igneous/sedimentary textures giving way to strongly foliated schists, mylonite, phyllonite and cataclasite

Age Range Archean to Tertiary - most important examples are Archean, with some important Paleozoic to Mesozoic examples

Depositional Environment In regionally extensive transpressive shear zones, mainly at depths in excess of 5 km, associated on regional basis with batholith emplacement

Tectonic Setting transpressive zones inboard of subduction zones, associated with oblique plate convergence and development ot plutono-metamorphic belt - most deposits in accreted terranes

Associated Deposit Types (spatially) associated Cyprus, Besshi and Kuroko/Noranda-type massive sulfide, Algoman-type BIF, komatiite or dunite-hosted Ni-Cu, genetically-related Grass Valley-type and pocket-type Au-quartz veins, saddle reef quartz veins, placer Au-PGE

DEPOSIT DESCRIPTION

Mineralogy Au closely associated with (can be as solid solution within) pyrite, arsenopyrite (commonly see several textural varieties in single specimen), less commonly pyrrhotite. Very minor base metal sulfides, rare base metal and Au, Ag, and Hg tellurides, rare sulfosalts - scheelite and/or molybdenite in some examples. In wall rocks as well, Fe-sulfides dominant

Texture/Structure veins massive 'bull' to ribboned, may be sheared and disrupted - typically moderately to strongly recrystallized. Occur as steep fissure-fillings, sets of en echelon shear veins, or flat 'ladder'-type extension veins on various scales. Crustiform or similar textures essentially absent. Alteration zones may preserve original rock texture or be massive granoblastic or sheared

Alteration dependent on wall rock composition - ultramafic rocks -> magnesite-quartz-Cr-muscovite-Fe sulfide; mafic rocks Fe-dolomite/ankerite-quartz-albite or sericite-pyrite±arsenopyrite± pyrrhotite; quartzofeldspathic rocks albite-Fe-dolomite or calcite-pyrite, Fe-rich sediments siderite-quartz-pyrrhotite. Tourmaline may be present as trace to very abundant. In amphibolite grade rocks, biotite occurs instead of sericite, may include calcic amphiboles, garnet

Ore Controls First order control is major steeply-dipping fault within accretionary orogen - second order control is paleodepth (usually expressed in terms of metamorphic grade). Local controls are subsidiary faults, fault deflections or intersections. Lithology typically has minor role, but Fe-rich rocks (or those with high Fe/Mg) form better hosts for wall rock replacement ore

Weathering quartz veins may form prominent white outcrops - Fe-carbonate bearing alteration forms gossanous orange outcrops. major placer districts common in association with these deposits where located in unglaciated areas

Geochemical Signature Au (Ag) - Ag:Au almost always <1 to <<1), As, (Sb, Hg), Te, W, Mo, base metals not enriched or only weakly enriched relative to background

EXAMPLES

Worldwide:

Kennedy, USCA
Keystone, USCA
Bunker Hill, USCA
Harvard, USCA
Pine Tree-Josephine, USCA
Timmins district, CNON
Kerr-Addison, CNON
Sigma, CNQU
Nor-Acme, CNMN
San Antonio, CNMN
Vaucluse, USVA
Pine Cove, CNNF
Yellowknife district, CNNT
Kalgoorlie, AUWA
Carolin, CNBC
Treadwell, USAK

WSRA Project Area and Vicinity:

Rochester
Antelope district
Arabia district
Imlay district
Haystack district

DESCRIPTIVE MODEL OF KUROKO MASSIVE SULFIDE
(modified from Singer, 1986b)

<u>APPROXIMATE SYNONYM</u> Noranda type, volcanogenic massive sulfide, felsic to intermediate volcanic type.

<u>DESCRIPTION</u> Copper- and zinc-bearing massive sulfide deposits in marine volcanic rocks of intermediate to felsic composition.

<u>GENERAL REFERENCES</u> Ishihara (1974), Franklin and others (1981), Hutchinson and others (1982), Ohmoto and Skinner (1983).

GEOLOGICAL ENVIRONMENT

<u>Rock Types</u> Marine rhyolite, dacite, and subordinate basalt and associated sediments, principally organic-rich mudstone or shale. Pyritic, siliceous shale. Some basalt.

<u>Textures</u> Flows, tuffs, pyroclastics, breccias, bedded sediment, and in some cases felsic domes.

<u>Age Range</u> Archean through Cenozoic.

<u>Depositional Environment</u> Hot springs related to marine volcanism, probably with anoxic marine conditions. Lead-rich deposits associated with abundant fine-grained volcanogenic sediments.

<u>Tectonic Setting(s)</u> Island arc. Local extensional tectonic activity, faults, or fractures. Archean greenstone belt.

<u>Associated Deposit Types</u> Epithermal quartz-adularia veins in Japan are regionally associated but younger than kuroko deposits. Volcanogenic Mn, Algoma Fe.

DEPOSIT DESCRIPTION

<u>Mineralogy</u> Upper stratiform massive zone (black ore)--pyrite + sphalerite + chalcopyrite ± pyrrhotite ± galena ± barite ± tetrahedrite - tennantite ± bornite; lower stratiform massive zone (yellow ore)--pyrite + chalcopyrite ± sphalerite ± pyrrhotite ± magnetite; stringer (stockwork) zone--pyrite + chalcopyrite (gold and silver). Gahnite in metamorphosed deposits. Gypsum/anhydrite present in some deposits.

<u>Texture/Structure</u> Massive (>60 percent sulfides); in some cases, an underlying zone of ore stockwork, stringers or disseminated sulfides or sulfide-matrix breccia. Also slumped and redeposited ore with graded bedding.

<u>Alteration</u> Adjacent to and blanketing massive sulfide in some deposits--zeolites, montmorillonite (and chlorite?); stringer (stockwork) zone--silica, chlorite, and sericite; below stringer--chlorite and albite. Cordierite and anthophyllite in footwall of metamorphosed deposits, graphitic schist in hanging wall.

<u>Ore Controls</u> Toward the more felsic top of volcanic or volcanic-sedimentary sequence. Near center of felsic volcanism. May be locally brecciated or have felsic dome nearby. Pyritic siliceous rock (exhalite) may mark horizon at which deposits occur. Proximity to deposits may be indicated by

sulfide clasts in volcanic breccias. Some deposits may be gravity-transported and deposited in paleo depressions in the seafloor. In Japan, best deposits have mudstone in hanging wall.

Weathering — Yellow, red, and brown gossans. Gahnite in stream sediments near some deposits.

Geochemical Signature — Gossan may be high in Pb and typically Au is present. Adjacent to deposit-enriched in Mg and Zn, depleted in Na. Within deposits--Cu, Zn, Pb, Ba, As, Ag, Au, Se, Sn, Bi, Fe.

EXAMPLES

Worldwide:	WSRA Project Area and Vicinity:
Kidd Creek, CNON	Jackson Mountains (?)
Mt. Lyell, AUTS	Pine Forest Range (?)
Brittania, CNBC	Pueblo Mountains (?)
Buchans, CNNF	

DESCRIPTIVE MODEL OF BESSHI MASSIVE SULFIDE

(modified from Cox, 1986h)

APPROXIMATE SYNONYM Besshi type, Kieslager.

DESCRIPTION Thin, sheetlike bodies of massive to well-laminated pyrite, pyrrhotite, and chalcopyrite within thinly laminated clastic sediments and mafic tuffs.

GENERAL REFERENCES Klau and Large (1980), Fox (1984).

GEOLOGICAL ENVIRONMENT

Rock Types Clastic terrigenous sedimentary rocks and tholeiitic to andesitic tuff and breccia. Locally, black shale, oxide-facies iron formation, and red chert.

Textures Thinly laminated clastic rocks. All known examples are in strongly deformed metamorphic terrane. Rocks are quartzose and mafic schist.

Age Range Mainly Paleozoic and Mesozoic.

Depositional Environment Uncertain. Possibly deposition by submarine hot springs related to basaltic volcanism. Ores may be localized within permeable sediments and fractured volcanic rocks in anoxic marine basins.

Tectonic Setting(s) Uncertain. Possibly rifted basin in island arc or back arc. Possibly spreading ridge underlying terrigenous sediment at continental slope.

Associated Deposit Types None known.

DEPOSIT DESCRIPTION

Mineralogy Pyrite + pyrrhotite + chalcopyrite + sphalerite ± magnetite ± valleriite ± galena ± bornite ± tetrahedrite ± cobaltite ± cubanite ± stannite ± molybdenite. Quartz, carbonate, albite, white mica, chlorite, amphibole, and tourmaline.

Texture/Structure Fine-grained, massive to thinly laminated ore with colloform and framboidal pyrite. Breccia or stringer ore. Cross-cutting veins contain chalcopyrite, pyrite, calcite or galena, sphalerite, calcite.

Alteration Difficult to recognize because of metamorphism. Chloritization of adjacent rocks is noted in some deposits.

Ore Controls Uncertain. Deposits are thin, but laterally extensive and tend to cluster in en echelon pattern.

Weathering Gossan.

Geochemical Signature Cu, Zn, Co, Ag, Ni, Cr, Co/Ni >1.0, Au up to 4 ppm, Ag up to 60 ppm.

EXAMPLES

Worldwide:

Besshi, JAPN
Motoyasu, JAPN
Kieslager, ASTR
Raul, PERU

WSRA Project Area and Vicinity:

Rio Tinto deposit, Elko Co.

DESCRIPTIVE MODEL OF CYPRUS MASSIVE SULFIDE
(modified from Singer, 1986a)

APPROXIMATE SYNONYM Cupreous pyrite.

DESCRIPTION Massive pyrite, chalcopyrite, and sphalerite in pillow basalts.

GENERAL REFERENCE Franklin and others (1981).

GEOLOGICAL ENVIRONMENT

Rock Types Ophiolite assemblage: tectonized dunite and harzburgite, gabbro, sheeted diabase dikes, pillow basalts, and fine-grained metasedimentary rocks such as chert and phyllite.

Textures Diabase dikes, pillow basalts, and in some cases brecciated basalt.

Age Range Archean(?) to Tertiary--majority are Ordovician or Cretaceous.

Depositional Environment Submarine hot spring along axial grabens in oceanic or back-arc spreading ridges. Hot springs related to submarine volcanoes producing seamounts.

Tectonic Setting(s) Ophiolites. May be adjacent to steep normal faults.

Associated Deposit Types Mn and Fe-rich cherts regionally.

DEPOSIT DESCRIPTION

Mineralogy Massive: pyrite + chalcopyrite + sphalerite + marcasite + pyrrhotite. Stringer (stockwork): pyrite + pyrrhotite, minor chalcopyrite and sphalerite (cobalt, gold, and silver present in minor amounts).

Texture/Structure Massive sulfides (>60 percent sulfides) with underlying sulfide stockwork or stringer zone. Sulfides brecciated and recemented. Rarely preserved fossil worm tubes.

Alteration Stringer zone--feldspar destruction, abundant quartz and chalcedony, abundant chlorite, some illite and calcite. Some deposits overlain by ochre (Mn-poor, Fe-rich bedded sediment containing goethite, maghemite, and quartz).

Ore Controls Pillow basalt or mafic volcanic breccia, diabase dikes below; ores rarely localized in sediments above pillows. May be local faulting.

Weathering Massive limonite gossans. Gold in stream sediments.

Geochemical Signature General loss of Ca and Na and introduction and redistribution of Mn and Fe in the stringer zone.

EXAMPLES

Worldwide:
Cyprus deposits, CYPS
Oxec, GUAT
York Harbour, CNNF
Turner-Albright, USOR

WSRA Project Area and Vicinity:
Big Mike deposit, Sonoma Range

DESCRIPTIVE MODEL OF FRANCISCAN-TYPE VOLCANOGENIC MANGANESE.

(modified from Mosier and Page, 1988)

DESCRIPTION Lenses and stratiform bodies of manganese oxide, carbonate, and silicate in chert associated with sedimentary and mafic volcanic rocks. Genesis related to volcanogenic processes.

GENERAL REFERENCES Koski (1986).

GEOLOGIC ENVIRONMENT

Rock Types Chert, shale, sandstone, graywacke, jasper, tuff, basalt, and serpentine. Thin- and thick- bedded red or white chert and jasper are the predominant host rocks. Tholeiitic and alkaline volcanic rocks.

Textures White, red, brown, and green chert in thin-bedded or massive lenses, commonly with shale partings. Some of chert contains radiolarians.

Age Range Paleozoic to Jurassic.

Depositional Environment Sea-floor hot spring, deep water in a zone of oceanic upwelling at or near a continental margin.

Tectonic Setting(s) Oceanic ridges and rifted marginal basins (backarc setting) obducted onto a continental margin.

Associated Deposit Types Hot-Spring mercury, silica-carbonate mercury, podiform chromite.

DEPOSIT DESCRIPTION

Mineralogy Abundant psilomelane, pyrolusite, rhodochrosite, hausmannite, braunite, and neotocite; minor bementite, wad, rhodonite, inesite, pyrochroite, tephroite, ganophyllite, dannemorite, pyroxmangite, stilpnomelane, spessartine, pyrophanite, nsutite, manganite, cryptomelane, jacobsite, manjiroie, Mn-phlogopite, todorokite, piedmontite, hollandite, manganocalcite, birnessite, alleghanyite, galaxite, and alabandite.

Texture/Structure Fine-grained massive crystalline aggregates, botryoidal, colloform in bedded and lensoid masses; veinlets and disseminations.

Alteration Primary carbonates and silicates altered to oxides; some silicates altered to carbonates.

Ore Controls Sufficient structure and porosity to permit sub-sea-floor hydrothermal circulation and sea-floor venting; redox boundary at sea floor/seawater interface around hot springs; supergene enrichment to upgrade Mn content.

Weathering Strong development of secondary manganese oxides (psilomelane, pyrolusite, todorokite, birnessite, manganite) at the surface and along fractures.

Geochemical Signatures Mn, Fe, Cu, Hg, and Ba.

EXAMPLES

Worldwide:

Ladd mines, USCA
Noda-Tamagawa, JAPN

WSRA Project Area and Vicinity:

Black Diablo deposits
Buffalo Mountain district
Jersey Valley district
Black Rock Mine (Buffalo Valley district)

DESCRIPTIVE MODEL OF SEDIMENTARY EXHALATIVE Zn-Pb
(modified from Briskey, 1986)

APPROXIMATE SYNONYMS Shale-hosted Zn-Pb; sediment-hosted massive sulfide Zn-Pb.

DESCRIPTION Stratiform basinal accumulations of sulfide and sulfate minerals interbedded with euxinic marine sediments form sheet- or lens-like tabular ore bodies up to a few tens of meters thick, and may be distributed through a stratigraphic interval over 1,000 m.

GENERAL REFERENCES Large (1980, 1981, 1983).

GEOLOGICAL ENVIRONMENT

Rock Types Euxinic marine sedimentary rocks including: black (dark) shale, siltstone, sandstone, chert, dolostone, micritic limestone, and turbidites. Local evaporitic sections in contemporaneous shelf facies. Volcanic rocks, commonly of bimodal composition, are present locally in the sedimentary basin. Tuffites are the most common. Slump breccias, fan conglomerates, and similar deposits, as well as facies and thickness changes, are commonly associated with synsedimentary faults.

Textures Contrasting sedimentary thicknesses and facies changes across hinge zones. Slump breccias and conglomerates near synsedimentary faults.

Age Range Known deposits are Middle Proterozoic (1,700-1,400 m.y.); Cambrian to Carboniferous (530-300 m.y.).

Depositional Environment Marine epicratonic embayments and intracratonic basins, with smaller local restricted basins (second- and third-order basins).

Tectonic Setting(s) Epicratonic embayments and intracratonic basins are associated with hinge zones controlled by synsedimentary faults, typically forming half-grabens. Within these grabens (first-order basins), penecontemporaneous vertical tectonism forms smaller basins (second-order basins) and associated rises. Smaller third-order basins (tens of kilometers) within the second-order basins (102-105 km) are the morphological traps from the stratiform sulfides.

Associated Deposit Types Bedded barite deposits.

DEPOSIT DESCRIPTION

Mineralogy Pyrite, pyrrhotite, sphalerite, galena, sporadic barite and chalcopyrite, and minor to trace amounts of marcasite, arsenopyrite, bismuthinite, molybdenite, enargite, millerite, freibergite, cobaltite, cassiterite, valleriite, and melnikovite.

Texture/Structure Finely crystalline and disseminated, monomineralic sulfide laminae are typical. Metamorphosed examples are coarsely crystalline and massive.

Alteration Stockwork and disseminated sulfide and alteration (silicification, tourmalization, carbonate depletion, albitization, chloritization, dolomitization) minerals possibly representing the feeder zone of these deposits commonly present beneath or adjacent to the stratiform deposits. Some deposits have no reported alteration. Celsian, Ba-muscovite, and ammonium clay minerals may be present.

Ore Controls — Within larger fault-controlled basins, small local basins form the morphological traps that contain the stratiform sulfide and sulfate minerals. The faults are synsedimentary and serve as feeders for the stratiform deposits. Euxinic facies.

Weathering — Surface oxidation may form large gossans containing abundant carbonates, sulfates, and silicates of lead, zinc, and copper.

Geochemical Signature — Metal zoning includes lateral Cu-Pb-Zn-Ba sequence extending outward from feeder zone; or a vertical Cu-Zn-Pb-Ba sequence extending upward. NH3 anomalies may be present. Exhalative chert interbedded with stratiform sulfide and sulfate minerals; peripheral hematite-chert formations. Local (within 2 km) Zn, Pb, and Mn haloes. Highest expected background in black shales: Pb = 500 ppm; Zn = 1,300 ppm; Cu = 750 ppm; Ba = 1,300 ppm; in carbonates: Pb = 9 ppm; Zn = 20; Cu = 4 pmm; Ba = 10.

EXAMPLES

Worldwide:

Sullivan mine, CNBC
Navan, Silvermines, Tynagh, IRLD

DESCRIPTIVE MODEL OF VOLCANOGENIC U
(modified from Bagby, 1986)

DESCRIPTION Uranium mineralization in epithermal veins composed of quartz, fluorite, and iron, arsenic, and molybdenum sulfides.

GENERAL REFERENCE Nash (1981).

GEOLOGICAL ENVIRONMENT

Rock Types High-silica alkali rhyolite and potash trachytes. Peralkaline and peraluminous rhyolite host ore.

Textures Porphyritic to aphyric vesicular flows and shallow intrusive rocks.

Age Range Precambrian to Tertiary.

Depositional Environment Subaerial to subaqueous volcanic complexes. Near-surface environment, association with shallow intrusive rocks is important.

Tectonic Setting(s) Continental rifts and associated calderas.

Associated Deposit Types Roll-front uranium in volcaniclastic sediments. Fluorite deposits.

DEPOSIT DESCRIPTION

Mineralogy Coffinite, uraninite, brannerite are most common uranium minerals. Other minerals include pyrite, realgar/orpiment, leucoxene, molybdenite, fluorite, quartz, adularia, and barite. Gold is present in some deposits. Deposits associated with alkaline complexes may contain bastnaesite.

Texture/Structure Open-space filling in breccias. Uraninite commonly encapsulated in silica.

Alteration Kaolinite, montmorillonite, and alunite are common. Silicification, accompanied by adularia, affects wallrocks spatially most closely associated with ore.

Ore Controls Through-going fractures and breccias formed along the margins of shallow intrusives. Vugs in surface flows are of minor importance.

Weathering Near-surface oxidation produces jordisite and a variety of secondary uranium minerals. Supergene uranium enrichment is generally not important.

Geochemical Signature Li and Hg are zoned away from the ore. High anomalous As, Sb, F, Mo ± W occur near and with the ore. Mo is deep, Hg is shallow. REE may be highly anomalous. Anomalously radioactive.

EXAMPLES

Worldwide:

Marysvale, USUT
Aurora prospect, USOR
Rexspar, CNBC

WSRA Project Area and Vicinity:

McDermitt caldera area
Virgin Valley area
Soldier Meadows area

DESCRIPTIVE MODEL OF SANDSTONE U

(modified from Turner-Peterson and Hodges, 1986)

APPROXIMATE SYNONYMS Tabular U ore, roll front U.

DESCRIPTION Microcrystalline uranium oxides and silicates deposited during diagenesis in localized reduced environments within fine- to medium-grained sandstone beds; some uranium oxides also deposited during redistribution by ground water at interface between oxidized and reduced ground.

GENERAL REFERENCE Turner-Peterson and Fishman (1986), Granger and Warren (1969).

GEOLOGICAL ENVIRONMENT

Rock Types Host rocks are feldspathic or tuffaceous sandstone. Pyroclastic material is felsic in composition. Mudstone or shale commonly above and/or below sandstones hosting diagenetic ores.

Textures Permeable--medium to coarse grained; highly permeable at time of mineralization, subsequently restricted by cementation and alteration.

Age Range Most deposits are Devonian and younger. Secondary roll-front deposits mainly Tertiary.

Depositional Environment Continental-basin margins, fluvial channels, braided stream deposits, stable coastal plain. Contemporaneous felsic volcanism or eroding felsic plutons are sources of U. In tabular ore, source rocks for ore-related fluids are commonly in overlying or underlying mud-flat facies sediments.

Tectonic Setting(s) Stable platform or foreland-interior basin, shelf margin; adjacent major uplifts provide favorable topographic conditions.

Associated Deposit Types Sediment-hosted V may be intimately associated with U. Sediment-hosted Cu may be in similar host rocks and may contain U.

DEPOSIT DESCRIPTION

Mineralogy Uraninite, coffinite, pyrite in organic-rich horizons. Chlorite common.

Texture/Structure Stratabound deposits. Tabular U--intimately admixed with pore-filling humin in tabular lenses suspended within reduced sandstone. Replacement of wood and other carbonaceous material. Roll front U--in crescentic lens that cuts across bedding, at interface between oxidized and reduced ground.

Alteration Tabular--Humic acid mineralizing fluids leach iron from detrital magnetite-ilmenite leaving relict TiO_2 minerals in diagenetic ores. Roll front--Oxidized iron minerals in rock updip, reduced iron minerals in rock downdip from redox interface.

Ore Controls Permeability. Tabular--Humin or carbonaceous material the main concentrator of U. Roll front--S species, "sour" gas, FeS_2. Bedding sequences with low dips; felsic plutons or felsic tuffaceous sediments adjacent to or above host rock are favorable source for U. Regional redox interface marks locus of ore deposition.

Weathering: Oxidation of primary uraninite or coffinite to a variety of minerals, notably yellow carnotite as bloom in V-rich ores.

Geochemical and Geophysical Signature: U, V, Mo, Se, locally Cu, Ag. Anomalous radioactivity from daughter products of U. Low magnetic susceptibility in and near tabular ores.

EXAMPLES

Worldwide:

Colorado Plateau
Grants, USNM
Texas Gulf Coast
USWY

DESCRIPTIVE MODEL OF PLACER Au-PGE

(modified from Yeend, 1986)

DESCRIPTION Elemental gold and platinum-group alloys in grains and (rarely) nuggets in gravel, sand, silt, and clay, and their consolidated equivalents, in alluvial, beach, eolian, and (rarely) glacial deposits.

GENERAL REFERENCES Boyle (1979), Wells (1973), Lindgren (1911).

GEOLOGICAL ENVIRONMENT

Rock Types Alluvial gravel and conglomerate with white quartz clasts. Sand and sandstone of secondary importance.

Textures Coarse clastic.

Age Range Cenozoic. Older deposits may have been formed but their preservation is unlikely.

Depositional Environment High-energy alluvial where gradients flatten and river velocities lessen, as at the inside of meanders, below rapids and falls, beneath boulders, and in vegetation mats. Winnowing action of surf caused Au concentrations in raised, present, and submerged beaches.

Tectonic Setting(s) Tertiary conglomerates along major fault zones, shield areas where erosion has proceeded for a long time producing multicycle sediments; high-level terrace gravels.

Associated Deposit Types Black sands (magnetite, ilmenite, chromite); yellow sands (zircon, monazite). Au placers commonly derive from various Au vein-type deposits as well as porphyry copper, Cu skarn, and polymetallic replacement deposits.

DEPOSIT DESCRIPTION

Mineralogy Au, platinum-iron alloys, osmium-iridium alloys; gold commonly with attached quartz, magnetite, or ilmenite.

Texture/Structure Flattened, rounded edges, flaky, flour gold extremely fine grained flakes; very rarely equidimensional nuggets.

Ore Controls Highest Au values at base of gravel deposits in various gold "traps" such as natural riffles in floor of river or stream, fractured bedrock, slate, schist, phyllite, dikes, bedding planes, all structures trending transverse to direction of water flow. Au concentrations also occur within gravel deposits above clay layers that constrain the downward migration of Au particles.

Geochemical Signature Anomalous high amounts of Ag, As, Hg, Sb, Cu, Fe, S, and heavy minerals magnetite, chromite, ilmenite, hematite, pyrite, zircon, garnet, rutile. Au nuggets have decreasing Ag content with distance from source.

EXAMPLES

Worldwide: Sierra Nevada, USCA
Victoria, AUVT

WSRA Project Area and Vicinity:

Humboldt Range (Imlay, Unionville, Rochester and
Spring Valley districts)
Kamma Mountains area (Placerites, Rabbit Hole,
Rosebud and Sawtooth districts)
Battle Mountain district

APPENDIX 4

PROPOSED OUTLINE/TABLE OF CONTENTS FOR FINAL PRODUCT OF RESOURCE ASSESSMENT

SUMMARIES (Doebrich)

One-page Bullet Summary for Congressional Staff, etc

Five-Ten Page Non-Technical Summary

Executive Summary

INTRODUCTION (Doebrich)

GEOGRAPHIC INFORMATION

OBJECTIVES

STRATEGY

PREVIOUS ASSESSMENTS/CONCURRENT PROJECTS

GEOLOGIC SUMMARY (Doebrich)

PALEOZOIC GEOLOGY

- Early Paleozoic autochthonous rocks (miogeoclinal rocks)
- Early Paleozoic allochthonous rocks (Roberts Mountains allochthon and Antler Orogeny)
- Late Paleozoic autochthonous (Antler Sequence and equivalent rocks)
- Late Paleozoic allochthonous rocks (Havallah sequence and Sonoma Orogeny)

MESOZOIC GEOLOGY

- Review of allochthonous terrane theories
- Triassic shelfal, platformal and basinal rocks (Jungo terrane)
  - Koipato Volcanics
  - Star Peak Group
  - Auld Lang Syne Group
- Jurassic arc-related rocks (Jackson terrane)
  - Happy Creek Volcanic Complex
  - King Lear Formation (?)
- Cretaceous lacustrine rocks (King Lear Fm ?)
- Cretaceous intrusive rocks
- Discussion on Mesozoic Structure and Tectonics

CENOZOIC GEOLOGY

- Late Eocene to early Miocene "arc-related" calc-alkalic magmatism
  - Interior andesite-rhyolite volcanic assemblage
  - Intrusive rocks
- Middle Miocene to present continental magmatism, extension, and sedimentation
  - Bimodal basalt-rhyolite assemblage
  - Northern Nevada Rift
  - Midas Trough
  - Lacustrine rocks, Lake Lahanton sediments

SUMMARY

GEOCHEMICAL SUMMARY (King)

SOURCES OF DATA

- NURE, RASS, New USGS...

METHODS OF DATA MANIPULATION

Single element analysis (percentiles, histograms, probability)
Multivariate manipulations (New USGS data and other complete data sets)
INTERPRETATION
Useful elements and their geographic distribution
Relationships of high trace-metal concentrations to known deposits
Geochemical evidence for undiscovered deposits
Areas of contamination (Hg, As, ...)

GEOPHYSICAL SUMMARY (Plouff and Hanna)
INTRODUCTION
DATA DESCRIPTION
INTERPRETATION OF GEOPHYSICAL DATA
Gravity and magnetic derivative maps
Inferred plutons
Estimating thickness of Cenozoic rocks

HYDROTHERMAL ALTERATION CLASSIFICATION (Raines and others)
PURPOSE OF MAPPING
DEFINITION OF TERMINOLOGY
Types of alteration observed
Types of alteration observed
Limonite
Propylitic alteration
Solfataric alteration
Zeolitic alteration
Argillic alteration
Advanced argillic alteration
Skarns
Important types not observed by the satellite measurements
Opalitization
Silicification
De-calcification
Potassic alteration
SOURCES OF DATA
Color-ratio composite process with thematic classification based on a Munsell-transform
Western Mining Corporation (WMC) alteration maps
Kennecott Archive
References to computer processing methods
Field studies associated with this study
SUMMARY DESCRIPTION OF HYDROTHERMAL ALTERATION MAP
Altered areas associated with known mining districts
Altered areas not associated with known mining districts

ASSESSMENT FOR NON-FUEL MINERAL RESOURCES