

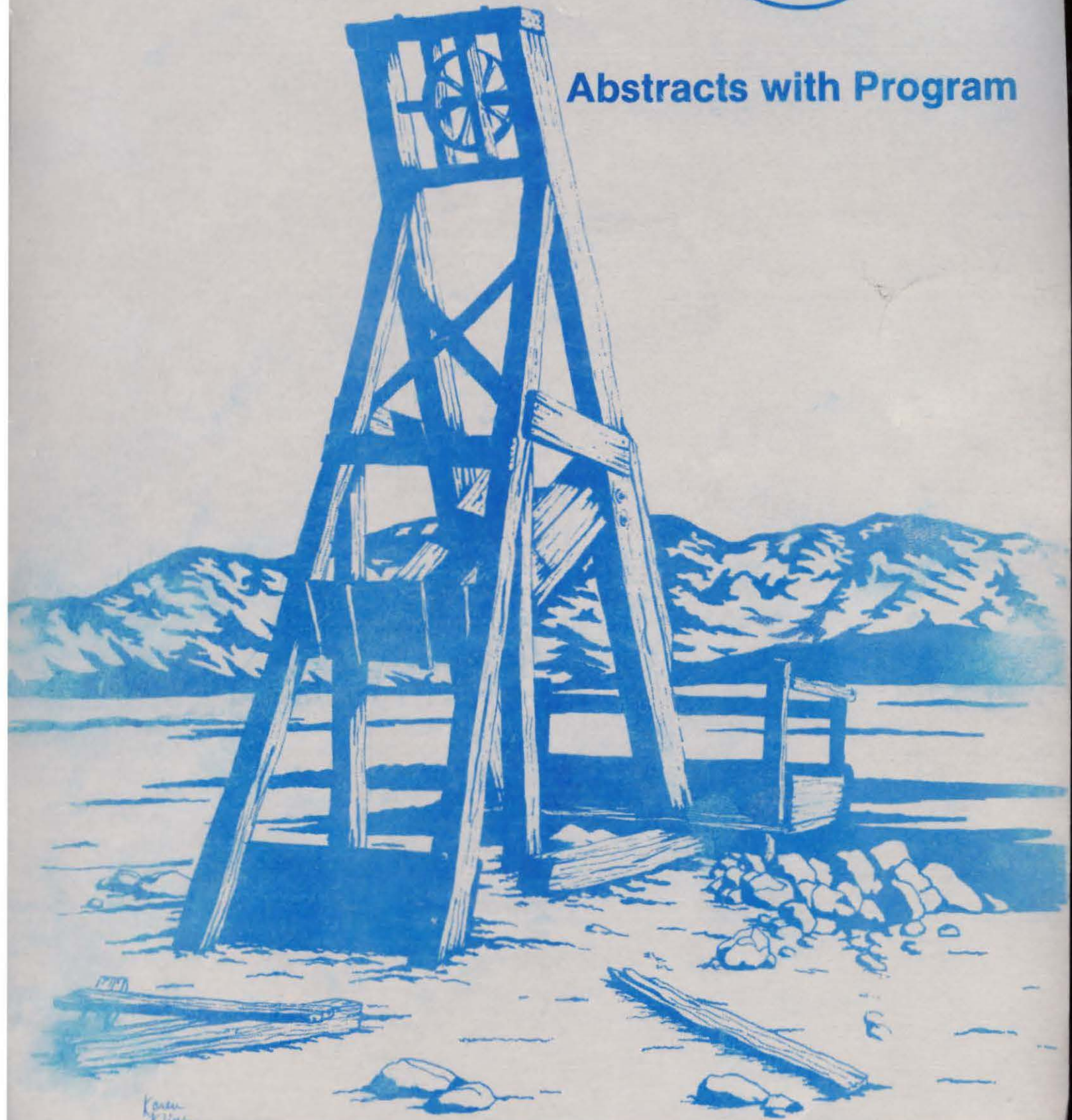
**EXPLORATION FOR ORE DEPOSITS
OF THE NORTH AMERICAN CORDILLERA**

*SYMPOSIUM OF THE ASSOCIATION
OF EXPLORATION GEOCHEMISTS*

Reno, Nevada • March 25-28, 1984



Abstracts with Program



*Karen
Kline*

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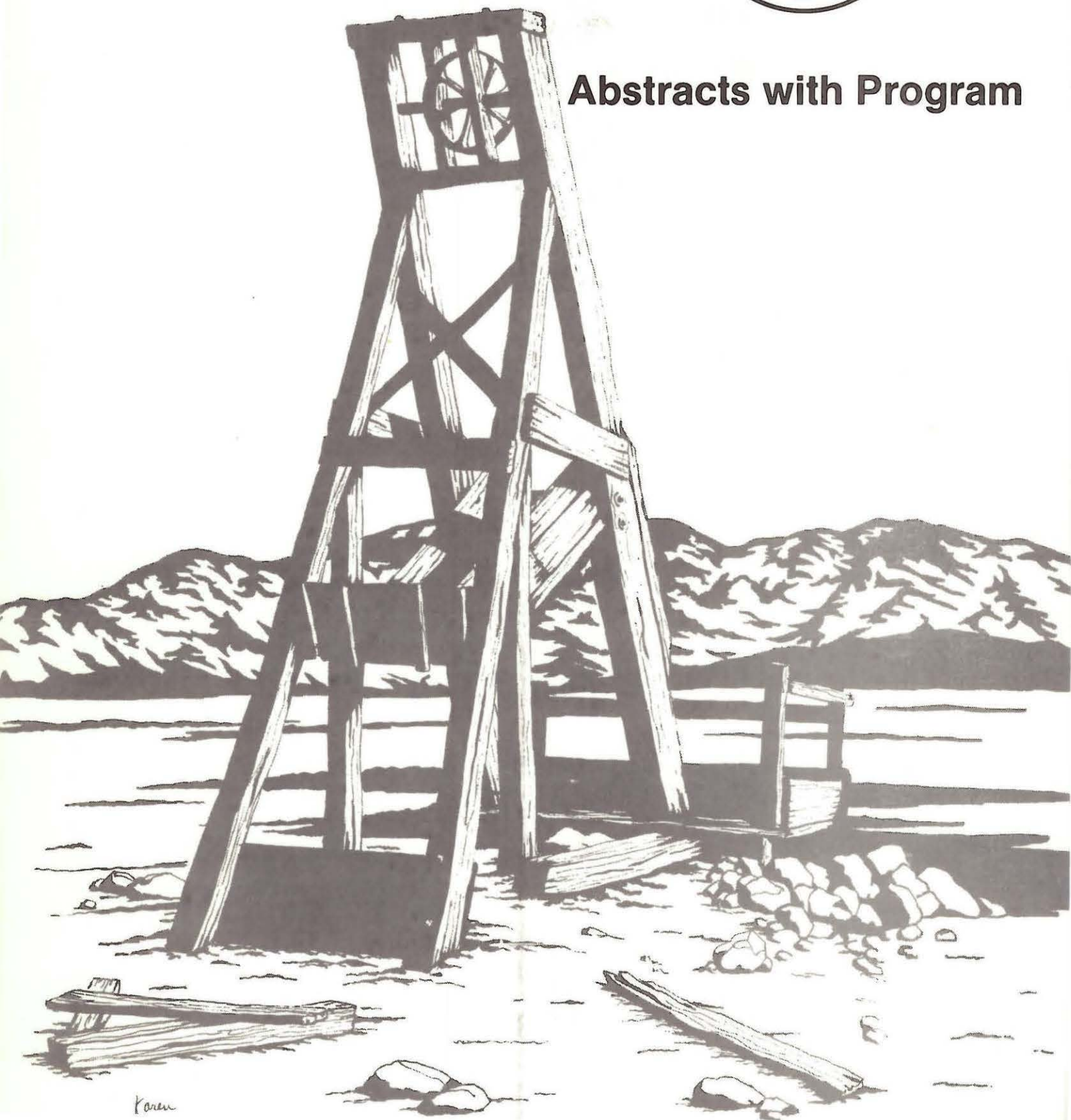


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— Illustrations by Kris Covington and Karen Kling —

THE ASSOCIATION OF EXPLORATION GEOCHEMISTS

1983-84 OFFICERS

President	L. G. Closs	Colorado School of Mines Golden, Colorado
Vice Presidents	R. G. Garrett	Geological Survey of Canada Ottawa, Ontario, Canada
	I. Thomson	Placer Development Ltd. Vancouver, B.C., Canada
Secretary	R. E. Lett	Barringer Magenta Toronto, Ontario, Canada
Treasurer	R. G. Jackson	Sulpetro Minerals Toronto, Ontario, Canada

1984-85 OFFICERS

President	R. G. Garrett	Geological Survey of Canada Ottawa, Ontario, Canada
Vice Presidents	I. Thomson	Placer Development Ltd. Vancouver, B.C., Canada
	G. H. Allcott	U.S. Geological Survey Reston, Virginia
Secretary	R. E. Lett	Barringer Magenta Toronto, Ontario, Canada
Treasurer	R. G. Jackson	Sulpetro Minerals Toronto, Ontario, Canada

RENO SYMPOSIUM EXECUTIVE COMMITTEE

Symposium Chairman	Chester E. Nichols	Nichols Associates
General Secretary	John C. Barnett	Garratt Geoservices, USA
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Telephone Sales	Bert W. Jeffries	Desert Ventures, Inc.
Telephone Sales	Robert D. Thomas, Jr.	Callahan Mining Corporation
Telephone Sales	Michael W. Brady	Ranchers Exploration and Development Company
Social and Guest Program Chairman	Alan J. Morris	Fischer-Watt Mining Company, Inc.
Editor Abstracts with Program	Lynne E. Volpi	Consultant



THE ASSOCIATION OF EXPLORATION GEOCHEMISTS

On behalf of the exploration community in Nevada, welcome to Reno!

Thank you for coming to what we hope will be a milestone meeting in the growth of the Association of Exploration Geochemists. Please don't let the name of our Association intimidate you if you don't think of yourself as a geochemist. The vast majority of our members are really exploration geologists.

Please take special notice of our exhibitors and make them feel that their effort to meet you was more than worthwhile.

I want to extend a warm welcome to all of you for the big party in Virginia City Monday evening. It promises to be a gala event that you will long remember.

Very truly yours,

Chester E. Nichols

Chester E. Nichols
Symposium General Chairman

SCHEDULE OF EVENTS

SYMPOSIUM OF THE ASSOCIATION OF EXPLORATION GEOCHEMISTS
 RENO, NEVADA • MARCH 25-28, 1984
 MGM GRAND HOTEL

Friday, March 23	
08:30-17:15	Geochemical Exploration Program Design (Short Course)
Saturday, March 24	
08:30-17:00	Geochemical Exploration Program Design (Short Course)
Sunday, March 25	
9:00-21:00	Registration
10:00-14:00	Champagne Brunch in Ziegfeld Theatre
14:00-22:00	Poster Session and Trade Exhibition in Grand Ballroom
15:00-17:00	Outgoing Council Meeting
17:00-19:00	Suppliers Reception in Grand Ballroom
Monday, March 26	
06:30-16:00	Registration
07:30-16:00	Trade Exhibition and Poster Session in Grand Ballroom
08:00-08:15	Opening Remarks , <i>Chester E. Nichols, Symposium General Chairman</i>
08:15-10:00	Volcanic-hosted Precious Metal Deposits in Fronton Conference Center <i>Larry J. Buchanan, Fischer-Watt Mining Co., Sparks, Nevada</i> <i>William C. Bagby, U.S. Geological Survey, Menlo Park, California</i>
8:15-8:30	Characteristics Distinguishing Types of Epithermal Deposits <i>Daniel O. Hayba, N. K. Foley, and P. Heald-Wetlaufer</i>
8:30-8:45	Fluid Dynamics Associated with the Boiling Zone in Epithermal Fissure Veins, Topia, Durango, Mexico <i>Robert R. Loucks</i>
8:45-9:00	The Geochemistry of Majuba Hill, Nevada <i>Karen J. Wenrich, Joseph F. Mascarenas, and Miles L. Silberman</i>
9:00-9:15	Mineralogy and Geochemistry of Hydrothermal Alteration at Glass Buttes, South Central Oregon <i>Michael L. Cummings and Michael L. Johnson</i>
9:15-9:30	Precious Metal Mineralization at the Zaca Mine, Alpine County, California <i>Peggy Merrick</i>
9:30-9:45	Precious Metals and Andean Cenozoic Volcanism in Chile <i>Jose Cabello</i>
9:45-10:00	Preliminary Geochemical Data on the "Chlorite Breccia" of Metamorphic Core Complex Detachment Zones and Thoughts on Associated (?) Base and Precious Metal Mineralization <i>William A. Rehrig</i>
10:00-10:20	Break
10:20-12:00	Applications of Biogeochemistry to Exploration for Precious Metals in Fronton Conference Center <i>James A. Erdman, U.S. Geological Survey, Denver, Colorado</i> <i>Roland R. Ridler, Gold Fields Mining Corporation, Lakewood, Colorado</i>
10:20-10:40	Biogeochemical Exploration for Cambrian-Hosted Gold Deposits in the Homestake District, South Dakota <i>W. C. Riese, R. B. Johnson, and K. L. Howard</i>
10:40-11:00	Biogeochemistry as an Aid to the Exploration for Precious Metals in Saskatchewan, Canada <i>Colin E. Dunn</i>
11:00-11:20	Biogeochemical and Soil Geochemical Studies at the Borealls Mine, Mineral County, Nevada <i>Chi-I Huang</i>
11:20-12:00	Panel and Open Discussion: Biogeochemical Exploration for Gold—Analytical and Field Methods <i>J. Erdman, U.S. Geological Survey, Denver, Colorado</i> <i>E. Hoffman, McMaster University, Hamilton, Ontario, Canada</i> <i>D. McKown, U. S. Geological Survey, Denver, Colorado</i> <i>C. Smith, Amselco Exploration, Inc., Sparks, Nevada</i> <i>R. Ridler, Gold Fields Mining Corporation, Lakewood, Colorado</i>
12:00-13:30	LUNCHEON: Keynote Address by R. W. Boyle, Geological Survey of Canada "Geochemical Methods of Exploration for Gold and Silver Deposits" in Ziegfeld Theatre

Note: In case of multiple authors, author listed first will be presenting the paper.

- 13:30-15:15** **Theoretical Aspects of Gold-Silver Transport and Deposition** in Fronton Conference Center
Frank W. Dickson, Oak Ridge National Laboratory, Oak Ridge, Tennessee
Samuel B. Romberger, Colorado School of Mines, Golden, Colorado
- 13:30-13:55 **Mechanisms of Deposition of Gold in Low Temperature Hydrothermal Systems**
Samuel B. Romberger
- 13:55-14:15 **Arsenic Minerals as Indicators of Conditions of Gold Deposition in Carlin-Type Gold Deposits**
James J. Rytuba
- 14:15-14:40 **Transport and Deposition of Gold and Silver in Boiling Hydrothermal Systems**
David R. Cole and S. E. Drummond
- 14:40-15:00 **Physical Chemical Processes Affecting Deposition of Silica in Carlin-Type Gold Deposits**
F. W. Dickson and A. S. Radtke
- 15:00-15:15 **Ammonia Alteration is a Geochemical Link in Gold Deposits of the Carlin-Midas Belt**
Edward I. Bloomstein
- 15:15-15:30 Break
- 15:30-17:10** **Deposits in Porphyry Systems** in Fronton Conference Center
Marco T. Einaudi, Stanford University, Stanford, California
James E. DeLong, Gold Fields Mining Corporation, Reno, Nevada
- 15:30-15:50 **Elemental Dispersion at the Hall (Nevada Moly) Porphyry Molybdenum Deposit, Nye County, Nevada and Its Relationship to Features of Alteration and Mineralization** *Stephen A. Shaver*
- 15:50-16:10 **The Use of Geochemistry in the Search for Molybdenum Deposits** *Gerhard Westra*
- 16:10-16:30 **Trace Elements in Sphalerite, Galena, and Pyrite from Molybdenum and Non-molybdenum Systems** *Roger C. Steininger*
- 16:30-16:50 **Geochemical and Geological Exploration for Gold-Copper Deposits in Southern Luzon, The Philippines** *Laurence P. James*
- 16:50-17:10 **Geochemical and Fluid Zonation in the Skarn Environment at the Tomboy-Minnie Gold Deposits, Lander County, Nevada** *Ted G. Theodore, Stephen S. Howe, David W. Blake and Patrick R. Wotruba*
- 17:10-23:15** **Virginia City Saloon Party**
- Tuesday, March 27**
- 07:30-16:00** **Registration**
- 08:00-9:55** **Advances in Analytical Geochemistry and Data Processing** in Fronton Conference Center
Gary M. Fechko, Hunter Mining Laboratory, Sparks, Nevada
S. Clark Smith, Amselco Exploration, Inc., Reno, Nevada
- 8:00-8:25 **Definition of Multivariate Geochemical Associations with Polymetallic Mineral Occurrences Using a Spatially Dependent Clustering Technique and Rasterized Stream Sediment Data—An Alaskan Example** *Susan K. Jenson and C. M. Trautwein*
- 8:25-8:50 **The Microcomputer in Geochemical Exploration** *Stanley J. Hoffman and Gerald G. Mitchell*
- 8:50-9:10 **Graphical and Computer Refinement of Cu-Mo-Pb-Zn-Ag Anomalies, Crow Springs Prospect, Esmeralda County, Nevada** *Christopher W. Krumm and D. E. Pride*
- 9:10-9:35 **Comparison of Analysis Techniques For Gold** *H. Blok, R. D. Morse and B. L. Twaites*
- 9:35-9:55 **Integrative Mercury Gas Geochemistry—A Comparison with Traditional Mercury in Soil Geochemistry at the Cinola, B.C. Gold Deposit** *John Dunkhase*
- 9:55-10:15 Break
- 10:15-12:15** **Sediment-hosted Precious Metal Deposits** in Fronton Conference Center
Peter E. Chapman, Consultant, Carson City, Nevada
Andy B. Wallace, Cordex Exploration Co., Reno, Nevada
- 10:15-10:35 **Application of Rank Sum Analysis to Soil Geochemistry at the Dee Gold Mine, Elko County, Nevada** *W. C. Bagby, W. J. Pickthorn, R. Goldfarb, and R. A. Hill*
- 10:35-10:55 **Geology of the Rain Disseminated Gold Deposit, Elko County, Nevada** *Gale C. Knutsen*
- 10:55-11:15 **Geology and Interpretation of Geochemistry at the Standard Mine, Humboldt Range, Nevada**
Charles J. Ronkos
- 11:15-11:35 **Geology and Geochemistry of the Quito Prospect** *Robert N. Whittemore and Russell S. Cowart*
- 11:35-11:55 **Geochemistry and Alteration Studies, Carlin Gold's Maggie Creek Deposit** *Charles Ekburg*
- 11:55-12:15 **Micron Gold-Associated Jasperoid: Fluid Inclusion Chemistry and Geothermometry**
Patricia H. Schnorr, Stephen E. Kesler and Paul L. Cloke
- 12:15-13:45** LUNCHEON: Presidential Address by L. Graham Closs, Colorado School of Mines
"Exploration Geochemistry 1984 - Some Observations on the Scene" in Broadway Room
- 13:45-16:00** **Geothermal Systems and Ore Deposits** in Fronton Conference Center
David L. Giles, Cimarron Exploration Inc., Lakewood, Colorado
Miles W. Silberman, U.S. Geological Survey, Denver, Colorado
- 13:45-14:10 **Monotonic and Prograding Geothermal Systems and Precious Metal Mineral Deposits**
R. B. Blakestad and W. R. Stanley
- 14:10-14:30 **Geochemical Patterns in an Altered Area of McGinnes Hills, Lander County, Nevada**
Daniel E. Wendell, Robert J. Casaceli and W. David Hoisington

Note: In case of multiple authors, author listed first will be presenting the paper.

14:30-14:50	Epithermal Au-Ag Mineralization Related to Volcanic Subsidence in the Custer Graben, Custer County, Idaho <i>Kathleen M. Johnson and David H. McIntyre</i>
14:50-15:10	Geology and Ore Deposits of the Thunder Mountain Mining District, Valley County, Idaho <i>Opal Adams</i>
15:10-15:35	An Exploration Strategy for Hot Spring Precious Metal Deposits <i>Byron R. Berger and Samuel S. Adams</i>
15:35-16:00	The Formation of Massive Sulfide at 21°N, East Pacific Rise <i>Robert Zierenberg</i>
16:00-17:00	Annual General Meeting
17:00-18:30	Reception for Past and Present Officers and Councillors of AEG
18:30-19:30	Questionnaire Results Panel in Fronton Conference Center
18:00-22:00	DINNER SHOW: "Hello Hollywood, Hello!"
Wednesday, March 28	
07:30-14:30	Registration
08:00-10:00	General Technical Session in Fronton Conference Center <i>Edwin V. Post, Skyline Labs, Inc., Wheat Ridge, Colorado</i> <i>Frank C. Canney, U.S. Geological Survey, Denver, Colorado</i>
8:00-8:20	Investigation of Stream Zn and Pb as Predictors of Stratiform Zn-Pb Deposits, Selwyn Basin, Yukon <i>G. F. Bonham-Carter and W. D. Goodfellow</i>
8:20-8:40	Relationship of the Cortez Caldera to the Cortez Disseminated Gold Deposit, Nevada <i>James J. Rytuba, Raul J. Madrid, and E. H. McKee</i>
8:40-9:00	A Stream Sediment Data Base for the State of Colorado <i>Stephen L. Bolivar</i>
9:00-9:20	Gold Occurrence at Island Copper Mine, British Columbia <i>John W. Gabelman and William M. Hanusiak</i>
9:20-9:40	A Hydride Generator for the Laboratory with a Limited Budget, and Applications to Selenium and Arsenic Determinations in Geologic Materials <i>Frederick N. Ward and Daniel L. Remington</i>
9:40-10:00	The Relation Between Tl, Rb, and K in the Carlin-Type Gold Deposits <i>Mohammed Ikramuddin, L. Besse, and P. M. Nordstrom</i>
10:00-10:20	Break
10:20-12:00	Massive Sulfide Deposits in Fronton Conference Center <i>Steven D. Scott, University of Toronto, Toronto, Ontario</i> <i>David H. Watkins, Nevcan Exploration, Inc., Delta, British Columbia</i>
10:20-10:40	Recognition of Alteration in Volcanic Environments: Computer Applications <i>E. C. Grunsky</i>
10:40-11:00	Alteration Accompanying Massive Sulphide Mineralization in the Delta District, East Central Alaska: Implications for Exploration <i>C. R. Nauman and N. A. Duke</i>
11:00-11:20	Massive Sulphide Mineralization at Green Mountain, Mariposa County, California <i>Paul R. Mattinen and George H. Bennett</i>
11:20-11:40	The Geochemical Environment of Westmin Resources' Buttle Lake Mine, Vancouver Island, British Columbia <i>Richard R. Walker</i>
11:40-12:00	Geology, Lithologic Association, and Depositional Environment of the Oposura Massive Sulphide Deposit, Sonora, Mexico <i>Christopher D. Marrs</i>
12:00-13:30	LUNCHEON: Address by Delos Flint, Freeport Exploration Co. "Geochemistry and the Discovery of the Bell Mine, Jerritt Canyon, Nevada" in Broadway Room
13:30-15:30	Applications of Hydrocarbons and Vapor Phase Geochemistry in Fronton Conference Center <i>Charles G. Clifton, Exploration Research Laboratories, Corvallis, Oregon</i> <i>J. Howard McCarthy, Jr., U.S. Geological Survey, Denver, Colorado</i>
13:30-13:40	Introduction <i>C. G. Clifton</i>
13:40-14:05	Alteration of Organic Matter Around Carbonate-Hosted Lead-Zinc Deposits <i>R. W. Macqueen</i>
14:05-14:30	Solution of Structural Problems in the Topia Ag-Ag-Pb-Zn District, Durango, Mexico, Using Laser Deprecitation and Capacitance Monometer Gas Analysis for Fluid Inclusion Geobarometry <i>Robert R. Loucks</i>
14:30-14:50	Factors Affecting Sulfur Gas Anomalies in Overburden <i>M. D. Gardner, S. E. Kesler, M. Creech, P. L. Cloke, and D. Stedman</i>
14:50-15:10	A New Approach to Multi-Component Gas Geochemistry in Metal Exploration <i>Ronald W. Klusman, Kent J. Voorhees, James C. Hickey, and Duane N. Bloom</i>
15:10-15:30	Gas Halos in Hydrothermal Clays Associated with Ore Shoots at Creede, Colorado <i>Patricia H. Schnorr, Jonathon A. Gorman, Stephen E. Kesler</i>
15:30-15:45	Break

Note: In case of multiple authors, author listed first will be presenting the paper.

15:45-17:05

Primary Dispersion of Ore Deposits in Fronton Conference Center

Arthur W. Rose, The Pennsylvania State University, University Park, Pennsylvania

Kenneth A. Lovstrom, AMAX Exploration, Inc., Golden, Colorado

15:45-16:05

Primary Gas Dispersion Halos in Disseminated Gold Deposits: Examples from Nevada and California *Charles G. Clifton*

16:05-16:25

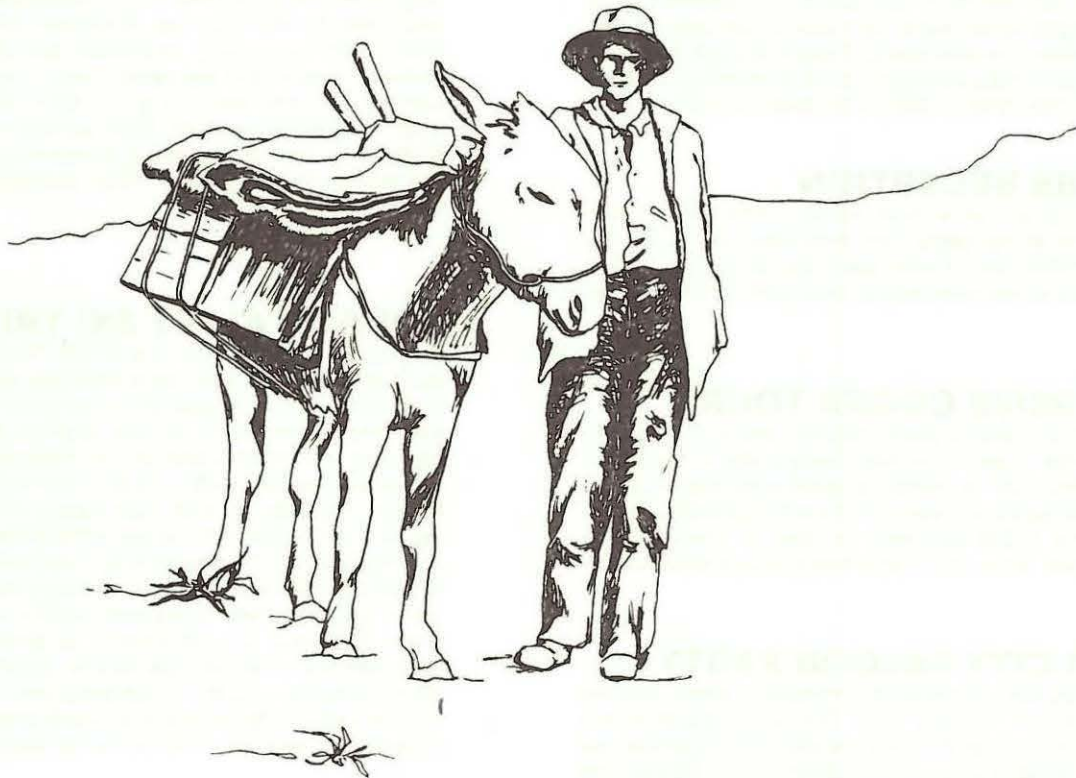
The Use of Lithogeochemical Patterns in Wallrock as a Guide to Exploration Drilling at the Jason Pb-Zn-Ag-Ba Deposit, Yukon Territory *Barry W. Smee and Richard J. Bailes*

16:25-16:45

Primary Dispersion of Trace Elements Fluid Inclusion Zoning, and Alteration Zoning at the Pueblo Viejo Au-Ag Deposit, Dominican Republic *Karr McCurdy, Norman Russell, and Stephen E. Kesler*

16:45-17:05

Stream Sediment Geochemistry of the McLaughlin Gold Deposit and the Knoxville District, Napa and Yolo Counties, California *C. Neil Upchurch*



Note: In case of multiple authors, author listed first will be presenting the paper.

SOCIAL PROGRAM AND GUEST TOURS

CHAMPAGNE BRUNCH

An extensive buffet of delicacies in the best Reno Sunday Brunch tradition with all you can eat and drink for \$5.95 (1983 price). Enjoy a delightful meal at a leisurely pace. This sumptuous repast is offered in the enormous Ziegfeld Theatre where the fabulous *Hello Hollywood, Hello!* show is given twice every evening. Both events are highly recommended by the organizing committee.

HELLO HOLLYWOOD, HELLO!

The world's largest stage holds a \$6 million extravaganza designed to mesmerize the audience with a cast of 150 glamorous performers including topless reviews. See the famous opening jet plane scene, the spectacular San Francisco earthquake and fire, alien space ships descend ominously from the ceiling, and much more. The dinner starts at 6 p.m. and the show starts at 8. The cocktail show starts at midnight; come **early** and ask to sit down front. Tickets are obtained on an individual basis through the MGM Grand Hotel rather than through the AEG meeting registration. Call (702) 789-2285 or (800) 648-3568 for reservations.

SUPPLIERS RECEPTION

Food and drinks will be served Sunday afternoon in the Grand Ballroom at the same time and place as the Poster Session and Exhibition. Come early to do justice to the numerous poster presentations and the many exhibit booths.

PROGRESSIVE COOKS TOUR

This luncheon tour, which lasts approximately 3½ hours on Monday, features three of the best restaurants in Reno. We begin with instruction in Caesar's Salad preparation at the 19th Hole, continue on to Leonardo's for Fettuccine Alfredo, and then to the MGM kitchens for one of their famous desserts. Recipes, wine, and a fabulous meal are all included.

VIRGINIA CITY SALOON PARTY

Monday evening the association completely takes over the old mining town of Virginia City! The party starts with a guided bus drive through the Virginia City district where you will see such eminent sites as the Combination Headframe and the legendary Comstock. An excellent buffet dinner with barbecue chicken and ribs will be served at the historic Red Garter. *Safaris and Tours* will recreate the atmosphere of Virginia City 100 years ago with various bands in the saloons, can-can reviews, lawless gunfighters and the hanging of an ill fated geologist! Your first four drinks are on the house. Shuttle service back to the MGM Grand will be from 9:00 to 11:30 p.m. This is the party by which you will remember the Reno Meeting. **Don't miss it.**

LAKE TAHOE TOUR

This Tuesday trip, which takes approximately 5 hours, stops first at a beautiful old Victorian restaurant in Truckee, California for lunch (cost included in tour). From there we wind through the western Sierras to rustic Tahoe City and a short shopping excursion. We then pass along the north shore of beautiful Lake Tahoe and over the shoulder of 10,778-foot Mt. Rose to Reno. For those who have never seen Lake Tahoe, this is truly a must experience.

RENO TOUR, GAMING SEMINAR, AND HARRAH'S AUTO COLLECTION

This event lasts approximately 5 hours on Wednesday. It begins with a short tour of the downtown Reno area, then proceeds to the Gaming Academy where two hours of instruction (including cocktails) are given on blackjack, roulette, craps and baccarat. Next is a quick behind-the-scenes visit with security at the Club Cal Neva, one of the major downtown casinos. Then we visit Harrah's Automobile Collection, the largest, most spectacular auto collection in the world, featuring over 1200 vintage cars, all in prime condition.

SQUAW VALLEY SKI TRIP

Busses will depart from the MGM Thursday, March 29, at approximately 7:30 a.m. for a fabulous day at Squaw Valley, one of the world's largest and most famous alpine ski resorts and site of the 1960 Winter Olympics. Included in this package is a professional ski instructor/guide for each 8 to 10 people, transportation to and from Squaw Valley, and lift tickets. You may ski with your instructor and others of your ability from beginner to expert all day long without standing in long lift lines. Those electing to rent skis, boots, and poles (price includes equipment insurance) will be fitted on a previous day and their equipment taken to the mountain for them. The area is well known for excellent grooming of beginner and intermediate slopes. Snow conditions in late March average a 12 to 18-foot base with fresh powder snow. Squaw Valley is truly a skier's dream come true, with 26 lifts, 2 gondolas, and over 5000 acres of skiable terrain.

NOTE: Availability of tickets for the guest activities and special events can only be guaranteed to approximately 24 hours prior to the function.

VIRGINIA CITY

THE "LIVEST"
GHOST TOWN IN THE WEST!

WELCOME TO VIRGINIA CITY

Safaris & Tours recreates Virginia City of a hundred years ago especially for the Association of Exploration Geochemists. We take over the famous Red Garter Saloon and the Washoe Millionaires Club for dinner, where Can-Can Reviews and turn-of-the-century entertainment will add spice and color to the delicious Chicken & Ribs buffet. Your drink tokens are also valid at the Mark Twain Saloon, as well as the Ponderosa Saloon, where you can take Virginia City mine tours.

But wait! Some of the old gunfighters of yesteryear are back, so be careful what you say to the stranger at the bar. Hangings (as well as shot-gun weddings) are commonplace in the Old West!

Don't miss your chance to relive the west as it really was — where gold meant life or death, and fabulous fortunes were made and lost.

Join us in Virginia City, Monday night, 6-11 p.m., March 26, when **Safari & Tours** creates a party of a lifetime.

Pick up your tickets now at the Registration Desk. Only \$31.00 per person includes dinner, four drink tokens, all entertainment, and a tour of Virginia City before the party!



In 1875 Leslie's Illustrated Weekly ran this drawing of 'C' Street on the front page.

RED GARTER Saloon & Gambling Hall

Barbara, one of the most sought-after ladies of the night in Nevada during the 1880's, met Judge Orville Hardison and, for his love, gave up her career. As both a token of her affection and an offering of her sincerity, Barbara presented the Virginia City judge with a wooden box inscribed:

*"To Judge Orville Hardison from his
loving wife, Barbara, on the occasion of Her
Retirement and our marriage.
July 23, 1893."*

The box contained her 41 caliber, ivory-handled Colt Deminger, a bone handled dagger that she carried, and the famous Red Garter.



TRANSPORTATION

By virtue of the projected number of people, **special air fares** have been negotiated for attendees at the Reno Meeting. These rates are probably lower than your own travel agency can obtain. Reservations may be made by calling **United Airlines** at 800-521-4041. Callers must identify themselves as attending the Association of Exploration Geochemists meeting at Reno and give the code number 0410. United will honor excursion fares at the current rate and waive the normal restrictions like staying over a certain day of the week or for a specified minimum period of time. The rate reduction is in the vicinity of 40% to 50% below regular coach fares.

Although the above offer is good only in the 50 states, attendees from elsewhere in North America may call **Travel Advisors**, the official travel agent, at 702-329-6161, collect, for guaranteed lowest fare from their location. Please identify the meeting to the receptionist who answers your call. Those traveling from points in the United States not served by United Airlines may also receive this guaranteed service. Office hours are from 9 a.m. until 5 p.m. Pacific time. Correspondence may be addressed to The Travel Advisors, Inc., 1557 South Virginia Street, Post Office Box 2411, Reno, Nevada 89505.

Travel Advisors will maintain a desk in the registration area during the week of the meeting, but only during the following hours:

Sunday, March 25	17:00-19:00
Monday, March 26	07:30-08:30
Tuesday, March 27	07:30-08:30
Wednesday, March 28	07:30-08:30

The Reno office of **National Car Rental** (702) 785-2756 has been chosen for its best offer of convention rates and services. Daily rates range from \$31 for economy size to \$34 for a full-sized four-door sedan. There is no mileage charge, but this rate does not include gasoline, optional insurance, and tax.

Reservations may be made by calling (800) 328-4567 or writing Peter Kranz, National Car Rental System, Inc., P.O. Box 10306, Reno, Nevada 89510. Our convention rates may be obtained by identifying yourself as an attendee at the Association of Exploration Geochemists Symposium when making reservations in advance or by presenting this page when arriving at the airport in Reno.

MISCELLANEOUS ANNOUNCEMENTS

Various AEG publications will be sold at the registration desk.

Registration Desk Phone 789-2797.
Message Desk Phone 789-2482

Refreshments: Complimentary hot beverages and breakfast rolls will be available in the Grand Ballroom (Exhibition Hall) on Monday beginning at 07:00. Hot beverages will be available until 16:30.

Morning Breaks: Complimentary hot beverages and breakfast rolls will be available at the following times and locations:

Monday 10:00	Grand Ballroom (Exhibition Hall)
Tuesday 09:55	Fronton Foyer
Wednesday 10:00	Fronton Foyer

Afternoon Breaks: Complimentary hot beverages will be available at the following times and locations:

Monday 15:15	Grand Ballroom (Exhibition Hall)
Wednesday 15:30	Fronton Foyer

NO SMOKING, NO CAMERAS IN TECHNICAL SESSIONS

People attending the technical sessions on Monday, Tuesday, and Wednesday are asked to refrain from smoking until the sessions adjourn. As a courtesy to speakers, cameras will not be allowed in these sessions.



1. Sediment-hosted Gold Deposits	March 22-24	FULL
2. Sediment-hosted Precious Metal Deposits	March 29-31	FULL
3. Precious Metal Districts in Southern and Western Nevada	March 22-24	FULL
4. Precious Metal Districts in West-Central Nevada	March 29-30	FULL
5. Cancelled		
6. Massive Sulfide Deposit	March 29	\$ 75
7. Porphyry Molybdenum Deposits	March 29-31	\$160
8. Sulphur Mining District	March 23-24	FULL
9. Bedded Barite Deposits	March 23-24	\$110
10. Skarn Deposits	March 22-24	\$145
11. Virginia City Mining District	March 29	\$ 50
12. Gooseberry Mine	March 29	\$ 50

Those persons interested in post-meeting field trips may check for available openings at the field trip desk in the registration area.

FIELD TRIP DESCRIPTIONS

1. SEDIMENT-HOSTED GOLD DEPOSITS

This trip goes to the **Pinson, Carlin,** and **Jerritt Canyon** mines on Thursday, Friday, and Saturday before the meeting. The deposits are of the Carlin-type with strong structural control and interesting geochemical relationships. **Leader:** Dana Durgin, Amselco Exploration.

2. SEDIMENT-HOSTED PRECIOUS METAL DEPOSITS

Northumberland, Alligator Ridge and **Taylor** mines will be visited Thursday, Friday, and Saturday after the meeting. Northumberland and Alligator Ridge are Carlin-type deposits, whereas Taylor is a silver deposit that has many characteristics similar to the sediment-hosted gold deposits. **Leader:** Charles Hauntz, Amselco Exploration.

3. PRECIOUS METAL DISTRICTS IN SOUTHERN AND WESTERN NEVADA

This tour departs from **Las Vegas** at noon on the Thursday before the meeting and arrives in Reno on Saturday evening. It visits the **Sterling** mine (underground and open pit sediment-hosted disseminated gold), **Goldfield** district (volcanic-hosted, disseminated gold-silver), and **Tonopah** district (volcanic-hosted bonanza silver-gold), and **Borealis** mine (volcanic-hosted hot springs gold-silver). **Leaders:** Larry Garside and Hal Bonham, Nevada Bureau of Mines and Geology.

4. PRECIOUS METAL DISTRICTS IN WEST-CENTRAL NEVADA

This tour is similar to trip 3, but departs from Reno Thursday morning after the meeting and returns to Reno about 6 p.m. Friday night. It visits the **Candelaria** mine (sediment-hosted disseminated silver-gold), **Goldfield** district (volcanic-hosted bonanza gold), **Tonopah** district (volcanic-hosted bonanza silver-gold), and **Bell Mountain** (bulk-mineable, volcanic-hosted, silver-gold quartz vein). Those who wish to go underground at Bell Mountain should bring their own mine lamps. **Leaders:** Larry Garside and Hal Bonham, Nevada Bureau of Mines and Geology.

5. CANCELLED

Trip five is replaced by trip 7.

6. MASSIVE SULFIDE DEPOSIT

Western World is a massive sulfide deposit hosted by Mesozoic volcanic rocks in the northern foothills of the Sierra Nevada. This deposit will be visited along with its regional setting. Busses leave Reno Thursday morning after the meeting and return Friday evening. **Leader:** Steve Kilbreath, NevCan Exploration.

7. PORPHYRY MOLYBDENUM DEPOSITS

Anaconda's **Nevada Moly** open pit, Amax's **Buckingham** deposit and Getty's **Pine Grove Molybdenum** deposit will be visited Thursday through Saturday after the meeting. Pine Grove is a rhyolite-type deposit, whereas both Nevada Moly and Buckingham are of the quartz monzonite type. Pine Grove and Buckingham provide the opportunity to view the lithocap of major porphyry systems in their undisturbed condition. The trip terminates in **Salt Lake City**. **Leader:** Thomas Irwin, Exxon Minerals.

8. SULPHUR MINING DISTRICT

The **Sulphur** mining district represents a mineralized hot springs system of Pleistocene age. Gold and silver values occur associated with antimony, mercury, and sulfur in favorable stratigraphic horizons along fault zones. The area of silicified and pyritized Pliocene and Pleistocene sedimentary host rocks is approximately 1½ by 3 miles. This trip will leave the MGM hotel at 2:00 on the Friday before the meeting and return Saturday evening. After supper on Friday there will be a presentation of slides and maps on the Sulphur mining district. **Leaders:** Andy Wallace, Cordex Exploration and Steve Friberg, Sierra Exploration Associates.

9. BEDDED BARITE DEPOSITS

Three barite mines will be visited prior to the symposium. The **Greystone** mine of Dresser Minerals, the **Argenta** mine of Milchem Incorporated, and the **Mountain Springs** mine of FMC are located in the vicinity of Battle Mountain, Nevada. These deposits consist of bedded barite within the Devonian Slaven chert. **Leader:** Jeffrey Long, Old Soldier Minerals.

10. SKARN DEPOSITS

This trip begins on Thursday before the meeting with a visit to the tungsten skarns of the Bishop, California area including the **Black Rock** skarn. The following day it will go to the **Pilot Mountain** tungsten deposit and the polymetallic skarns of the Hawthorne area in Nevada. During the final day the skarns of the **Yerington** district, including the **Casting** copper skarn and the **Pumpkin Hollow** magnesian iron-copper deposit will be visited. **Leader:** Reiner Newberry, University of Alaska.

11. VIRGINIA CITY MINING DISTRICT

This is a one-day trip to the **Virginia City** area to visit precious metal vein systems and surrounding hot spring alteration zones. **Leader:** Donald Hudson, United Mining Corporation.

12. GOOSEBERRY MINE

The **Gooseberry** mine is a precious metal vein system in the Kate Peak Formation of Pliocene age. Gold and silver with minor chalcopyrite, sphalerite and galena occur in quartz-carbonate veins. A one-day trip is planned to visit surface exposures at and near the mine. **Leader:** Jose Lanchester, Amselco Exploration.

SUPPLIERS RECEPTION

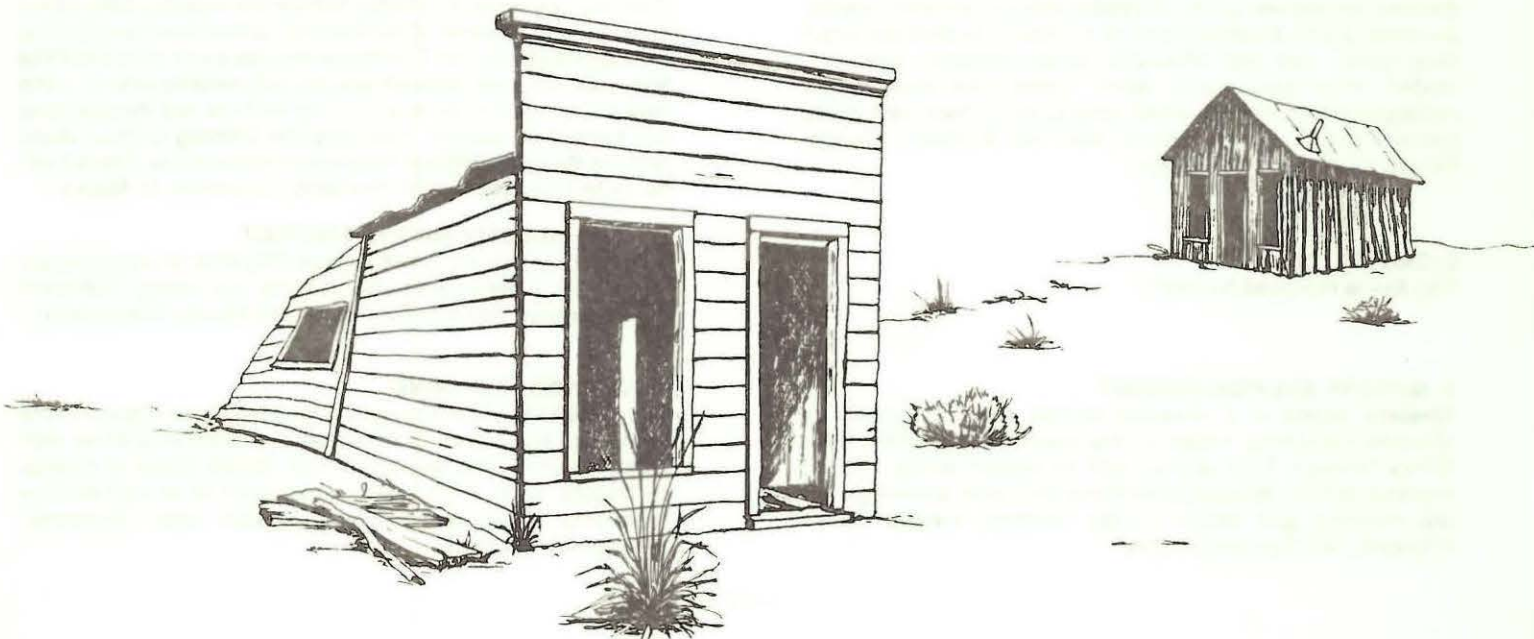
SUNDAY, MARCH 25

Sergent, Hauskins, and Beckwith Consulting Geotechnical Engineers	Phoenix, Arizona
Hazen Research, Inc.	Golden, Colorado
Rocky Mountain Geochemical	West Jordan, Utah
Dawson Metallurgical Laboratories, Inc.	Murray, Utah
MolyCorp, Inc.	Englewood, Colorado
Hydro-Search, Inc.	Reno, Nevada
Long Lac Mineral Exploration, Inc.	Reno, Nevada
Harrisons and Crosfield (Pacific), Inc.	Emeryville, California
Monitor Geochemical Labs	Elko, Nevada and Hesperia, California
Nevada Resources Inc.	Reno, Nevada

DOOR PRIZE CONTRIBUTORS

LACANA MINING INC. of Reno, Nevada has donated a 0.17 oz. (5.30 grams) gold assay button from the Relief Canyon Deposit in Pershing County, Nevada. This button was struck courtesy of **PINSON MINING COMPANY** in Humboldt County, Nevada.

The Silver Peak, Nevada Operations of **SUNSHINE MINING COMPANY** has donated a 10.0 oz. silver bar of .999 fineness. Sunshine Mining Company mines and refines its own silver, which is then minted by Tentex.



BEST PAPER AWARDS

FIRST PLACE: 5.65 oz. silver bar donated by **Coeur Exploration** of Reno, Nevada. The silver in this bar was produced at Coeur d'Alene Mines Corporation's Coeur Mine in Idaho, which is currently being mined at a rate of 2.5 million tons per year by ASARCO.

SECOND PLACE: 1.0 oz., .999 fine silver Commemorative Medallion, struck by Johnson-Matthey Refining Inc. in Rochester, New York. This is a proof medallion, the highest quality produced, and contains a serial number and the Johnson-Matthey mint mark on the edge. This award was donated by **United Mining Corporation** of Virginia City, Nevada.

THIRD PLACE: 0.252 oz. dore' button poured from gold and silver mined from the Chipmunk ore body belonging to **Cyprus Northumberland Mining Company**, near Austin, Nevada. This button assays 439.39 gold fine and 529.77 silver fine (total dore' fineness of 969.16), and was cast on March 6, 1984.

BEST POSTER AWARDS

FIRST PLACE: 5.61 oz. silver bar donated by **Coeur Exploration** of Reno, Nevada. The silver in this bar was produced at Coeur d'Alene Mines Corporation's Coeur Mine in Idaho, which is currently being mined at a rate of 2.5 million tons per year by ASARCO.

SECOND PLACE: 1.0 oz., .999 fine silver Commemorative Medallion, struck by Johnson-Matthey Refining Inc. in Rochester, New York. This is a proof medallion, the highest quality produced, and contains a serial number and the Johnson-Matthey mint mark on the edge. This award was donated by **United Mining Corporation** of Virginia City, Nevada.



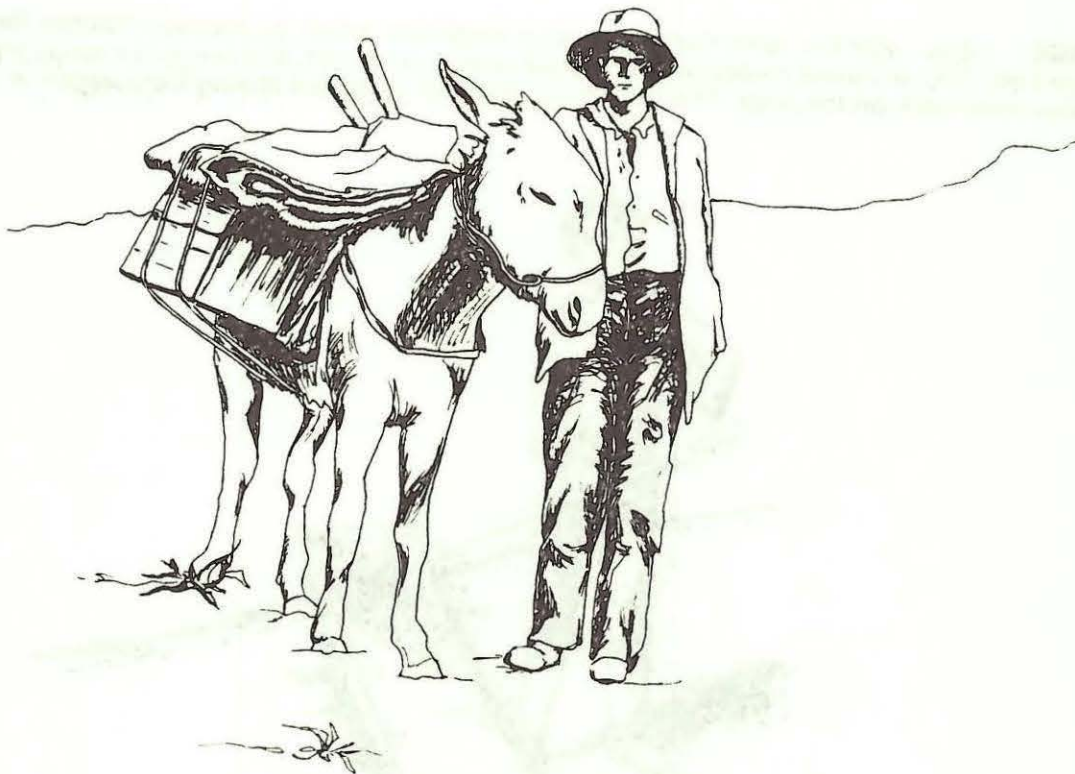
QUESTIONNAIRE RESULTS PANEL

The results of the questionnaire which was published in the Third Circular will be presented on Tuesday evening at 6:30 in the Fronton Conference Center. The results were compiled by Clifford R. Stanley, a graduate student in geochemistry at the University of British Columbia, and Bruce W. Downing, who is employed by Newmont Exploration of Canada Ltd. in Vancouver, British Columbia. The following panel members will discuss these results and entertain questions and comments from the floor.

Stanley J. Hoffman
Norman G. Lavery
Paul F. Matysek
Steven E. Kesler

B.P. Minerals, Ltd.
Exxon Minerals Company
Anaconda Canada Exploration, Ltd.
University of Michigan

Vancouver, B.C., Canada
Missoula, Montana
Vancouver, B.C., Canada
Ann Arbor, Michigan



PUBLICATIONS IN PRINT

Exploration Geochemistry Bibliography to January 1981 (1982), special Volume 11, compiled by H.E. Hawkes. 388 pp. References to past literature on geochemical exploration for minerals were scattered in seven publications covering various time spans, and some years were completely uncompiled. This volume, with about 6000 entries, brings together in one volume all literature from pre-1940 to January 1981, and provides a comprehensive index. The effort of compilation has been directed by H.E. Hawkes, assisted by a committee of nine geochemists from North America, Europe, and Australia. The coverage focuses on geochemistry applied to exploration for deposits of solid minerals. Some coverage of related fields, such as analytical chemistry, agricultural chemistry, environmental geochemistry, and ore genesis, is also included.

The indexing of the volume allows a variety of different paths to references. Geographic entries allow recognition of previous surveys and studies in states, provinces, and countries. Element entries include references to analytical methods, geochemistry and abundance of elements, and specialized survey methods. Deposit-type entries list references applicable to specific types of ores. Other types of entries cover sample types (soil, water), and various special topics (sampling, geochemical provinces, arid environments).

The volume is a necessity for exploration geochemists and exploration groups, and will be valuable to economic geologists, general geochemists, environmental geochemists, and others.

Precious Metals in the Northern Cordillera (1982), special Volume 10, A.A. Levinson, editor, Proceedings of AEG-GAC Symposium. 214 pp. This book contains papers presented at a Symposium held in April 1981, in Vancouver, British Columbia. The Symposium was devoted to geology, geochemistry, and exploration for gold and silver. Case histories illustrate the latest exploration techniques for these metals in the Northern Cordillera.

Geochemical Exploration 1978 (1979), special Volume 7, J.F. Watterson and P.K. Theobald, editors. Proc. 7th Intern. Geoch. Expl. Sympos., Golden, Colorado. 504 pp. Proceedings of the Seventh International Geochemical Exploration Symposium held in Golden, Colorado, in April, 1978. Papers on many aspects of both regional and local geochemical exploration make this a valuable addition to the geochemical literature.

Applications of Probability Graphs in Mineral Exploration (1976) by A.J. Sinclair. 95 pp. This classic publication describes a simple and practical method for evaluating geochemical data. Actual data are used to illustrate the applications of probability plots to such problems as sample and data populations and threshold. This clearly written book will be valuable to anyone doing geochemical exploration.

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11th INTERNATIONAL GEOCHEMICAL EXPLORATION SYMPOSIUM

The Association of Exploration Geochemists extends an invitation to attend the 11th International Geochemical Exploration Symposium in Toronto from April 28 to May 2, 1985. The Symposium will take place in Canadian National's new L'Hotel and Tower complex in Toronto.

TECHNICAL PROGRAM

The three and one-half day technical program will be held on April 29 and 30, and May 1 (a.m.) and 2 in the Main Ballroom of L'Hotel. Topics will be:

BEDROCK GEOCHEMISTRY	OVERBURDEN GEOCHEMISTRY
REGIONAL SURVEYS AND CASE HISTORIES	BIOGEOCHEMISTRY
ENVIRONMENTAL GEOCHEMISTRY	NEW APPROACHES
GEOCHEMISTRY FOR DEVELOPMENT	OTHER SUBJECTS

WORKSHOPS

Several two-day workshops are planned immediately prior to the Symposium on April 27 and 28, 1985. Topics will be:

BIOGEOCHEMISTRY	ELECTROGEOCHEMISTRY
RARE-EARTH GEOCHEMISTRY	TILL GEOCHEMISTRY
ANOMALY INTERPRETATION AND DATA PRESENTATION (GRAPHICS)	OTHER

SOCIAL PROGRAM

A wine and cheese WELCOME RECEPTION will be held on the evening of Sunday, April 28, in L'Hotel. On Wednesday, May 1, an EVENING AT THE CN TOWER will feature cocktails, dinner and dancing in the revolving restaurant atop the CN Tower.

FIELD TRIPS

Pre- and post-symposium field trips are being planned. Exploration case histories and visits to ore deposits will be the focus of these excursions. Proposed field trips are:

1. GEOCHEMICAL LABORATORIES, TORONTO AREA
2. ONTARIO CENTRE FOR REMOTE SENSING, TORONTO
3. GLACIAL SEDIMENTOLOGY, TORONTO AREA
4. GLACIAL SEDIMENTOLOGY AND OVERBURDEN GEOPHYSICS, TORONTO AREA
5. GOLD DEPOSITS, GEOLOGY AND EXPLORATION ENVIRONMENTS, HEMLO, ONTARIO
6. GOLD DEPOSITS, BEDROCK AND SURFICIAL GEOLOGY, KIRKLAND LAKE AREA, ONTARIO
7. GOLD AND MASSIVE SULPHIDE DEPOSITS, BEDROCK AND SURFICIAL GEOLOGY, TIMMINS AREA, ONTARIO
8. TIN-TUNGSTEN-URANIUM MINERALIZATION IN NEW BRUNSWICK AND NOVA SCOTIA

EXHIBITS

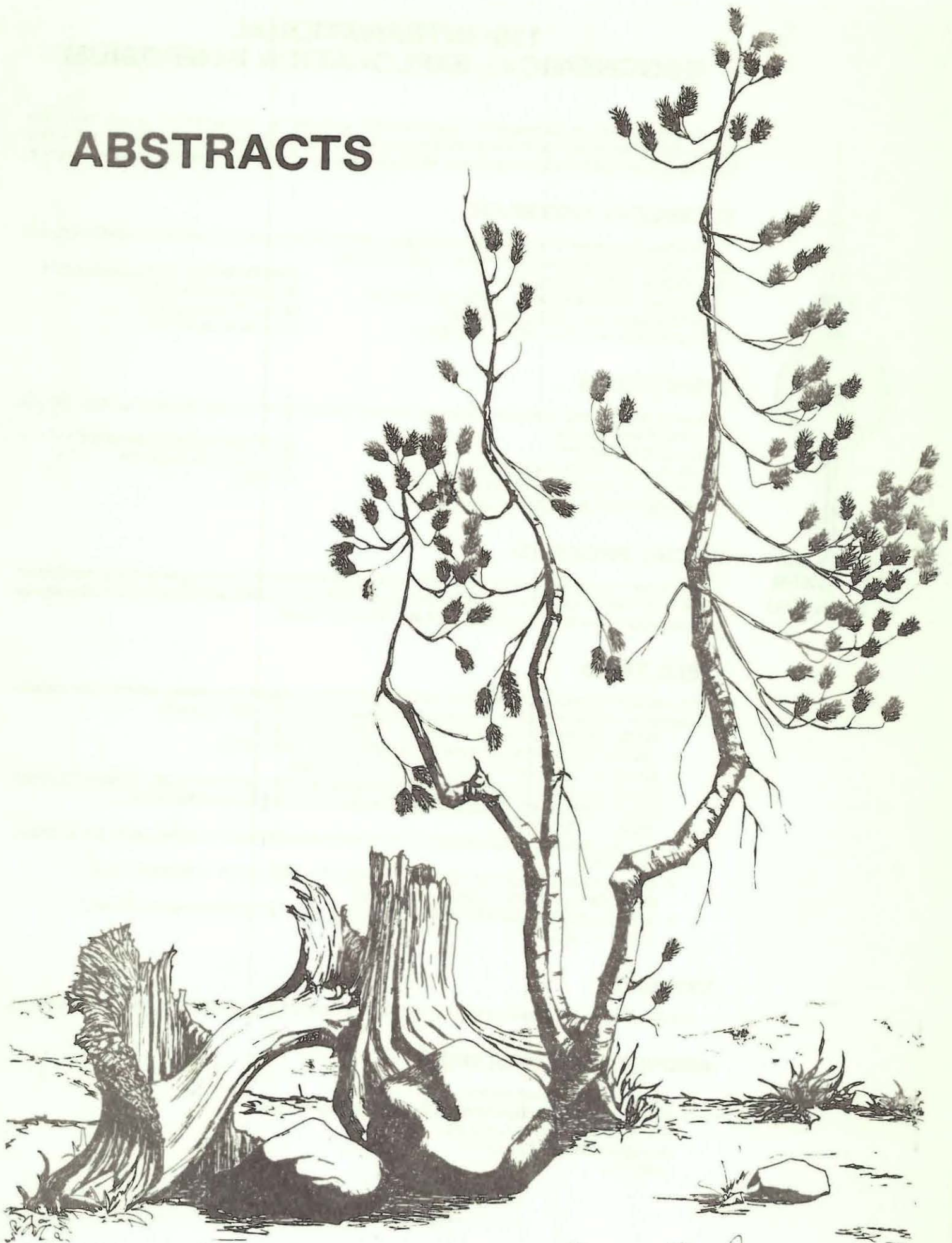
Exhibit space will be available for displays by industry, government and other organizations.

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ABSTRACTS



VOLCANIC HOSTED PRECIOUS METALS

Characteristics that Distinguish Types of Epithermal Deposits

D.O. Hayba, N.K. Foley, and P. Heald-Wetlaufer, U.S. Geological Survey, 959 National Center, Reston, VA 22092

Three distinctive groupings of epithermal deposits were recognized from a literature study of fifteen well-described precious- and base-metal epithermal districts, supplemented by L. J. Buchanan's 1981 compilation of data from 47 less-completely documented deposits. The three groups are distinguished primarily by the type of alteration and the sulfur fugacity indicated by the vein mineral assemblage. Additional discriminating criteria include composition of the host rock, timing of ore deposition relative to emplacement of the host, and relative abundances of gold, silver, and base-metals. The first group, typified by Goldfield, Nevada, has advanced argillic alteration and a vein mineral assemblage (enargite + pyrite ± covellite) which reflects relatively high sulfur fugacities. Both gold- and silver-rich members are present and have moderate concentrations of base metals, notably copper. Ore deposition in this group closely followed emplacement of the host which in most cases is rhyodacite. The second group, typified by Creede, Colorado, has sericitic ± argillic alteration, a less-sulfidized vein mineral assemblage, and adularia. This group tends to have high concentrations of silver and moderate to high concentrations of base metals, especially lead and zinc. The third group, for example, Round Mountain, Nevada, has sericitic alteration, a vein mineral assemblage that reflects low sulfur fugacities, and adularia. Compared with the other groups, sulfides and sulfosalts are rare. The main ore minerals are native gold and silver, and electrum, with silver/gold ratios near unity. For the latter two groups, ore deposition usually occurred significantly later (> 1 m.y.) than emplacement of the host rocks. These distinguishing features provide significant constraints for genetic models of epithermal mineralization.

Fluid Dynamics Associated with the Boiling Zone in Epithermal Fissure Veins, Topia, Durango, Mexico:

Robert R. Loucks, Dept. of Geosciences, Purdue University, West Lafayette, IN

Well constrained distribution patterns of Ag, Au, Pb, and Zn, determined in four structurally simple, andesite-hosted, crustification-banded, fissure veins, employing assays of ~ 5800 channel samples spanning the fissure width only, a graphical method of trend analysis, and contouring of arrays of metal ratio and metal grade (not grade x width) data on longitudinal vein sections reveal that along each vein, the ore horizon comprises a high-grade sinusoidal ore "ribbon" which has a vertical width of only 25-100 m but oscillates vertically over an amplitude of 150-250 m along a strike length of several km. In the Veta Madre, in which the configuration of the ore band is best constrained by an extensive assay data array 3.5 km long, the periodicity or "wavelength" of subvertical lobes in chemical contours is reasonably regular at ~ 75-100 m, but ranges from 50 to 150 m. Locations of upward-directed lobes in chemical contours correlate well with intervals of relatively large fissure aperture (oreshoots) along the pinching and swelling structures, as revealed in vein isopach sections. The vein structure tends to pinch with depth to a relatively tight ramified fault zone below the productive simple-fissure horizon.

Extensive fluid inclusion studies indicate that very coarse-grained sphalerite, galena, pyrite, and intergrown freibergite, which dominate vein filling in the high-grade ore band, were precipitated from non-boiling solutions, but intercalated quartz/chert crustification bands associated with sphalerite leaching episodes record fluid inclusion and textural evidence of repeated descent of the base of the boiling zone to depths within the main ore horizon in response to salinity decrease and possibly CO₂ increase or release of confining pressure.

Late-stage events of this kind can clearly be associated with textural evidence of hydrofracturing of sealed veins at high levels in the system. The ratio of chert/comb quartz increases upward in the veins as sulfides diminish, substantiating evidence that a zone of persistent boiling probably occupied upper levels of the fractures most of the time during ore deposition at slightly greater depths.

The mineralized vertical interval in each fissure vein is dimensionally analogous to a 2-5 km Hele-Shaw cell some 200-500 m high, bounded above by gradation to reduced permeability in response to accelerated silica precipitation in a steep (boiling) temperature gradient, and bounded below by gradation to reduced permeability due to decreasing structural stability of open space with increasing lithostatic load. For the pertinent model case of a 12.5 wt % NaCl solution that begins to boil isenthalpically at 230°C, with 7 wt % vaporization, the temperature falls to 195°C, salinity of the residual liquid increases to 13.4 wt % NaCl, and the liquid density increases by about 5% from .933 to .976 g/cm³ over a vertical interval of 400 m. Taking into account the flow-impeding effect of the large volumetric fraction of vapor (nearly 90%) in the upper part of this interval, the marked gravitational instability of the inverted liquid density gradient is indicated by values of the Rayleigh number (R) in the range 10⁵-10⁸ for fissures of 5-40 cm open-space aperture at intermediate filling stages. For the case of a 137 m interval in an all-liquid column at its boiling temperature in the 230-195°C interval (non-adiabatic wall rocks), R ≈ 10⁶-10⁹ in fissures 5-40 cm wide. These two boiling models, which should bracket the behavior range of the natural system, both indicate that the liquid should be involved in vigorous partial recirculation in the form of convection cells superposed on the general fluid flux in the bottom and out the top of the zone of interest. Due to the greater permeability requirements of the more voluminous upwelling flow, upwelling limbs of the cells are expected to coincide with intervals of greater fissure aperture. Because the downwelling liquid is denser than hot, non-boiling liquid entering the zone of interest from below, the downwelling currents should penetrate below the boiling zone. Vertically-telescoped ore deposition may occur below the base of the boiling zone as downwelling, cooler, higher pH (by acid volatile loss) liquid and hotter brines ascending from greater depth undergo mixing along the base and upwelling limbs of the convection rolls. Mineral saturation fronts are expected to reflect the configuration of isotherms, which are inflected upward in zones of upwelling flow, thus possibly accounting for the sinusoidal configuration of the ore zones in Topia veins. Conductive cooling models can yield fluid isotherm configurations that reflect the distribution of permeability variations along the fissures, but cannot account for telescoped ore deposition from non-boiling solutions.

The Geochemistry of Majuba Hill, Nevada

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Majuba Hill is the erosional remnant of a mineralized volcanic complex of rhyolite porphyry stocks, dikes, sills and irregular masses of breccia intruded into Triassic (?) argillites. Majuba Hill is best known for its Cu and Sn ore; in addition, it was mineralized with other metals of possible economic significance, most notably, Mo, Ag, and U.

Although this is an intrusive complex with no evidence of any extrusive phases, it was intruded sufficiently near the surface to develop a porphyritic texture. Intense sericitic and argillic alteration affected all stages of intrusion. Fresh rocks were not available for K-Ar analyses. Several samples of feldspars and sericite from altered zones yielded K-Ar ages for

the alteration of 24.7 to 25.5 m.y. The tight clustering of ages suggests that all stages of the complex were altered within less than 1 m.y.

The black breccia and late rhyolite porphyry were host to most of the mineralization. The black breccia is host to the Sn mineralization, acquiring its color and name from tourmaline that replaced the feldspar. Many trace elements have anomalous concentrations in Majuba Hill, compared to the average crustal abundance for silicic igneous rocks. They include Ag, As, Cu, F, Ga, Li, Mo, Pb, Se, Sn, Th, U, and Zn. In addition, many elements including B, Bi, Cr, Ni, Rb, and the rare earths, are locally concentrated. The Ag content is routinely above 1 ppm, and values exceeding 100 ppm are not uncommon; Ag appears to associate most commonly with Pb and occurs in Cu-As-rich samples. The sulfur content for most samples is low, less than 0.1 percent, except in concentrates of fine-grained pyrite and some Cu-rich rocks. The U is concentrated primarily in the late rhyolite porphyry, which is strongly enriched in the incompatible elements that are characteristically concentrated by late-stage silicic magmatic processes. One sample with U concentrations of 200 ppm has values of 800 ppm for Th and 2000 ppm for Li and has similarly high concentrations of rare-earth elements. Although the Th/U ratio is normal for igneous rocks, the U concentrations are higher than the 50 ppm believed to be an approximate maximum for normal magmatic enrichment processes. Because of the high Th concentrations, and the immobility of Th in low temperature fluids, the mineralizing fluid that transported the Th and U could not have been low temperature.

Oxygen isotope data show strong depletion of ^{18}O in feldspars—both from surface exposures of rhyolite porphyry and from an orthoclase vein cutting K-silicate altered porphyry at a depth of 800 meters. These relations suggest that the rocks of Majuba Hill were altered by an ^{18}O -depleted fluid of probably meteoric origin. The alteration affected rocks to a considerable depth in the complex, suggesting a deep convective hydrothermal circulation system.

Mineralogy and Geochemistry of Hydrothermal Alteration at Glass Buttes, South Central Oregon

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Glass Buttes, a Pliocene silicic volcanic complex within the High Lava Plains Province of Oregon, was erupted approximately 5.0 to 5.8 m.y. ago. The eastern portion of the complex is underlain by rhyolitic glass domes, flows and rare pyroclastic flows. Basalt flows are interlayered with and onlap the silicic glass. Younger basalt flows, erupted from local vents, overlie silicic glass and onlapping basalts.

The eastern end of Glass Buttes is hydrothermally altered at the surface; a weak geothermal anomaly coincides with the altered areas. Alteration, localized by NW trending faults, occurs primarily as opalite replacement of rhyolite glass. Replacement opalite is opal C-T (disordered alpha cristobalite, alpha tridymite) and can be differentiated from precipitated opalite, opal-A (highly disordered, nearly amorphous), by X-ray diffraction. Replacement by opalite away from fractures appears to be more extensive in dense flow banded rhyolite glass than in inflated glass from domes.

Indicated alteration paragenesis is: (1) fracturing and replacement by opal C-T. Opalization is a volume-for-volume replacement accompanied by profound depletion of major and trace elements, including transition elements and REE. (2) Refracting of opal C-T is commonly associated with re-cementation by opal C-T plus cinnabar. Cinnabar also occurs as fracture coatings and vug linings. Deposition of opal-A in fractures may have been contemporaneous.

(3) Alunite occurs as: pink alunite plus opal C-T in veins; in euhedral form in open cavities in the shallow subsurface; and within white friable powder in acid-leached zones at the surface. (4) Hematite, orange and ruby, coats fractures, lines vugs, and occurs as late-stage surficial stainings. (5) Water-clear botryoidal silica varies from opal-A to alpha quartz and, where it occurs, coats all previous alteration.

Alteration in the subsurface occurs to the west and southwest in areas underlain at the surface by unaltered rocks. Carbonate, alpha quartz, abundant pyrite, and minor nontronite occur in vugs and fractures, and partially replace downhole basalts. Pyrite separates from disseminations and veins within the basalt and altered rhyolite glass contain up to 13 ppm Au. The pyrites are also anomalous with respect to Ag, As, and Sb.

Absence of clays and zeolites, and profound depletion of major and trace elements in zones of alteration characterize Glass Buttes. Blind precious metal mineralization in young silicic volcanic centers may have similar geochemical and mineralogical patterns.

Precious Metal Mineralization at the Zaca Mine, Alpine County, California

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The Zaca Mine in Alpine County, California has been mined for precious metals intermittently for the past 120 years. Recently, California Silver, Inc. has defined approximately seven million tons of low grade gold and silver mineralization that is amenable to open pit mining and heap leaching. The area is located in the eastern Sierra Nevada in a thick sequence of late Miocene andesitic flows. The Zaca Mine's mineralization (age \approx 5 m.y.) is restricted to, and nearly contemporaneous with, a 1500 ft. diameter, near-surface rhyolite plug. Drilling by California Silver, Inc. has delineated an elongate, pod-shaped deposit with the mineralization predominantly in fractures. Precious metals are also found as disseminations, in veins, vugs, and irregular chimney-like shoots. Throughout the rhyolite, the mineralization is controlled by cooling joints, bulges in the rhyolite contact, and multiple chill margins, as well as regionally-controlled fracture patterns. Mineralized fractures can contain quartz, pyrite, limonite, sphalerite, argentite, silver-bearing tetrahedrite, proustite-pyrargyrite, gold, \pm rhodochrosite and huebnerite. The gold (5 micron size avg.) is present predominantly as blebs associated with the silver minerals and pyrite. In the mineralized zone, the rhyolite has been weakly silicified and fractures locally have silicified and/or sericitized selvages. Within the Zaca Rhyolite, mineralization is known to occur over 1400 vertical feet with an associated systematic change in silver to gold ratio from approximately 5:1 at the highest elevation to at least 30:1 in the deepest underground workings. Base metals also increase with depth.

Precious Metals and Andean Cenozoic Volcanism in Chile

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Cenozoic evolution of the Andean Cordillera corresponds to predominant subaerial volcanism of cal-alkalic composition, generated by a magmatic arc system related to the subduction of the Pacific oceanic plate along the western border of the South American continent. Granodioritic intrusives and dacitic subvolcanic bodies are co-magmatic with the extrusive suite. Several compressive and extensional stages related to the evolution of the arc are identified, as well

as a general eastward migration of magmatism. Normal faulting (NS and NE), plus block tectonism gave rise to modern physiographic features, younger volcanic cone alignments and control of geothermal fields.

At least four precious metal occurrences (Choquelimpie (Ag, Au), La Coipa (Ag, Au), El India (Au-Ag-Cu) and Minas del Prado (Au-Ag), hosted by volcanic rocks are considered as examples of the possible relationship between this type of metallic mineralization and Upper Cenozoic volcanism.

Considering geological environment, hydrothermal alteration patterns and ore-gangue mineral assemblages, these deposits could be classified as sub-volcanic, high-level, epithermal type. In the areas of precious metal mineralization, andesitic to dacitic extrusive rocks predominate, as well as dacitic-dioritic, granodioritic intrusives, some of them of domal type. A relationship with structures, sometimes of caldera type, is evident. Hydrothermal alteration assemblages are: advanced argillic, quartz-sericitic and silicification (including chalcedonic type) with external propylitic halos. Most common ore minerals are native gold and silver, base metal sulphides, and sulphosalts, all in a quartz-pyrite gangue. Ore bodies are described mainly as vein type, but disseminations and mineralized hydrothermal breccias are also known.

Preliminary Geochemical Data on the "Chlorite Breccia" of Metamorphic Core Complex Detachment Zones and Thoughts on Associated (?) Base and Precious Mineralization

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The unique tectonic setting of metamorphic core complexes (MCC) has recently focused much exploration attention for precious metals within low-angle normal faults or detachment zones. Lower plate rocks of MCC appear unusually depleted in metal deposits but occurrences abound in close spatial association with juxtaposed detachment zones of intense brecciation and propylitic alteration or the fragmented upper plate. Accordingly, uncertainty exists concerning the origin of the mineralization and the possible role of detachment or MCC processes.

Preliminary whole rock, major/minor-element, geochemical data from rocks of the vertical sequence from undeformed protolith through mylonite and "chlorite breccia" to upper plate volcanics indicate that detectable to significant chemical and mineralogical changes have occurred throughout the deformation interval. The general character of additions and losses suggests chemical transmissibility facilitated by the upward increase and mobility of water through the mylonite sequence. The erratic but highly anomalous concentration increase of many elements within the "chlorite breccia" indicates that fluids concentrated at this upper horizon probably resulted in the characteristic brecciation and propylitization. The "chlorite breccia" appears spatially and genetically tied to the presence of subjacent mylonites. Therefore, fluids and geochemical additions presumably were derived from mylonitization processes. Preliminary isotopic and fluid inclusion data give mixed conclusions regarding origin of fluids involved (magmatic-metamorphic vs. meteoric), which underscores the complexity and multiplicity of fluid history. For chlorite breccia and economic mineralization, this history incorporates superimposed aspects of metamorphism, subvolcanic intrusion and meteoric circulation. No wonder it is difficult to sort out.

Sampling in chlorite breccia zones below detachment faults show them to be relatively sterile in economic metals, whereas these commodities appear to concentrate at or just above the fault, in upper or middle plates. The geology, geochemistry and possible origin for these deposits are briefly discussed, as is the polarization between gold and non-gold bearing occurrences.

KEYNOTE ADDRESS

Geochemical Methods of Exploration for Gold and Silver Deposits

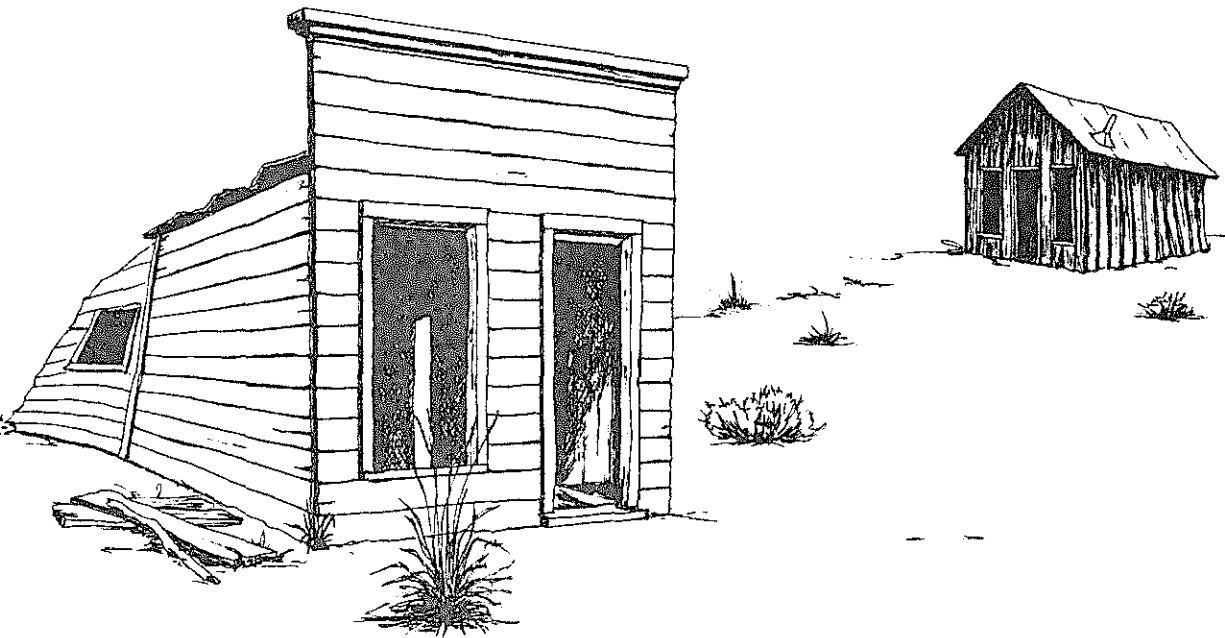
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The principal types of gold and silver deposits are described, followed by a discussion of the geochemical methods for their discovery, including lithochemical (rock), pedochemical (soil), hydrochemical (water and drainage sediments), atmochemical (gases and volatile elements, e.g. mercury), and biogeochemical methods.

For gold deposits the most satisfactory methods are heavy mineral (panning) surveys based on soils, weathered residuum, glacial materials, and drainage sediments. In some terranes, leakage halo surveys utilizing chloritized, sericitized, and silicified zones, jasper, etc., are particularly effective; in other terranes, humus (A horizon) surveys have proven useful.

All the geochemical methods employed in searching for gold deposits apply to the search for argentiferous deposits. In many terranes, drainage sediment surveys are the most effective methods for localizing argentiferous belts, followed by soil and/or humus surveys, leakage halo surveys, and more detailed lithochemical surveys.

The most serious problem in utilizing geochemical surveys in the search for auriferous deposits concerns adequate sampling and accurate gold analyses. Few problems are generally encountered with silver analyses.



THEORETICAL ASPECTS OF GOLD/SILVER TRANSPORT AND DEPOSIT

Mechanisms of Deposition of Gold in Low Temperature Hydrothermal Systems

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The behavior of gold in hydrothermal systems is evaluated as a function of pH and oxygen fugacity at temperatures to 250°C. Under conditions of stability of pyrite and argillic alteration assemblages, gold will be transported as bisulfide complexes. In systems containing significant amounts of arsenic, thioarsenide complexes may be important. Oxidation, dilution and cooling would cause gold deposition under these conditions. Adsorption and coprecipitation are possible mechanisms of deposition for gold in certain low grade epithermal deposits. Low concentrations of gold in the transporting solutions and the resultant deposits, combined with the significant solubility of gold as bisulfide complexes, suggest hydrothermal solutions are rarely saturated with gold and coprecipitation with sulfides may be an important initial depositional process. Recrystallization of the sulfides in the presence of hydrothermal solution would be responsible for release of gold to more stable sites. This mechanism is supported by the close association of gold with pyrite in these deposits.

Arsenic Minerals as Indicators of Conditions of Gold Deposition in Carlin-type Gold Deposits

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Arsenic minerals commonly occurring in Carlin-type gold deposits include orpiment and realgar and, more rarely, native arsenic and arsenopyrite. Other arsenic-bearing phases present include arsenian pyrite and stibnite and a number of thallium and mercury sulfides. Under conditions of constant temperature and pressure, the relative stability of arsenic minerals is a function of sulfur activity. At high sulfur activity, orpiment is the stable phase. As sulfur activity is decreased, more sulfur-deficient arsenic phases become stable with the progressive formation of realgar, native arsenic, arsenopyrite, and finally, loellingite at very low sulfur activity. The relative stability of the arsenic phases is independent of f_{O_2} . Three univariant equilibrium assemblages: orpiment+realgar, realgar + native arsenic; and native arsenic + arsenopyrite; are useful indicators of sulfur activity and commonly occur in the epithermal environment.

During main-stage gold deposition in the Carlin gold deposit, sulfur activity was low enough for native arsenic to be stable but sufficiently high to preclude the formation of arsenopyrite. Native arsenic was deposited in carbonaceous ores as the native metal, was coprecipitated with pyrite, and was adsorbed onto the surface of preexisting pyrite grains to form arsenian pyrite. Late-stage deposition of realgar and orpiment on fractures and in calcite veins which cut the ore indicate that sulfur activity and/or temperature of the fluids changed dramatically during the waning stage of hydrothermal activity. A similar paragenesis of arsenic minerals is observed in the Getchell gold deposit where main-stage gold deposition occurred at low sulfur activity with arsenopyrite ± native arsenic being stable and late stage realgar ± orpiment occurring in veins and fractures which cut the ore.

The change from arsenic + arsenopyrite stable to realgar + orpiment stable in Carlin-type deposits can be explained by any of the following changes in the hydrothermal fluid: (1) isothermal increase in sulfur activity by two orders of magnitude; (2) decrease in temperature of about 75°C at constant sulfur activity; or (3) decrease in temperature and sulfur activity. Process 3 is most likely because dilution, boiling, and sulfidization reactions would decrease sulfur activity and temperature during the waning stage of hydrothermal activity.

Transport and Deposition of Gold and Silver in Boiling Hydrothermal Solutions

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Precious metal ore deposits have been historically classified according to their Ag/Au ratios, mineralogy, host rock affiliation and alteration. Typically, the Ag/Au ratios range from less than about 0.01 to over 1000 and exhibit a distinct bimodal distribution (veins plus disseminations). The deposits falling in the low Ag/Au mode are dominated by native Au, electrum, tellurides, and Ag_2S ; regional propylitic alteration with minor alunite; and adularia + quartz + calcite in veins. Native Ag, if present, is a very minor phase. The high Ag/Au deposits (upper mode) are characterized by Ag_2S , base-metal sulfides, silver sulfosalts, electrum and native Ag; regional propylitic alteration; and quartz-rich veins. Native Au is subordinate to all other precious metal phases.

These trends, the range of Ag/Au ratios and their distribution (e.g., vertical zoning = Ag + base metals low; Au⁰ high in system) in a given deposit are commonly attributed to variations in source rock-type, fluid flow patterns and velocities, transport properties (e.g., T, pH, salinity, total S), and depositional mechanisms (e.g., boiling, mixing, cooling). The purpose of this study is to understand, through chemical modeling, the transport and depositional mechanisms for Ag and Au in boiling hydrothermal systems. Boiling is singled out because the majority of the precious metal deposits studied, particularly precious metal veins, exhibit some evidence of two-phase behavior.

Several hundred model calculations were carried out for the following conditions: T = 150-300°C, Cl = 0.1-1.0 m; H_2S = 0.1-10⁻⁵m; pH = 4-6; ΣSO_4 ΣH_2S = 0.1-10⁻⁹. The following trends were observed:

- (1) Ag/Au ratios in solution range from ~0.001 to ~200.
- (2) Ag/Au ratios in solution display a distinct bimodal distribution, with major modes between 0.001-0.01 and 10-100.
- (3) Regardless of Cl concentration and pH, Ag/Au ratios < 10 are associated with 150° to 200°C fluids; Ag/Au ratios > 10 are dominated by 250°-300°C fluids.
- (4) Ag/Au ratios decrease with increasing total H_2S .
- (5) Ag/Au decreases with increasing pH, but overall, pH is subordinate in its effect on Ag/Au ratios.
- (6) For Ag/Au ratios < 10, $Au(HS)_2^-$ is the dominant complex; at Ag/Au > 10, $AuCl_2$ predominates.
- (7) The stable silver phase at Ag/Au < 10 is Ag_2S ; for Ag/Au > 10, Ag⁰ predominates.
- (8) Metals that are bisulfide-complexed are deposited more sluggishly during boiling than metals complexed by chloride.
- (9) $Au(HS)_2$ can, however, destabilize allowing for Au deposition during boiling.
- (10) When Au occurs predominantly as $Au(HS)_2^-$ (Ag/Au < 10, high ΣH_2S), there should be considerable spatial separation between native Au and sulfides during the boiling event (e.g., vertical zonation).
- (11) In this case, Ag will occur primarily as Ag_2S with base-metal sulfides which deposit early in the boiling process.
- (12) If Au is chloride-complexed (Ag/Au > 10, low ΣH_2S), native Au and Ag can occur together, but will be deposited later in the boiling process compared to the base-metal sulfides.

The bimodal nature of Au in solution (as either as a HS^- or Cl^- complex) results in two distinctly different Ag/Au populations in solutions over the range of expected natural conditions. Boiling can be an effective agent in separating Au from Ag, thereby resulting in Au-rich and Ag-rich zones and enhanced bimodality in precious metal deposits.

Physical Chemical Processes Affecting Deposition of Silica in Carlin-type Gold Deposits

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Carlin-type gold deposits are remarkably similar with regard to key geological and geochemical characteristics, which implies a common mode of origin. Mass balance calculations on elements introduced during main-stage and post main-stage mineralization of the Carlin deposit, Nevada, based on numerous chemical analyses of rocks and experimental solubilities, account for each component except for two: Al_2O_3 in the ore body; and SiO_2 in late veins. Main-stage deposition was from slowly moving solutions which precipitated quartz, pyrite and trace elements including gold, from 140-190°C, by a coupled replacement reaction that also simultaneously removed carbonate minerals. Post main-stage deposition was from rapidly moving solutions, from 190-300°C, that filled fractures with barite and sparse base metal sulfides. Post main-stage fluids amounted to at least ten times the amount of main-stage fluids, and they were accompanied by boiling. The rapid switch from slow replacive deposition of the main-stage to rapidly moving fluids that deposited a different set of minerals is difficult to account for. Invoking two different sources does not fit in with the remarkable similarities of the different deposits.

Possible insights stem from experimental studies at ORNL on the reaction of quartz (Q) with aqueous solutions (AQ). This reaction is commonly written: $SiO_2(Q) + 2 H_2O(AQ) = H_4SiO_4(AQ)$, and it is considered to be a first order, single step reaction by most previous workers. However, ongoing work at ORNL on the reaction from 125-300°C indicates that under some conditions another solid phase appears as tight coatings on the quartz grains. The surface coating (SC) is probably metastable, and it would be expected to disappear eventually. So long as it exists, however, it acts as a barrier between quartz and solution. A two-step reaction can be written: $SiO_2(Q) + n H_2O(AQ) = SiO_2nH_2O(SC)$; and, $SiO_2nH_2O(SC) + (2-n) H_2O(AQ) = H_4SiO_4$. The experimental data reveal that the rate of dissolution of quartz is two to eight times faster than the rate of precipitation. Quartz precipitated from main stage fluids possibly because of the slow and passive nature of the reactions, but none was deposited during post main-stage events because of the rapidity with which the fluids moved through the ore bodies. Barite shows different behavior; it has been reported to grow, for example, on inside walls of pipes containing cold, upward moving oil field brines supersaturated with both barite and quartz, without concomitant deposition of quartz. Post main-stage fluids would be expected to transport silica to zones at or near the surface, forming the silicified rocks and jasperoids so prominently developed above Carlin-type deposits.

The experiments on quartz reaction kinetics provide data useful in interpreting features of ore deposits formed in shallow portions of the earth's crust, where departures from equilibrium are common and metastable phases can be created.

Ammonia Alteration is a Geochemical Link in Gold Deposits of the Carlin-Midas Belt

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Budingtonite and NH_4^+ -micas occur in two distinct geologic environments: organic-rich black shales and hydrothermally altered volcanic rocks. Ammonium-rich hydrothermal solutions are very effective gold carriers and gold is precipitated, whereas silver remains in solution when pH rises in these solutions. Thus, gold is enriched in the deposits relative to silver.

The following is a hypothesis suggesting that NH_4^+ -alteration links carbonate- and volcanic-hosted gold deposits. Carbonate- and volcanic-hosted deposits that are rich in gold and poor in silver occur in juxtaposition along the northwest-trending fault-controlled Carlin-Midas belt. Within the fault zone, ammonia is leached by hydrothermal solutions from underlying organic-rich shales of the Roberts Mountains Formation. The formation of NH_4OH significantly enhances gold solution and transport. The spatial distribution of the gold deposits trending northwest from Rain to Maggie Creek, Carlin, Blue Star, Dee and Ivanhoe marks where that ammonium-rich solution ascended along the fault zone. Widespread budingtonite alteration was recently identified in the youngest and most shallow hot-spring type gold prospect at Ivanhoe. This suggests that in the presence of NH_4^+ , the carbonate-hosted gold deposits formed as the root portions of volcanic-hosted, hot spring deposits.

DEPOSITS IN PORPHYRY SYSTEMS

Elemental Dispersion at the Hall (Nevada Moly) Porphyry Molybdenum Deposit, Nye County, Nevada, and its Relationship to Features of Alteration and Mineralization

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Each of two molybdenum-bearing, quartz monzonitic stocks were emplaced at 66-70 m.y.b.p. and underwent continuous inward crystallization which was interrupted three times by the successively deeper release of hydrothermal fluids. The stocks are concentrically zoned texturally and each contains three stacked molybdenum ore bodies and overlapping zones of alteration and mineralization. Mapping and petrographic/fluid inclusion studies indicate that in each alteration/mineralization pulse, early quartz-molybdenite \pm chalcopyrite-pyrite veinlets with K-feldspar envelopes ($T=470-750^{\circ}\text{C}$; Wt. % NaCl eq. = 8-19%) were followed by quartz-muscovite \pm pyrite and fluorite (greisen) veinlets with envelopes of coarse-grained (1-23 mm) muscovite. Later fluids in some pulses formed quartz-magnetite veinlets or chlorite-enveloped quartz-pyrite-chalcopyrite \pm magnetite veins, but all pulses were ultimately closed by quartz-galena-sphalerite-chalcopyrite tetrahedrite, pyrite veins having no alteration envelopes ($t = 370-450^{\circ}\text{C}$; Wt.% NaCl eq. = 30-41%).

Regional structure and paleomagnetic data indicate that during Tertiary time, the stocks were tilted eastward about 70° . Alteration/mineralization zoning is consistent with such a tilt and trace elemental dispersion patterns are interpreted in this context. Molybdenum ore bodies are related to quartz-molybdenite veinlets, with successively deeper ore bodies related to veinlets produced by successively deeper phases of each stock. Copper highs (200-1000 ppm) generally occur with molybdenum highs (600-2000 ppm) as a result of the nearly ubiquitous occurrence of chalcopyrite in the quartz-molybdenite veinlets. Fluorine highs (3000-21000 ppm) are related to greisen veinlets and occur 30-60 meters outward of molybdenum highs. Tin and tungsten anomalies are generally weak (0-25 ppm) and, although they locally occur together and with fluorine highs, they are more typically sporadic in distribution. Anomalies of lead (300-5000 ppm), zinc (200-4000 ppm), manganese (300-3000 ppm), and silver (5-30 ppm) are related to base metal veins and occur 40-80+ meters outward of molybdenum highs. Arsenic is sporadically distributed in general, but correlates well with Pb-Zn-Mn-Ag highs where copper anomalies are also present.

The Use of Geochemistry in the Search for Molybdenum Deposits

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Geochemistry can play an important role in the discovery and development of stockwork molybdenum deposits:

On a continent scale, different types of molybdenum deposits are associated with geochemically distinct igneous source rocks. Relative levels of potassium enrichment, Nb, Rb and Sr contents and Rb/Sr ratios in combination with age dates, can be used to outline potential metallogenic belts favorable for the occurrence of calc-alkaline or Climax-type molybdenum deposits. These belts may form the basis for launching a regional reconnaissance program.

On the prospect scale, a knowledge of element dispersion patterns around a central molybdenum shell can be used in conjunction with surface geochemical data to predict location and size of, and depth to the molybdenum zone. During the exploration phase of the Mount Hope stockwork molybdenum deposit in Nevada, a detailed surface geochemical program was conducted. Rock chip and soil samples collected on a 400 foot grid were analyzed for Mo, F, Cu, Pb, Zn, Ag, Sn, W and Bi. Sn, W and Bi did not prove to be useful but metal distribution patterns of the other elements accurately pinpointed the loca-

tion of the molybdenum zone in the deposit. Using an empirical exploration model, the strong Pb, Zn, and Ag anomalies and weak F anomalies over the eastern part of the igneous complex were correctly interpreted as indicating a relatively shallow erosion level. Strong Mo and F anomalies over the western portion of the stock were thought to indicate shallow mineralization. Surface work was followed by an extensive drilling program that established a well-defined metal zoning pattern at Mt. Hope and confirmed our assumptions. An outer and upper zone is characterized by anomalous lead and silver values, an intermediate zone shows high zinc, silver and sulfur concentrations and a lower zone is enriched in copper and tin. Fluorine is concentrated directly above the ore zone but patterns may be disturbed by the presence of biotite hornfels which preferentially concentrates fluorine. A tungsten-anomalous zone overlaps with the lower part of the molybdenum zone.

On the deposit scale, metal zoning patterns are used to establish the presence of faults, show direction of movement and outline exploration potential for faulted-off portions of the deposit.

Trace Elements in Sphalerite, Galena, and Pyrite from Molybdenum and Non-molybdenum Systems

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Sphalerite, galena, and pyrite are common constituents of molybdenum deposits, as well as base metal sulfide deposits. In many instances these sulfides are one of the very few surface expressions of buried molybdenite mineralization. Trace element abundance was studied in these sulfides, from molybdenum and non-molybdenum systems, to determine if there is a characteristic suite of elements that separates the two types of deposits.

Base metal sulfides were collected from and peripheral to the Climax, Henderson, and Redwell Basin-Mount Emmons molybdenum deposits of Colorado, and the Kitsault molybdenum deposit of British Columbia. Base metal sulfides from non-molybdenum related mineralization were collected from the Leadville, Empire, and Freeland-Lamertine districts.

Sphalerite from molybdenum systems generally contains significantly more calcium, bismuth, cobalt, molybdenum, and tin and slightly more barium and manganese compared to sphalerite from non-molybdenum systems. Sphalerite from molybdenum systems is generally depleted in iron, silver, arsenic, lead, antimony, and tungsten compared to non-molybdenum systems. Galena from molybdenum systems generally contains significantly more calcium, magnesium, silver, bismuth, cadmium, and manganese compared to galena from non-molybdenum systems. There may be a slight depletion in antimony in galena from molybdenum systems. Pyrite from molybdenum systems commonly contains significantly more magnesium, bismuth, cobalt, manganese, molybdenum and tungsten compared to pyrite from non-molybdenum systems.

Although the above element to mineral relationships represent a general case, there are some inconsistencies. A simplified list of consistent element to mineral relationships include: sphalerite that is enriched in tin, and possibly molybdenum; galena enriched in bismuth; and pyrite enriched in bismuth, and possibly molybdenum and tin. In the search for molybdenum deposits, base metal districts that contain sulfides with these trace element signatures should be considered excellent exploration targets.

Geochemical and Geological Exploration for Gold-Copper Deposits in Southern Luzon, The Philippines

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The Philippines are a major gold and copper producer from bulk-mineable deposits. Four significant types of gold deposits serve as models for exploration. Gold-rich copper porphyries occur in differentiated dioritic plutons. They show strong variations in gold content (0.2-1.0ppm). Large wide enargite vein systems in argillized volcanics contain 2-3% Cu, 4-5ppm Au, and 16-20ppm Ag. Epithermal gold systems include stockworks, siliceous aprons and veins. Gold-base metal vein systems show diverse metal contents. Thick laterite and jungle conceal structures and plutons. Leaching commonly is intense. Known porphyry deposits show highly variable copper anomalies in overlying soil. Gold, as traces in soil and as placers, forms distinct anomalies. Only limited data have been published on the geochemical expressions of the other deposit types.

An exploration program in southern Luzon used mapping, panning, soil and stream geochemistry, and IP surveys to seek gold targets. Gold showed pronounced soil anomalies, while lead showed low-level "spikes" over ore. Panning of soil grids and drill sludge, using cheap labor to seek trace gold, was combined with analysis of concentrates. One quartz-pyrite-chalcopyrite-gold system, rich in cobalt and bismuth tellurides, and low in silver, arsenic, lead, and zinc was drilled and sampled. Fluid inclusion, ore microscopy, and trapped gas analyses to date show only partial similarities to known models.

Geochemical and Fluid Zonation in the Skarn Environment at the Tomboy-Minnie Gold Deposits, Lander County, Nevada

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The Tomboy-Minnie gold deposits are related to the middle Tertiary porphyry copper system centered at Copper Canyon. Gold-silver ores in the deposits occur mostly in a pyrrhotite- and pyrite-rich, basal, 30-m-thick sequence of altered calcareous conglomerate belonging to the Middle Pennsylvanian Battle Formation. The entire mineralized system contained at least about 3.3 million troy oz. Au before large-scale mining operations began. Alteration in the Tomboy-Minnie deposits includes actinolite- and chlorite-dominant assemblages, in marked contrast to the skarn, potassic, and phyllic assemblages characterizing the more proximal copper-gold-silver deposits of the system. Introduction of gold occurred penecontemporaneously with replacement of early diopside-salite(?) alteration assemblages by actinolite and chlorite. Metals are zoned strongly in the Copper Canyon system: the West and East ore bodies occur in a copper-gold-silver zone that is followed outward by a gold-silver zone which includes the Tomboy deposit and in turn, is succeeded by a lead-zinc-silver zone. Locations of drill holes that have Au/Ag assay ratios of ≥ 1 clearly outline the Tomboy-Minnie deposits within an area of rocks with Au/Ag ratios of ≈ 0.5 . Fluid inclusion studies suggest wide variations in temperature and chemistry prevailed in the fluids associated with mineralization at the Tomboy. Early fluids associated with diopside-salite-quartz assemblages probably were dominantly $MgCl_2$ -rich brines and were boiling at temperatures higher than 500°C. These fluids were progressively enriched in Na and K over time, and during the hydrosilicate stages, temperatures probably ranged from 320°C to 500°C at the time actinolite formed, and from 220°C to 320°C at the time chlorite was dominant. Sulfur isotopic data suggest that magmatic sulfur with a $\delta^{34}S$ of 4±1 per mil was transported by hydrothermal fluids as aqueous H_2S to the West, East, and Tomboy deposits.

ADVANCES IN ANALYTICAL GEOCHEMISTRY/DATA PROCESSING

Definition of Multivariate Geochemical Associations With Polymetallic Mineral Occurrences Using a Spatially Dependent Clustering Technique and Rasterized Stream Sediment Data—An Alaskan Example

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The application of an unsupervised, spatially dependent clustering technique (AMOEBa) to interpolated raster arrays of stream sediment data has been found to provide useful multivariate geochemical associations for modelling regional polymetallic resource potential. The technique is based on three assumptions regarding the compositional and spatial relationships of stream sediment data and their regional significance. These assumptions are: (1) compositionally separable classes exist and can be statistically distinguished; (2) the classification of multivariate data should minimize the pair probability of misclustering to establish useful compositional associations; and (3) a compositionally defined class represented by three or more contiguous cells within an array is a more important descriptor of a terrane than a class represented by spatial outliers.

AMOEBa was used to spatially define regional geochemical associations within two geologic domains in the southern half of the Nabesna 1°x3° quadrangle, Alaska. Ten stream sediment variables (Cu, Mo, Pb, Zn, Cr, Ni, Au, Ag, Fe, and Mn) were selected to describe polymetallic associations on the basis of known mineral occurrences within the study area. Original semiquantitative emission spectrographic data were log transformed, registered to a Universal Transverse Mercator reference base, and interpolated using a minimum curvature algorithm to create coregistered, 129 line-by-291 sample, raster arrays of 450m x 450m (ground equivalent) cells for each element. The application of AMOEBa to this data base established 41 spatially-significant compositional classes. Stratification of these classes, using mean copper concentration/class and a geochemically zoned porphyry-type system as a model objective, resulted in the definition of spatially consistent, polymetallic zoning associated with known porphyry centers. In addition to the definition of classes characterizing multivariate associations related to known levels of erosion within these systems, AMOEBa classes also reflected significant geochemical differences between the regional geologic domains and their associated porphyries.

Advantages realized using this technique in a computer-based mode to define multivariate associations within regional stream sediment data include: (1) it is based on a simple and rational model for the data; (2) it is fast and noniterative; (3) it can accommodate a very large number of geochemical variables and enormous arrays; (4) the expected number of clusters need not be specified and no interaction with the investigator is required; (5) cells that cannot, within the theoretical framework, be assigned to any cluster can be assigned to a reject classification; and (6) spatial outliers can be tagged for subsequent processing.

The Microcomputer in Geochemical Exploration

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A microcomputer system can be a powerful interpretive tool in the hands of the explorationist, particularly for his geochemical surveys. Field data entry and plotting of site parameters and/or trace element values on 19 x 25 cm maps, on site can be carried out at reasonable cost with available technology. Plotting characteristics of some microcomputer systems are the equal to those of mainframes.

All geochemical data, even for surveys of 38 elements with up to four sample media, can be displayed by a large plotter as ten single element plots (19x25) on each of four map sheets. Plotting 2,000 points for ten elements requires five hours and can be scheduled for overnight operation. Elements showing meaningful variations can be replotted subsequently at larger scales using character and/or symbol formats. Examples of geochemical plots are given for soil and stream sediment surveys and for drill core litho-geochemical studies.

The microcomputer can calculate statistics; however, large numbers of such calculations are slow. Transfer of data to a mainframe computer allows access to fast, sophisticated statistical software. The mainframe can also provide high quality laser-printed paper copy and can be used for fail-safe archiving.

Graphical and Computer Refinement of Cu-Mo-Pb-Zn-Ag Anomalies, Crow Springs Prospect, Esmeralda County, Nevada

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A geochemical survey was made of a sixteen square mile area encompassing the Crow Springs prospect thirty miles northwest of Tonopah, Nevada. A total of 289 soil and 189 rock samples were collected and analyzed quantitatively by atomic absorption spectrophotometry. Copper, molybdenum, lead, zinc, and silver were chosen for detailed studies.

The percentages of anomalous samples (of the total number of samples) for each element and each analytical technique were plotted as histograms. The relative strengths of the anomalies were defined according to background values established for the Tonopah region. Moderately to strongly anomalous samples were found for the five elements studied in the Crow Springs prospect.

Computer-generated isochemical maps were plotted for each element for the soil and rock data to determine the spatial distributions of anomalous samples. These data for each element then were refined by subtracting the sixth order trend surface (the highest order surface generated) from the data, leaving those positive residual anomalies that persist at the sixth order. The residual anomalies mark the location of samples that were determined graphically to be moderately to strongly anomalous.

Contoured isochemical data, the locations of the sixth order residuals, and the locations of surface outcrops of quartz monzonite porphyry have been plotted on individual maps for the five elements being studied. A total of ten maps summarizes the chemical information for copper, molybdenum, lead, zinc, and silver for the Crow Springs prospect, five each for the soil and rock data.

Comparison of Analysis Techniques for Gold

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Current demands for lower detection limits and better accuracy and precision at sub-gram/tonne levels of gold have led to a proliferation of gold analysis techniques. This presentation is intended to describe the salient features of the most relevant techniques including relative cost, time required to complete, accuracy and precision at selected concentration ranges, suitability of the method for proposed usages, and range of subsample sizes readily handled by the technique. The techniques described for the analysis of gold are as follows:

- (a) Direct Instrumental Neutron Activation.
- (b) Fire Assay Preconcentration followed by atomic absorption analysis of the dissolved dore bead.
- (c) Fire Assay Preconcentration followed by instrumental neutron activation.
- (d) Aqua Regia wet digestion followed by atomic absorption analysis.
- (e) Classical Fire Assay (gravimetric determination).
- (f) Cyanide leach of amenable ores followed by atomic absorption analysis.

Some comparative data will be presented for specific ore types.

Integrative Mercury Gas Geochemistry—A Comparison With Traditional Mercury in Soil Geochemistry at the Cinola, B.C. Gold Deposit

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Mercury gas has a great potential as a "pathfinder" element for "blind" mineralization. This appears to be especially true for the "bulk-mineable" low grade, epithermal, precious metal deposits in the western Cordillera. It is also applicable to many other types of mineralization in other geologic environments.

Mercury gas geochemistry has received much research and exploration attention in the recent past. The results have been highly equivocal. Studies have shown that gas signals in general and the mercury gas signal in particular are highly influenced by atmospheric variations and soil geochemistry. Complicating atmospheric variations include both soil and air temperature, pressure, and humidity on both daily and seasonal scales. The composition of soils, especially their organic content, Fe-Mn oxide and hydroxide content, clay content, and moisture content also cause difficulties in the interpretation of the gas signal in traditional soil mercury gas-geochemical exploration programs.

The mercury cup is a simple mercury gas integrative device particularly suited to geochemical exploration since it eliminates many of the complications in the interpretation of the mercury signal caused by these atmospheric and soil variations. The technique involves the use of a precious metal detector mounted in a plastic cup that is buried in the ground and allowed to collect mercury by amalgamation for some appropriate period of time (usually 15-45 days). The device is later collected and analyzed for its mercury content.

This technique was tested over the Cinola, B.C. gold deposit. This deposit is a "bulk-mineable" epithermal deposit in a volcanic host environment. The integrated mercury values were compared to previously published traditional mercury in soil and mercury in rock studies. The integrative technique was found to be highly reproducible and have a very strong positive correlation to the ore deposit whereas the soil mercury did not.

SEDIMENT HOSTED PRECIOUS METAL DEPOSITS

Application of Rank Sum Analysis to Soil Geochemistry at the Dee Gold Mine, Elko County, Nevada

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The Dee mine is a sediment-hosted, disseminated gold deposit in the Roberts Mountains allochthon of north central Nevada. Soil samples were collected from the C horizon in undisturbed areas over the deposit in order to investigate the usefulness of soil geochemistry in identifying this type of deposit. The depth of sampling varied between 12" and 16", depending upon soil development. Each sample was sieved to -80 mesh and analyzed quantitatively for Au, Ag, As, Sb, Hg, Tl and semi-quantitative data for an additional 31 elements. Individual element plots delineate known ore zones with variable success. Factor analysis of the quantitative data is not useful for ore zone identification using the total data set. However, rank sum analysis (Goldfarb, 1983) is successful for the Au, Ag, As, Sb, Hg, Tl suite, even though bedrock geology is disregarded. This method involves data transformation into a total element signature by ranking the data in ascending order and summing the element ranks for each sample. The rank sums are then divided into percentile groups and plotted. The rank sum plot for the Dee soils unequivocally identifies three of four known ore zones. The success of this statistical method for the Dee mine area indicates that it can serve as a powerful exploration tool for this type of deposit where outcrop is sparse and bedrock is largely unknown.

Geology of the Rain Gold Deposit, Elko County, Nevada

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The 686,000 ounce Rain ore body is an epithermal, sediment-hosted, disseminated gold deposit located along an alignment of deposits that includes the Carlin gold mine. The Rain deposit lies largely within siltstones of the Mississippian Webb Formation and is associated with a high angle reverse fault which is a major element of the hydrothermal plumbing. Rain, an essentially blind ore body, exhibits similarities to the Alligator Ridge gold mine in White Pine County, Nevada, including a jasperoidal surface expression.

Geology and Interpretation of Geochemistry at the Standard Mine, Humboldt Range, Nevada

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The Standard Mine, 26 miles north-northeast of Lovelock, Nevada, produced approximately 750,000 tons of 0.08 oz. Au/ton from two pits between 1939 and 1948. Both ore bodies are in shaly limestone of the Early Triassic Prida formation.

The Prida Formation lies unconformably above the Permian Rochester Formation rhyolite flows and ashflows which are the district's oldest rocks. Locally, younger Middle to Late Triassic Natchez Pass Formation massive limestone is thrust over the Prida Formation. Younger Late Triassic Grass Valley Formation phyllitic shale is thrust over the Natchez Pass and Prida Formations. A later thrust plate of Natchez Pass and Prida Formation limestone overrides the Grass Valley Formation.

A north-south striking normal fault formed a conduit for mineralizing fluids spreading along the youngest thrust fault in the South Pit. A north-south striking fracture zone formed a conduit for the North Pit mineralizing fluids which spread laterally along the thrust contact below the impermeable Grass Valley shale. Silicification, the mineralizing solutions' most prominent alteration effect, is pervasive along normal and thrust faults. Increases in grain size and abundance of vugs in matrix quartz of jasperoid approaching mineralization centers are similar effects found by Lovering and Heyl (1974) in the Taylor Silver District. In addition, increase in brecciation and limonite pseudomorphs after pyrite are also important characteristics approaching mineralization centers at the Standard Mine. Geochemistry of silicification indicates a wide range of gold, silver, and arsenic concentrations producing various anomalies including false and leakage anomalies.

Geology and Geochemistry of the Quito Prospect

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The Quito prospect is located about 10 miles south of the town of Austin in the Toiyabe Range. Literature research in early 1979 indicated the favorable potential of the area, which was supported by a field examination later in the year. After a successful geochemical sampling program, land acquisition began in 1980. Extensive surface sampling in 1980 was successful in outlining two major gold anomalies and numerous indicator-element anomalies. Subsequent investigation has identified additional anomalous areas. Drilling was initiated in 1981 and has continued to the present. To date, one ore body has been discovered; widespread weak gold mineralization occurs in several other areas. Current reserves are between 200,000-400,000 ounces gold contained in about 1.5 million tons, averaging 0.2 oz/T Au.

The prospect is located in the Dry Canyon window of the Roberts Mountains Thrust. Detailed mapping has revealed the presence of at least three other thrust faults, below the Roberts Mountains Thrust, that juxtapose the Cambrian through Silurian sediments. High-angle faulting cuts all units and complicates the geologic picture.

The defined ore zone occurs in the lower Antelope Valley limestone immediately below the Roberts Mountains Thrust. The mineralization appears to be controlled by high-angle structures intersecting thrust zones in the favorable lower-plate rocks.

The mineralization is typical of most sediment-hosted micron gold deposits in Nevada. Arsenic, antimony, and mercury are all anomalous along with the gold; the gold:silver ratio is high.

Geologic mapping and detailed geochemical sampling have shown that the system is widespread; anomalies occur throughout the 19-square-mile claim block. The property shows high potential for discovery of additional ore bodies.

Geochemistry and Alteration Studies at Carlin Gold's Maggie Creek Deposit

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In recent years Newmont Exploration Ltd. has developed a quantitative method for the measurement of alteration minerals in altered wall rock. This method is termed "mineralic contouring." Mineralic contouring is usually a direct measure of mineral intensities and often provides vectorial clues to geochemical and alteration trends. This method was first applied to disseminated gold deposits at the Carlin Mine in Nevada and later to the Maggie Creek and Gold Quarry deposits south of the Carlin Mine.

Impure Paleozoic limestones, of the "upper plate" transitional facies at Maggie Creek, have been decarbonized to altered siltstones and shaly units along vertical faults and permeable stratiform horizons. Advanced stages of silicification accompanied the decarbonization.

Anomalous arsenic correlates closely with gold mineralization at Maggie Creek. Zinc and barium correlate roughly with the distribution of gold and arsenic.

Micron Gold-Associated Jasperoid: Fluid Inclusion Chemistry and Geothermometry

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Jasperoid is commonly associated with Carlin-type or micron gold deposits. It may constitute the bulk of the ore, as at Pinson, or be developed only in isolated areas, as at Carlin. Fluid inclusion studies of jasperoid utilizing traditional methods have been largely unsuccessful due to the extremely small size of the inclusions and the opacity of jasperoid. We have attempted to obtain information on the geothermometry and chemistry of these inclusions by thermal decrepitation and analysis of the evolved gases by gas chromatography. The fluid inclusions must be heated past their homogenization temperature in order to generate a sufficient internal pressure to decrepitate them. Stepheating tests indicate an optimum decrepitation temperature of 350°C. The fluids evolved from these decrepitated inclusions contain up to 14 mole percent CO₂, 2 mole percent CO, 5 mole percent N₂, and negligible CH₄. Water comprises greater than 90 mole percent of most inclusions. Gas equilibrium calculations for analyzed inclusions from Carlin indicate probable mineralization temperatures of 250°C to 270°C if the fluids were in equilibrium with graphite (e.g. carbonaceous limestone). Our inclusion analyses are permissive for a greater depth of jasperoid formation than has commonly been proposed.

GEOTHERMAL SYSTEMS AND ORE DEPOSITS

Monotonic and Prograding Geothermal Systems and Precious Metal Mineral Deposits

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Fossil geothermal systems can result in a variety of surface manifestations, including tufa deposits, siliceous sinters and advanced argillic alteration zones (solfataras). These characteristics generally result from distinctively different geothermal and geochemical systems. Mineral deposits may form as a result of any of these types of systems, but only one appears capable of forming near-surface economic precious metal deposits.

Silica-rich systems appear to be most often associated with epithermal mineral deposits. There appear to be two distinct types of geothermal systems which result in siliceous surficial deposits. Monotonic systems are characterized by static and generally low geothermal gradients, opaline sinters, simple veins and a very compressed zone of precious metal deposition. Prograding systems have steep geothermal gradients and may exhibit chalcedonic sinters, explosive phenomena, and complex veining and mineralization. Prograding geothermal systems appear to be the only ones that have the attendant geochemical attributes necessary to generate near-surface economic precious metal mineralization.

Geochemical Patterns in an Altered Area at McGinness Hills, Lander County, Nevada

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Andesite and rhyolite flows of Oligocene age host two juxtaposed zones of hydrothermal alteration that are distinct in age, mineral assemblage, and trace element composition. A two square mile area of mixed illitic-argillic alteration with localized zones of hypogene quartz and alunite has been dated at 34.8 ± 1.7 m.y. by K/Ar determinations on alunite. A smaller one square mile area of layered sinter up to 80 feet thick with associated quartz veins and intrusive breccia has been dated at 2.2 ± 0.4 m.y. and 3.2 ± 0.4 m.y. by K/Ar determinations on adularia in quartz vein selvages. Anomalous concentrations of Mo (≤ 130 ppm) and F ($< 2.0\%$) in outcrop suggests that the older zone of illitic-argillic alteration may be an upper-level expression of a porphyry molybdenum system. The younger sinter and related veins display localized anomalies of Hg, Sb, As, and Au (< 2.0 ppm) and are interpreted as a weakly mineralized hot spring system. The juxtaposition of these two distinct hydrothermal systems may have been controlled by deep-seated crustal structures presently apparent as east-west lineaments on Landsat images.

Epithermal Gold-Silver Mineralization Related to Volcanic Subsidence in the Custer Graben, Custer County, Idaho

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The Custer graben is a 13 by 32 km northeast-trending volcano-tectonic graben in the Challis volcanic field of central Idaho. Four major rock types are present in the graben: Paleozoic sedimentary rocks and Eocene andesites, pyroclastic rocks, and rhyolites. Graben subsidence began about 48 m.y. ago. Hydrothermal alteration and epithermal mineralization took place about 44 m.y. ago in parts of the graben where there was both silicic intrusive activity and persistent fault movement.

Andesites, rhyolites, and associated pyroclastic rocks host vein and disseminated gold-silver deposits that are localized along discrete northeast- and northwest-trending fracture zones. Ore minerals in vein deposits are electrum, native gold and silver, chalcopyrite, and various sulfosalts in a gangue of pyrite and fine-grained quartz.

At the Sunbeam Mine, near the center of the graben, vein and disseminated gold-silver mineralization occurred in hydrothermally altered rhyolite and pyroclastic rocks. The host rock has been pervasively silicified, and the feldspars altered to clay minerals. Analyses of surface and drill-core samples show that altered rocks are variably enriched in gold, silver, molybdenum, arsenic, zirconium, and selenium. Intense silicification is shown by SiO_2 values as high as 93%.

Northeast-trending fractures, parallel to the graben-bounding fault zones, played an important part in localizing ore at the Sunbeam Mine. Pipe-like masses of silicified breccia, interpreted to be hydrothermal-explosion breccia, were formed along the northeast-trending fractures; the most prominent of these is crudely funnel-shaped and pinches out downward. Movement along some fault zones continued after the period of alteration and mineralization, ultimately juxtaposing altered and unaltered rocks.

Geology and Ore Deposits of the Thunder Mountain Mining District, Valley County, Idaho

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The Thunder Mountain mining district is located in Valley County, central Idaho. Epithermal Au-Ag mineralization occurs in Eocene Challis volcanics and volcaniclastic sediments. Alteration is characterized by pervasive, fracture controlled silicification and argillization. At the Sunnyside Mine gold and silver occur at a 3:1 ratio along goethite-hematite coated fractures within the upper ash flow tuffs. The mineralization occurs as very fine free gold and electrum. One K-Ar date from quartz-adularia veins over the ore zone yields a date of 41.8 ± 1 million years. This age is no more than two to five million years later than the emplacement of host rocks.

Mineralization at the Dewey Mine occurs as free gold and electrum in siliceous and carbonaceous sediments along shear zones. In limited geochemical sampling, Hg and As are significantly higher in the ore zone of both deposits.

Petrographic and whole rock analyses indicate the volcanics are rhyolitic to dacitic in composition. A vent area proximal to the mineralized zone has been defined and is characterized by a more mafic composition. Several periods of syn- and post-volcanic normal faulting have resulted in a blocky fault pattern and extensive erosion of portions of the ore deposit.

The volcanic hosted Sunnyside deposit has an announced grade and tonnage of 2.1 million tons of .09 oz gold/ton. The sedimentary hosted Dewey deposit has a reported 1.5 million tons of .11 oz gold/ton.

An Exploration Strategy for Hot-Spring Precious-Metal Deposits

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The discovery of economic precious-metal deposits related to physical-chemical processes in the near-surface portions of high-temperature hot-spring systems has led to intensive exploration efforts for this deposit type. To increase the probability of success, these exploration programs should

(1) be based on the most important visually recognizable or readily measurable deposit-model criteria, (2) be able to identify specific targets within the best search areas, and (3) be able to rank the order of priority among the targets.

We propose a process-recognition exploration strategy for hot-spring deposits that has been developed from data from precious-metal occurrences at several localities in the western United States, including Round Mountain, Tonopah Divide, and Sulphur, Nevada; DeLamar, Idaho; and Knoxville district, California. The exploration model is based on the degree to which recognizable geologic and geochemical criteria are favorable or unfavorable to the occurrence of an economic deposit, either through their presence or absence.

In the broadest context, the areas for exploration must contain (1) evidence for a relatively near-surface heat source, (2) fracturing suitable for the movement of large volumes of meteoric water over extended periods of time, (3) the availability of large volumes of meteoric water, (4) a host rock of sufficiently low permeability to allow the focusing of hot fluids within specific fracture sets, and (5) evidence of the occurrence of processes for transporting and precipitating metals. Near-surface heat sources are best exemplified by volcanic flows and intrusions. The most favorable structures for transporting fluids include caldera-related fractures, rift zones or grabens, and normal fault zones. The absence of these features makes the areas highly unfavorable. Endogenous and/or exogenous domes of quartz latite to rhyolite composition are moderate to highly favorable indicators by their presence, but their absence is only low to moderate "bad news," because intrusive rocks, *per se*, are not exposed in many important precious-metal districts. Areas with bimodal basalt-rhyolite volcanism are also favorable. The availability of large volumes of meteoric water to make up the ore fluid is indicated by the presence of lacustrine sediments, large mountain edifices, or regionally extensive artesian aquifers. Time periods of high annual rainfall may be reconstructed from the fossil record or from published paleoclimatological data. Because of the need to focus hot fluids into confined fracture volumes, host rocks of low permeability are moderately to highly favorable for the occurrence of higher grade ores. Generally, rocks of high permeability will tend to disperse the thermal waters over large volumes of rock, and are only weakly to moderately favorable hosts for economically mineable grades. The most favorable evidence for the processes needed to transport metals are siliceous sinter and extensive near-surface silicification. The absence of both of these features is a highly unfavorable criterion. The metal precipitation processes are best evidenced by periodic self-sealing, followed by rupturing of the seal. The occurrence of these processes is recognized by multiple episodes of silicification, cross-cutting quartz veins, silica-cemented breccia pipes or breccia veins.

Criteria related to all of the above processes are numerous, and any combination might be chosen for exploration. More effective, however, is the selection of a few criteria that significantly increase the likelihood that a discovery will be an economic deposit rather than a lesser result of a hydrothermal system. Jasperoid and As-Sb anomalies, for example, are widespread; therefore, these features become effective exploration criteria only in areas demonstrated to have had favorable structures and hydrologic systems. Grass roots exploration emphasis is best placed on the development of screening criteria that help assure that detailed mapping, sampling, and claim staking are conducted in areas that have the potential for ore.

The Formation of Massive Sulfide at 21°N, East Pacific Rise
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The discovery of actively-forming massive sulfide deposits at 21°N, East Pacific Rise, confirmed the prediction that large scale hydrothermal circulation of seawater through ocean crust at spreading centers is an important ore-forming process. Seawater, heated by interaction with hot oceanic basalt, becomes an acidic ore fluid capable of leaching metals from basalt and transporting them to the seafloor. Hot fluids vent onto the seafloor at temperatures in excess of 350°C, forming mounds and chimneys of hydrothermally precipitated sulfides and sulfates. Anhydrite is precipitated from seawater sulfate due to heating of seawater by the hydrothermal fluid. Base metal sulfides are precipitated due to cooling of the hydrothermal fluid by mixing with cold seawater. Although the deposits are still forming, the sulfides show a complex paragenesis and extensive replacement. Zoning in active and inactive chimneys suggests that the highest temperature sulfide phases are pyrrhotite and cubic cubanite, followed by wurtzite and chalcopyrite, and finally sphalerite, pyrite and marcasite. The paragenesis results from temperature decrease and fO_2 - fS_2 increase due to mixing of hydrothermal fluid with seawater. Textural evidence for extensive replacement of sulfides is consistent with the lack of isotopic equilibrium between sulfides. The source of sulfur, as indicated by sulfur isotope ratios, includes both basaltic sulfur and seawater sulfate reduced to sulfide by interaction with basalt. In addition to ore grade concentrations of zinc and copper, the sulfides contain significant silver, but only minor gold and platinum metals.

GENERAL TECHNICAL SESSION

Investigation of Stream Zinc and Lead as Predictors of Stratiform Zn-Pb Deposits, Selwyn Basin, Yukon

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Bedrock and surficial geology maps digitized with 50 m pixel resolution and combined with digitized drainage basins have been used to improve the prediction of known deposits from stream data gathered in the Nahanni River area. A statistical mixing model allows the prediction of geochemical background from the surficial and bedrock composition of the catchment basin for each stream sample. Positive residuals are corrected for dilution using catchment area. Evaluation of the resulting mineralization ratings indicates that they are better predictors of known deposits than the uncorrected data. This approach is likely to be more successful in mountainous terrain than in areas of low relief, due to the short residence time of water in the drainage system.

Two-dimensional correlograms for zinc indicate that spatial autocorrelation of background has a range of several kilometers and is anisotropic, probably due to the outcrop pattern of lithologic units. Residuals have negligible autocorrelation, suggesting that mineralization is too local for the present sample density to provide reliable interpolation. Maps showing catchment basins shaded according to mineralization rating are clearly preferable to contour maps (although contoured background would be acceptable) and indicate several interesting areas having mineral potential.

Lead, because of its relative insolubility, has moved only as clastic detritus, and can only indicate deposits with surface exposure. Zinc, being much more soluble, can be transported as clastic detritus, as soluble ions, and as precipitated grains, depending on local conditions. Total stream transport, therefore, requires an estimate not only of zinc concentration but also the mass flux of water and sediment. Sediment flux is difficult to measure, yet if it were possible, total zinc flux would be a powerful tool for discovering deposits with no surface exposure. Some preliminary attempts to estimate total zinc flux are discussed, using catchment basins with known deposits.

Relationship of the Cortez Caldera to the Cortez Disseminated Gold Deposit, Nevada

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The Cortez caldera is an oval structure ten km in diameter formed by caldera collapse and is located in the northern part of the Toiyabe Range, central Nevada. Collapse resulted from eruption of the Caetano Tuff about 32.5 m.y. ago, and subsequent eruptions filled the caldera with more than 2.5 km of Caetano Tuff. Interstratified with the intracaldera tuff are beds of collapse breccia consisting of large blocks of Paleozoic Rock Canyon and Vinini Formation in a matrix of the ash-flow tuff. Trap door-type resurgence uplifted the central and western part of the caldera, and tilted the resurgent block to the east as much as 30°. The moat of the southern part of the caldera was filled with water-laid tuffs and sediments. The Cortez caldera occupies the eastern part of a previously described, east-west trending volcano-tectonic depression in which the Caetano Tuff is largely confined (Gilluly and Masursky, 1965; Stewart and McKee, 1977). A large unnamed caldera occupies the western part of the depression and the area between this caldera and the Cortez caldera is covered by the outflow facies of the Caetano Tuff.

The Cortez gold deposit, a carbonate-hosted disseminated gold deposit, is located three km northeast of the northern margin of the Cortez caldera. Dikes within the Cortez gold deposit have a similar age and composition as the Caetano Tuff and strike N 30-40° W, subparallel to the caldera margin

and dip up to 45° toward the caldera. The Cortez gold ore bodies are spatially associated with the dikes and have a strike and dip similar to that of the dikes. Remnants of the outflow facies of the Caetano Tuff near the Cortez deposit indicate that the deposit formed near the Oligocene paleosurface. Dikes within the Cortez deposit and in adjacent areas form a dike complex just outside the margin of the Cortez caldera. The Cortez gold deposit formed within this dike complex at small levels in the crust.

A Stream Sediment Data Base for the State of Colorado, USA

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A data base containing 16,819 stream sediment samples for the state of Colorado is described. The samples were collected as part of the Department of Energy's National Uranium Resource Evaluation Program (NURE). The state of Colorado covers about 170,000 km² in the southern Rocky Mountains. This region is underlain by a diverse collection of igneous, metamorphic, and sedimentary rocks and provides an excellent area in which to evaluate the feasibility of using NURE samples for reconnaissance-scale evaluations.

Each sample has analyses for up to 45 elements: U is analyzed by delayed neutron counting, Al, Au, Ba, Ca, Ce, Cl, Co, Cr, Cs, Dy, Eu, Fe, Hf, K, La, Lu, Mg, Mn, Na, Rb, Sb, Sc, Sm, Sr, Ta, Tb, Th, Ti, V, Yb, and Zn are analyzed by neutron activation analyses; Ag, Bi, Cu, Nb, Ni, Pb, Sn, W, Cd, As, and Zr are analyzed by x-ray fluorescence, and Be and Li are analyzed by arc-source emission spectroscopy. Sample analyses were interpolated to a 179 x 155 rectangular grid by universal kriging. There are 33,110 cells; the resolution of each cell is three km².

The relationships between geology, physiographic features, and elemental concentrations are examined. It was found that for most elements these data can be an invaluable aid for reconnaissance-scale geochemical investigations and for identifying areas with potential for ore deposits.

Gold Occurrence at Island Copper Mine, British Columbia

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The Island Copper oceanic porphyry deposit of Utah International, Inc., is superimposed on a quartz-feldspar porphyry dike intruded into Jurassic Bonanza Formation andesitic pyroclastics. Described alteration zones comprise outwardly-progressing biotite, chlorite, and epidote in andesite, and sericite-chlorite and sericite in the dike, capped by pyrophyllite breccia. Pulsationally-shattered areas near the metallization center were healed by several generations of quartz. Mill heads average about 0.2 ppm Au, about half of which is recovered in copper concentrate. Bulk ore/concentrate tests have suggested that half the total Au resided in chalcopyrite, a fourth in pyrite, and the balance elsewhere. Blast-hole sample analyses show Au and Cu distributions to be generally similar. SEM and X-ray fluorescence analysis indicated possible substitutions of Au into the lattices of five chalcopyrite, two magnetite, and one apatite grain out of 363 grains analyzed. Systematic search at +500 magnification, of at least a three by three cm surface in each of 27 differently altered and metallized rocks, revealed 26 native gold particles, from 0.5 to 20.8 microns in size (averaging 1.5 x 2.5 microns), loosely held in

fluid inclusion cavities in, or weakly appendaged to, larger grains of quartz, hydrobiotite, pyrite, chalcopyrite, magnetite, molybdenite, monazite, and calcite in that order of prevalence. Distribution is erratic, but crudely clustered. Trace elements apparently substituted into Au are Fe, Zn, Cu, Ag, Pd, Ti, Ni, As, and In. Assays for Au, Ag, Cu, Mo, and Fe show Au to be most correlated with Cu, perhaps due more to paragenetic timing than to geochemical affinity. Possibly five Au generations are spread paragenetically from early alteration to the chalcopyrite stage, peaking during one of five generations of shatter-healed quartz.

A Hydride Generator for the Laboratory with a Limited Budget, and Applications to Selenium and Arsenic Determinations in Geologic Materials

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The construction of a hydride generator using relatively inexpensive materials is described. This apparatus has application in the atomic absorption determination of hydride-forming elements—specifically selenium and arsenic—in geologic materials. The borohydride reductant is introduced by a syringe into the feed tubing from a nitrogen source leading into a commercially available impinger that contains the acid sample solutions and selected masking reagents. The volatile hydrides are swept out of the impinger into a heated quartz tube mounted on top of a burner head in the path of the discharge from a source lamp. In the tube, decomposition occurs and the ground state atoms absorb energy. The absorption is compared with that of known materials. Under the conditions described here, the results obtained for selenium and arsenic in geologic materials compare favorably with those obtained earlier with proven methods.

The Relation Between Tl, Rb, and K in the Carlin-type Gold Deposits

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Recent studies on the relationship between Tl, Rb, and K in gold-silver bearing veins and associated volcanic rocks (Ikramuddin et al., 1982, 1983; Ikramuddin, 1983; Massa et al., 1983) suggest that the high concentration of Tl and low K/Tl and Ba/Tl ratios can serve as potential guides to mineral deposits of hydrothermal origin. To test the usefulness of these relationships in the Carlin-type gold deposits, samples of mineralized and unmineralized rocks from five localities in the Western United States have been analyzed for Tl, Rb, K, Ba, Sr, Au, Ag, and several other selected elements. The sediment-hosted precious metal deposits studied include: Carlin, Jerritt Canyon, and Alligator Ridge, Nevada; Mercur, Utah; and the North Moccasin mining district, Montana.

The relationship between Tl, Rb, and K in the Carlin-type deposits supports our earlier conclusions that Tl in hydrothermally altered and mineralized rocks (compared to unaltered and unmineralized rocks) is more enriched than Rb which, in turn, is more enriched than K. The enrichment of Tl in the mineralized rocks of Carlin-type deposits is significantly greater than that observed in the volcanic rocks and associated veins.

The research work conducted to date indicates that the high concentration of Tl and/or low K/Tl and Ba/Tl and high Tl/Sr ratios can prove to be very useful guides in locating the Carlin-type gold deposits.

MASSIVE SULFIDE DEPOSITS

Recognition of Alteration in Volcanic Environments: Computer Applications

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A recently completed study in Ben Nevis Township, Ontario has successfully used techniques for recognizing altered or "anomalous" zones within an Archean volcanic sequence using litho-geochemistry. This area contains both base and precious metal deposits.

The presentation examines methods used to normalize the geochemical data for application of statistical techniques in order to discriminate between potentially mineralized and non-mineralized rocks. One approach calculates rock types and computes residual values as the result of normalization. Altered rocks generally exhibit high residual values.

The geochemical data was studied using three types of statistical analysis to examine anomalous features. Spatial analysis involved plotting raw and normalized geochemical data to produce maps indicating zones of anomalous geochemistry. Cluster analysis was used in order to statistically group the components (R-mode) into common associations. This enables recognition of anomalous component behaviour. Q-mode cluster analysis was used to statistically group samples with common associations so that abnormal rocks associated with anomalous geochemical patterns were recognized. Correspondence analysis was used to statistically group both the components (R-mode) and the samples (Q-mode) with common association. Thus, rocks displaying an anomalous pattern with one component can be separated from rocks showing anomalous behaviour in another component.

Alteration Accompanying Massive Sulphide Mineralization in the Delta District, East Central Alaska: Implications for Exploration

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Extensive exploration over the past seven years has delineated a new massive sulfide district on the north flank of the east-central Alaska Range, Alaska. The district, covering approximately 400 square miles, contains numerous stratiform, transposed and lesser replacement type sulfide occurrences ranging in size from less than one million tons to greater than 20 million tons, within a thick sequence of rift related metavolcanic and metasedimentary rocks comprising the Delta Schist Belt. The Devonian age metavolcanics which host the base and precious metal bearing massive sulfides demonstrate a petrochemical heterogeneity typical of a spilite-keratophyre-quartz keratophyre suite. Integral to the volcanic suite are numerous synvolcanic tholeiitic greenstone sills which have both a spatial relationship to the various massive sulfide bodies, and a genetic relationship to the effusive volcanic suite.

From an exploration viewpoint, the various overlapping stages of hydrothermal alteration focused around the greenstone sills can be used to indicate the likelihood of spatially related massive sulfide mineralization. Intense chloritization, silicification, sericitization, and pyritization have resulted from high fluid flow along sill margins. Further, these assemblages

are overprinted by late stage carbonate alteration accompanied by albitization and breakdown of sphene to rutile. Lead-silver-gold-sulfur fixation in the form of auriferous and argentiferous galena occurs sporadically at these altered sill-sediment contacts.

Where metal-laden fluids discharged above the sills, a variety of exhalative chemical and sedimentary rocks, including massive sulfide lenses, were deposited. In regions of highest fluid flow beneath the exhalative centers foot wall felsic volcanics and/or mafic sills are pervasively chlorite, silica, carbonate, sulfide and locally stilpnomelane altered. Rocks footwall to precious metal-rich massive sulfides are further altered through enrichment of aluminum, potassium and barium manifest in white micas, stilpnomelane and local kyanite and kaolinite. It appears therefore, that the abundance and variety of sulfide mineralization in the Delta district likely stems from evolving hydrothermal activity accompanying a prolonged period of syndepositional Mg-Fe tholeiite sill injection into near surface volcanic and sedimentary debris within a marginal rift setting.

Massive Sulphide Mineralization at Green Mountain, Mariposa County, California

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The Green Mountain deposit is located 20 miles east of Merced, California. It is hosted by metasedimentary rocks ± mafic volcanics of the Jurassic age Mariposa Formation, one of three volcano-sedimentary domains hosting numerous massive sulphide occurrences within the Foothills Copper-Zinc Belt of central California. The 4.0 million ton deposit is sheet-like in form and enclosed within epiclastic rocks of probable volcanic derivation that have been tightly folded about a steeply plunging overturned anticline. Adjacent Sierran plutonism has imparted amphibolite facies metamorphic grades. The predominant sulphide is pyrrhotite with lesser sphalerite and chalcopyrite. The deposit is weakly zoned with respect to copper and zinc with a prominent, but narrow, zinc-rich fringe. A stringer zone and distal exhalite apron have not been recognized. A blanket-like body of anthophyllite-cordierite (± spinel) mineralogy forms the foot wall to the massive sulphide sheet.

Comparative rock chemistry suggests that this zone has been derived from the original sedimentary host through strong soda depletion and magnesium enrichment within a seafloor exhalative system.

It is suggested that the Green Mountain deposit and other sulphide occurrences within the Mariposa Formation are in a rift-related basinal setting (forearc or backarc) and have similarities to the Besshi/Guymas type massive sulphide occurrences.

The Geochemical Environment of Westmin Resources' Buttle Lake Mine, Vancouver Island, British Columbia

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Polymetallic massive sulfide deposits associated with felsic volcanic rocks occur in the Paleozoic Sicker Group at the center of Vancouver Island, B.C. Westmin Resources Ltd. has mined these ores since 1967. Past production plus reserves in the existing mines, at the end of 1982, totalled 6,225,300 short tons of 0.06 oz. Au/T, 3.2 oz. Ag/T, 1.4% Cu, 1.17% Pb, and 7.6% Zn. A new mine and mill is under construction to exploit the recently discovered H-W ore body, currently estimated to contain 15,232,000 short tons grading 0.07 oz. Au/T, 1.1 oz. Ag/T, 2.2% Cu, 0.3% Pb, and 5.3% Zn.

The Buttle Lake deposits occur as many lenses of massive sulfide grouped into several major zones within a flat plunging volume of rock approximately 19,000 feet long, 4,000 feet wide and 3,000 feet high. The ore zones are distributed laterally and vertically within a folded and faulted 1,500 foot thick sequence of bedded volcanic and volcanoclastic rocks and subordinate sedimentary rocks. Compositions range from basalt to rhyolite with andesitic and volcanoclastic phases predominant. All ore bodies occur within, or in contact with, rhyolitic rocks. Volcanoclastic rocks of the mine sequence commonly contain highly variable but widespread enrichments of base and precious metals associated with iron sulfide in contrast to least altered massive volcanic rocks. These sulfides occur as disseminated grains, stringers and clasts of massive sulfide. To date, our rock geochemical targets have been defined by visual estimate and traditional assay procedures.

The metalliferous mine sequence is exposed in only three limited areas on steep mountain sides due to erosion of glaciated valleys across the hinge of a major, flat-plunging, anticlinal structure. Under valley floors the mine sequence is buried beneath thick glacial, fluvial and landslide sediments, but low on the valley walls overburden comprises thin till and colluvium. Geochemistry of these thin surficial deposits reflects the presence of both ore zone exposures as well as the broader signature of the enclosing mine sequence. Both the nature and thickness of overburden affects the geochemical expression. Although all three surface exposures of known ore zones were found by prospectors prior to 1920, it is evident that detailed silt and soil geochemistry would have been an efficient method of primary exploration for these small targets.

Geology, Lithologic Association, and Depositional Environment of the Oposura Massive Sulphide Deposit, Sonora, Mexico

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The Oposura massive sulfide deposit is located in the Sierra La Huerta, approximately 150 km east of Hermosillo, Sonora. Stratabound and stratiform lenses of massive and thinly bedded sulfides vary in thickness from several centimeters to 3.5 meters. These lenses and beds are interbedded in a sedimentary, volcanoclastic and pyroclastic section of limestone, water-lain fine crystal tuff, and lithic tuff known as the Arenillas Formation.

Mapping has shown that localization of sulfides in this volcano-sedimentary sequence occurs spatially between two thicker, more extensive volcanic units; the footwall Revancha Rhyolite ignimbrite and a hanging wall sequence of dacitic tuff breccia, lithic tuff, and feldspathic tuff. Locally, the rhyolite is intensely silicified and displays eutaxitic texture. The overlying dacitic sequence is characterized by chlorite-epidote-pyrite alteration. The age of the Oposura Volcanic Group is estimated at upper Cretaceous to Paleocene.

Field and laboratory examinations identified four types of mineralization. The most common type consists of beds of fine-grained sphalerite and galena hosted by fine crystal tuff. It is associated with chlorite, epidote, and important amounts of manganese, either as rhodonite or rhodochrosite. The mineralization is interpreted to have formed syngenetically with deposition of crystal tuffs and limestone in a shallow sub-aqueous volcano-sedimentary environment.

APPLICATION OF HYDROCARBONS AND VAPOR PHASE GEOCHEMISTRY

Alteration of Organic Matter Around Carbonate-Hosted Lead-Zinc Deposits

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Mississippi Valley-type lead-zinc deposits in carbonate rocks commonly have associated organic matter, including hydrocarbons. Where deposits formed at temperatures higher than average host rock temperatures, systematic changes in organic matter are expected, and have been documented at Pine Point, N.W.T., Canada. This low temperature deposit ($\approx 100^\circ\text{C}$ or less) developed within host rocks whose maximum temperature was $\approx 60^\circ\text{C}$. Compared to that of the surrounding host rocks, organic matter in or near the orebodies is altered thus: vitrinite-like material in kerogen shows an increase in reflectivity ($\approx 0.4\text{--}\approx 1.0\%$ Ro), and indigenous bitumens are altered from soft material to hard, glassy pyrobitumen by polymerization of asphaltenes and resins. Much altered bitumen remains partly soluble; extracts contain more hydrocarbons and higher saturated-aromatic ratios. Although local in scale, these changes are non-reversible and could be used as an exploration tool where not obscured by later burial and attendant elevation of host rocks/deposits to temperatures above $\approx 150^\circ\text{C}$. Pine Point pyrobitumen alteration can be shown to result from organic matter-sulfate reactions, based on analyzed atomic H/C ratios, sulfur contents, and sulfur isotope ratios. These reactions liberated large volumes of H_2S , believed responsible for ore deposition. These reactions may involve generation of hydrocarbon gases, or changes in the amounts or proportions of hydrocarbon gases (especially methane and ethane) close to and remote from orebodies. J. S. Carter has described such variations in hydrocarbon gases for some British lead-zinc deposits (unpublished Ph.D. thesis, Imperial College, London, 1981). If widely present, such hydrocarbon gas distributions may offer promise as a regional exploration tool for lead-zinc ore bodies in carbonate rocks.

Solution of Structural Problems in the Topia Ag-Au-Pb-Zn District, Durango, Mexico, Using Laser Decrepitation and Capacitance Manometer Gas Analysis for Fluid Inclusion Geobarometry

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In the Topia district, epithermal fissure vein mineralization is exposed in early Tertiary andesites over an area $\sim 3 \times 5$ km. Post-ore rhyolite ignimbrites surround the district on all but the southwest side, cutting off vein exposures. Exploration has not proceeded to a significant extent under the rhyolite cover. Prior to eruption of the rhyolites, the ore-host andesites were tilted $\sim 25^\circ$ to the southwest. Following eruption of rhyolites, the volcanics and northeast-trending veins were displaced by northwest-trending normal faults displaying a scissor-like increase in displacement toward the south and southeast (Lemish, 1955).

Studies of metal distribution based on channel sample assays in six veins reveal that in each vein, ore is confined to a sub-horizontal band spanning an elevation range of $\sim 150\text{--}250$ m, with a suggestion that the ore horizon drops slightly in elevation at the southwest ends of some veins. In the vein-to-vein succession from north to south, the productive elevation interval in the six veins shows a systematic decrease in elevation, lying at 1600-1850 m in the most northerly vein and 1000-1200 m in the most southerly. In the Tonopah, Oatman, Pachuca, and Real del Monte epithermal districts, the productive elevation interval is known to constitute a district-scale flat dome, which raises the question of whether the variation in elevation of the productive interval in the Topia district corresponds to about two-thirds of an incompletely explored ore dome (with the missing third hidden under

post-ore rhyolites) or whether the variation may be due to post-ore tilting and faulting of the veins. Whether regional tilting of host rocks was pre- or post-ore was determined from fluid inclusion geobarometry, as was the significance of post-ore fault block rotation.

PCO_2 and PH_2O were determined from studies of fluid inclusions trapped during boiling in samples from four veins, spanning a strike length of two km in one vein and an elevation range of 545 m among the veins. PH_2O was determined from heating and freezing tests on approximately 200 liquid-rich inclusions of 0.6-4 wt % NaCl equiv. salinity associated with vapor-rich inclusions, yielding sample mean values of PH_2O in the range of 19-62 atm. for $T_H = 210\text{--}280^\circ\text{C}$, varying systematically over the 545 m depth range of the samples. PCO_2 was determined by a method developed by Sommer, involving selective decrepitation of individual liquid-rich fluid inclusions in vacuo by a Nd laser (blast area $\sim 50\mu$ diameter) and collection of the liberated volatiles in a liquid N_2 cold trap. Analysis of $\text{CO}_2/\text{H}_2\text{O}$ was by fractional distillation into a capacitance manometer (detection limit $\approx 7 \times 10^{-11}$ moles of gas, ≈ 1 fluid inclusion 15μ diameter). Analytical precision of $\text{CO}_2/\text{H}_2\text{O}$ determinations is better than $\pm 15\%$ of the mean. Among the samples, mean $m\text{CO}_2$ varies from 0.32 to 0.57, yielding calculated PCO_2 at T_H of 35-56 atm. A plot of relative sample elevations versus T_H shows that the data are nearly coincident with the boiling-point-with-depth curve with a 2% NaCl, 0.4 m CO_2 solution, establishing that tilting of host rocks is pre-mineralization, and that post-ore fault-block rotation resulted in relative post-ore displacements of veins that are on the order of tens, not hundreds, of meters. Therefore, the southwestward vein-to-vein trend of decreasing elevation of the ore horizon reflects a trend of increasing depth of ore formation and is a primary feature whose recognition may be of exploration significance in the district.

Factors Affecting Sulfur Gas Anomalies in Overburden

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It has been shown experimentally that weathering of sulfide minerals produces COS and CS_2 , rather than H_2 that is predicted thermodynamically. Halos of these two gases should develop over weathering sulfide deposits, but the availability of C will control the halo size. Possible C sources include carbonate minerals, organic material, and CO_2 . Weathering experiments in sterile environments show that bacterial activity does not produce COS or CS_2 . These gases are also not produced when pyrite is thoroughly washed in an organic solvent and weathered experimentally, even in the presence of abundant CO_2 . Therefore, COS and CS_2 probably derive their S from sulfide minerals and their C from organic (but not alive) material. This suggests that S-gas anomalies in igneous and high-grade metamorphic, but not sedimentary, terrane will be restricted to deposits exposed to surface organic material.

Model pyrite deposits with differing overburden thicknesses have generated significant quantities of COS and CS_2 in laboratory experiments. CS_2 appears in air above these lab deposits much more rapidly than does COS. CS_2 concentrations in air inversely correlate to overburden-thickness: pyrite-thickness ratios, whereas CS_2 adsorbed on overburden is independent of this ratio. COS in air appears only in lab deposits with overburden: pyrite ratios less than 2.5. COS adsorbed on overburden inversely correlates to the overburden: pyrite thickness. These experiments indicate that weathering sulfides generate CS_2 more rapidly than COS, and that overburden adsorbs COS more efficiently than CS_2 . Therefore, S-gas exploration methods should be designed to detect CS_2 in soil gas or COS adsorbed on soil.

A New Approach to Multi-Component Gas Geochemistry in Metal Exploration

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The detection and measurement of volatile species offers promise of increasing the effectiveness of geochemical exploration programs. A multi-variate approach to exploration, utilizing a newly developed collection technology and mass spectrometry analysis has been used for oil and gas exploration in 70 recent surveys in the U.S. since mid-1983. These surveys have demonstrated advantages of the increased discriminatory capability afforded by analysis for multiple components of trace volatile emanations.

Spectra of surface emanations related to a given type of petroliferous accumulation are shown to be "fingerprints" of that accumulation. These spectral fingerprints can be used to identify and delineate similar accumulations by collecting volatiles just below the soil surface.

Similar gas collection devices have been used to collect surface emanations over several mineralized zones. Fingerprint spectra contain many organic and inorganic species which allows mineralization to be readily differentiated from background.

Gas Halos in Hydrothermal Clays Associated With Ore Shoots at Creede, Colorado

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Although epithermal vein systems are extensive, mineable ore shoots, which are the actual exploration targets, are much more restricted in distribution. We report here preliminary tests on a method of locating buried ore shoots in epithermal vein systems by gas analysis. Laboratory tests show that CO_2 , N_2 , and H_2O are quickly adsorbed onto illite/smectite, even under conditions of low concentration and low temperature, and are released upon heating. Clays developed during the hydrothermal alteration accompanying mineralization have the potential to adsorb gases, especially in systems where the mineralizing fluid boiled, the process generally thought to cause ore deposition in these systems. We have tested this possibility at Creede, Colorado, where the host volcanics to the OH vein are extensively argillized. The clay cap to the vein system consists of a mixed-layer illite/smectite that is best developed in feldspar phenocrysts. Gas chromatographic analysis of the gases adsorbed onto this clay reveals a strong correlation between C-bearing gas species and proximity to mineralization. The ratio $\text{CO}_2:\text{CO}_2+\text{H}_2\text{O}$ is high in the clay cap above the vein, low in the footwall, and decreases with increasing distance from the vein in the hanging wall. Other gas species detected (CH_4 , C_nH_n , and CO) show this relationship less well. Analysis of clay for these gases is rapid (20 minutes per sample) and requires less than 0.5 g of material, making the technique applicable to large scale exploration surveys.

PRIMARY DISPERSION

Primary Gas Dispersion Halos in Disseminated Gold Deposits: Examples from Nevada and California

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All hydrothermal systems contain significant amounts of volatiles, either as dissolved aqueous species, as free gaseous species, or both. As hydrothermal solutions traverse or permeate a rock mass, gases are "deposited" in the rock in several ways, including: adsorption onto alteration phyllosilicates (clays and micas), entrapment in vugs, and encapsulation in fluid inclusions. The gases are easily liberated from wallrock material by heating and are identified by gas chromatography/mass spectrometry. Primary gas dispersion halos occur as anomalous concentrations of individual gases (H₂S, SO₂, CO₂, etc.) or as groups of gases (total hydrocarbons, total sulfur gases, etc.). On a weight basis, the amount of gas introduced to the wall rocks often exceeds the total amount of trace elements. This, coupled with high mobility, makes primary gases in wall rocks valuable geochemical indicators, particularly for deeply buried deposits which are not associated with strong trace element signatures.

Primary gas dispersion halos have been identified in every epithermal deposit studied to date by Exploration Research Laboratories. The halos are of two types: (a) broad halos of general gas enrichment which reflect the aerial extent of pervasive hydrothermal fluid flow, and (b) restricted halos which reflect local disequilibrium in the system and are associated with mineral deposition and/or development of alteration phases.

Gases incorporated into wallrock material do not appear to directly reflect the abundance or speciation of gases originally present in the hydrothermal solutions. Rather, the distribution is controlled by the affinity of different clays and micas for polar or non-polar gases, and reactions of dissolved gases with primary minerals. Local variations in the primary gas dispersion halo may reflect subtle changes in alteration mineralogy and thus, indirectly, local variations in the chemistry of the hydrothermal system.

The results of studies of primary gas dispersion in several disseminated gold deposits will be presented. These will include the Horse Canyon and Getchell "Carlin-type" deposits in Nevada and the Hayden Hill volcanic-hosted deposit in northeast California.

The Use of Lithochemical Patterns in Wallrock as a Guide to Exploration Drilling at the Jason Pb-Zn-Ag-Ba Deposit, Yukon Territory

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The MacMillan Pass shale-hosted mineral district is located 400 km northeast of Whitehorse, Yukon Territory. On the Jason property, surface exploration based primarily on geological mapping and soil geochemistry has led to the discovery of three massive to laminated deposits rich in Pb, Zn, Ag, Ba and Fe. To date, diamond drilling has outlined geological reserves of 14.1 million tonnes grading 7.09% Pb, 6.57% Zn and 79.9 gms/t Ag.

One of these deposits, known as the South Zone, exhibits classical zonation; a high grade massive to thick banded Pb-rich facies is interpreted as being proximal to a vent source. A well laminated facies consisting of layers of chert, barite and sulphides is more distal from the vent. Pb/Pb + Zn ratios decrease outward from the presumed vent area. A program of systematic sampling of selected drill core from the wall rocks of the South Zone was instituted to identify geochemical halos which could be attributed to ore emplacement and which

could be used as a predictive guide to new ore. Significant Cu and As concentrations are restricted to the foot wall rocks in the immediate vicinity of the presumed vent. A Mn deficiency in hanging wall rocks immediately above the sulphide-rich portion of the South Zone is noted. Ba concentrations well above the regional background occur in hanging wall rocks in excess of 50 m above the distal or pooling facies of the South Zone. The shape of the Ba diffusion curve into the hanging wall can be used as guide to either the source of the Ba-rich solutions, or to the direction of the greatest brine pooling.

Primary Dispersion of Trace Elements, Fluid Inclusion Zoning, and Alteration Zoning at the Pueblo Viejo Au-Ag Deposit, Dominican Republic

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Zoning of hydrothermal alteration minerals is the most useful indicator of Au-Ag mineralization at the Pueblo Viejo Au-Ag hot spring deposit. Mineral sequence is characterized by an alteration funnel with high level massive jasperoid underlain successively by quartz-pyrophyllite and alunite and surrounded by regionally extensive calcite.

The distribution and degree of enrichment of trace elements within and surrounding the Au-Ag mineralization reveals that Te, Au, and As are very abundant in the funnel-shaped zone of hydrothermal alteration. Assay values from 343 non-oxidized rock samples for Au, Ag, Cu, Zn, Pb, As, Sb, Hg, Te, and Se show that Au is well dispersed in the upper portion of the mineralized system.

The degree of enrichment of trace elements assayed from 53 oxidized rock samples shows that Au, Ag, Pb, As, Sb, Hg, Te, and Se are more enriched in the oxidized zone than in the non-oxidized ore zone. However, these elements' distributions are much more irregular, denoting leaching and secondary enrichment of all elements with the exception of Au (Kesler et al., 1981). Gold geochemistry surveys have delineated the Pueblo Viejo ore bodies, but other elements, especially Hg, Te, and As, could also be used as pathfinders to potential Pueblo Viejo Au-Ag mineralization.

Fluid inclusions from 33 jasperoid samples taken from within and surrounding the Pueblo Viejo ore body have been analyzed for their H₂O, Ar, CH₄, CO, CO₂, H₂, N₂, and O₂ gas contents. Fluid inclusion gases from within the ore zone are H₂O rich and CO-CO₂ poor, while inclusions surrounding the ore body are CO-CO₂ rich.

Stream Sediment Geochemistry of the McLaughlin Gold Deposit and the Knoxville District, Napa and Yolo Counties, California

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A series of stream sediment geochemistry orientation studies were conducted in the Knoxville mercury mining district of lyzed for Au, Ag, As, Sb and Hg. Many samples were separated into eight size fractions. Some were also separated into light; nonmagnetic, heavy; and magnetic, heavy mineral fractions. All fractions were analyzed separately. Analyses were also performed on the entire -½ inch size fraction of all samples.

A study of sample fractions shows that Au, Sb and As tend to be more concentrated in the +40 mesh fractions and that Ag is more concentrated in the -40 mesh fractions. The Au/Ag ratio is generally greater than one in all +40 mesh fractions and less than one in the -40 mesh fractions. The only consistent habit of Hg is its increased concentration in the nonmagnetic fraction of heavy minerals. The sorting tendency of each metal suggests the form in which it is traveling.

POSTER SESSION

ADAMS, O. *Geology and Ore Deposits of the Thunder Mountain Mining District, Valley County, Idaho / Abstract on p. 34*

BONHAM-CARTER, G. F. and GOODFELLOW, W. D. *Investigation of Stream Zn and Pb as Predictors of Stratiform Zn-Pb Deposits, Selwyn Basin, Yukon / Abstract on p. 36*

BROADHEAD, R. J. *Latest Developments in Atomic Spectroscopy Instrumentation*

Latest Developments in Atomic Spectroscopy Instrumentation

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In the past few years, many new analytical instruments and methods have become available to the analyst. This paper will explain these latest instruments, their theory of operation, and their advantages and disadvantages. A list of metals will be presented that can be determined best by each instrument, with approximate detection limits. Some comparative results for these metals will be presented.

The instruments discussed will be:

Atomic Absorption (A.A.)

Graphite Furnace (G.F.)

Hydride Methods (Hyd)

Inductively Coupled Plasma Atomic Emission Spectrophotometer (I.C.P.A.E.S.)

CABELLO, J. L. *Precious Metals and Andean Cenozoic Volcanism in Chile / Abstract on p. 22*

CHAFFEE, M. A. *Results of Regional Geochemical Studies, Walker Lake 1° x 2° Quadrangle, California*

Results of Regional Geochemical Studies, Walker Lake 1° x 2° Quadrangle, California and Nevada

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A regional geochemical survey was conducted by the U.S. Geological Survey in the Walker Lake 1° x 2° quadrangle (long. 118°-120° W. and lat. 38°-39° N.) as part of the Conterminous United States Mineral Assessment Program. The area exhibits widely varying climate, topography, and geology, and many types of mineral deposits are known or suspected to occur therein. A total of 815 rock samples, 1,116 minus-60-mesh stream-sediment samples, and 1,005 non-magnetic heavy-mineral concentrate samples were analyzed by several methods for as many as 31 different elements (Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Th, Ti, V, W, Y, Zn, and Zr).

Suites of mineralization-related elements in the stream-sediment and concentrate samples were evaluated by using R-mode factor analysis as an objective technique, and by using SCORESUM as a subjective technique in which the evaluator selects the suite of elements for study and weights their analytical values according to parameters, such as their concentration and associated lithology. Anomalies resulting from the two techniques identified most known mineralized areas, as well as untested areas considered favorable for the following types of mineral deposits: (1) precious metals with or without base metals, (2) complex base and precious metals, (3) disseminated copper and/or molybdenum, and (4) contact-metasomatic tungsten.

Some significant conclusions of the Walker Lake regional geochemical study include the following:

1) Deep-seated molybdenum deposits may be present in districts where deposits of precious metals or contact-metasomatic tungsten were previously exploited.

2) Favorable ground in the vicinity of some known deposits or districts may be more extensive than previously thought. In some cases this ground extends in a linear configuration that may be associated with some major deep-seated structural control.

3) The distribution of the element suite Ba, Co, Fe, and Sr in nonmagnetic-concentrate samples seems to be a good guide to those areas of hydrothermal alteration that are characterized by concentrations of pyrite and barite, as well as by argillization, silicification, and/or bleaching of the host rock.

CLARK, J. R., ADRIAN, B. M., GRUZENSKY, A., AND ARBOGAST, B. F. *A Comparison of Geochemical Sampling and Analytical Techniques Used for Precious Metal Exploration in Northeastern Gunnison County, Colorado*

A Comparison of Geochemical Sampling and Analytical Techniques Used for Precious Metal Exploration in Northeastern Gunnison County, Colorado

J. Robert Clark, B. M. Adrian, A. Gruzensky, and B. F. Arbogast, U.S. Geological Survey, Denver, CO 80225

Rock, stream-sediment, and panned-concentrate samples from the Fossil Ridge area between Tin Cup and Gunnison, Colorado, were collected and analyzed using both conventional and newly developed methods of analysis. Bismuth and Au were determined to be the best pathfinders for gold veins. Although Ag, Cu, Sb, Pb, As, Zn, Cd, and Mo were associated with both gold and silver deposits, anomalies of these elements were found to be most strongly associated with Ag-rich replacement deposits in the area.

Rock samples were analyzed (1) by a fusion, multi-element organic extraction, atomic absorption procedure and (2) by optical emission spectroscopy. Both methods were used successfully to detect anomalies associated with precious metal deposits. The fusion and extraction procedure provided better precision, accuracy, and detection limits for several trace elements.

Minus-80-mesh stream sediments were analyzed (1) with a cold reducing leach, multi-element extraction, atomic absorption procedure and (2) by optical emission spectroscopy. The cold leach procedure provided significantly improved detection and much greater anomaly contrast for most of the trace elements associated with the precious metal deposits.

Panned concentrates were not subjected to magnetic or heavy-liquid separations. Spectrographic analysis of these concentrates was effective for detecting metals that would be found in sulfide mineral grains and in particles from weathering gossans. An HBr-Br₂ leach of each panned concentrate followed by methyl isobutyl ketone extraction and atomic absorption determination of gold provided the most useful information for this type of sample.

The cold reducing leach analysis of stream sediments and gold analysis of panned concentrates were found to be the most valuable procedures for use in reconnaissance geochemical exploration for precious metal vein and replacement deposits in the Fossil Ridge area.

GABELMAN, J. W. and HANUSIAK, W. M. *Gold Occurrence at Island Copper Mine, British Columbia / Abstract on p. 36*

GARDNER, M. D., KESLER, S. E., CREECH, M., CLOKE, P. L., and STEDMAN, D. *Factors Affecting Sulfur Gas Anomalies in Overburden / Abstract on p. 40*

GILLERMAN, V. S. *Geochemical Associations and Alteration Halos of Tungsten and Copper Skarns in the Railroad Mining District, Nevada*

Geochemical Associations and Alteration Halos of Tungsten and Copper Skarns in the Railroad Mining District, Nevada
Virginia S. Gillerman, Anaconda Minerals Company, 5400 Equity Avenue, Reno, NV 89502

Zoned garnet-pyroxene skarns at Railroad surround weakly-altered quartz monzonite. The skarns and pluton predate mid-Oligocene rhyolitic porphyries and Ag-Pb-Zn-Cu replacement ores. A metasomatic aureole extends 1000 feet above the tungsten-bearing Grey Eagle exoskarn. An upper zone of Si-Fe⁺³-B-F-Cu metasomatism in limey dolomite includes diopside-andradite veins with associated magnesium borates.

In the deep zone diopside-andradite veins with sparse scheelite cut calcite-brucite marble. Significant tungsten, as yellow-fluorescing scheelite (3-25 mole % Mo) is confined to the sulfide-poor, Grey Eagle brown garnet-pyroxene zone. Blue-fluorescing scheelite (≤ 3 mole % Mo) is found in late, sulfide-rich veins and skarn. The Delmas skarn, mined for Cu-Ag, is stratigraphically and structurally higher than and petrographically distinct from the Grey Eagle skarn. The Delmas skarn is characterized by its abundance of sulfides and green andradite garnet. Sulfides are later than the silicates, with sphalerite concentrated in the hedenbergite zone and bornite only in the green garnet zone. Oxygen fugacity, buffered initially by the original sediments and magma, subsequently by the skarn silicates, and finally by the sulfide-bearing hydrothermal fluids, was a critical control on localization of the ore minerals. Contrasts between the Delmas and Grey Eagle exoskarns and between the shallow and deep zones of the Grey Eagle aureole mimic major differences between copper and tungsten skarns. As Cu-B and W-Mo-F associations are not commonly found in the same geological environment, the unusual polymetallic mineralization at Railroad may reflect high boron and fluorine contents in the melt.

GINTAUTAS, P. A. and LEVINSON, A. A. *Lake Sediment and Lake Water Studies from the Nechako Plateau, British Columbia*

Lake Sediment and Lake Water Studies from the Nechako Plateau, British Columbia

P. A. Gintautas and A. A. Levinson, Department of Geology and Geophysics, University of Calgary, Calgary, Alberta, T2N 1N4 Canada

Eight partial extractions were performed sequentially on fifty lake sediment samples from the study area. These extractions and subsequent trace metal analyses were an attempt to identify the absolute quantity and relative proportions of trace metals associated with various phases in these lacustrine sediments.

The contents of Ag, Cr, Cu, Fe, Mn, Ni, Pb and Zn were determined by atomic absorption spectrophotometry in each of the eight extracts from each sediment sample. Phase concentration factors were calculated for each sample. The phase concentration factors show that most of these metals are enriched in the organic phases and depleted in the carbonate phases.

Dissolved oxygen, pH, conductivity, and temperature profiles were measured upward through the water column above each sample site. Changes in these physical conditions within individual lakes can be responsible for significant differences in the metal content of individual phases, as well as in the total metal content, in the lake sediments. One example of this was a small lake from which sediment samples were collected at two sites. The pH at one site was 3.6 whereas at the second site it was 2.8. Cu, Fe, Mn and Ni concentrations in the sediment from the first site were an order of magnitude different than the concentrations in the sediment from the second site.

Four processes by which trace metals are incorporated into lacustrine sediments were considered. Adsorption on and incorporation in organic molecules is the most important in this area. The next most important is coprecipitation with hydrous Fe and Mn oxides and with carbonate minerals. The third factor is adsorptive bonding on fine-grained minerals and the least important factor is incorporation in detrital minerals.

This knowledge of the partitioning of trace elements among various components of the lake sediments combined with the knowledge of the physical conditions in the lake waters enable us to better understand the complex processes by which the metals have been incorporated into the sediments. The data also show the importance of these variables in interpreting geochemical data from lake sediments and waters.

GRUNSKY, E. C. *Recognition of Alteration in Volcanic Environments: Computer Applications / Abstract on p. 38*

HENDERSON, F. B. *Global Satellite Remote Sensing for Energy, Minerals, and Other Resources: Abstract Not Available*

HOFFMAN, S. J. and MITCHELL, G. G. *The Microcomputer in Geochemical Exploration / Abstract on p. 30*

HUANG, C. *Biogeochemical and Soil Geochemical Studies at the Borealis Mine, Mineral County, Nevada: Abstract on p. 24*

IKRAMUDDIN, M., BESSE, L., and NORDSTROM, P. M. *The Relation Between Tl, Rb, and K in the Carlin-type Gold Deposits / Abstract on p. 37*

ILCHIK, R. P. and BRIMHALL, G. H. *The Type and Maturity of Organic Matter at Alligator Ridge, Nevada, and Its Relation to Mineralization*

The Type and Maturity of Organic Matter at Alligator Ridge, Nevada, and Its Relation to Mineralization

Robert P. Ilchik and George H. Brimhall, Department of Geology and Geophysics, University of California, Berkeley, CA 94720

The organic matter (OM) of the Mississippian Pilot Shale (Mp), which hosts the disseminated Au mineralization at Alligator Ridge, Nevada, has been investigated in an attempt to find an alteration parameter which reflects precious metal distribution more accurately than mineralogical alteration patterns. Alligator Ridge is similar to other disseminated Au deposits in the Great Basin. Visible alteration features, consisting of quartz replacement of carbonates and oxidation of sulfides and OM, do not correspond well spatially with Au distribution.

In this study, the type, abundance and maturity of OM in the Mp were determined using techniques standard to petroleum exploration. The type and abundance of OM in background and mineralized samples are similar. Transmitted light examination of kerogen concentrates shows that most of the OM consists of fine amorphous (algal) aggregates with a minor amount of vitrinite. This corresponds with type 1 OM of Tissot (1978) which is derived from a marine source. Total organic carbon (TOC) makes up 1-3% of most carbonaceous Mp rocks at Alligator Ridge.

The maturity of OM, as determined by pyrolysis and vitrinite reflectance (R_0), in mineralized samples is considerably higher than background. Hydrogen index (HI) values for mineralized samples are generally < 40 ($H/C \sim 0.5$) compared with a background of 230-315 for HI ($H/C \sim 1$). Changes in R_0 show a similar, but less dramatic change. Mineralized samples have R_0 values of 1-2%; background R_0 is 0.4-0.5%. All R_0 values, however, are anomalously low due to the extremely small grain size of the vitrinite present in the Mp and cannot be used to determine paleotemperatures.

Spatially, HI contours increase concentrically away from mineralization, except near the lower Mp contact, where HI isopleths are nearly concordant and parallel other alteration features. The spatial pattern indicates that hydrothermal flow was dominantly along this contact and away from mineralization.

This study shows that the OM in the Mp is of a marine sedimentary origin. The TOC of mineralized and background material is similar, indicating that OM was not added to the Mp hydrothermally. However, hydrothermal activity has increased the maturity of the OM, suggesting that maturation studies can be useful in future exploration programs.

JAACKS, J. A. and KLUSMAN, R. W. *A Comparison of Instantaneous Versus Integrative Techniques in Soil-Gas Sampling*

A Comparison of Instantaneous Versus Integrative Techniques in Soil-Gas Sampling

J. A. Jaacks, and R. W. Klusman, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, Colorado 80401

Simultaneous measurements of Hg, Rn, He, meteorologic, and season variables were conducted for 22 months over an unmineralized site in Colorado. Considerable variation in gas emission was directly attributable to short-term meteorologic conditions. Methods of reduction of short-term noise in gas emanation data were examined using instantaneous and integrative measurements of varying durations. Mercury emission was measured at two and one half hour intervals and integrated for 24 hour and 168 hour periods. Radon was sampled at 24 hour and 168 hour intervals. Helium emanation was measured at 24 hour intervals.

Duplicate measurements showed a correlation of .491 for He and .922 for Rn measured at 24 hour intervals. As the integrative time interval increased from hourly through daily and weekly periods, correlation between gases and between gases and meteorological variables increased. The variance predicted by stepwise regression ranged from 36% for He which is an instantaneous technique to 91% for TrackEtch® Rn, which is an integrative technique sampled at weekly intervals. Mercury integrated for two and one half hour intervals was 55% predictable and Rn integrated for 24 hour intervals was 89% predictable.

Integrative techniques were found to be superior to instantaneous techniques for soil-gas sampling. The ability to predict gas emission and emanation rates as a function of meteorologic influences is directly related to integration time. Increased integration times resulted in greater predictability when modeling gas emission rates with meteorologic data. Integrating emission data smoothes out noise created by short-term meteorologic variation enabling greater discrimination between background noise and anomalous emissions. Duplicate analyses indicated increased precision for sampling periods of longer duration. The data suggest greater emphasis should be placed on the development of integrative methods in the field of gas geochemistry.

JAMES, L. P. *Geochemical and Geological Exploration for Gold-Copper Deposits in Southern Luzon, The Philippines / Abstract on p. 29*

JENSON, S. K. and TRAUTWEIN, C. M. *Definition of Multivariate Geochemical Associations with Polymetallic Mineral Occurrences Using a Spatially Dependent Clustering Technique and Rasterized Stream Sediment Data—An Alaskan Example / Abstract on p. 30*

JOHNSON, M. L. and CUMMINGS, M. L. *Mineralogy and Geochemistry of Hydrothermal Alteration at Glass Buttes, South Central Oregon / Abstract on p. 22*

KNOPER, M. W. and IKRAMUDDIN, M. *Determination of Au, Ir, Pd, Pt, Rh, and Ru in Geological Materials by Solvent Extraction and Electrothermal Atomic Absorption Spectrophotometry*

Determination of Au, Ir, Pd, Pt, Rh, and Ru in Geological Materials by Solvent Extraction and Electrothermal Atomic Absorption Spectrophotometry

Michael W. Knoper and Mohammed Ikramuddin, Geochemistry Laboratory, Department of Geology, Eastern Washington University, Cheney, WA 99004

The determination of Au, Ir, Pd, Pt, Rh, and Ru in geological materials was achieved by solvent extraction and the use of an atomic absorption spectrophotometer equipped with a graphite furnace. Samples were first digested with HCl-HF and then fused with a Na₂O₂-NaOH flux. After fusion, the

samples were dissolved in dilute HCl and filtered to remove the undissolved salt. Depending on the concentration of Cu, Fe, and Cr in the samples, one of two extraction procedures was used. One procedure was used for sample solutions containing greater than 50 mg/L of Cu, which were extracted using methyl iso-butyl ketone. This procedure consisted of an initial extraction of Au as a chloride complex, a second extraction of Pd and Pt as iodide complexes, and a third extraction of Ir, Rh, and Ru as 2-mercaptobenzothiazole complexes. The second procedure was used for sample solutions containing high concentrations of Fe, Cr, and less than 50 mg/L of Cu. These solutions were treated with SnCl₂ and diphenylthiourea, and extracted using chloroform. After use of a suitable extraction procedure, 0.02 ml of the solvent was injected into a graphite tube for subsequent electrothermal atomization. This method has been applied to samples containing large amounts of chromite as well as samples with considerable amounts of the sulfide minerals, and should find application in mineral exploration by determining micro-amounts of Au, Ir, Pd, Pt, Rh, and Ru in geological materials.

LOUCKS, R. R. *Fluid Dynamics Associated with the Boiling Zone in Epithermal Fissure Veins, Topia, Durango, Mexico / Abstract on p. 21*

LOUCKS, R. R. *Solution of Structural Problems in the Topia Ag-Au-Pb-Zn District, Durango, Mexico, Using Laser Deprecitation and Capacitance Manometer Gas Analysis for Fluid Inclusion Geobarometry / Abstract on p. 40*

MACQUEEN, R. W. *Alteration of Organic Matter Around Carbonate-Hosted Lead-Zinc Deposits / Abstract on p. 40*

MARRS, C. D. *Geology, Lithologic Association, and Depositional Environment of the Oposura Massive Sulphide Deposit, Sonora, Mexico / Abstract on p. 39*

MASCARENAS, J. F. WENRICH, K. J., and SILBERMAN, M. L. *The Geochemistry of Majuba Hill, Nevada / Abstract on p. 21*

MASSA, P. J. and IKRAMUDDIN, M. *The Behavior of Trace Element Ratios in the Rocks of the Como Mining District, Lyon County, Nevada, with Applications for Exploration of Precious Metals*

The Behavior of Trace Element Ratios in the Rocks of the Como Mining District, Lyon County, Nevada, With Applications for Exploration of Precious Metals

Philip J. Massa and Mohammed Ikramuddin, Geochemistry Laboratory, Department of Geology, Eastern Washington University, Cheney, WA 99004

Ninety-two lithogeochemical samples of quartz veins, altered andesites, and unaltered andesites were analyzed for Ti, Rb, K, Sr, Ba, Au, and Ag.

The data indicate that Au and Ag concentrations along with the Ti/Sr and Rb/Sr ratios increase from the unaltered andesites to the altered andesites and quartz veins while the K/Ti, K/Rb, and Ba/Ti ratios decrease.

The ternary relationships of Ti-Rb-K, Ti-Rb-Sr, Ti-Ba-Sr, Ti-Ba-K, and Ti-Ba-Rb show that the altered rocks and quartz veins and the samples having high Au and Ag values plot toward the Ti apex while the unaltered andesites plot toward the Ba and Sr apexes. The trends of element ratios and the ternary relationships demonstrate that Ti, Rb, and K are enriched during hydrothermal alteration while Ba and Sr are depleted.

The data suggests that low K/Ti, K/Rb, Ba/Ti and high Ti/Sr and Rb/Sr ratios and ternary diagrams using Ti, Rb, K, Ba, and Sr may be useful in determining hydrothermally altered andesites and in prospecting for Au and Ag mineralization. These techniques may prove to be particularly useful when the type of alteration, hypogene versus supergene, is not readily apparent from hand specimen or when inaccurate Au and Ag values result due to sampling or analytical problems.

MCCURDY, K., RUSSELL, N., and KESLER, S. E. *Primary Dispersion of Trace Elements, Fluid Inclusion Zoning, and Alteration Zoning at the Pueblo Viejo Au-Ag Deposit, Dominican Republic* / Abstract on p. 42

MCHUGH, J. B. and FICKLIN, W. H. *A Method for Determining Gold in Natural Water* / Abstract Not Available

MERRICK, P. *Precious Metal Mineralization at the Zaca Mine, Alpine County, California* / Abstract on p. 22

PRUDDEN, J. H. *Geochemical Evaluation of Placer Gold Deposits*

Geochemical Evaluation of Placer Gold Deposits

James M. Prudden, 4809 Quail Point Road, Salt Lake City, Utah 84117

Physical and chemical characteristics of placer deposits must be related to a geologic model to facilitate practical cost effective evaluation of these very difficult ore deposit types. Economic geologists must combine total heavy mineral suite distribution, concentration, particle size, shape, and chemical composition with transport distance and provenance area to comply with a geologic model based on sedimentary history, external and internal geometry of the sediments, and form of the enclosing sedimentary basin. This increased general acceptance of the combined geochemical and geological appraisal of sediments has evolved from the practical use of clastic sedimentology in evaluating placer deposits spanning geologic time. The use of these measurable geological and mineralogical parameters is considered essential in locating, defining and mining placer deposits. Deviations from these predictable parameters can be attributed to local influxes of new gold and local sediment into the seemingly simple fluviate system. Orientation studies, relying on the above parameters, will determine sample density, spacings and size to produce a cost effective evaluation program. These exploration-phase deposit characteristics will be of great assistance in determining mining and beneficiation parameters at an early stage for timely production decisions.

REHRIG, W. A. *Preliminary Geochemical Data on the "Chlorite Breccia" of Metamorphic Core Complex Detachment Zones, and Thoughts on Associated (?) Base and Precious Metal Mineralization* / Abstract on p. 23

SCHMIDT, K. W. *Geology and Geochemical Signature of the Wenatchee Gold District, Chelan County, Washington—Work in Progress*

Geology and Geochemical Signature of the Wenatchee Gold District, Chelan County, Washington - Work in Progress

K. W. Schmidt, United Mining Corporation, Virginia City, Nevada

Gold-silver bearing quartz veins and disseminated gold-silver mineralization occur in a unique geologic environment hosted by arkosic sandstones and siltstones of the Paleocene-Eocene Swauk Formation in central Washington. The Wenatchee district is located within the confines of the Eocene Chiwaukum graben. The hydrothermal system appears to have developed under extensional stress regimes but has since undergone compressional deformation resulting in a complex structural scenario. Based on over 400 geochemical samples, and thin section analyses of several drill core and rock chip samples, precious metals-quartz vein mineralogy is characterized by native gold, electrum, and possible silver selenides, and exhibits anomalous Sb and Hg. Wall rock trace element geochemistry is characterized by high As, Hg and Ba content. The Au:Ag = 1:10. The hydrothermal system itself exhibits many characteristics similar to an epithermal hot springs-type genetic environment.

SCHNORR, P. H., KESLER, S. E., and CLOKE, P. L. *Micron Gold-Associated Jasperoid: Fluid Inclusion Chemistry and Geothermometry* / Abstract on p. 33

SCHNORR, P. H., GORMAN, J. A., and KESLER, S. E. *Gas Halos in Hydrothermal Clays Associated with Ore Shoots at Creede, Colorado* / Abstract on p. 41

TRAUTWEIN, C. M. and JENSON, S. K. *Applications of Digital Elevation Models in the Display and Evaluation of Stream Sediment Data*

Applications of Digital Elevation Models in the Display and Evaluation of Stream Sediment Data

C. M. Trautwein and Susan K. Jenson

Digital Elevation Models (DEMs) representing rasterized terrain elevations from standard U.S. Geological Survey 1:250,000-scale topographic maps are available for most of the conterminous United States and Alaska from the National Cartographic Information Center in Reston, Virginia. These data are formatted as 1° x 1° files on nine-track, 1600 byte-per-inch, computer-compatible tapes with each file consisting of 1201 lines by 1201 samples (601 samples in Alaskan files). Elevation data in this format can be processed to extract topographic measures that are useful in graphically displaying and statistically evaluating geochemical data acquired in regional stream sediment surveys.

In digital spatial data processing research currently being carried out at the Earth Resources Observation Systems (EROS) Data Center in Sioux Falls, South Dakota, several computer-based techniques have been applied to coregistered DEM and multivariate stream sediment data sets. For display purposes, Hue-Intensity-Saturation (HIS) transformations have been used to digitally merge interpolated stream sediment data with DEM-derived slope, aspect, and shaded relief images. The resultant cartographically referenced products provide a rapid, interactive, and efficient means of conveying prioritized geochemical and topographic information for qualitatively evaluating anomalies on the basis of their position within a drainage basin and for identifying areas that may require follow-up surveys. Digitally induced relief displacement has been applied to shaded relief images to produce stereo images of topography for follow-up field work. These products may incorporate single element or multivariate reductions using HIS transforms. Automated techniques for defining drainage lines and basin boundaries have been developed to provide derived data that is applicable in the statistical modelling and evaluation of anomalies. Measures such as surface area, drainage density, and stream gradient within respective basins are useful parameters for evaluating the significance of an anomaly with respect to an anticipated target size.

In addition to 1:250,000-scale DEM data, the U.S. Geological Survey is currently producing 1:24,000-scale DEM data. Approximately 10% of the conterminous United States is available in this format. Files are organized in 7.5' x 7.5' blocks consisting of about 475 lines by 335 samples in a Universal Transverse Mercator projection. With a 30-meter (ground equivalent) cell size, these data provide topographic control that is adequate for geochemical applications on a local scale.

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