CONTACT INFORMATION
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Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
520-770-3500
http://www.azgs.az.gov
inquiries@azgs.az.gov

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James Doyle Sell Mining Collection

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J. D. Sell

27

[illegible]

1971

Korean [illegible]

[illegible]

7th Exploration Meeting Nov 30 - Dec 3 1971

Riviera Hotel & Country Club
Palm Springs, California

7th Exploration Meeting

Nov. 30 - Dec. 3, 1971

Riviera Hotel & Country Club

Palm Springs, California.

Preliminary Program - Palm Springs, Calif. - 1971

Tuesday, November 30, 1971

A. Ore in Igneous Rocks

14 - Giesecke, A. - The Application of Nappe-Tectonics to the Arizona-Sonora Copper Province

37 - Williamson, H.C. - Recent Advances in the Identification of Leached Outcrops

38 - Graybeal, F.T. - The Partition of Cu, Zn, and Mn between Coexisting Biotite, Hornblende, and Chlorite in some Laramide Intrusive Rocks in Arizona

45 - Devere, B.J. - Resurgent Volcanic Centres and their Role in Porphyry Copper Localization

48 - Balla, J.C. - Relative Position of Porphyry Copper Deposits to Barren Laramide Stocks

24 - Gray, R.S. - Geochemical Indicators for W.A. Nickel Sulphide Deposits

Wednesday, December 1, 1971

B. Ore in Sedimentary Rocks

55 - Von Fay, S. - Common Factors in Stratiform Copper Bodies and their Significance as Exploration Guides

23 - Gray, R.S. - Selection of Areas Favourable for McArthur-type Sedimentary Base Metal Ores

46 - Walker, P.N. - Localization of Major Stratiform Ore Bodies

16 - Sprague, R.B. - An Exploration Project in North America Based on European Ideas of Ore Genesis

56 - Hoskins, W.G. - The Relationship of Organically Derived Material to Stratabound Ore Deposits

25 - Gray, R.S. - The Role of Gypsum in Formation of Base Metal Deposits

Thursday, December 2, 1971

C. Other Exploration

1 - Brown, R.L. - Metallogeny in the Northeastern Appalachians

3 - Gale, R.E. - Zonal Interpretation as an Exploration Tool

5 - Anzalone, S.A. - Asbestos Exploration by Optical and Chemical Analysis of Stream Silt and Soil Sample

C. Other Exploration (Continued)

60 - Whiting, K. - How to Find Asbestos

10 - Kurtz, W.L. - Drilling for Geologic Information

58 - James, L.D. - Geochemistry and the Exploration Department

59 - Moss, C.K. - Aeromagnetic Work in Arizona

Friday, December 3, 1971

D. Other subjects

(59)

EXPLORATION SERVICES DIVISION
3422 South 700 West
SALT LAKE CITY, UTAH 84119

October 13, 1971

RECEIVED
OCT 15 1971
EXPLORATION DEPT.

T.C.O.
OCT 15 1971

OCT 21 1971
J.V.D.

Mr. J. J. Collins
New York Office

EXPLORATION IDEAS
ANNUAL MEETING

Dear John:

I apologize for not replying previously on the above subject, but I have been preoccupied in recent weeks with the problem of keeping alive the geophysical follow-up of our aeromagnetic work in Arizona.

In this particular case I would justify my actions on the grounds that I have been trying to implement a "new exploration approach" which evolved out of yester-years' work, in place of submitting a newer suggestion.

I consider the follow-up of magnetics in Arizona to be a more important idea than any other new idea which I might bring into the exploration picture at the moment. (The large amount of magnetic data which we have accumulated in Arizona gives us a temporary advantage over our competitors in that area.)

I am sorry that we do not have a formal proposal to submit this year. Jerry Montgomery was considering an idea on gravity for presentation, but later decided he would not be able to acquire sufficient data this year to support it.

Ralph Falconer, likewise, decided that he was unable to develop a suitable topic.

In a general comment on new geophysical ideas, I believe the most important point which I could offer concerns the value of fitting geophysicists directly into the exploration picture at regional offices. Innovation

TO Jim Sell

FROM W. L. K.

OCT 29 1971

SUBJECT Annual Expl. Meeting Nov 29 - Dec 3 DATE / /

MESSAGE

You will attend meeting and have won the honor of the arrangements chairman. Check with Lois who has made room reservation in Palm Springs.

Also you have been chosen to be the southwest's number 1 discussion leader, haggler, heckler, etc etc. so please bone up on the literature related to the talks.

SIGNED

REPLY

SIGNED DATE / /

Rediform® 4S 472

SEND PARTS 1 AND 3 WITH CARBON INTACT - PART 3 WILL BE RETURNED WITH REPLY

JDS / Lois

Annual Meeting

Total # 24

6 reservations for Nov. 28

rest for Monday Nov. 29

Reservations — thru Friday night Dec. 3.

Breakfast 6:30

Meeting 8 – 12

afternoon free

dinner at 6

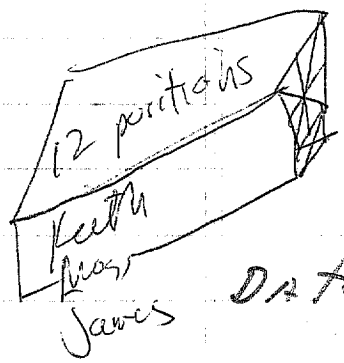
meetings 7–9 (beer and/or mixed)

J.J. Collins - Res. 212-288-3289

35MM / no lye

PALM SPRINGS AREA
(Avoid name if possible)

Resort Motel



24 - No. in group
- 10 Singles
- 7 Doubles

Sunday 4
Sunday 2
6

DATES: MON. 29 NOV. '71
FRI. 3 DEC. '71

PRICES: Competitive with other Resort Motels
(i.e.) $30.00 per day double (younger)
single

FRINGES: Golf Course - with Pure
Meals - B'fast

TRANSPORTATION:
check on ALL Flights in Palm Springs.

2nd Choice: Wigwam Resort N. of Phoenix
30.00

Riviera
& COUNTRY CLUB, PALM SPRINGS

BILL SHORT
Associate Director of Sales

1600 NORTH INDIAN AVENUE
PALM SPRINGS, CALIF. 92262
TELEPHONE: 714/327-8311

QUICK REFERENCE SCHEDULES TO AND FROM PALM SPRINGS

EASTBOUND SERVICE FROM PALM SPRINGS

FROM PALM SPRINGS TO:	LV PSP	ARRIVE	FLIGHTS	STOPS	ROUTING
Atlanta	10:00A	7:35P	AA 612 — EA 245	1	B
	12:45P	8:08P	AA 594 — EA 784	1	C
Boston	10:00A	6:56P	AA 612	1	A
	12:45P	11:39P	AA 594 — AA 628	2	B
Chicago	10:00A	3:25P	AA 612	0	A
	12:45P	7:34P	AA 594	1	A
	2:50P	9:12P	AA 54	1	A
Cincinnati	10:00A	6:41P	AA 612 — DL 379	1	B
	12:45P	9:19P	AA 594 — AA 32	1	C
Cleveland	10:00A	6:43P	AA 612 — NW 548	1	B
Dallas	12:45P	4:57P	AA 594	0	A
Detroit	10:00A	6:50P	AA 612 — AA 552	1	B
	2:50P	11:35P	AA 54	2	A
Houston	12:45P	6:33P	AA 594 — TT 917	1	C
London	10:00A	7:35A	AA 612 — PA 58	1	B
	12:00N	10:40A	AA 164 — BA 506	2	D
Memphis	12:45P	8:59P	AA 594 — AA 618	1	C
Miami	10:00A	8:11P	AA 612 — DL 7	1	B
	12:45P	11:07P	AA 594 — EA 529	2	C
Montreal	10:00A	7:45P	AA 612 — AC 734	1	B
New Orleans	12:45P	7:59P	AA 594 — EA 529	1	C
New York	10:00A	6:55P	AA 612 — AA 386	1	B
	12:00N	8:35P	AA 164	1	A
	2:50P	1:38A	AA 54 — UA 456	2	B
Oklahoma City	12:45P	7:19P	AA 612 — AA 622	1	C
Paris	10:00A	9:25A	AA 612 — AF 30	1	B
	12:00N	11:00A	AA 164 — AF 221	1	D
Philadelphia	10:00A	7:33P	AA 612 — TW 110	1	B
	12:45P	9:40P	AA 594 — AA 46	1	C
Rochester	10:00A	8:30P	AA 612 — AA 182	1	B
	12:45P	10:34P	AA 594	2	A
St. Louis	12:45P	7:25P	AA 594 — OZ 926	1	C
Syracuse	10:00A	8:27P	AA 612 — AA 562	2	B
	12:45P	11:34P	AA 594	3	A
Toronto	10:00A	6:16P	AA 612 — AA 220	1	B
Washington	10:00A	7:16P	AA 612 — AA 116	1	B
	12:45P	11:57P	AA 594 — TW 292	2	B

WESTBOUND SERVICE TO PALM SPRINGS

TO PALM SPRINGS FROM:	LEAVING	AR PSP	FLIGHTS	STOPS	ROUTING
Atlanta	7:30A	11:06A	DL 823 — AA 479	1	C
	9:55A	2:00P	EA 240 — AA 627	1	B
	4:10P	8:47P	DL 938 — AA 123	2	B
Boston	10:05A	2:00P	AA 627	1	A
	3:05P	8:47P	AA 123	3	A
Chicago	12:15P	2:00P	AA 627	0	A
	6:05P	8:47P	AA 123	1	A
Cincinnati	9:25A	2:00P	AA 645 — AA 627	2	B
	4:40P	8:47P	DL 376 — AA 123	2	B
Cleveland	10:35A	2:00P	UA 723 — AA 627	1	B
	4:50P	8:47P	UA 701 — AA 123	2	B
Dallas	10:30A	11:06A	AA 479	0	A
Detroit	8:25A	11:06A	AA 479	1	A
	11:25A	2:00P	AA 625 — AA 627	1	B
	5:20P	8:47P	AA 123	2	A
Houston	9:00A	11:06A	BN 126 — AA 479	1	C
London	3:00P	8:47P	PA 59 — AA 123	3	B
Memphis	7:10A	11:06A	AA 203 — AA 479	1	C
Miami	9:00A	2:00P	NW 717 — AA 627	1	B
	1:25P	8:47P	DL 18 — AA 123	1	B
Montreal	9:30A	2:00P	AC 731 — AA 627	1	B
	3:00P	8:47P	BA 567 — AA 123	2	B
New Orleans	8:00A	11:06A	BN 146 — AA 479	1	C
New York	9:30A	1:22P	AA 71	1	A
	4:00P	8:47P	AA 317 — AA 123	1	B
Oklahoma City	8:42A	11:06A	BN 239 — AA 479	1	C
Paris	11:30A	8:47P	AF 31 — AA 123	3	B
Philadelphia	9:20A	2:00P	UA 643 — AA 627	1	B
	3:45P	8:47P	TW 461 — AA 123	1	B
Rochester	8:30A	2:00P	AA 267 — AA 627	1	B
	3:00P	8:47P	UA 235 — AA 123	2	B
Syracuse	8:25A	2:00P	AA 571 — AA 627	1	B
Toronto	10:55A	12:15P	AA 457 — AA 627	1	B
	4:50P	8:47P	AA 459 — AA 123	1	B
Washington	10:35A	2:00P	AA 281 — AA 627	1	B
	4:20P	8:47P	AA 283 — AA 123	1	B

ROUTINGS: A THROUGH FLIGHT; B CHICAGO CONNECTION; C DALLAS CONNECTION; D NEW YORK CONNECTION.

American Airlines

FLIGHTS TO AND FROM PALM SPRINGS

EASTBOUND ASTROJETS FROM PALM SPRINGS

	612	164*	594	54*
Lv Palm Springs	10:00A	12:00N	12:45P	2:50P
Ar Dallas			4:57P	
Ar Chicago	3:25P		7:34P	9:12P
Ar Detroit				11:35P
Ar Rochester			10:34P	
Ar Syracuse			11:34P	
Ar New York		8:35P		
Ar Boston	6:56P			

WESTBOUND ASTROJETS TO PALM SPRINGS

	479	71*	627	123*
Lv Boston			10:05A	3:05P
Lv New York		9:30A		
Lv Detroit	8:25A			5:20P
Lv Chicago			12:15P	6:05P
Lv Dallas	10:30A			
Ar Palm Springs	11:06A	1:22P	2:00P	8:47P

* Flights marked * operate via Phoenix, for American Airlines is not authorized to carry passengers between Palm Springs and Phoenix.

EFFECTIVE JANUARY 11, 1970.

American Airlines

PALM SPRINGS MUNICIPAL AIRPORT
PHONE 327-8441

RIVIERA HOTEL & COUNTRY CLUB
1600 INDIAN AVENUE
PALM SPRINGS, CALIFORNIA 92262
(714) 327-8311

American Airlines

FOUR FLIGHTS DAILY

EAST FROM PALM SPRINGS

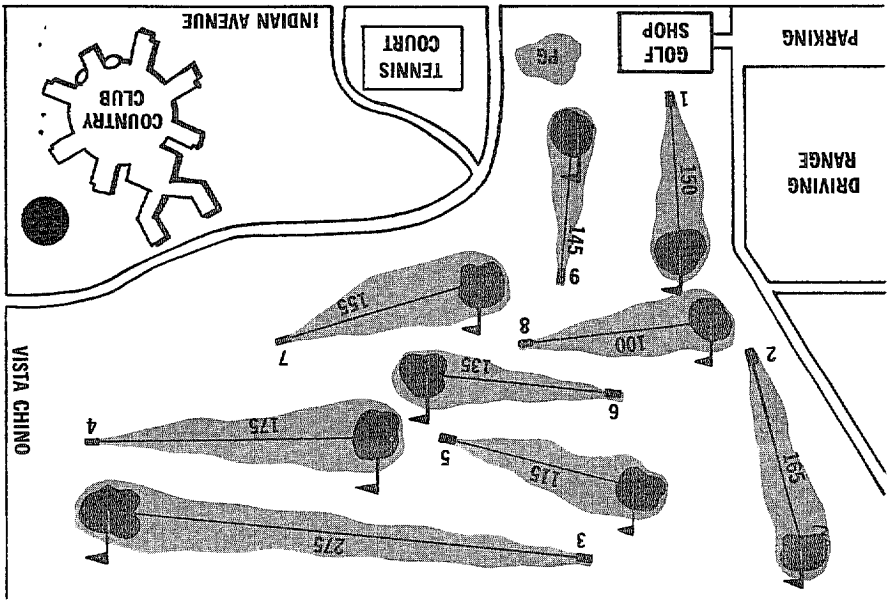
On January 11, 1970, American is adding a fourth daily Astrojet flight East from Palm Springs—at 12:45PM nonstop to Dallas.

Using American's nonstop service to Chicago or the new nonstop to Dallas, direct connections can be made to all major cities in the East. In addition, American offers through plane service to New York, Detroit, Boston, Rochester and Syracuse.

Quick reference schedules on the inside of this folder show examples of service between Palm Springs and key Eastern cities, as well as service to and from London and Paris.

Schedules of American's four Astrojet flights from Palm Springs and four Astrojet flights to Palm Springs are shown on the back of this folder.

Fly the American Way



Riviera

HOTEL & COUNTRY CLUB, PALM SPRINGS

RULES OF PLAY TO BE GOVERNED BY U.S.G.A. WITH THESE EXCEPTIONS:

1. OUT OF BOUNDS—STROKE ONLY
2. BALL MAY BE MOVED 2 CLUB LENGTHS FROM ALL TREES. NOT NEARER TO HOLE. NO PENALTY.
3. NO MULLIGANS OR PRACTICING ON COURSE.

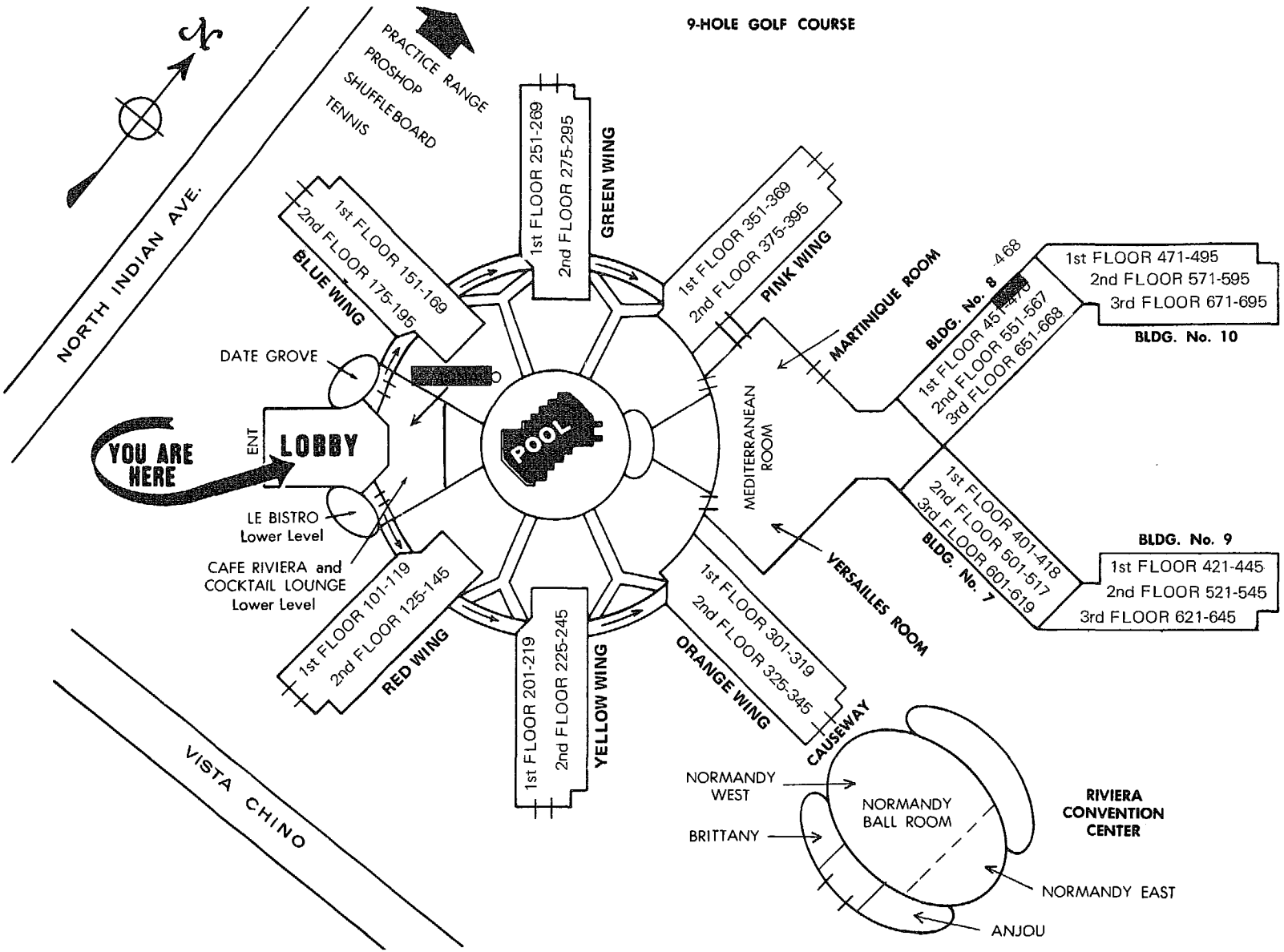
PAT DOLAN, P.G.A. Golf Professional

HOLES	YARDS	PAR	HANDICAP STROKES			GOLF HOLES DEDICATED TO		
1	150	3	13			DEAN MARTIN		
2	165	3	5			IRWIN SCHUMAN		
3	275	4	1			PHIL HARRIS		
4	175	3	3			BOB HOPE		
5	115	3	9			CHARLIE FARRELL		
6	135	3	11			BING CROSBY		
7	155	3	7			FRANK SINATRA		
8	100	3	17			MILT HICKS		
9	145	3	15			JERRY LEWIS		
OUT	1415	28						
10	150	3	14			DEAN MARTIN		
11	165	3	6			IRWIN SCHUMAN		
12	275	4	2			PHIL HARRIS		
13	175	3	4			BOB HOPE		
14	115	3	10			CHARLIE FARRELL		
15	135	3	12			BING CROSBY		
16	155	3	8			FRANK SINATRA		
17	100	3	18			MILT HICKS		
18	145	3	16			JERRY LEWIS		
IN	1415	28						
TOT.	2830	56						
HANDICAP								
NET SCORE								

GOLF COURSE & PRACTICE RANGE OPEN TO PUBLIC

Riviera
HOTEL & COUNTRY CLUB, PALM SPRINGS

THE WORLD'S MOST MAGNIFICENT DESERT RESORT



1600 NORTH INDIAN AVENUE • PALM SPRINGS, CALIFORNIA 92262 • PHONE (714) 327-8311

WHAT TO DO AND SEE — BACK PAGE

EVERYTHING FOR A PERFECT VACATION

TENNIS – Free tennis courts at the Riviera Hotel and Country Club. Instruction available through the Recreation Director. Inquire at front desk.

SWIMMING – The Riviera Hotel and Country Club's Olympic-size pool with temperature control is available to all guests of the hotel. Insturction is available through the recreation director.

SHUFFLEBOARD – Courts on the Riviera Hotel and Country Club grounds are for use by the hotel guests.

GOLF – There are 22 golf courses and many driving ranges in and around "America's Winter Golf Capital." Most of the courses are operated by private country clubs and are available to members and guests only. Inquire at the front desk for private courses available to Riviera Hotel and Country Club guests. The Palm Springs Golf Course is the area's first public golf links and is located at the southern city limits on Highway 111. Also open to the public: Indio's night-lighted municipal course and the nine-hole course at the Riviera Hotel and Country Club, as well as its putting green and driving range.

DESERT SANDS CASINO – In Cabazon, 10 miles north of Palm Springs. Patrons play draw poker, low ball, and pan.

BREAKFAST RIDES – Chuckwagon breakfasts with gorgeous desert backdrops are a must when vacationing in Palm Springs. Rides are held on Saturday mornings and by special arrangements through the Riviera Hotel and Country Club.

PALM SPRINGS AERIAL TRAMWAY – For the thrill of your life, take a ride on the spectacular Palm Springs Aerial Tramway. Enjoy the breathtaking view of Palm Springs and the desert area from 8,516 feet above the desert floor.

HORSEBACK RIDING – Several stables are located in the Palm Springs area where horses may be rented for trips over the desert or into the mountain canyons. Guides are available. Overnight pack trips can be arranged.

There are hundreds of miles of bridle paths near Palm Springs, winding across the desert, through cool canyons, over scenic mountain slopes. The Desert Riders use the biggest portion of their dues for the maintenance and construction of trails, opening up picturesque country that would otherwise seldom be seen.

DESERT MUSEUM — Lower gallery features semi-permanent exhibit, "Sage of the Desert," including 40-foot diorama showing museum's Desert Reserve and Wildlife Sanctuary in Palm Desert, plus changing exhibits in science and natural history. Upper gallery has changing exhibits in fields of fine art, primitive art and folk art. Classroom tours available through Museum Service League. Numerous special events calendared throughout the year. 135 East Tahquitz Drive, Palm Springs. Frederick W. Sleight, Director.

ANDREAS CANYON—Reached by toll gate at the end of South Palm Canyon Drive. The canyon is 5.2 miles from Palm Springs. An idyllic picnic spot, it boasts a number of ancient Indian caves and a fine stand of shady Washingtonia palms. Waterfalls are about four miles from the mouth of the canyon.

PALM CANYON RESERVE — Just a few minutes' drive from the center of Palm Springs in the rugged canyons to the south of town is a beautiful glade with a natural spring and pond. The canyon, in the Agua Caliente Indian Reservation, is a National Monument. More than 3,000 palms line the canyon—fan palms, the only palms native to the western United States, and the unique Washingtonia Filifera palms, whose origin is hidden in mystery. Botanists call them "a residual remnant of the days of the saber-tooth tiger" and they grow nowhere else in the world but in the canyons near Palm Springs and the Borrego Desert. Many of them are thousands of years old. A crystal-clear stream meanders through the long canyon. There is a picnic area and bridle trails leading up from the desert floor and continuing further into the primitive Andreas, Murray and Palm Canyons where once mining thrived. Wild stallions, mountain sheep and wildcats still come down to the reserve for night watering.

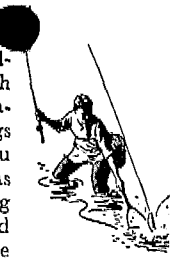
TAHQUITZ CANYON—Go west on Ramon Road from South Palm Canyon Drive to a trail branching off to the left. You may drive about a mile on this trail, then take to foot for the last mile to Tahquitz Falls.

THOUSAND PALMS CANYON—An ancient Indian campsite was located here among towering Washingtonia palms. Take Ramon Road east to Thousand Palms (about 10 miles) and continue east about two miles to the canyon. In Thousand Palms proper, there is the adobe Fort Oliver, built by Harry Oliver, desert rat.

DATE GARDENS — The center of the United States date industry is in the lower Coachella Valley. Many of the larger date farms maintain showrooms and sales shops along Highway 111 between Palm Springs and Indio.

FISHING—A well-stocked stream in Whitewater Canyon provides good trout fishing. The canyon is 12 miles north of Palm Springs near Interstate 10. A picnic area is provided and facilities are available to grill your fresh-caught fish. Good corvina fishing can be found at Salton Sea.

DESERT HOT SPRINGS — Twelve miles north of Palm Springs lies Desert Hot Springs, known for the healing qualities of its mineral springs — although many world travelers consider the curative powers of the baths at Palm Springs to excel all others. Whether or not you take the baths, you will enjoy the spas near Desert Hot Springs and watching the sun set, streaking the sky beyond the Pass with color and silhouetting the mountain peaks.



PIONEER TOWN—Frontier village where many Western movies have been made. Drive north on the Twenty-nine Palms road to Yucca Valley. Watch for a sign directing you to Pioneertown. Road branches off to the left, or northwest, out of Yucca Valley. (About 32 miles)

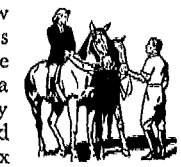
JOSHUA TREE NATIONAL MONUMENT—Good roads lead you to this national monument, to native flora, the twisted yucca cactus. At the highest point, Salton Sea may be viewed. Roads lead out of Twenty-nine Palms or Joshua Tree. (About 40 miles)

SALTON SEA—Swimming, boating, water skiing and salt water fishing are available at this "beach in the desert." Located at the far tip of Salton Sea (8.2 miles) are mud pots, or miniature volcanoes of bubbling mud, which are believed to lie directly over the San Andreas fault. The sea is 40.7 miles south of Palm Springs and is 35 miles long and 15 miles wide. Travertine Point lies 54.1 miles from Palm Springs via Highway 111. It is so named because the waterline of prehistoric Lake Cahuilla is clearly marked in white travertine, along the side of this small granite hill. About 37.3 miles south of Palm Springs can be found ancient Indian relics. Originally believed to be fish traps along the shoreline of Lake Cahuilla, these are now thought to be sites of Indian wickiups or brush shelters.

PAINTED CANYON — Dramatic colorations and sharply eroded walls of great beauty, punctured by a 15-foot dry fall at the upper end of the canyon a few miles east of Mecca. (41.5 miles)

PALMS-TO-PINES HIGHWAY—A magnificent loop of highway that traverses desert country, runs through mountain pine forests and through summer resorts in the mile-high regions. Take Highway 74, the Palms-to-Pines Highway, out of Palm Desert. Follow it to the fork branching off right to Idyllwild and Mountain Center. Follow this road down into the San Gorgonio Pass and Banning. Return to Palm Springs via Interstate 10, the freeway, and Highway 111. (About 110 miles round trip)

SANTA ROSA MOUNTAIN — Primitive wilderness road, with views of new development projects, greet you on this drive as you reach timberline and the view from the top, 8,045 feet above sea level. Take the Palms-to-Pines Highway out of Palm Desert, take the marked road leading off to the left. It's about six miles to the summit. (About 54.5 miles)



COURTESY OF PALM SPRINGS LIFE

J.C.
Reuter -
120 Broadway
N.Y. 10005
212-732-9500

Shop in sales office
next to Gift Shop

Riviera Hotel & Country Club
1600 N. Indian Ave. (1 blk. E of Cal. 111)
Palm Springs
327-8311 (Bill Schein)
Bill Short

S -- $16.00 (Will give the "top man" a suite at the
D -- $22.00 regular rate so you will have a place
to congregate and hold small meetings.)

ok

Meeting room, 35MM projector and screen -- no charge

9=hole executive golf course (smaller than regulation size,
but not a putting green size)
Can get them on other courses with no problem.

can arrange all rooms close together and close to meeting
room and cafe & dining room area.
[redacted] food function

El Mirador
1150 N. Indian Ave.
Palm Springs
325-1141 (Mr. Jack Jeffrey)

S -- $20.00
D -- $24.00

Meeting room, 35MM projector and screen -- no charge

Golf -- can get them on any courses -- usual greens fee
$10 and $15

Have coffee shop and main dining room.

Located on 20 acres.

Executive Office
1600 North Indian Avenue
Palm Springs
California 92262
(714) 327-8311

Riviera
HOTEL AND COUNTRY CLUB

November 23, 1971

Mr. James Sell
AMERICAN SMELTING & REFINING CO.
1150 North 7th Avenue
Tucson, Arizona 85703

Dear Mr. Sell:

Enclosed are two (2) copies of the program for your meeting on November 28 - December 4, 1971.

If you have any questions, comments or changes, please, do not hesitate to contact this office.

We look forward to serving you and your fine organization.

Cordially,

Marion Granfield

Marion F. Granfield
Convention Coordinator

MFG/pm
Enclosures

J J Collins 315
T Osborne 119

D Brown 110
S Anzalone 106
B Gale 104
S von Fay 212
B Hoskins 203
H Courtright 141
B Kurtz 133
J Balla 144
F Graybeal 142
J Sell 145
K Whiting 207

B Lacey 112
C Moss 215
M Barnes 210
L James 213
R Sprague 115
A Griesicke 143

C Williamson 108
P Walker 117
B Gray 109
B Devere 114

80 M d 109

DISTRIBUTION: Client (2), Reservations (2), Front Desk, Catering, Schein, Granfield, File

Gotham Hotels, Inc.

CONFIRMATION
MEETING ROOM ORDER

#6571

Hotel RIVIERA HOTEL & COUNTRY CLUB

Customer Mr. J. J. Collins

Date of Order October 29, 1971

Title Director of Exploration

Inquiry

Organization Name: AMERICAN SMELTING & REFINING CO.

Tentative

Address: 120 Broadway

Definite XX

New York, New York 10005

Telephone 212 Area Code No. 732-9500

Booked by BILL SCHEIN

No. of Persons: 24

Entered by

Meeting Room Assigned Date Grove

Evaluation Upon Completion

Set-Up: Aud. Conf. C/Rm. Other

Sleeping Rooms

Dates: Nov. 28 - Dec. 3, 1971

Food

Type of Function: Exploration Dept. Meeting

Beverage

Sleeping Rooms	Number	Rates:
Arrival See Below	Departure See Below	
Singles	24	$16. + 5% tax
Twins		
Triples		
Quads		

Rental

TOTAL $

24 ROOMS

John J. Collins

Suites One (1) Suite @ $16.00 for Mr. Collins

PROGRAM OF ARRANGEMENTS

(List each Activity by the hour & day by day)

Equipment and Services Required!

ARRIVALS: Nov. 28, 1971 - 6 Rooms
Nov. 29, 1971 - 18 Rooms Add.

DEPARTURES: ~~Dec. 3, 1971 - 12 Rooms~~
Dec. 4, 1971 - ~~12~~ 24 Rooms ~~Add~~

PLACE ALL SLEEPING ROOMS IN THE RED OR GOLD WINGS

RESERVE A 1-BEDROOM SUITE AT $16. FOR MR. COLLINS

FREE GOLF ON OUR COURSE

Nov. 29,30, Dec. 1,2,3, 1971

8:00-Noon and 7:00-9:00 PM

~~9:00am-5:00pm~~	Date Grove	Meeting	24
Morning	~~Date Grove~~ → Dining Room, spec. Tables	Breakfast	24
Noon	~~Date Grove~~ → Terrace, pool area, spec Tables	Lunch	24

Regional Exp. meeting
Run

104 Bob Sile
106 Al Angalone
108 Cay Williamson
109 Bob Gray
110 Walt Brown
112 Bob Lacy
114 Bert Devere
115 Red Sprague
117 Peter Walker
119 Tom Osborne
133 Bill Kurtz
141 Harold Courtright
142 Fred Grosshead
143 Al Grimaldi
144 John Bolla
145 Jim Sill

Over

203 Bill Hoekema
207 Keith Whiting
210 Marvin Barnes
212 Steve van Fay
213 Lloyd James
215 Col Moore
315 John Collins

TO: ALL DEPARTMENTS
FROM: MARION GRANFIELD

AMERICAN SMELTING & REFINING COMPANY
EXPLORATION MEETING
RIVIERA HOTEL AND COUNTRY CLUB
NOV. 28 - DECEMBER 4, 1971

MASTER ACCOUNT: MR. JAMES SELL, OPERATIONS MANAGER
BILLING TO: AMERICAN SMELTING & REFINING COMPANY
1150 NO. 7th AVENUE
TUCSON, ARIZONA 85703
B.S. PHONE: (602) 792-3014

ARRIVALS: SUNDAY, NOV. 28, 1971 — 8 ROOMS
MONDAY, NOV. 29, 1971 — 18 ROOMS ADD.

DEPARTURE: SATURDAY, DEC. 4, 1971

RATES:

	EUROPEAN PLAN
24 SINGLES	$16.00 + 5% TAX

NOTE: ONE 1-BR. SUITE - 125 @ $16.00 + 5% TAX FOR MR. COLLINS.

RESERVATIONS: THEY HAVE PROVIDED ROOMING LIST.
NOTE: HOUSE GROUP IN RED OR GOLD WINGS.

ALL STAFF NOTE: VIP'S WITH GROUP: MR. J.J. COLLINS, MR. TOM OSBORNE, MR. HAROLD COURTRIGHT

ACCOUNTING: INDIVIDUAL RESPONSIBLE FOR OWN ACCOUNTS.
FRONT DESK: ONLY MASTER ACCOUNT SIGNERS: MR. COLLINS,
CASHIER: MR. OSBORNE COURTWRIGHT

CAFE RIVIERA: GROUP WILL BE EATING ON OWN EXCEPT FOR FOOD FUNCTIONS
COUNTER SECTION: AS SCHEDULED.

GOLF PRO NOTE: GROUP MAY PLAY HOTEL COURSE AT NO CHARGE.

---

203 BH
2125VF

PROGRAMME

MONDAY, NOV. 29, 1971

CAFE RIVIERA
7:00 a.m.-8:00 a.m.
(24)

BREAKFAST
GROUP WILL ORDER OFF REGULAR MENU
INDIVIDUAL RESPONSIBLE FOR OWN
SEAT GROUP TOGETHER

CATERING NOTE: HAVE COFFEE & JUICE ON

DATE GROVE
8:00 a.m.-12:00 noon
7:00 p.m.-9:00 p.m.
(24)

MEETING
U-SHAPED SEATING (OUTSIDE ONLY)
NO CHAIRS AT HEAD TABLE END OF U
EASEL,CHALKBOARD, CHALK & ERASER
EASEL, BULLETIN BOARD
35 MM SLIDE PROJECTOR
SCREEN
PROJECTOR TABLE
EXTENSION CORDS

CATERING NOTE:
10:00 a.m. COFFEE ONLY
8:00 p.m. COFFEE ONLY
CHARGE TO MASTER ACCOUNT, SIGNED BY MR. COLLINS

POOLSIDE
12:00 noon-1:00 p.m.
(24)

(OR CAFE RIVIERA IF WEATHER IS BAD)

LUNCHEON
ARRANGEMENTS BY CATERING
GROUP WILL ORDER OFF LUNCHEON SPECIAL MENU
INDIVIDUAL RESPONSIBLE FOR OWN

CATERING & SETUP NOTE: SET UP ONE LARGE TABLE IN AS SECLUDED AREA AS POSSIBLE

NOTE: GROUP ON OWN FOR DINNER

TUESDAY, NOV. 30, 1971

CAFE RIVIERA
7:00 a.m.-8:00 a.m.
(24)

BREAKFAST
GROUP WILL ORDER OFF REGULAR MENU
INDIVIDUAL RESPONSIBLE FOR OWN
SEAT GROUP TOGETHER

CATERING NOTE: HAVE COFFEE & JUICE ON

DATE GROVE
8:00 a.m.-12:00 noon
7:00 p.m.-9:00 p.m.
(24)

MEETING
SAME AS PREVIOUS SETUP

CATERING NOTE:
10:00 a.m. COFFEE ONLY
8:00 p.m. COFFEE ONLY
CHARGE TO MASTER ACCOUNT, SIGNED BY MR. COLLINS

TUESDAY, NOV. 30, 1971, CONT'D

POOLSIDE 12:00 noon-1:00 p.m. (24) (OR CAFE RIVIERA IF WEATHER IS BAD)	LUNCHEON ARRANGEMENTS BY CATERING GROUP WILL ORDER OFF LUNCHEON SPECIAL MENU INDIVIDUAL RESPONSIBLE FOR OWN

NOTE: GROUP ON OWN FOR DINNER

WEDNESDAY, DEC. 1, 1971

CAFE RIVIERA 7:00 a.m.-8:00 a.m. (24)	BREAKFAST GROUP WILL ORDER OFF REGULAR MENU INDIVIDUAL RESPONSIBLE FOR OWN SEAT GROUP TOGETHER
CATERING NOTE:	HAVE COFFEE & JUICE ON
DATE GROVE 8:00 a.m.-12:00 noon 7:00 p.m.-9:00 p.m. (24)	MEETING SAME AS PREVIOUS SETUP
CATERING NOTE: 10:00 a.m. 8:00 p.m.	 COFFEE ONLY COFFEE ONLY CHARGE TO MASTER ACCOUNT, SIGNED BY MR. COLLINS
POOLSIDE 12:00 noon-1:00 p.m. (24) (OR CAFE RIVIERA IF WEATHER IS BAD)	LUNCHEON ARRANGEMENTS BY CATERING GROUP WILL ORDER OFF LUNCHEON SPECIAL MENU INDIVIDUAL RESPONSIBLE FOR OWN

NOTE: GROUP ON OWN FOR DINNER

THURSDAY, DEC. 2, 1971

CAFE RIVIERA 7:00 a.m.-8:00 a.m. (24)	BREAKFAST GROUP WILL ORDER OFF REGULAR MENU INDIVIDUAL RESPONSIBLE FOR OWN SEAT GROUP TOGETHER
CATERING NOTE:	HAVE COFFEE & JUICE ON
DATE GROVE 8:00 a.m.-12:00 noon 7:00 p.m.-9:00 p.m. (24)	MEETING SAME AS PREVIOUS SETUP
CATERING NOTE: 10:00 a.m. 8:00 p.m.	 COFFEE ONLY COFFEE ONLY CHARGE TO MASTER ACCOUNT, SIGNED BY MR. COLLINS

THURSDAY, DEC. 2, 1971, CONT'D

POOLSIDE
12:00 noon-1:00 p.m.
(24)

(OR CAFE RIVIERA IF WEATHER IS BAD)

LUNCHEON
ARRANGEMENTS BY CATERING
GROUP WILL ORDER OFF LUNCHEON SPECIAL MENU
INDIVIDUAL RESPONSIBLE FOR OWN

NOTE: GROUP ON OWN FOR DINNER

FRIDAY, DEC. 3, 1971

CAFE RIVIERA
7:00 a.m.-8:00 a.m.
(24)

BREAKFAST
GROUP WILL ORDER OFF REGULAR MENU
INDIVIDUAL RESPONSIBLE FOR OWN
SEAT GROUP TOGETHER

CATERING NOTE: HAVE COFFEE & JUICE ON

DATE GROVE
8:00 a.m.-12:00 noon
7:00 p.m.-9:00 p.m.
(24)

MEETING
SAME AS PREVIOUS SETUP

CATERING NOTE:
10:00 a.m. COFFEE ONLY
8:00 p.m. COFFEE ONLY
CHARGE TO MASTER ACCOUNT, SIGNED BY MR. COLLINS

POOLSIDE
12:00 noon-1:00 p.m.
(24)

(OR CAFE RIVIERA IF WEATHER IS BAD)

LUNCHEON
ARRANGEMENTS BY CATERING
GROUP WILL ORDER OFF LUNCHEON SPECIAL MENU
INDIVIDUAL RESPONSIBLE FOR OWN

NO FURTHER SCHEDULED FUNCTIONS

RECEIVED
NOV 4 1971
S. W. U. S. EXPL. DIV.

November 2, 1971

Mr. J.J. Collins
Director of Exploration
AMERICAN SMELTING & REFINING COMPANY
120 Broadway
New York, New York 10005

Dear Mr. Collins:

Enclosed is the Confirmed Booking for the November 28 - December 3, 1971 Exploration Department Meeting of the American Smelting and Refining Company at the Riviera Hotel and Country Club. All rates and arrangements are outlined on the booking, and if you have any changes or additions please let us know. Also, please sign and return one copy of the booking to this office for the completion of our file.

As we discussed with Mrs. Becker, all sleeping rooms would be placed in one wing, and a 1-bedroom suite has been set aside for your use, at the rate of $16.00. All of your members will have free golfing privileges on our course.

Please send your Rooming List to Hal Vaughan, Reservations Manager; your food function requirements to Bill Murray, Catering Manager; and your meeting room requirements to Marion Granfield, Convention Coordinator.

If you wish, Mr. Collins, we can serve luncheon to your members at poolside since the weather in Palm Springs, during this time, is very desirable.

We look forward to hosting this excellent piece of business, and if we can be of any further assistance please let us know.

Sincerely,

BILL SCHEIN
Director of Sales

BS/ls

Enclosures
CC: Mrs. Becker

DISTRIBUTION: Client (2), Reservations (2), Front Desk, Catering, Schein, Granfield, File

Gotham Hotels, Inc.

CONFIRMATION
MEETING ROOM ORDER

#6571

Hotel RIVIERA HOTEL & COUNTRY CLUB

Customer Mr. J. J. Collins

Title Director of Exploration

Organization Name: AMERICAN SMELTING & REFINING CO.

Address: 120 Broadway
New York, New York 10005

Telephone 212 Area Code ____ No. 732-9500

No. of Persons: 24

Meeting Room Assigned Date Grove

Set-Up: Aud. ____ Conf. ____ C/Rm. ____ Other ____

Dates: Nov. 28 - Dec. 3, 1971

Type of Function: Exploration Dept. Meeting

Date of Order October 29, 1971

Inquiry ____

Tentative ____

Definite XX

Booked by BILL SCHEIN

Entered by ____

Evaluation Upon Completion

Sleeping Rooms ____

Food ____

Beverage ____

Rental ____

TOTAL $ ____

Sleeping Rooms	Number	Rates:
Arrival See Below	Departure See Below	
Singles	24	$16. + 5% tax
Twins		
Triples		
Quads		

24 ROOMS

Suites One (1) Suite @ $16.00 for Mr. Collins

PROGRAM OF ARRANGEMENTS

(List each Activity by the hour & day by day)

Equipment and Services Required!

ARRIVALS: Nov. 28, 1971 - 6 Rooms
Nov. 29, 1971 - 18 Rooms Add.

DEPARTURES: Dec. 3, 1971 - 12 Rooms
Dec. 4, 1971 - 12 Rooms Add.

PLACE ALL SLEEPING ROOMS IN THE RED OR GOLD WINGS

RESERVE A 1-BEDROOM SUITE AT $16. FOR MR. COLLINS FREE GOLF ON OUR COURSE

Nov. 29,30, Dec. 1,2,3, 1971

9:00am-5:00pm	Date Grove	Meeting	24
Morning	Date Grove	Breakfast	24
Noon	Date Grove	Lunch	24

GHL-S-7

International Telegram Via

JDS

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NOV 5 1971
S. W. U. S. EXPL. DIV.

NY-9 FS (REV. 6-69)

Word Count _____ Full Rate Unless Checked (✓)

☐ Full Rate ☒ Letter Telegram Service (LT)

Date November 3, 1971

Sender's Name and Address
John J. Collins
American Smelting and Refining Company
120 Broadway, New York, N.Y. 10005

To (LT)

ASARCO PERTH
(Western Australia)

Via

insert "ITT"

If you send this blank to a Western Union Telegraph office, insert ITT here. If you telephone your message in, or use a desk fax or teleprinter, insert Via ITT after the address.

ANNUAL MEETING SCHEDULED FOR RIVIERA HOTEL PALM SPRINGS CALIFORNIA BEGINNING EIGHT O'CLOCK TUESDAY MORNING NOVEMBER THIRTIETH ENDING SATURDAY MORNING DECEMBER FOURTH stop INVITEES CAN ARRIVE SUNDAY OR MONDAY BY AIR VIA LOS ANGELES stop PLEASE INFORM YOUR SPEAKERS

COLLINS

Send Confirmation, Accounting Dept., File

XC-RBSprague, AGiesecke, WLKurtz, RKKirkpatrick, KWhiting, JHCourtright, RJLacy, SAAnzalone, RLBrown, LPEntwistle

All messages are accepted subject to rates, rules and regulations in the applicable tariffs on file with the Federal Communications Commission.

ITT World Communications Inc.
subsidiary of International Telephone and Telegraph Corporation

Dear,

JDS

Yes, there will be a

blackboard, projector & screen.

Sri

TO ~~John S. Collins~~ Wm Kurtz
~~New York~~ Tucson

FROM
American Smelting and Refining Company
Northwestern United States Exploration Division
ROOM 1401, W. 422 RIVERSIDE AVENUE
SPOKANE, WASHINGTON 99201

SUBJECT: Exploration Meeting DATE: Nov. 4, 1971

FOLD

Will there be a blackboard at the meeting?
We were be able to use one.

PLEASE REPLY TO → SIGNED Keith Whiting.

Wm Kurtz
also I trust you will arrange for the usual projectors.

DATE 11-8 SIGNED John

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NOV 11 1971
S. W. U. S. EXPL. DIV.

THIS COPY FOR PERSON ADDRESSED

GRAYARC CO., INC., BROOKLYN, N. Y. 11232

C931121

ROOM	LAST NAME	FIRST	INITIAL	RATE	IN DATE	OUT DATE
#38	AMERICAN SMELTING & REFINING					

87620

RIVIERA HOTEL & COUNTRY CLUB
PALM SPRINGS, CALIFORNIA
(714) 327-6311

STREET

ROOM CLERK

CITY AND STATE

DEPOSIT CREDIT

FOLIO NO.

FROM FOLIO _____ TO _____

	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
LOCAL PHONE CALLS							

DATE	REFERENCE		CHARGES	CREDITS	BALANCE	PREVIOUS BALANCE PICK-UP
NOV30F	EFOOD	38	A* 6.00		* 6.00	A* 6.00
NOV30F	DEVOE	38	* 21.00		* 27.00	A* 27.00
DEC-1F	EFOOD	38	A* 6.00		* 33.00	A* 33.00
DEC-2F	DEVOE	38	* 26.85		* 59.85	A* 59.85
DEC-3F	EMISC	38	A* 2.50		* 62.35	A* 62.35
DEC-3F	EFOOD	38	A* 10.15		* 72.50	

Mo Ofc X

REMARKS

TRANSFER TO CITY LEDGER

TYPE AND

W. L. Rawlins

New York, November 4, 1971

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NOV 8 1971
S. W. U. S. EXPL. DIV.

MEMORANDUM FOR: Division Supervisors

Annual Meeting - Asarco Exploration Department
8:00 AM, Nov. 30-Dec. 3, 1971

Riviera Hotel, Palm Springs, California
Tel. 714-327-6723 (Mgr. Mr. Sheim)

Several airlines serve Palm Springs, most flights go via Los Angeles.

Lois CM to all

Overseas travellers should arrive Sunday to allow time for their biologic clocks to adjust. Others should arrive Monday, November 29. Jim Sell (Tucson) is Operations Manager for the Meeting.

Invited speakers are:

Tucson: Harold Courtright, Bill Kurtz, John Balla, Fred Graybeal
Salt Lake City: Bob Lacy, Al Moss, Lloyd James, Marvin Barnes
Spokane: Keith Whiting
Denver: Steve Von Fay
Vancouver: Bob Anzalone, Bob Gale
Toronto: Dick Brown
Europe: Rod Sprague, Al Giesecke
Australia: Bob Gray, Cay Williamson, Bert Devere, Peter Walker
New York: John Collins, Tom Osborne

Afternoons will be free for recreation. Business will be conducted 8 AM to noon and 7-9PM with dinner at 6 PM. Schedule of topics will approximate:

Tuesday - Ore in igneous rocks
Wednesday - Ore in sedimentary rocks
Thursday - Exploration Services Division
Friday - Personnel and other topics *

Copies of all suggested ideas have been mailed to Division Supervisors. I look forward to hearing your discussions.

John J. Collins

John J. Collins

W L/F — Keep

JUL 29 1971
W.L.K.

W.E.S.

W. E. Saegart

JUL 6 1971

New York, July 1, 1971

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JUL 2 1971
S. W. U. S. EXPL DIV.

MEMORANDUM FOR: Division Supervisors
Asarco Exploration Department

Annual Meeting

We have not had a decisive exploration advantage over our competitors since Messrs. Courtright and Richard began interpreting leached outcrops nearly a quarter-century ago. Meanwhile the opposition has caught up. We must try to generate a new idea or technique, or apply an existing one in a better way. Hopefully we can find the means within our own Department.

To aid this effort, our next Annual Meeting will be an idea meeting rather than a recital of the year's work. Attendance will be limited to the dozen or so geologists who come up with the most helpful suggestions. Messrs. Osborne, Courtright and I will be the judges. Please inform your staff of this opportunity.

Each candidate should prepare a one-page summary of an idea on ore finding, ore localization, or whatever will help us find a major deposit, and send it to Mr. Courtright with a carbon copy to me. An individual may submit two different topics but the one-page limitation is absolute for each one. The deadline is November 1, 1971. We will notify the successful writers before November 15 so they will have time to prepare illustrations, etc. in defense of their proposals. The meeting will be held in January, 1972. The accepted summaries will be circulated in November so that each member will have to research the other subjects and prepare fruitful discussions.

In order to encourage discussion and yet keep the meeting within bounds, no one will be present except the judges and the chosen geologists. Company officials will not attend. No one is obliged to submit a proposal, but not even a Division Supervisor can come if he does not submit, ahead of the deadline, a one-page summary that the judges select. Remember that the subject is more geologic ideas than mechanics of prospecting. Please inform me by October 1st as to those on your staff who plan to submit ideas. Start them thinking now.

We will go back to the previous type of general progress report meeting in 1973 when other members of the staff can expect to have their turn on the rostrum.

John J. Collins

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

August 11, 1971

To:

J.C. Balla	F.T. Graybeal
H.L. Crittendon	J.R. King
R.B. Cummings	D.C. Rees
S.R. Davis	J.D. Sell
W.G. Farley	G.J. Stathis
B.E. French	N.P. Whaley

ANNUAL EXPLORATION MEETING

The attached memorandum from John Collins is self-explanatory. I encourage all of you to submit your topic or topics to Mr. Courtright and Mr. Collins as soon as possible. Mr. Graybeal should consider presenting the topic "copper in biotite-chlorite-hornblende as an exploration guide"; and Mr. Balla should consider presenting the topic "relative position of porphyry coppers in relationship to Laramide intrusive masses".

W.L. Kurtz

W.L. Kurtz

WLK:kre

cc: J.J. Collins - New York Office
J.H. Courtright - Tucson Office

Sell

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

August 16, 1971

TO: Geologists

FROM: W. L. Kurtz

GEOLOGIC INFORMATION AND
WILDCAT DRILLING

As you are all very well aware, the most difficult phase of the exploration business is the location of a valid drilling target. In our district we need to have at least two well conceived drilling projects underway at all times to give ourselves a reasonable chance for the discovery of a porphyry copper and/or moly deposit. We prefer drilling projects in which Asarco has a 100% interest, however, in this day of high cost exploration, will consider any joint venture.

I strongly believe we can enhance our rate of locating valid drilling targets through the year round use of a "geological drill". This "geological drill" would have the primary function of supplying geological data (e.g., thickness of overburden, structure, stratigraphy, alteration, mineralization, geochemical samples). This type of data should allow you to make much more definitive geological conclusions and interpretations of the porphyry copper and/or moly potential of an area. A certain number of strictly "wildcat" holes could also be drilled.

The type of rig I have in mind is a CF-15, which will give rotary depth capability of over 2,000 feet and capability of taking spot cores. I think, however, we should plan on the majority of the holes being drilled to depths between 500 - 1200 feet.

Though a firm yearly contract price for such services is not definitely known, it might be in the range of $150,000 to $175,000 and we might anticipate footage costs of $3.50 to $4.00 per foot.

This is a large exploration expense and I should like each of you to evaluate the merits of such a program, and whether you think it will generate enough drilling targets to warrant the expense. If your answer is affirmative, please make a specific list of areas in which we could place such a drill to keep it occupied for a year. (I would anticipate 3,000 feet of drilling per month.)

I plan to have a general meeting of the staff soon and the "geologic drill" will be one of the subjects for discussion.

W. L. Kurtz Van

W. L. Kurtz

WLK:sg

Same title to be submitted for Annual Expl. Meeting 1971.

WLKurtz

W. L. K.

SEP 8 1971

J.D.Sell

RECEIVED

SEP 8 1971

S. W. U. S. EXPL. DIV.

New York, August 30, 1971

MEMORANDUM FOR: Division Supervisors
Asarco Exploration Department

Annual Meeting

ok by me

In response to my memorandum of July 1 it appears that many geologists already have their ideas well in mind and perhaps we can advance the date of the meeting from January to the week of December 1st. This would necessitate moving the deadline for one-page summaries up to October 5th so choices can be made and notices sent out in time for preparation of supporting data.

Please let me know if your interested geologists could not meet the advanced deadline.

Further, it seems probable we will want to convene a meeting of Division Supervisors in January to arrange the implementation of the useful ideas presented in December. What dates would suit you best?

John J. Collins

CC-JHCourtright

J.D.Sell

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

September 14, 1971

TO: All Geologists

FROM: W. L. Kurtz

Staff Meeting

I should like to hold a staff meeting at 8:30 AM on Monday, September 20, in my office. I should like you all prepared to discuss the following subjects:

1. Annual drilling program:

   Feasibility of such a program;
   Outline of areas in which drilling can be conducted.

2. Oxide copper deposits:

   Please bring your list of all oxide copper deposits in which Asarco might have an exploration interest and those in which our Acid Sales Department might be interested.

3. Annual Exploration Meeting:

   A short discussion of subjects that might be presented by our district.

4. Copper in biotite:

   Discussion of exploration potential and methods of instituting the copper in biotite program.

W. L. Kurtz

WLK:lad

J.D.SELL

September 16, 1971

TO ALL GEOLOGISTS:

Please be advised that the meeting scheduled for 8:30 AM on Monday, September 20, in Mr. Kurtz' office has been changed to 8:30 AM on Tuesday, September 21.

Leo

SWED Staff meeting
Sept 22 '71

1. 3000' - 4000' per month - [illegible] - say 2 shifts - 150' per day
— + 1200' caps - 1500 [illegible] - 5½ dia —
possibility — of drilling water well for a farmer —

2. check map gradients — — — — —

3. Drill for water samples?

4. Area No of Pocket Butte - basalt caps - may overly —
[illegible] well [illegible] —

5. Bentonite — sample [illegible] Tuscan [illegible] —

6. Gyp [illegible] — [illegible] — [illegible] Gypsum and
[illegible] — which [illegible] (JC [illegible])
[illegible] — —

7. Area of Study — Tombstone - J Bado —
[illegible] —

Shades of "Careers"

This should stimulate your desire to participate

W. L. Kurtz

New York, September 24, 1971

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SEP 29 1971
S. W. U. S. EXPL. DIV.

OCT 5 1971
W. L. K.

MEMORANDUM FOR: Division Supervisors
Asarco Exploration Department

Meeting Places

The first six of our annual departmental meetings have been held in or near the center of the major porphyry copper district in the USA, and we have taken advantage of proximity to expose nearly all of our own geologists and associates to this type of deposit.

Now we might consider going somewhere else to increase the range of our exposure. For example, the calcareous reef environment is host, or suspected host, to a vast tonnage of ore around the world. Yet I think relatively few of our geologists have seen a live reef. Exploration should be improved by acquaintance with it.

Would you care to nominate some other environments to which we could beneficially expose ourselves in the course of our next few annual meetings? Certain limitations should apply, for some time at least:

(a) The majority of our personnel is in North America and therefore the meetings should be in this hemisphere.

(b) The site should be served by fast transportation and have sufficient accommodations, at reasonable cost.

(c) Experts on the subject environment (and related ore deposits) must be available to lead field trips, laboratory sessions, and give lectures. They need not be Asarco employees. They could be consulting scientists or mining geologists whom we would pay for carefully planned instruction.

Unless you propose a better location in the near future, we will have the December meeting on a coral rimmed island in the Caribbean, probably Puerto Rico, and Lawson Entwistle is nominated to organize the environmental instruction, being part of the territory with which he is familiar. What say?

John J. Collins

John J. Collins

J D Sell

W. L. Kurtz

RECEIVED
OCT 14 1971
S. W. U. S. EXPL. DIV.

New York, October 8, 1971

MEMORANDUM FOR: Division Supervisors
Exploration Department

Herewith is a copy of each of the idea summaries accepted for our next Annual Meeting about December 1, 1971. The accepted speakers should prepare to illustrate their own topics and prove their points with specific examples. Each subject has wide application and we hope to inspire action in more than one Division. Speakers should also prepare to discuss the other topics.

Next week we will send a set of the remaining 40 manuscripts which, for reasons of economy, were not chosen. They contain many good ideas which we appreciate and hope to use. You will be encouraged to do so. Please make sure your staff has the opportunity to read these papers.

Incidentally, the ideas were judged without reference to the identity of the author. My secretary used a number for each paper and blanked out the author's identification before Xeroxing copies for the three judges. We will send the master list of names and titles with the 40 papers.

Do you have it?

W. L. K.
OCT 14 1971

John J. Collins

LIST OF EXPLORATION IDEAS SUBMITTED

1. R. L. Brown - Toronto - Metallogeny in the Northeastern Appalachians
2. E. B. Nicholls - Toronto - The Application of Gravity Data to Exploration
3. R. E. Gale - Vancouver - Zonal Interpretation as an Exploration Tool
4. E. Bayley - Vancouver - Trace Element Distribution and Geochronology of Plutonic Rocks
5. S. A. Anzalone - Vancouver - Asbestos Exploration by Optical and Chemical Analysis of Stream Silt and Soil Sample
6. J. D. Sell - Tucson - Hyperaltitude-U2-Astronaut Photos and Radar Scanning
7. J. D. Sell - Tucson - Exploration Technique for Hidden Plutons
8. L. P. Entwistle - Tucson - Study of Mineral Belts
9. J. R. King - Tucson - Application of Copper in Biotites in the Search for Buried Porphyry Copper Deposits
10. W. L. Kurtz - Tucson - Drilling for Geologic Information
11. C. E. Beverly - Denver - Greisen ... Virgin Potential for Ore Search
12. Jeffrey Burton - Knoxville - Proposals for Mid-Tennessee Exploration
13. A. V. Greene - Bunker, Mo. - Proposed Study of Ore Deposits - Application of Similarities in Searching for Ore Deposits
14. A. Giesecke - Lisbon - The Application of Nappe-Tectonics to the Arizona-Sonora Copper Province
15. J.J. Sample - Dublin - Exploration for Nickel Orebodies in the North American Cordillera
16. R. B. Sprague - London - An Exploration Project in North America Based on European Ideas of Ore Genesis
17. J. J. Merz - Madrid - Geographic Place Names as an Exploration Tool
18. D. M. Fletcher - Perth - Exploration Guides for Stratiform Deposits
19. M. Kriewaldt - Adelaide - Fluid Science Can Help Find Ore
20. R. Barker - Adelaide - Regional Stratigraphic Study as an Exploration Method for Stratiform Mineral Deposits
21. A. J. Hoskins - Adelaide - The Application of Plate Tectonics Theory in the Search for Ore
22. A. J. Hoskins - Adelaide - The Search for Copper in Arenites
23. R. S. Gray - Perth - Selection of Areas Favourable for McArthur-type Sedimentary Base Metal Ores

24. R. S. Gray - Perth - Geochemical Indicators for W.A. Nickel Sulphide Deposits

25. R. S. Gray - Perth - The Role of Gypsum in Formation of Base Metal Deposits

26. D. P. Cadwell - Darwin - Acquisition of Large Land Positions

27. D. P. Cadwell - Darwin - Oceanographic Studies

28. J. A. Staargaard - Spain - Put the Accent on Regional Mapping

29. J. A. Staargaard - Spain - Form a Special Group of Field Geologists to Help Stimulating Regional Geological Mapping

30. B. C. Morrison - Salt Lake - ~~Geologic Environment of Mesozoic and Tertiary Hydrothermal Ore Deposits~~ Plate Tectonics

31. B. E. Kilpatrick - Madrid - Optimizing Stream Sediment Surveys Through Use of a Broad-Spaced Sample Interval and Special Sample Collection Technique

32. B. E. Kilpatrick - Madrid - Mineral Zoning and Trace Element Halos as Exploration Guides

33. Cecil von Hahn - Madrid - Peripheral Zones of Sedimentary Deposits

34. Cecil von Hahn - Madrid - Core Logs of Oil Companies

35. R. Dingwall - Adelaide - Plate Tectonics and Geobotany

36. R. Dingwall - Adelaide - Plate Tectonics and Geobotany

37. H. C. Williamson - Perth - Recent Advances in the Identification of Leached Outcrops

38. F. T. Graybeal - Tucson - The Partition of Cu, Zn, and Mn between Coexisting Biotite, Hornblende, and Chlorite in Some Laramide Intrusive Rocks in Arizona

39. L. R. Dodds - Adelaide - A New Approach to the Localization of Basemetal Sulphides Within Altered Acid Extrusives

40. J. J. Martins - Perth - Thermal Infrared Imagery in Gold and Base Metal Exploration

41. S. El-Raghy - Perth - Ore-Intrusive Relationship

42. W. J. Lorimer - Perth - Geomorphology and Linears in Arid Regions

43. M. P. Barnes - Salt Lake - Geologic Environment of Mesozoic and Tertiary Hydrothermal Ore Deposits

44. E. A. Swanson - Buchans - Proposed Exploration Technique

45. B. J. Devere - Perth - Resurgent Volcanic Centres and their Role in Porphyry Copper Localization

46. P. N. Walker - Mt. Isa - Localization of Major Stratiform Ore Bodies

47. J. N. Biery - Knoxville - Exploration Technique -- Possible "Roll-Front" Color Changes in Overlying Shales and Clastic Portions of Carbonate Host Rocks in Miss. Valley type Deposits

✓ 48. J. C. Balla - Tucson - Relative Position of Porphyry Copper Deposits to Barren Laramide Stocks

49. Arnold Franks - Perth - Uses of Infra-Red Photography Coupled with Magnetometer Surveys

50. Arnold Franks - Perth - Kimberlite Pipes and Carbonotite

51. J. C. Rishel - Knoxville - Possible Exploration Guides for Massive Sulfide Deposits in Sediments

52. R. B. Cummings - Tucson - Ore Fluid Chemistry as a Guide to Porphyry Copper Mineralization

53 Jan Krason - Denver - Hydrogeochemical Examination of Ground water as a method for Base Metal Exploration (Abstract).

54. Jan Krason - Denver - Test to above topic.

✓ 55. S. von Fay - Denver - Common Factors in Stratiform Copper ~~Deposits~~ and their Significance as Exploration Guides.

56. W. G. Hoskins - Denver - The Relationship of Organically Derived Material to Stratabound Ore Deposits.

57. D. R. Davis - Tucson - Secondary Biotite Halos.

✓ 58. L. D. James - Salt Lake - Geochemistry & the Exploration Department

✓ 59. C. K. Mess - Salt Lake - Magnetics & Exploration.

W. L. Kurtz

10-14-71

From: J. J. Collins

To: Division Supervisors
Exploration Department

In accordance with Mr. Collins' memorandum of October 8, enclosed is a set of the remaining 41 manuscripts. Also enclosed is a master list of the names and titles of the papers.
(Index placed in front of a. [illegible] papers

M. Morris
Secretary to Mr. Collins

RECEIVED
OCT 18 1971
S. W. U. S. EXPL. DIV.

METALLOGENY IN THE NORTHEASTERN APPALACHIANS

R. L. BROWN

I remember no paper dealing with the subject of metallogeny at the past few exploration meetings. Since I believe metallogeny to be an important analytic technique, which can be very useful to the exploration geologist in the identification of areas which might be explored for various commodities, I propose to present a paper which would deal with the metallogeny of the northeastern folded Appalachian system, firstly to demonstrate the technique and secondly to outline various areas in the northeastern Appalachians where various commodities might be found. The direct purpose of all metallogenic studies is to determine the factor which control the specific localization of mineral deposits in space and time. Metallogenic studies can yield precise data concerning areas in which various commodities or mineral assembalages may be found and can provide a basis for the determination of the optimum exploration method or technique required.

The term metallogeny is widely misunderstood. Metallogeny is not merely the simple posting of the location of mineral showings and occurrences on maps; it is a technique whereby the occurrence of various ore minerals in the earth's crust is plotted against the structural, historical and lithological components of a given area. Metallogeny is a technique which fits metallogenic provinces and metallogenic epochs into the context of the geological history of a district.

The Appalachian system is a folded belt of the Alpine type in which there were two tectonic pulses (Taconic, late Ordovician, and Acadian, late Devonian) and a late Devonian pulse of igneous intrusive activity. The geologic history of the area ended with Carboniferous taphrosynclinal formation and intrusive activity. In general the period from the close of the Pre-cambrian to the late Ordovician was one of accumulation of carbonate and terrestrial sediments and the period from the late Ordovician to the late Devonian was one of folding, of volcanic activity, and of igneous intrusion.

The metallogenic model to be discussed is shown, in brief, below:

TIME PERIOD	MAJOR GEOLOGIC EVENTS	METALLOGENIC EVENTS	AREAS INVOLVED
Latest Pre-cambrian	deposition carbonate rocks & some arenecious rocks	Zn - Pb in carbonates	extreme western Nfld., northern Gaspe, western Vermont
		TACONIC OROGENY	
Late Ordovican	deposition arenecious rocks, volcanic activity & deposition intrusive rocks emplaced	deposition Zn - Pb - Cu Fe in volcanics	Buchans Bathurst
Late Devonian		Mo, Wo Au in many environments	Central N.S. Central N.B. Maine
		ACADIAN OROGENY	
Carboniferous	deposition red sandstones	U - Cu deposits	Central N.B. Nova Scotia

JDSell

Toronto, November 9, 1971

MEMORANDUM for
Exploration Supervisors:

Annual Exploration Conference

Mr. Collins has asked that speakers circulate references used in the preparation of their presentations.

I will refer to the following papers:

Beland, J. et al Metallic Mineralization in the Appalachians of Southern Quebec; Canadian Mining Journal Vol. 83, No. 4, pp 97-100

Dugas, J. et al Metallogenic Concepts in Gaspe; C.I.M.M. Bull. Vol. 62, No. 6, pp 846-853

McCartney W. P. and Potter, R.R. Mineralization as related to structural deformation; Igneous activity and sedimentation in folded geosynclines Canadian Mining Journal, Vol 83, No. 4, pp 83-87

Poole, W. H. Tectonic Evolution of the Appalachian Region of Canada: Geologic Association Canada, Spec. Paper No. 4

Semenov, A.I., and Labazin, G. S. Basic Problems of Investigation in the Field of Metallogeny; International Geol. Review Vol 4, No. 2, pp 139-150

Gabelman, J. W. Metallotectonic Zoning in the North American Appalachian Region. XXIII International Geol. Congress Vol.7 pp 17-33

Brummer, J. J. Supergene Copper - Uranium Deposits in Northern Nova Scotia. Econ. Geol. Vol 53, pp 515-587

Wilson, J. T. Cabot Fault, and Appalachian Equivalent of the San Andreas and Great Glen Faults and Some Implications for Continental Displacement. Nature, Vol. 195, No.4837, pp 135-138

Wilson, J. T. Did a Lower Paleozoic Ocean through New England Close and then Reopen to Form the Atlantic. Geol. Soc. Amer, Northeastern Section , Boxton, 1967

Kay, M. North American Geosynclines, Geol. Soc. Amer. Memoir 48

Clark, T. H. Appalachian Tectonics, University of Toronto Press 1967

Neale, E. R. W. and Williams, H. The Geology of the Atlantic Region Geol. Assoc. of Canada, Special Paper No. 4, 1967

R. L. Brown

R. L. Brown

cc: JJCollins, TCOsborne, JH Courtright

(2)

THE APPLICATION OF GRAVITY DATA TO EXPLORATION

ABSTRACT

An examination is made of the regional gravity data for Canada. This information is provided by gravity maps published by the Gravity Division of the Department of Energy, Mines and Resources, Ottawa. The country is now nearly completed with stations spaced at 10 - 15 KM intervals and the maps are the results obtained by reducing to the Bouger gravity.

Although regional gravity surveys are not aimed at direct detection of ore bodies, they provide fundamental information regarding the nature of the structure of the earths' outer shell, which may have a profound influence on the future search for mineral deposits.

In this? paper, the larger variations of the gravitational field are examined in relation to major structural elements. Particular attention is given to the relationship of the gravity anomalies (variations) and known ore deposits. It will be seen that there appears to be a distinct relationship between the gravity data and ore deposits.

Using this established relationship it appears possible to predict areas which will contain mineralization, with this information, together with data obtained from aeromagnetic interpretation and the known geology, it should be possible for geologists and geophysicists working in close co-operation to define exploration areas more accurately.

There appears to be no reason why this method cannot be applied wherever regional gravity data is available.

Algal Growths.

Recently Malan (1964) discovered well preserved stromatolitic structures at the western fringe of the 'B' orebody at Mufulira. He described the close association between algal growths, bioherms, and copper-iron sulphides, which Garlick (1964) compared with that in the Katanga and with the Mt. Isa silica dolomite bodies, in which stromatolites have subsequently been discovered (A. Bennett, in Press). The disseminated copper mineralization at Matsitamma in Botswana, discovered by RST in 1963, is in calcareous arenites and argillites flanking an algal bioherm.

Fig. 23 shows the relations at Mufulira of a bioherm with stromatolitic structures and meagre copper, adjacent to well bedded lagoonal sediments rich in copper sulphide.

In all the known associations, stromatolite structures are rare or absent within bodies of rich disseminated copper mineralization. Bioherms with stromatolites in situ are nearly barren or very low grade, but silica dolomite breccias and detrital carbonate muds flanking the bioherm may be extremely rich in copper, or other sulphides, and sufficiently extensive to justify recognition as a special sedimentary facies.

Classification of sedimentary facies.

Under the heading 'Special Features' mineralization has been described in rocks of various lithological types, some with characteristic features recognized in modern sediments. The various lithological types are just as much facts of observation, but in discussing such rocks it is desirable to relate them to their depositional environment, and in some cases this may introduce controversial interpretations.

The Zambian arenaceous orebodies, contrary to impressions given in much of the literature, do not occur in ortho-quartzite and rarely in quartzite. The meta-sediments of aeolian origin are nearest to the definition of felspathic quartzite, but they are significantly barren. Ore occurs in aqueous sediments with considerable range in content of felspar and argillaceous material - the latter now altered to sericite or biotite. The meta-sediments of the ore horizon form a gradational series of lithological types, each of which represents a sedimentary facies. They are:-

1. Arkose
2. Felspathic arenite or subarkose
3. Sericitic arenite
4. Arenaceous slump breccia
5. Carbonaceous graywacke

Any of these five sedimentary facies may lie side by side in one horizon with gradational or inter-fingering contacts. Minor beds of pebbly grit, argillite, and dolomite may be inter-bedded, and under or over lie the various facies of the ore horizon. These are also mineralized in places.

Beyond the orebody fringe, the ore horizon is either a barren felspathic arenite or arkose, commonly crossbedded and containing a little detrital iron-oxide, or alternatively a pyritic arenite which may or may not be argillaceous. An orebody commonly occurs in the same horizon between the barren and the pyritic facies, and therefore discovery of a pyritic facies of a thick arenite may be the first step towards discovery of an orebody.

A few thin beds of dolomite in the Lower Roan succession appear to be excellent chrono-stratigraphic markers, for unlike the ore horizons, they show practically no

EXPLORATION IDEA - ZONAL INTERPRETATION AS AN EXPLORATION TOOL

Although most geologists have long known and used zonal concepts of alteration and mineralization in a general way in their work, it is probable that there is a large amount of new data and a number of new concepts on zoning which should be brought together, interpreted, and put in useable form for the economic geologist's use in evaluation of prospects. In combination with use of geophysics, and geological interpretation, use of zonal concepts can lead to discoveries of ore deposits.

Zonal data of three broad types should be recognized, studied, and applied.

(1) Metallogenetic zoning in mineral belts or provinces.
(2) Zoning in mineral camps or districts.
(3) Zoning within individual deposits.

In all three classes of zoning, there is evidence of predictable variation in zones of silicate alteration as well as within zones of associated metallic mineralization. The gangue and ore minerals involved differ with different types of ore deposits, porphyry copper deposits, magmatic copper-nickel deposits, stratiform lead-zinc deposits, asbestos deposits, etc. Many deposits, especially porphyry coppers, show a zonation which is roughly symetrical about a fault zone, intrusive center, or some other mappable feature.

Recognition of significant zonal features is particularly important in study of individual deposits or mineral districts, and especially in the search for porphyry coppers, where zonation is often very subtle. Especially in areas of abundant overburden such as British Columbia, developing a zonal concept on a potentially large porphyry prospect may involve piecing together data from a few small outcrops in a wide covered area.

The most useful tool in outlining the zonal limits of mineralization (which are often represented by a wide pyrite halo) is an induced polarization survey. I.P. data which outlines zones of variable response in response to variation in the zoning, or content, of pyrite in the rocks, should indicate relative pyrite-rich and copper-rich zones of mineralization. Other zonal information from geology, should point to the most favorable rocks for copper ore occurrence, i.e., in areas of intermediate I.P. response between the core area of an intrusive and the pyrite-rich fringe.

Just as successful interpretation of leached outcrops on partially exposed porphyry copper deposits led to the discovery of chalcocite-enriched ore deposits beneath gossans, interpretation of the zonal significance of I.P.-geology data, can establish potential ore zones in poorly exposed porphyry copper deposits.

R.E. Gale

REG:sm

R.E. Gale.

TRACE ELEMENT DISTRIBUTION AND GEOCHRONOLOGY OF PLUTONIC ROCKS AS A GUIDE TO ECONOMIC MINERALIZATION

Systematic rock sampling of plutonic complexes that includes trace element analyses for a dozen or more selected elements as well as radiometric dating, could provide a wealth of data leading to previously unsuspected "favorable" intrusive areas.

A recent study of the copper and zinc content of rocks from the Guichon Batholith in Southern British Columbia, has inferred that "favorable" intrusive complexes might be recognized by the distribution pattern of their contained elements. It has also been recognized that most disseminated ore deposits in B.C. are associated with intrusive rocks of Upper Triassic to Middle Jurassic Age, suggesting that searching for "time-favorable" plutons could be of value.

The data generated by a regional rock sampling program that combines geochemistry and geochronology, would form an ample data base for sophisticated computer treatment. Geochemical patterns suggestive of metallogenic trends could indicate economically favorable areas when synthesized with absolute age dates and regional structure.

Emery Bayley

Emery Bayley.

EB:sm

(55)

COMMON FACTORS IN STRATIFORM COPPER BODIES AND THEIR SIGNIFICANCE AS EXPLORATION GUIDES

Von Fay

A porphyry copper specialist, J.D. Lowell, in a recently published estimate of copper in the upper mile of the earth's crust, states that at grades better than .25% Cu, there may be 4×10^9 tons as porphyry copper, magmatic segregation and massive magnetite copper deposits; and 3×10^9 tons of copper as "stratabound and red-bed deposits." Porphyry coppers are cylindrical, with a narrow cross section (1 mile or less) and a longer vertical axis. Stratiform copper deposits have very large lateral dimensions, of many square miles. This geometry should render stratiform deposits easier to locate with vertical probing. Grades of primary porphyry coppers are commonly less than .4% Cu, while stratiform coppers are much higher grade. If it is feasible to search for laterally limited porphyry coppers (or their characteristic haloes) below thick post mineral cover, it is also feasible to search for stratiform coppers (or their characteristic alteration haloes) below younger sediments.

Stratiform coppers occur in rocks ranging in age from Middle Precambrian to Cretaceous, and from highly metamorphosed to essentially unconsolidated. Commercial ore bodies occur in Asia, Africa, Europe, and North America. These deposits either outcropped or the suboutcrop was close to the surface. Good exploration potential exists for unrecognized ore bodies.

Regardless of genetic theory, known stratiform copper ore bodies occur: in sedimentary basins known to contain sub-ore grade copper bearing beds; are generally in an oscillating (cyclic) sedimentary sequence with copper at an interface between water lain and continental beds, or beds of two different permeabilities; are generally in permeable clastic rocks such as arkoses and quartzite; or in somewhat less permeable rocks such as shales at the contact with the permeable beds; are commonly localized in areas of younger structural events; commonly are associated with disseminated organic material; may show a spatial relationship to uranium, vanadium, molybdenum, zinc, and lead in the same beds; and show many other similarities.

Regardless of the method of introduction of the copper ion from water into sediment (marine water or ground water), copper mineralogy is exactly controlled by solubility products, and the copper minerals can be read to define the oxidation-reduction state of the copper bearing beds.

It follows that to find stratabound copper ore the exploration geologist should determine that host rocks are known to contain copper and have enough volume to bear ore in sufficient tonnages; determine structural pattern, amount, and variation of carbon, permeability, etc; test by drilling to locate the position of the oxidation-reduction interface, and/or determine location within the reduced zone; and test laterally along or within this zone for favorable mineralized lithology and structure.

Garlick, a premier proponent of sygenetic origin of stratiform coppers in Africa, in his paper states that beyond the ore, the ore bed has detrital iron oxide in one direction and pyrite in the other. "The ore body occurs in the same horizon between the barren (iron oxide) and the pyritic facies, and therefore discovery of a pyritic facies of a thick arenite may be the first step toward discovery of an orebody." Garlick's thesis is exactly as the last two steps above. One apparently searches for ore bodies in Africa in a manner similar to the search for copper in the Permian, in the U.S.

Von Fay

EXPLORATION IDEA

ASBESTOS EXPLORATION BY OPTICAL AND CHEMICAL ANALYSIS OF STREAM SILT AND SOIL SAMPLE

The extensive belts of ultramafic rocks located along the Western Cordillera have received considerable exploration attention during the past twenty years, principally during the search for asbestos occurrences. A considerable portion of these areas have been surveyed aeromagnetically by the GSC, and the obvious outcropping zones of serpentinized peridotite were recognized at an early stage as a result of their associated mag response, or as a consequence of their vivid color anomalies. If new asbestos mines are to be located within this region, assuming no obvious outcropping deposits have been overlooked, some consideration should now be given to utilizing techniques similar to those presently employed in reconnaissance geochemical prospecting for metallic mineral deposits.

Exploration for hidden or obscure asbestos deposits has been hampered to some extent by the absence of obvious and related geochemical indicator minerals. Nickel, cobalt, iron, and chromium minerals, have long been known to be associated with serpentinized ultramafic rocks. Unfortunately, while these minerals may assist in locating zones of serpentine, they are not a direct aid in pinpointing the location of asbestos fiber. To assist in the task of locating non-outcropping or obscure asbestos prospects, the following suggestion or "Exploration Idea" is offered.

(1) Accelerate reserach on perfecting techniques designed to detect microscopic amounts of asbestos fiber in soils and stream silt sediments.

Preliminary work conducted by members of the Vancouver office staff suggest that asbestos fiber can be identified in stream silt samples deposited at a considerable distance from the source of fiber. Examination of stream silts under binocular, petrographic and Electron Microscopes, the optical equivalent of the determination of ppm by chemical means or x-ray, could result in the location of a worthwhile prospect.

(2) An attempt should be made to develop suitable geochemical trace element techniques designed to locate overburden-covered areas of strong serpentine alteration. Reports from the Spokane office exploration staff suggest that magnesia is anomalous in soils covering serpentine areas.

The above-mentioned prospecting techniques are recommended as a procedure that will assist considerably in Asarco's exploration efforts designed to locate potentially important asbestos prospects.

S. A. Anzalone

S.A. Anzalone.

SAA:sm

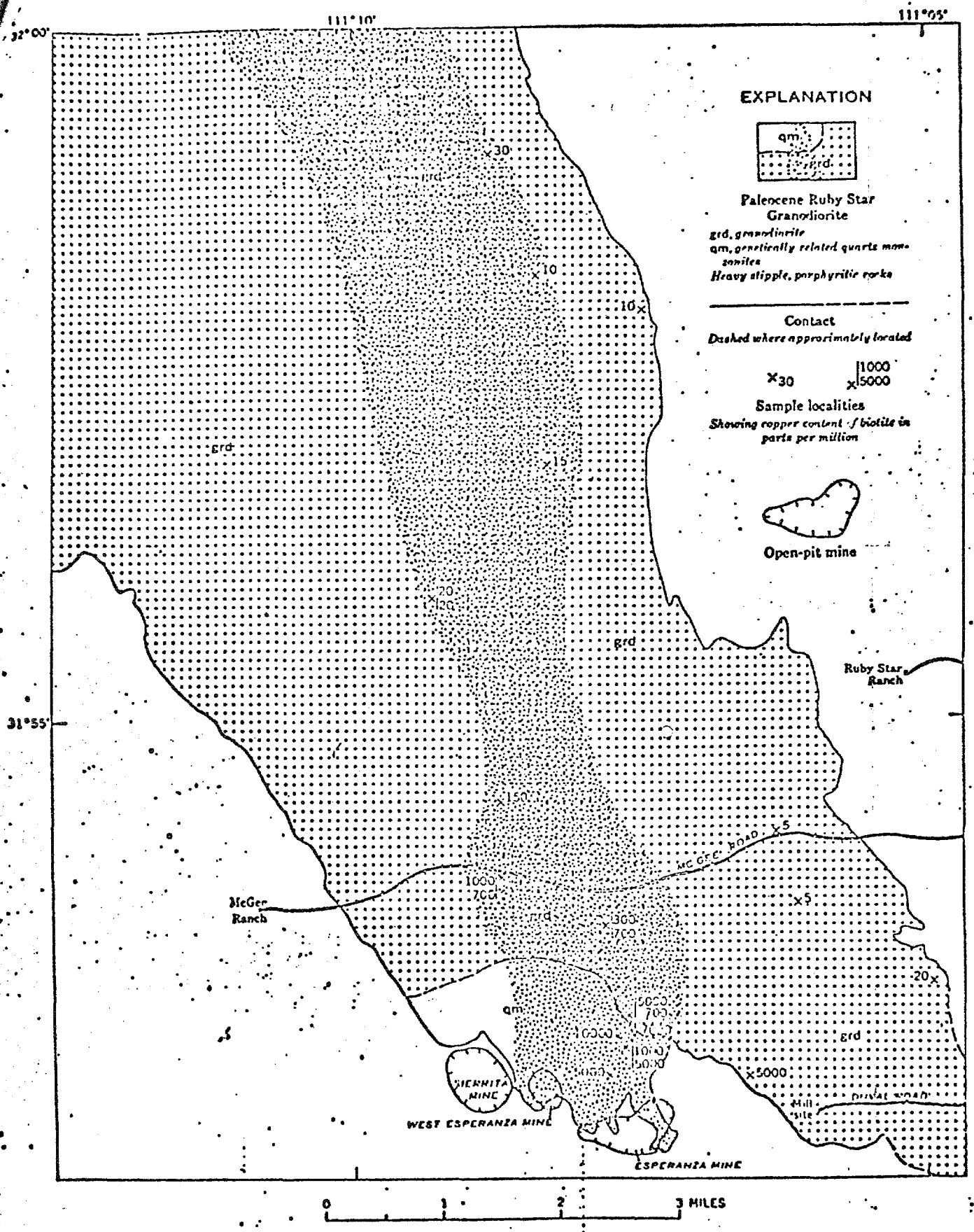

FIGURE 2.—Generalized map of composite stock and associated ore deposits in the southwestern part of the Pima mining district, east of the Sierrita Mountains, showing sample localities and copper content of biotite.

JJCollins

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SEP 29 1971

EXPLORATION DEPT.

September 27, 1971

HYPERALTITUDE-U2-ASTRONAUT PHOTOS AND RADAR SCANNING

Abstract

Recent development of high resolution photographs and radar scanning, covering large areas of the earth's surface in few photo sheets, is now available for integration of district and regional studies. Basic evaluation of structure and probable rock units can now be secured on new areas or difficult access areas in selection of those areas for intensive and critical review by outcrop examination.

Mega-thinking of ore district controls can now be expanded by the use of this new photo coverage in that the entire district framework is visible on a few sheets. Expanding the technique by looking in covered areas for partial structures which, when properly evaluated suggest the whole, will be a valuable part of the studies.

James D. Sell

James D. Sell
ASARCO
Southwestern Exploration Division

48

J Balla

Annual Exploration Meeting

Subject: Relative position of porphyry copper deposits to barren Laramide stocks.

Mapping along the northeast trending lineament between Casa Grande and Miami has shown that there are a number of barren, Laramide granitic stocks in this zone, and that these stocks are internally zoned. These barren stocks are aligned such that the long axis of the stock is parallel with the regional structure. The ends of these stocks are zones of strong cross fracturing, and it is in these zones that porphyry copper deposits are most likely to occur.

This setting, which occurs elsewhere in Arizona (see attached sheet as an example) can be used as a guide to looking for buried porphyry copper deposits. If part of a barren stock is exposed in a mountain range, the orientation of the barren stock will give a clue as to the direction of the regional structure, and hence the direction along which to look for a buried porphyry copper deposit.

September 27, 1971

EXPLORATION TECHNIQUE FOR HIDDEN PLUTONS

Abstract

A useable technique for the location of hidden plutons, in three dimensional settings, has evolved from published geochronological studies. Basically it has been found that mineral ages in rocks are effected by subsequent thermal events and specifically by introduced sulfide mineralization events.

Orders of magnitude can be established for the extent of the disturbance based on the size of the pluton as well as the relative stability of minerals and the geochron analytical method.

K-Ar ages of biotite are most sensitive to outside effects and are reset up to the diameter distance of the intruding pluton. The relative stability of mineral ages has been found to be hornblende K-Ar is greater than muscovite Rb-Sr, is greater than muscovite K-Ar, is greater than biotite Rb-Sr, which is greater than biotite K-Ar. Thus, using hornblende-biotite mineral pairs and analyzing for K-Ar across an older rock-younger intrusive contact, an age concordance would be found in the older rock at a distance greater than the younger intrusive diameter, while within some distance (say half) of the contact the hornblende would retain the older date whereas the biotite would be set to some younger date, and a sample pair taken at the contact would show both hornblende and biotite set to an age near the younger intrusive age. Variability is paramount and interpretation demands geologic control and evaluation of the possible parameters.

A case in point is found at Silver Bell. Here, a Rb-Sr whole rock date of 112 m.y. was determined for the Alaskite, the oldest intrusive unit in the area based on field relationships. A further geochron study sampled the Alaskite at a distance of 4000 feet from the nearest known Quartz Monzonite unit and ore zone and a 65 m.y. K-Ar biotite age was determined. The biotite age is a reset date due to the later thermal and intrusive history. Had post-mineral cover rocks been over the Monzonite and ore zone while the Alaskite outcropped, it is reasonable that the knowledge of a reset date coupled with the observable alteration effects would have been sufficient to initiate a probing program to determine the cause.

Presently in the literature are numerous age-date conflicts. Further critical study of the areas may indicate associated altered and/or structural zones interpretable as lead-in features to an ore deposit.

James D. Sell
ASARCO
Southwestern Exploration Division

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
P.O. BOX 5747, TUCSON, ARIZONA 85703

J. H. COURTRIGHT
CHIEF GEOLOGIST

1150 NORTH 7TH AVENUE
TELEPHONE 602-792-3010

November 5, 1971

Mr. Jim Sell
American Smelting and Refining Company
P.O. Box 5747
Tucson, Arizona 85703

Dear Jim,

This will acknowledge your submittals entitled "Hyperaltitude-U2-Astronaut Photos and Radar Scanning" and "Exploration Technique for Hidden Plutons", in response to Mr. Collins' letter of July 1st. Although not scheduled for the meeting this year, both ideas, we believe, are worthy of further consideration and study. So, it is suggested that you expand "mega-thinking" about district ore controls and come up with specific proposals.

Meanwhile, we wish to express our appreciation for your efforts and urge you to continue the search for ways of improving the effectiveness of ASARCO'S Exploration Department.

Sincerely yours,

J. H. Courtright

J.H. Courtright

JHC:kre

cc: J.J. Collins - New York Office
T.C. Osborne - New York Office

MEMO TO J. H. COURTRIGHT

LOCALIZATION OF MAJOR STRATIFORM ORE BODIES

Comparison of the present active base metal sulphide depositing geothermal systems of the Red Sea and Salton Sea with known stratiform ore bodies gives rise to criteria which can be used to define areas of high potential for the occurrence of this type of orebody.

The Red Sea system is forming deposits more closely analagous to known orebodies, e.g. Mount Isa and McArthur River, than the Salton Sea, but the two systems show remarkable similarities. The Red Sea deposits occur in a localised basin in the median trough of the Red Sea trench, where a high density, hot, chloride brine occurs. The median trough represents a zone of crustal separation with a steep geothermal gradient in the crust providing the energy for the system. Both areas show steep geothermal gradients and brine solutions transporting the metals and depositing them in the case of the Red Sea in a restricted basin of deposition.

Fossil evidence of steep geothermal gradients and hot brines is difficult to detect but the tectonic setting, chemical and mineralogical changes in sedimer and the environment of deposition for this type of deposit can be recognised. The Red Sea sediments show alteration of calcite to dolomite, formation of chloite a nd a high iron content occurring as pyrite in the sulphide horizons and as haematite and goethite at other horizons. The sediments are dominantly chemical precipitates.

Both Mount Isa and McArthur River deposits occur at the margins of narrow troughs and are in dominantly chemically deposited sediments, principally dolomites and dolomitic shales, which,at McArthur River at least, were deposited in a restricted basin. They both occur adjacent to major faults bordering the trough and these appear to be zones of presistent crustal fracturing.

Exploration for major stratiform deposits should be focused on fossil structual troughs and rift structures, particularly where there is dominant chemical and/or biochemical sedimentation adjacent to thebordering major faults. Dolc mitic and ferruginous (both hematitic and pyritic) sediments, particularly when deposited in a restricted basin, (e.g. back reef basins) constitute favoura ble zones. The faults appear to provide the major plumbing for the circulating metal rich brines.

As the metals appear to be derived from country rock, no abnormal metal source is required, so deposits need not occur in major metal provinces, but due to the mobility of base metals in chloride brines, some clustering of minor showings of Pb, Zn or Cu can be expected near a major deposit.

The Proterozoic appears most favourable for this type of deposit, possibly du to the incipient breakup of a proto-continent and greater prevalence of anerobic conditions permitting formation and preservation of the deposits.

P. N. Walker

c.c. J. J. Collins

P. N. WALKER
1.10.71

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AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

September 23, 1971

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SEP 27 1971
EXPLORATION DEPT.

Memorandum To: Mr. J. H. Courtright
Chief Geologist

From: L. P. Entwistle

Re: DECEMBER MEETING
TOPIC FOR DISCUSSION

As a long-term project to assist world-wide exploration, the Department could undertake a study of mineral belts and their related geology.

The first step would be to prepare continental metallogenic maps from all available data. These maps would show the principal ore deposits with their type, the metals being won, and highly generalized regional geology as related to the deposits in each belt. This work would cross national frontiers regardless of present-day political and/or economic considerations.

From this basic data, work could then be expanded in a more detailed way into particular regions, making use of trends and other information from the surrounding regions.

Much of the original research could be done by junior men working at one center.

This type of information has been gathered and used successfully on a divisional basis.

ORIGINAL SIGNED BY
L. P. ENTWISTLE

L. P. Entwistle

LPE:mt
cc: J.J. Collins

(8)

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

September 23, 1971

Memorandum To: Mr. J. H. Courtright
Chief Geologist

From: L. P. Entwistle

Re: DECEMBER MEETING
TOPIC FOR DISCUSSION

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L. P. Entwistle

LPE:mt
cc: J.J. Collins

(9)

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

September 14, 1971

RECEIVED
SEP 16 1971
EXPLORATION DEPT.

TO: J. H. Courtright

FROM: J. R. King

ANNUAL EXPLORATION MEETING

Over the last ten years several independent researchers have reasonably proven that biotites in acid intrusives will anomalously concentrate copper with proximity to hydrothermal cupriferous mineralization. Preliminary ASARCO research conducted by L. James, F. Graybeal, and the author, indicates that the more significant the copper mineralization is, the greater is the probability that a geochemically observable "Cu in biotite" halo will persist several miles away from recognizable mineralization. ASARCO work has demonstrated a 500 ppm copper anomaly in biotites exists in the Ruby Star granite for a distance of one to three miles from the Sierrita-Esperanza mines.

Even though there are numerous questions which need to be answered to ideally understand the problems involved, I feel there is a good potential for finding a major, enriched porphyry copper deposit by the use of biotite geochemistry with follow-up geological and geophysical work. Biotite geochemistry will probably never be an end in itself for determining copper deposits. It does, however, offer a quick and relatively cheap means by which a large number of porphyry intrusives could be examined. Hopefully, several high potential target areas could then be projected under post-mineral cover.

If "copper in biotite" geochemistry is applicable to porphyry exploration then the company which does the field work first will be the company with "a decisive exploration edge". I, therefore, recommend a biotite geochemistry exploration program be immediately initiated in southern Arizona.

John R. King

John R. King

JRK:sg

cc: JJCollins - New York Office

(10)

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

September 15, 1971

RECEIVED
SEP 20 1971
EXPLORATION DEPT.

Mr. J. J. Collins - New York Office
Mr. J. H. Courtright - Tucson Office

Annual Exploration Meeting

As is well known, especially by explorationists, the search for porphyry coppers in the southwestern United States is becoming increasingly more difficult and more expensive. The areas of exposed alteration and mineralization have been mapped and sampled and much geophysical work has been conducted along "porphyry copper trends".

I believe future success in the discovery of major porphyry coppers in the southwest will be the direct result of good geologic study and thinking. A tool which can greatly enhance the geologic study and thinking and, therefore, give us a competitive edge is the Geologic Information Drill.

I strongly believe that the factual, physical data obtained by drilling is the one most important piece of information a geologist can use to guide his thinking, structural studies, and projections. The Geologic Information Drill can also provide additional useful information such as: geochemical data, magnetic susceptibility, age dates, I.P. response, in-hole I.P. surveys, density measurements, etc. The one big plus in favor of an exploration program that utilizes the Geologic Information Drill is the simple fact that it provides the one most basic and definitive item in geology -- a rock sample.

Continued successful porphyry copper exploration will utilize the Geologic Information Drill.

W. L. Kurtz

W. L. Kurtz

WLK:lad

Burt Devere

45

RESURGENT VOLCANIC CENTRES AND THEIR ROLE IN PORPHYRY COPPER LOCALIZATION

Many of the world's great base metal deposits are directly associated with centres of volcanic activity, these deposits are of two general types massive sulfide and disseminated sulfide. This paper deals with the disseminated sulfide deposits and is based on a number of characteristics that show that intrusives containing disseminated sulfides are related to a type of resurgent volcanic centre which can be identified by conventional geologic methods.

With the application of geologic mapping, tectonic interpretation, petrographic and mineralogic identification, volcanic areas can be screened and placed into three groups for further exploration. The groups are:

(1) Pyroclastic-granitic radial-ring complexes (Butte type). Very favourable for mineralization. The Butte type of resurgent volcanic centre has many similarities with the mineral districts of Santa Rita, Climax and Toquepala. This type of centre is developed through a series of volcanic and tectonic events which incorporate radial and concentric fracture development, pyroclastic eruptions, coherent crustal subsidence, resurgent doming and uplift and intrusive emplacement with or without extrusive equivalents.

(2) Pyroclastic-andesitic complexes (Bougainville type). Favourable for mineralization. The Bougainville type of volcanic centre resembles in many ways the volcanic environment in which the Kerwin, Poison Ridge and Atlas deposits are associated. The Bougainville type of centre is developed by a series of catastrophic events, which include violent eruptions of pyroclastic and andesitic flows, chaotic subsidence, resurgent doming and intrusive emplacement with or without extrusive equivalents.

(3) Mafic-shield complexes (Kilauea type). Not favourable for mineralization The Kilauea type complex is exemplified by violent eruptions of mafic flows, subsidence, rejuvenation of volcanism and extrusion of mafic flows, and intrusive emplacement with or without extrusive equivalents.

Upon completion of the initial screening, areas of interest can be further ranked on a basis of alteration along the following guidelines:

(a) Areas of secondary biotite with fringes of argillic and or propylitic alteration with possibly areas of secondary potassic alteration are most favourable indications of base metal deposition within the vent at a relatively shallow depth - less than 1,000 feet.

(b) Areas of alteration consisting mostly of montmorillonite and silica represent fumerolic sulfateric breakdown of the volcanic rocks and does not infer base metal deposition at shallow depths.

(c) Areas of volcanic sulfur deposits and active sulfateric areas are generally related to zones of pyroxine rich andesites, quartz andesites and dacites and are not favourable indicators of base metal deposition at depth.

The evaluation of volcanic provinces using the suggested criteria could improve the odds of discovery and at the same time open a new horizon in porphyry copper-molybdenum exploration.

Greisen . . . Virgin Potential for Ore Search

C. E. Beverly

It is apparent that an overlooked (in this country) area of prospecting worth lies in the greisen environment of acid batholiths and stocks where "pneumatolytic? fluids" penetrate. A greisen by definition, (A.G.I.) is: "a pneumatolytically altered granitic rock composed largely of quartz, mica and fluorite-rich minerals" and commonly it contains assessory base-metal sulphides especially tin, tungsten, and molybdenum. At Mt. Antero, Colorado large masses of strong and moderate greisen with related aplitic and milky quartz dikes outcrop erratically within a mineralized zone, which occurs marginal to the well-known Mt. Antero granite stock. Micaceous, mica-quartz and quartz greisens have been observed in core at Antero with sparse to moderate disseminations of Mo, Cu, Zn, Be, and possibly tungsten? or bismuth? Lateral zoning is evident at Antero and our deepest hole (stopped in a strong mica selvage (?) zone at 960 ft.) appears to show an increase in silica with depth, indicating a trend toward possible vertical zoning. Greisen outcrops at Antero appear to be identical to those described by Russian geologists. Therefore, it appears that the key in finding large greisen ore bodies is a comprehensive knowledge of greisen alteration and vertical zoning.

Greisen is associated with many granitic intrusive masses throughout the world and is particularly common in Russia and Australia, although other well-known occurrences are in England, France, China and Egypt. In most of the major localities tin, tungsten, and molybdenum (within greisen and its associated high temperature veins) are in quantities large enough to make ore. The most important characteristic of all known ore-bearing greisens, and in particular the Russian occurrences, is a well-documented vertical zoning in alteration and mineralization, whereby non-commercial scattered sulphide mineralization within muscovite and quartz-muscovite greisens is commonly underlain at depth by ore-grade mineralization in quartz greisens and veins. Undoubtedly, Russia has significant "academic knowledge" of the greisen environment, and as a direct result has developed important mineral reserves of molybdenum, tin, tungsten, and beryllium. In this country there are few greisen descriptions in the literature and most are over fifty years old. Based on a comprehensive, but not inclusive, literature search, sulphide bearing greisens are known to occur in North America in the following areas: Western Seward Pennisula, Alaska (several); Lake George and Mt. Antero areas, Colorado; near Fredricktown, Missouri; the Franklin Mountains near El Paso, Texas; near Winslow, Maine and Caguas, East Central Puerto Rico (several). In my opinion, there may be many unrecognized greisen zones in other areas marginal to batholiths and stocks. Greisen alteration bordering late veins of coarse molybdenite has also been described recently from the lower (younger) alteration stage at the Henderson deposit.

The fact remains that greisens are perhaps the least studied (here in the USA) and most overlooked rock type in the igneous alteration suite, and consequently may offer one of the virgin potentials for ore search in North America.

The idea of accepting greisens as significant targets is new, but the exacting alteration similarities of the Antero greisens and others including the Kounrad deposit in Russia are too real to ignore. The mere fact that our competitors have failed to recognize such potential ore zones utilizing vertical zoning concepts demonstrates only their unfamiliarity with Slavic literature, and should not preclude our exploratory interest.

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FT Graybeal

ANNUAL EXPLORATION MEETING TOPIC:
The Partition of Cu, Zn, and Mn Between Coexisting Biotite, Hornblende, and Chlorite in Some Laramide Intrusive Rocks in Arizona

The partition (distribution) of Cu, Zn, and Mn between coexisting biotite and hornblende was investigated in the Patagonia granodiorite and the Cornelia pluton. Roozeboom diagrams show that Cu, Zn, and Mn obey the Nernst distribution law, and that Cu and Mn partitioning are sensitive to variations in temperatures of crystallization. In an igneous rock the major portion of trace element partitioning occurs between the mineral and the adjacent melt. Thus Cu, Zn, and Mn are actually distributed in equilibrium between biotite or hornblende and the coexisting magma. Trace element concentrations in the minerals are therefore governed by trace element distributions in the magma.

Analyses of chlorite, which occurs as a hydrothermal alteration product of biotite, show that Cu, Zn, and Mn maintain a constant distribution ratio between chlorite and biotite. This suggests that the Cu, Zn, and Mn contents of biotite were in equilibrium with the Cu, Zn, and Mn contents of the coexisting hydrothermal fluid at the instant the magma solidified.

The above conclusions, as well as the extreme variations of the copper content of biotites studied in this investigation, support work by Parry and Nackowski (1961) and Lovering et al (1970), that the copper content of biotite is a useful exploration tool. However, this study has revealed that low as well as high concentrations of copper in biotite can indicate a favorable exploration target, and that proper interpretation of the analytical results depends on a clear understanding of the geologic history of the intrusion. It is therefore suggested that if a biotite sampling program is initiated, it should be carried on as a supplement to related field work and not as an independent saturation-type survey.

RECEIVED
SEP 24 1971
EXPLORATION DEPT.

AMERICAN SMELTING & REFINING CO.
2640 Broadway, N. E.
Knoxville, Tennessee
September 22, 1971

(12)

MEMORANDUM TO MR. J. H. COURTRIGHT:

ANNUAL MEETING REPORT

When exploring for Mississippi Valley Type ore deposits it is frequently the case that the ore bodies are blind, and the only reliable geologic guides to ore are to be found in drill core. Such is the case in Mid-Tennessee. The object of this report is to propose a method for accumulating and evaluating data from our drill core in Mid-Tennessee in a systematic way that would help eliminate the possibility of overlooking any geologic phenomenon that might be a guide to ore. The method, which is outlined below, would also put more emphasis on locating local geochemical barriers in Mid-Tennessee. To date, most of our attention has been focused on regional geochemical barriers, and regional and local structures.

A brief outline of the method is as follows:

1. Start out with wildcat drilling over a large portion of a district to accumulate data on regional geologic features, both structural and chemical, establish regional correlation of units, marker beds, and to locate favorable sub areas for more detailed drilling.

2. After drilling has progressed to the point where several relatively close spaced holes have been drilled in one or more sub areas (a sub area being 50 square miles or less as in Mid-Tennessee), drilling should be stopped. A detailed geological examination of the core should then be undertaken.

3. A close spaced drilling program in each sub area based on geological interpretations from step (2) should then be carried out.

Step (1) and the first part of step (2) have already been completed in Mid-Tennessee.

An elaboration of some of the procedures to be used in the second part of step (2) is as follows. Core should be studied carefully for the following geological features: Local changes, in color and lithologies in individual units; color changes in sands, shale partings, stylolites, silts and solution cavities; pyritization; bleaching; and secondary silicification. The above data should be used in conjunction with local structural features inferred from the core to determine future drilling sites. In order to study the above data most effectively, I believe several acetate overlays should be made for each hole dipicting all pertinent geologic phenomenon observed. The method outlined above could probably be used, with modifications, in exploring for Mississippi Valley Type ore bodies in other districts.

JEB:gs

Jeffrey Burton

cc: JJCollins ✓

(37)

RECENT ADVANCES IN THE IDENTIFICATION OF LEACHED OUTCROPS

H.C. Williamson

The appraisal of leached outcrops has in the past been largely dependent on macroscopic examination and field work (as per Blanchard & Richards) and the recognition of secondary minerals formed from metal sulfides.

In Western Australia, widespread and intense surface oxidation, leaching and laterization have resulted in a preponderance of leached outcrops. These conditions hamper mapping and the recognition of leached outcrops due to sulfides. Local geologists are developing three techniques to improve their ability to recognise leached outcrops especially over base metal sulfides. The three techniques are:

Geochemistry
Microscopic examination of polished and thin sections
The study of polished sections by the electron probe.

The application of these methods has played a paramount role in the recent discoveries of Kambalda, Poseidon and other deposits in Western Australia.

The further development and the use of these techniques together with the ones already used by Asarco geologists will enable us to regain "the decisive exploration advantage over our competitors". The three methods are briefly outlined below:

The advent of AAS methods for the determination of the presence of trace amounts of elements has enabled the identification of very low concentrations of metals in leached rocks and gossans. Thus Woodall was able to establish the presence of anomalous quantities of Te (of the order of ·1 ppm Te) in the Kambalda gossans by a method developed by the CSIRO for use in Te halo studies of Kalgoorlie goldmines. (D.E.S. Davis et al, 1969.) The presence of this quantity of Te in Kambalda gossans was evidence to Woodall that the gossans were derived from Magmatic base metal sulfides. The geochemical analysis of leached rock chips will often determine the rock type sampled. Example: Ni and Cr results from a leached ultramafic.

A microscopic study of polished surfaces of Western Australian gossans by Travis in 1968 showed that many of the characteristic textures of the supergene sulfides are preserved in surface gossans. Thus in the case of the Kambalda, St. Ives and Poseidon gossans the characteristic feature of the supergene sulfide assemblages of violarite-pyrite-siderite is preserved especially where silification has fixed the indigenous limonite. In the case of cellular gossans, impregnation with suitable plastics will enable a polished slide to be made. Many of the oxidised rocks in W.A. are silicified, or they can be impregnated with plastic so that a thin section of the rock can be made for microscopic examination of their texture and mineralogy. Thus their identity is often confirmed by features not readily seen under the hand lens.

The third method of appraisal is to examine selected polished sections prepared for microscopic examination with the electron microprobe. The electron probe can locate the position of any anomalous element concentrations on the polished surface. If this work is related to micrographic study then the identity of the pseudomorph sulfide is often revealed. The method is being perfected by the CSIRO in Sydney and Perth on material supplied by Selection Trust and WMC. Other examples were noted by J.J. Collins (memo of June 4, 1971).

APPLICATION OF SIMILARITIES IN SEARCHING FOR ORE DEPOSITS

In the study of ore deposits, the likelihood of revolutionary new concepts is remote. As in other branches of science, growth of knowledge of ore deposits will consist of an accumulation of details and of modifications of existing concepts. New methods of study (fluid inclusions, isotopes, temperatures) will be increasingly used and will add to general detail. But one aspect of ore deposits apparently has been largely neglected: an application of similarities. That is, conditions that are favorable for one type of ore body frequently are favorable for other types. For example, the common association of mineralization to adjacent sandstone or quartzite beds in the Park City district of Utah has its counterpart in the Illinois-Kentucky fluorospar district. Replacement deposits in both districts are in carbonates adjacent to sandy or quartzitic layers. Can this similarity be projected into other areas; or can special applications be made, such as sandy horizons faulted against favorable carbonate? Another example: the ore deposits at Leadville have long been described as occurring in the Leadville "limestone". In fact, the occurrences at Leadville (and in most carbonate replacement deposits in the Rocky Mountains) are in dolomite, a feature in common with most Mississippi Valley type deposits. Then, in the Rocky Mountain region, as in the Mississippi Valley region, is carbonate composition a significant factor in exploration? And can other similarities be applied?

In studying ore deposits, a common tendency is to limit the study to the immediate area of the deposit; frequently no consideration is given to the regional relationship or to a comparison with other deposits.

If significant advances are made in the knowledge of ore bodies, these will very likely result from a study and comparison of different types of deposits, and not from an individual concentration on one type or occurrence. One approach to this study would be a state-by-state compilation of mineral occurrences with mineral association (lithology, structure, special features). A completed state study would consist of a map with mineral occurrences and major lithologic and structural features, plus a brief summary of the association of individual occurrences.

Geochemical Indicators for W.A. Nickel Sulphide Deposits

R S Gray

Geochemical values for nickel, by themselves, are of little use in detecting nickel sulphide deposits. Not only does serpentinite contain a high Ni background, but erratic nickel enrichments occur within the weathering profile. Nickel sulphide gossans are usually severely depleted in Ni near surface.

Copper is a more reliable indicator because background Cu content in ultramafics is low, and Cu becomes enrichad in the weathered zone.

Wallrocks in contact with the ultramafics frequently contain higher Cu backgrounds, or erratic Cu concentrations. Experience in W.A. indicates that these Cu concentrations are usually accompanied by relatively high Zn, whereas Zn values in ultramafics are very low. Thus, high Cu associated with low Zn is favourable for Ni, but high Cu Zn is unfavourable.

Cobalt is another sorting element, useful for two main reasons: (a) lateritic Ni concentrations are accompanied by high Co values, and (b) Mn scavenging is more readily indicated by Co than by Cu or Ni. Although anomalous Co can be expected with material derived from Ni sulphides, Cu values are usually several times higher than Co. High Co Ni with low Cu usually represents lateritic concentration. High Cu Co Ni, with Co higher than Cu requires additional checking for Mn.

Se, Pt, Pd, S and Bi can also be used as indicators, but are not normally required for routine work.

The above criteria may be applied to soil, rock-chip, or possible gossan samples, and with minor limitations to auger or percussion drill samples. Absolute values are less important than metal ratios, because background values vary from area to area.

In summary, the most favourable conditions are represented by (a) coincident high Cu Ni values, (b) low Zn values, and (c) anomalous Co, but with Co much lower than Cu.

The Application of Nappe-Tectonics to the Arizona-Sonora Copper Province.

Many interpretations about the structure within the Arizona-Sonora Copper Province have consciously, or unconsciously, been based on the concept of the autochthonous nature of the ore deposits. Under this concept, however, no universally valid theory about the regional structure and the distributional pattern of the ore deposits seems to emerge, even after many decades of intense efforts. To the author, this indicates that one of the underlying principles may not be correct

Tentatively, another approach is offered here : allochthonous geology. Under this concept, nothing remained at its original place, but has travelled from far away. Such large and long-range transport is well known from many places of the world. The movements take place in the form of sheet-like Nappes which are tectonic rather than stratigraphic units. Often, such Nappes occur together in overlapping positions. Generally, they originate from the same source area, and their movements are uni-directional. The result of Nappism is a highly complicated structural situation which cannot be explained by "Lineaments", "Trends", or fault patterns.

The application of Nappism to the Arizona-Sonora Copper Province holds the promise to permit hitherto impossible insights into the regional structure which might prove of great value to locate additional ore deposits.

With respect to the source area of the nappes, considerations about the Laramide orogeny, its volcanism, and the age and genesis of the Copper deposits of Arizona-Sonora point to a specific belt : the batholiths of Baja California and California. Possibly, the Nappes represent the original roof of these batholiths. Then, the "Unroofing" would have been the work of Nappe tectonics, i.e. the removal of large sheets of roof via lateral sliding. In such a way, the Laramide metal concentrations which had collected in the roof of the batholiths, was carried away more or less intact, - and did not fall victim to the normal process of erosion which would have destroyed these metal concentrations. In other words : Nappism might have been the salvation of the Laramide ore deposits, removing them to a distant safe place of rest. The price, though, was high : the ore deposits might have been sliced many times, and spread thruout the area of nappe movement.

The distance of lateral movement would be about 200 miles, and the direction of movement from SW to NE.

In order to arrive at an undisturbed picture of the nappes, any "Post-Nappe" tectonics must be refitted, e.g. the San Andreas fault and its southerly extensions.

Recommendations :

1. Try a fresh approach. It might get us unstuck.
2. Apply Nappism. Try to identify each nappe(tectonic unit). Carry out mapping of nappe borders. Try to establish mineralization patterns for each nappe ("Puncture Pattern"). Correlate patterns from one nappe to the next, either upwards, or downwards.
3. Carry out exploration in the source areas : the batholiths. Try to stack the nappes back again. Try to project features of nappes down into the batholith, - and vice versa.

Lisbon, Sept. 16, 1971

cc.JJCollins/

A. Giesecke

R. W. KISTLER *U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025*
J. F. EVERNDEN *Nuclear Monitoring Research Office, ARPA, Washington, D.C. 20301*
H. R. SHAW *U.S. Geological Survey, Washington, D.C. 20242*

Sierra Nevada Plutonic Cycle: Part I, Origin of Composite Granitic Batholiths

ABSTRACT

Intrusion of Mesozoic batholiths in California and the western North America Cordillera began in the Late Triassic 210 m.y. ago and ended in the Late Cretaceous 80 m.y. ago. Emplacement of granitic rocks was apparently not continuous but was accomplished during five major epochs of intrusion at approximately 30 m.y. intervals, each epoch taking 10 to 20 m.y. to complete. A progressive transgression of epicontinental seas onto the midcontinent occurred during the same interval of time as the batholithic emplacement to the west. A penecontemporaneous deformation near the loci of granitic emplacement and a temporary regression during the major progressive transgression of seas onto the midcontinent are correlated with each intrusive epoch. The locus of Mesozoic granitic rocks was a source of sediments during most of the period of time required to emplace the batholiths; the origin of the batholithic magmas cannot be related only to localized downwarping of geosynclines. The source of the major proportion of the mobile granodioritic magmas of the Sierra Nevada was within the mantle, as is indicated by Sr isotope data. All plutons now exposed in the Sierra Nevada, whether of Cretaceous age or older, were emplaced at depths of a very few kilometers, the shallowest having been emplaced at depths of 4 km or less. The spatial relationships among these synchronous geologic phenomena and the geochemical and geophysical data from the same region are accounted for by a northwestward drift of North America in the region of the western Cordillera of the United States onto and across a Mesozoic feature that had characteristics like present-day oceanic rises.

INTRODUCTION

The problem of origin and source of the magmas that are now represented by the large volumes of granitic rock exposed in the Sierra Nevada batholith is a dominant theme in two recent articles (Batemen and Eaton, 1967; Hamilton and Myers, 1967). Essentially the same geologic, geochemical, and geophysical data pertaining to the Sierra Nevada batholith were reviewed in both papers, but the conclusions concerning origin of the batholithic magmas in each were radically different. Bateman and Eaton (1967) have suggested that batholiths are confined to the geosynclinal environment and they appeal to a generative mechanism which requires that sediments of granitic composition are downbuckled with the original crust in a synclinorium to achieve a thickness of about 60 km, and that subsequent heating due to radioactive decay of potassium, uranium, and thorium eventually causes melting in the crust and sediments with the production of granitic magma. Hamilton and Myers (1967), on the other hand, concluded that granite magmas are not necessarily generated in the geosynclinal environment but can form anywhere in the high-heat flow regions of the continent and that the primary source of the granitic melts is partially melted fractions of the lower crust and upper mantle. In the former model, a crustal prism thickened by deformation in a synclinorium and subsequent production of granitic magmas are cause and effect, respectively. In the latter model, granitic magmas are the effect of high-heat flow but no cause is specified for the abnormal concentrations of heat in batholithic regions.

More recently (for example, Hamilton, 1969; Gilluly, 1969), it has become popular to explain the generation of the magmas that resulted in the Mesozoic batholiths of western North America as the effect of heat produced along hypothetical Benioff zones at the junction between continental crust and an underthrust oceanic plate.

A geochronologic study (Evernden and Kistler, 1970), utilizing the potassium-argon

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No. 4

that of the Cretaceous granitic rocks has a northerly trend (Fig. 1). The Sierra Nevada, the principal area of exposure of batholithic rocks, is made up of representative plutons of all five intrusive epochs. In the central part of the batholith, large volumes of younger granitic rock now occupy terrains previously occupied by older plutons. The width of the belt of granitic rocks of each intrusive epoch averages about 40 km. Major compositional differences between the granitic rocks, that is, predominantly quartz diorite in the western Sierra Nevada and granodiorite in the eastern Sierra Nevada (Moore, 1959), are independent of the age of the rocks.

Deformational events of regional extent occurred in California and western Nevada immediately preceding and, in part, contemporaneously with each of the periods of

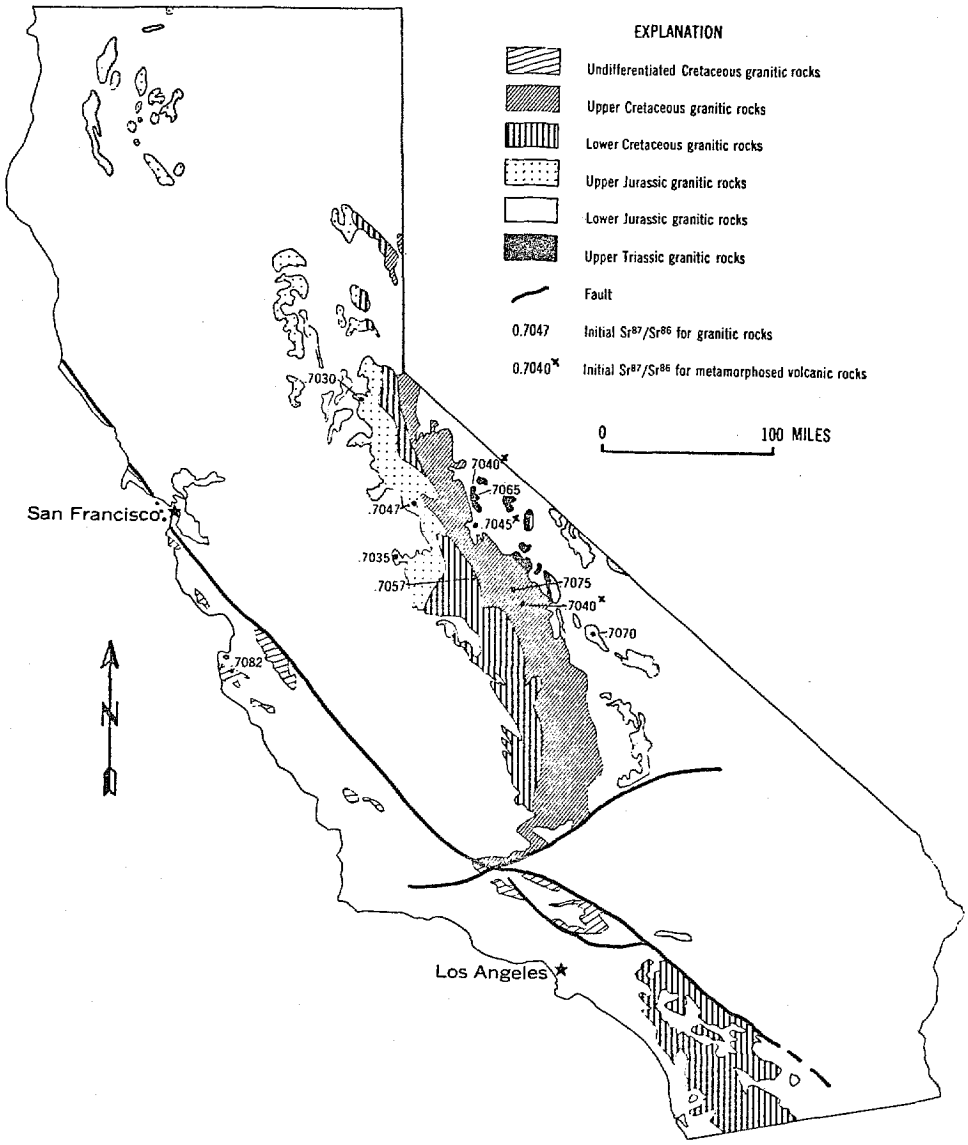

Figure 1. Map showing distribution of granitic rocks intruded during the five epochs of Mesozoic plutonism in California. (Modified *from* Pl. 1 *of* Evernden and Kistler, 1970.)

voluminous magma intrusion
Evernden and Kistler, 1970).
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The present level of exposu
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taceous sediments indicate ra
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again suggesting shallow emp
a rising eroding axis.

NORTH AMERICAN EPE EPICONTINENTAL SEAS SIERRA NEVADA BATH

Evernden and Kistler (19
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Available data allow extensi
of the major Jurassic and Cre
matic activity from California i
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Granitic rocks have a rema

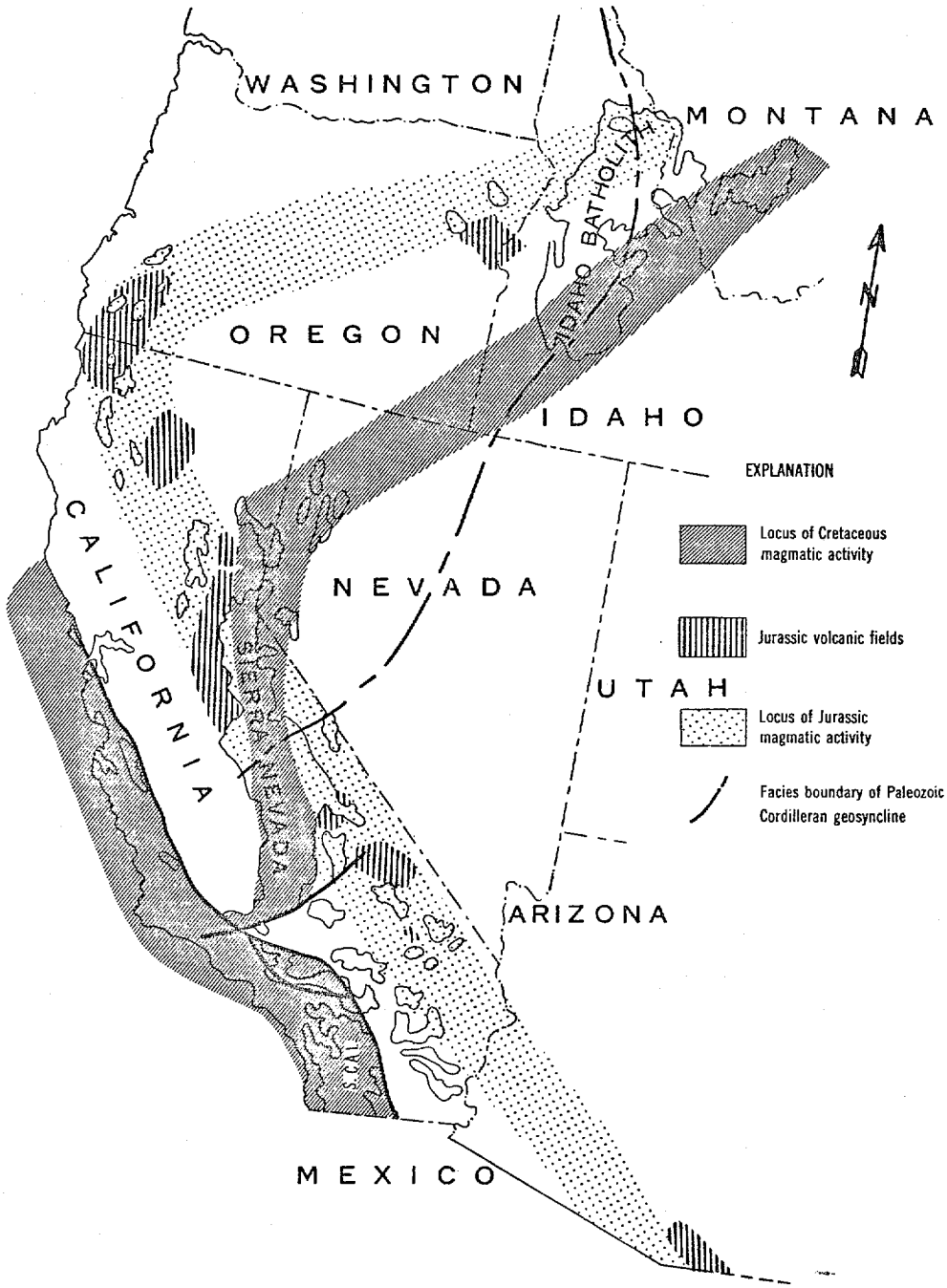
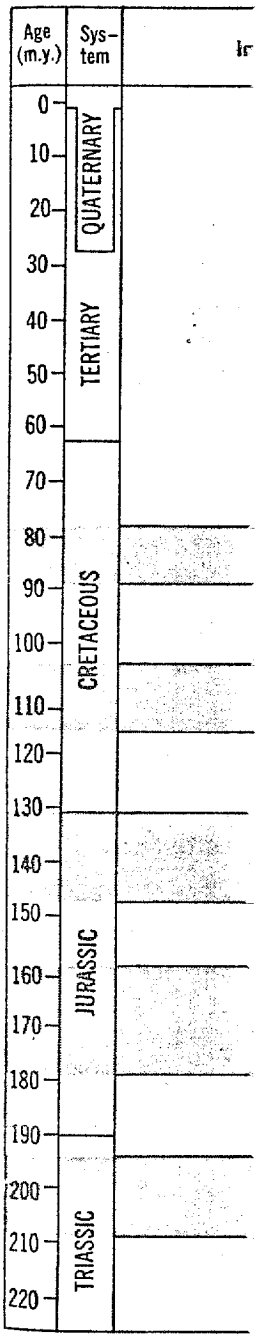


Figure 2. Generalized map showing loci of principal plutonic and volcanic activity during the Jurassic and Cretaceous in the Cordillera of the United States. Jurassic volcanic fields are *from* McKee and others (1956) and Hayes and others (1965).



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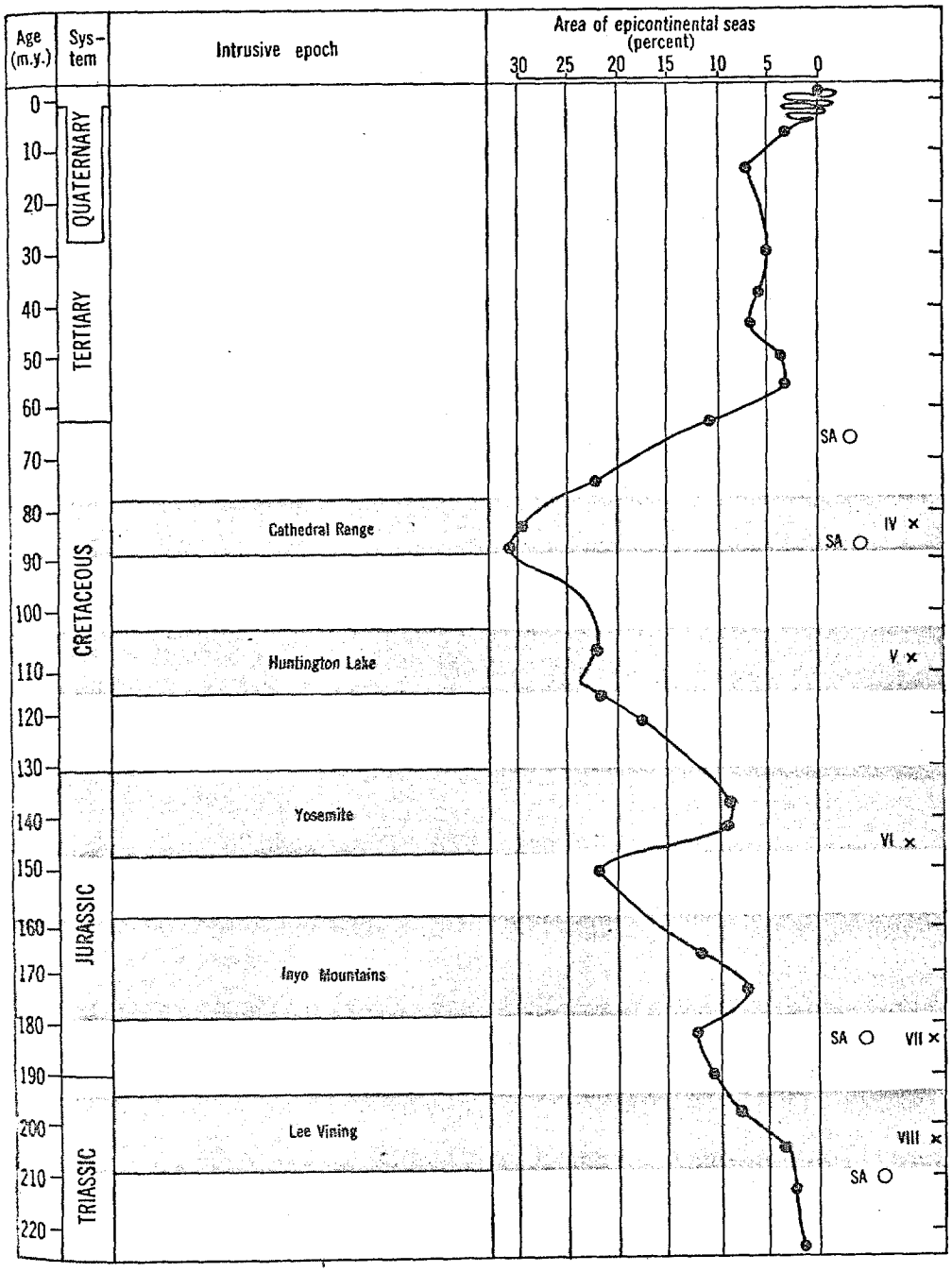

Figure 3. System boundaries *from* Harland and others (1964). Curve showing extent of North American epicontinental seas, *after* Damon and Mauger (1966). Intervals of intrusive epochs *after* Evernden and Kistler (1970). SA O marks oldest age of South American intrusive rock series. VII x marks oldest age in British Columbia intrusive rock series (*after* Gabrielse and Reesor, 1964).

PERATURES

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THE SOCIETY APRIL 28, 1971
FORCE CAMBRIDGE RESEARCH
FORD, MASSACHUSETTS 01730

JAMES G. SMITH
EDWIN H. MCKEE } *U.S. Geological Survey, Menlo Park, California 94025*
DONALD B. TATLOCK
RICHARD F. MARVIN *U.S. Geological Survey, Denver, Colorado 80225*

Mesozoic Granitic Rocks in Northwestern Nevada: A Link between the Sierra Nevada and Idaho Batholiths

ABSTRACT

Extensive areas in northwestern Nevada are underlain by granodiorite and quartz monzonite plutons, as well as less common smaller bodies of quartz diorite. Twenty-six K/Ar age determinations on rocks from this suite range from about 175 to 85 m.y., but most of the plutons are between 105 and 85 m.y. old. This Late Cretaceous intrusive epoch extending from 105 to 85 m.y. ago is here named the Lovelock intrusive epoch. Twenty-three whole-rock chemical analyses show that the granitic rocks of northwestern Nevada form a homogeneous differentiation series with a narrow range in major element distribution. The granitic plutons of northwestern Nevada are chemically and petrographically indistinguishable from granitic intrusives of equivalent age in the Sierra Nevada and Idaho batholiths, and form a link between these two major batholiths.

INTRODUCTION

The region of this study includes parts of Humboldt, Pershing, and Washoe Counties, Nevada, west of Interstate Highway 80 (Figs. 1, 2). Within this region, nearly half the pre-Tertiary outcrops are granitic intrusive rocks. East of Interstate 80, granitic intrusive bodies make up only a small portion of the pre-Tertiary terrane, and display a wide range in composition and age.

Our data consist of 26 K/Ar age determinations, 22 whole-rock chemical analyses, and 24 modal analyses. All samples were collected in conjunction with mapping projects in the region (Smith, 1966; Tatlock, unpub. data).

GEOLOGIC SETTING

Large areas of granitic rock are exposed throughout northwestern Nevada along the northward continuation of the Sierra Nevada granitic terrane. These rocks form a petrologically and chemically homogeneous group similar to the younger Sierran intrusives, that is, the John Muir sequence, Tuolumne Intrusive Se-

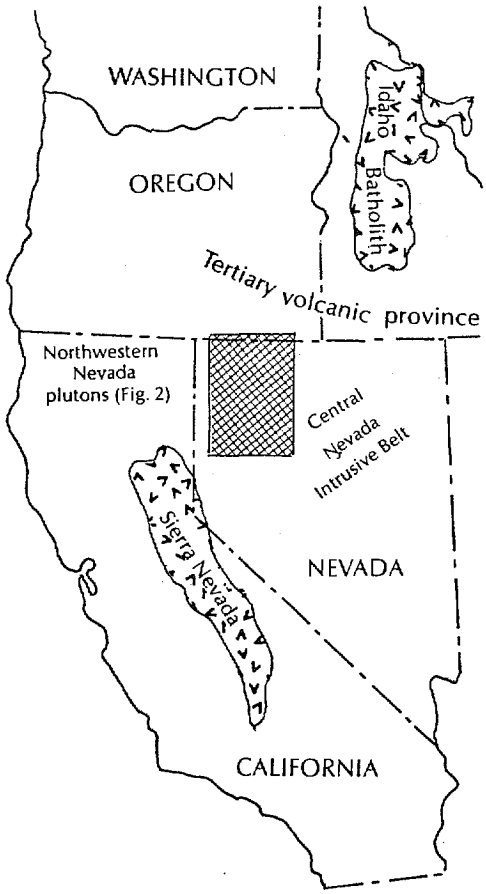

Figure 1. Index map of the western United States showing the Sierra Nevada and Idaho batholiths and the area of northwestern Nevada underlain by extensive granitic intrusive rocks described in this paper.

Geological Society of America Bulletin, v. 82, p. 2933-2944, 6 figs., October 1971

No 10

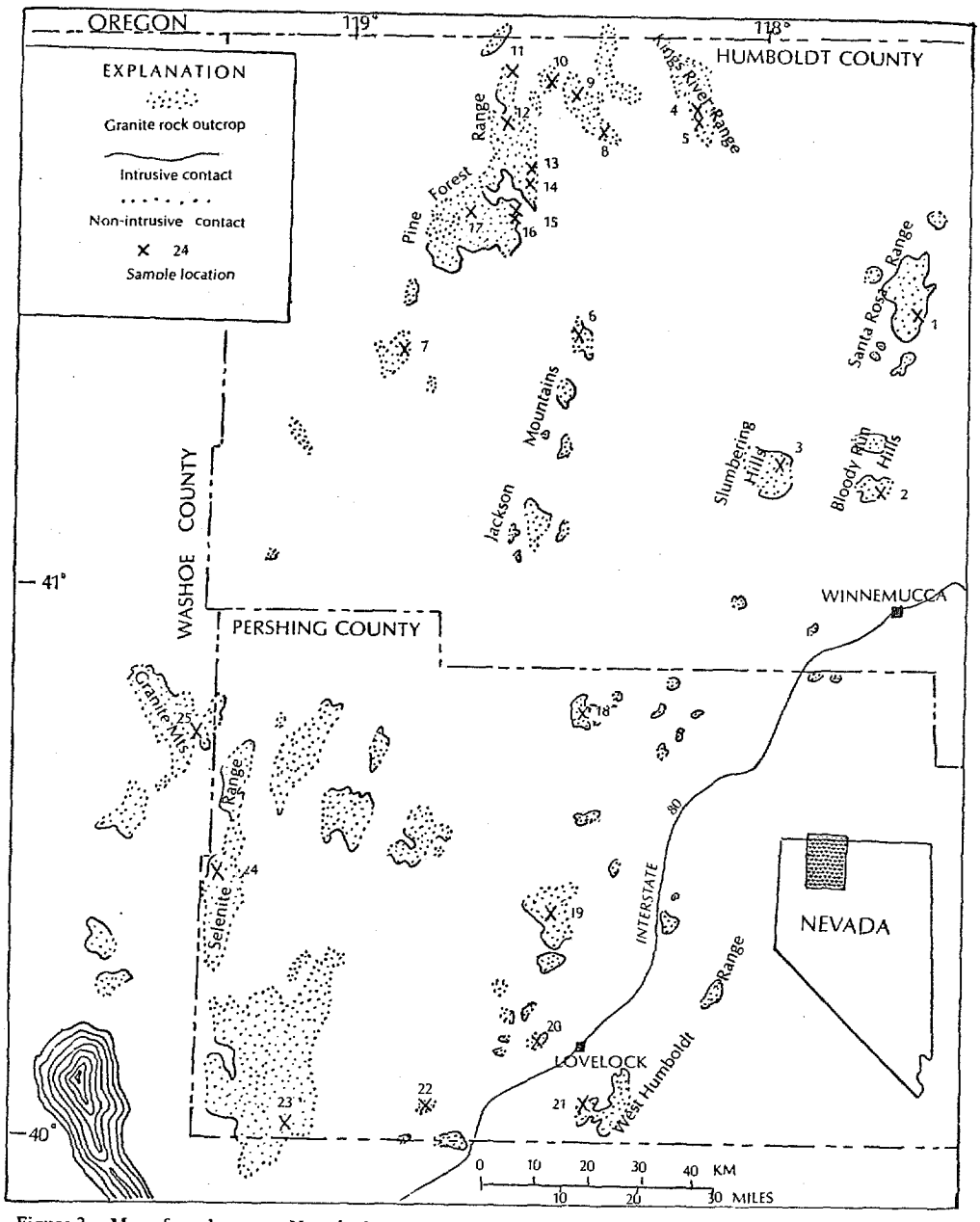

Figure 2. Map of northwestern Nevada showing outcrop areas of granitic rock and locations of chemically analyzed and dated samples. See Tables 1 and 2 for exact locations and descriptions of samples.

ries, and Shaver sequence of the Sierra Nevada batholith as described by Bateman and Dodge (1970, p. 411). The intrusive rocks of northwestern Nevada were emplaced during an interval of about 20 m.y. in Late Cretaceous time (Fig. 3). These rocks constitute a separate intrusive epoch, here named the Lovelock intrusive epoch. This intrusive epoch extended from 105 to 85 m.y. ago, temporally between the Cathedral Range and Huntington Lake intrusive epochs of Evernden and Kistler (1970, p. 17). Scattered, older, partly reset dates are evidence of earlier intrusive events during the Jurassic, about 175 m.y. ago, and are contemporaneous

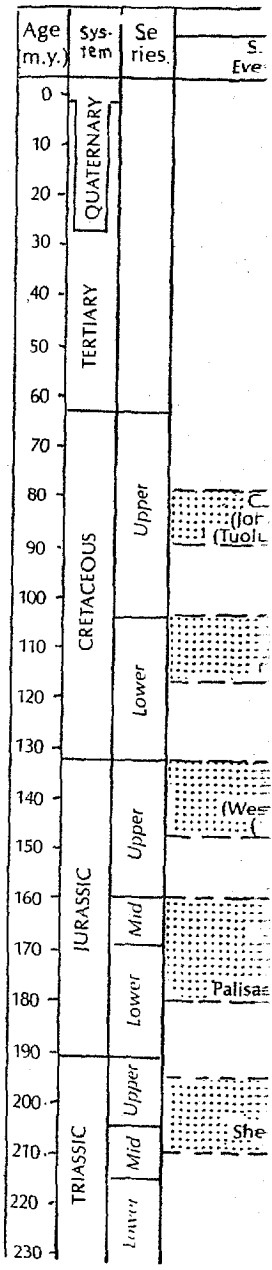

Figure 3. Chronology of
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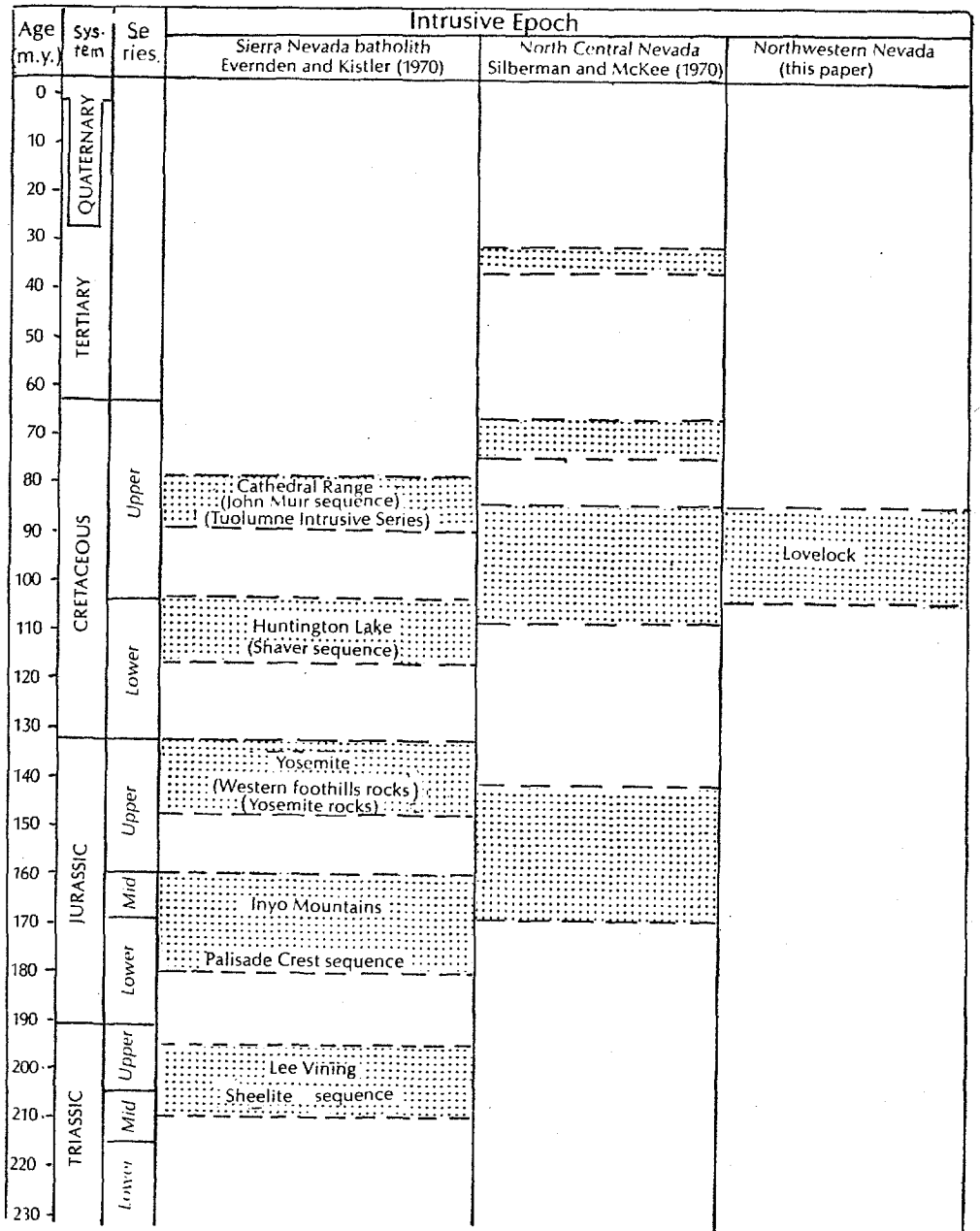

Figure 3. Chronology of emplacement of granitic rocks in the Sierra Nevada batholith and in north-central and northwestern Nevada.

with Evernden and Kistler's (1970, p. 18) Inyo Mountains intrusive epoch.

The plutons exposed in Pershing and Humboldt Counties, Nevada, form a northern continuation of the granitic terrane of the Sierra Nevada. At the present level of erosion, these granitic bodies are relatively small (average size about 45 sq mi), isolated plutons compared with the Sierra Nevada batholithic complex. North and northeast of Pershing and Humboldt Counties, all rocks older than Oligocene are blanketed by younger Tertiary sedimentary

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TABLE 1. POTASSIUM-ARGON ANALYSES OF GRANITIC ROCKS FROM NORTHWESTERN NEVADA

Sample number See Figure 2	Unit name	Mineral dated	K_2O percent	Ar^{40} rad 10^{-10} mole/g	Ar^{40} rad / Ar^{40} total	Apparent age (m.y.)
1	Santa Rosa pluton	Biotite*	9.08 9.13	13.50	.90	97.8±3.5
		Hornblende*	0.48 0.49	0.73	.56	99.5±5.0
7	Battle Creek pluton	Biotite*	9.34 9.35	13.64	.90	96.3±3.5
8	Bilk Creek pluton	Biotite*	8.90 9.01	12.78	.77	94.2±3.7
9		Biotite*	9.07 9.10	12.45	.71	90.6±3.2
14	Rattlesnake Canyon pluton	Biotite*	8.51 8.52 8.55 8.55	10.16	.82	79.0±2.8
		Hornblende*	0.834 0.838	1.26	.67	98.7±5.0
			0.839 0.845	1.31	.69	102.9±5.0
15		Hornblende*	0.495 0.497	1.12	.49	147.4±7.5
16	Theodore pluton	Hornblende*	0.34 0.36	0.94	.51	173.9±8.0
		Biotite*	8.88 8.92	12.99	.88	96.3±3.5
17	Duffer Peak pluton	Biotite*	9.18 9.21	13.41	.90	96.2±3.5
18	Haystack Butte pluton	Biotite†	8.98 9.00	12.51	.81	92.0±3.9
		Hornblende†	0.77 0.77	1.110	.94	95.2±6.3
19	Trinity Range pluton	Biotite†	9.07 9.28	13.02	.94	93.7±3.9
		Hornblende†	0.75 0.75	1.016	.92	89.6±5.9
20	Granite Point pluton	Biotite††	8.25	12.84	.91	103 ±4
21	West Humboldt pluton	Biotite†	8.39 8.42	13.26	.96	104 ±4
22	Ragged Top pluton	Biotite†	7.61 7.70	9.826	.93	85.1±3.6
		Hornblende†	0.67 0.68	0.9045	.87	88.0±6.0
23	Shawave pluton	Biotite†	8.94 9.01	11.83	.95	87.2±3.7
		Hornblende†	0.69 0.69	0.9410	.77	90.2±6.1
24	Selenite pluton	Biotite†	9.54 9.63	13.23	.95	91.3±3.8
		Hornblende†	0.82 0.84	1.180	.92	93.9±6.0
25	Granite Range pluton	Biotite†	9.03 9.009	12.49	.96	91.2±3.1
		Hornblende†	0.54 0.58	0.7783	.76	91.9±6.1

Constants used in all age determinations are: $\lambda\varepsilon = 0.585 \times 10^{-10}\ yr^{-1}$
$\lambda\beta = 4.72 \times 10^{-10}\ yr^{-1}$
K^{40} / K total = 1.19×10^{-4} moles/mole

* Argon analyses at U. S. Geol. Survey isotope laboratory, Menlo Park, California, by E. H. McKee.

† Argon analyses at U. S. Geol. Survey isotope laboratory, Denver, Colorado, by R. F. Marvin and H. H. Mehnert.

†† Argon analysis at U. S. Geol. Survey isotope laboratory, Denver, Colorado, by J. D. Obradovich.

16

R B Sprague

SEP 24 1971

EXPLORATION DEPT.

AN EXPLORATION PROJECT IN NORTH AMERICA
BASED ON EUROPEAN IDEAS OF ORE GENESIS.

Strata-bound mineral deposits, that is deposits in which the metallic elements have been introduced contemparaneously or pene-contemparaneous with the materials forming the host rocks, are relatively a much more important source of metals and have been recognized and studied longer and in more detail in Europe than in North America. This is in part due to the chances of geology and distribution but in addition is the result of a longer history of mining as metallic minerals in deposits in fissure fillings or coarsely crystallized for any reason.are simpler to concentrate and smelt and have historically been the first to be exploited in any mineral region.

The terms 'syngenetic', 'remobilized' or 'hydro-thermal' deposits should be avoided in exploration thinking as the sources of their metals could be strata bound or igneous. Any movement due to increase of temperature or pressure involves solutions and sedimentary metals can become hydro-thermal. For exploration planning recognition of the strata bound or other source of the elements is the most important factor.

The thesis presented is that deposits of this type or original source have been relatively less sought in North America, a portion of the exploration effort or a special project should be devoted to their study and recognition in North America and to exploration for additonal deposits. It is believed that this could reveal areas which have not been previously explored because no potential was recognized or indicate portions of mineral districts unexplored due to misinterpretation of the source of the metals. The geologists who would undertake this work would need a command of German and French and access to the geological literatures in these languages.

The approach to the work would be search for an unrecognized area or extension of a known mineral bearing environment the objectives of Asarco's present study of the Huelva Metallogenic Province in Spain and Portugal. Another approach is study of world literature which suggests certain elements were available in greater abundance in certain geological periods followed by study of local stratigraphy for indications of volcanic activity, one common source of metallic elements in strata bound deposits combined with geochemical study of trace elemtns which can indicate favourable strata for exploration. An example of the latter is the recent campaign of prospecting of one stratigraphic horizon all the way across Europe where as a result of geochemical indications in Turkey major tungsten deposits have been discovered in Austria, Switzerland and possibly France and Spain.

Competition for Annual Meeting 1972

Exploration for Nickel Orebodies in the North American Cordillera: A Summary

In view of the stable demand for nickel as compared to other base metals the writer recommends that the American Smelting and Refining Company expend more effort in exploring for nickel orebodies. The writer considers that the alpine ultrabasic belt of the North American Cordillera is one of the best targets for nickel exploration (the ultrabasic belt extends from Northern California through Alaska). The major nickel producers have largely ignored this belt because their exploration methods are designed for work within the Canadian Shield (airborne e.m. cannot be used effectively in the Cordillera due to the rugged topography).

Reasons for choosing the Cordilleran ultrabasic belt are as follows:

1. The belt has had a favourable genetic history. There are structural and lithological similarities between the Cordilleran ultrabasic belt and the Thompson nickel belt.

2. The belt can be treated as a single, continuous metallogenetic province. There are four types of nickel deposits which may be expected to occur within the belt: (a) Irregular pods of massive sulphide and zones of disseminated sulphide within bodies of ultrabasic material; (b) Blankets of residual ore formed on top of ultrabasic bodies due to lateritic weathering; (c) Vein-like massive sulphide deposits (often with parallel zones of disseminated sulphides) at the contacts between the ultrabasic bodies and the country rock; (d) Bodies of massive sulphide introduced into favourable structural features (faults and folds) and/or disseminated sulphides introduced into favourable host rocks at some distance away from the ultrabasic bodies along strike within the mobile belt. Mining companies working in the Cordillera have treated the ultrabasics as individual bodies. Consequently they have neglected some possibilities in catagory (c) and they have completely ignored catagory (d) (The two producing nickel mines within the Cordillera fall into catagories (a) and (b), the Giant Mascot Mine at Hope, B.C. and the Hanna Mining Company, Nickel Mountain Mine at Riddle, Oregon). -- The writer knows of one mineral occurence in the State of Washington which falls within catagory (d). A grab sample of massive breccia sulphide (pyrrhotite and pentlandite) assayed better than 4% nickel. -- The owners of the property have never assayed for anything other than gold.

The writer is confident that we can find new nickel orebodies within the Cordillera by treating the ultrabasic belt as a continuous unit and using existing exploration techniques.

The following program is recommended:

Geological mapping
Geochemical sampling
Airborne mag
Ground mag
Ground e. m.
Diamond drilling

Respectfully submitted,

JS

Jeff Sample.

AMERICAN SMELTING AND REFINING COMPANY - LONDON

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SEP 24 1971

EXPLORATION DEPT.

(16)

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R. B. Sprague

(17)

GEOGRAPHIC PLACE NAMES AS AN EXPLORATION TOOL

by

JOY J. MERZ

Statistically, mineralization is a rarity in the earth's crust. Often it is accompanied by peculiar alteration, weathering, vegetation or mineralization phenomena which contrast markedly enough with the local terrain that some descriptive aspect of the phenomena is incorporated as a geographic place name.

As a clue to exploration possibilities in new and unfamiliar areas, sometimes the analysis of place names may serve as a guide.

An English language example of this is Red Hill, Arizona, whose name is at least two hundred years old. The color of the hill is due to iron gossan overlying sulfide mineralization. Mining potential in the environs of Red Hill has long been recognized, but it was only relatively recently that the San Manuel orebody was drilled and proven below Red Hill.

In the English-speaking world, the geologically significant place names are obvious enough so that most of them have been looked into. The geologist working in a foreign country, however, has a different problem in deciphering meanings of geographic place names.

For one thing, he will generally find that besides the language in current usage, many place names are in another language. To further complicate matters, often the other language is dead or very unusual, and the original pronounciation of a place name has been sufficiently changed to make it only barely recognizable in the currently-spoken language of the country.

For example, in Peru, Anaconda's recently expropriated porphyry copper is located on a hill known for several centuries as "Cerro Verde." Cerro Verde is current usage Spanish for "Green Mountain" whose green color is due to staining from copper minerals. Within the same cultural and geographic province, there are well-known producing mines such as Quiruvilca and Julcani. Both of these place names have the same Quechua (pre-Spanish indian language) root, although in each case somewhat modified by the conquering Spaniards. The original Quechua root means "silver", reflecting that the Inca civilization had mined silver from the area prior to 1500.

In Spain, geologically significant place names are found in Spanish, Arabic, and Latin.

Geographic Place Names as an Exploration Tool by Joy J. Merz

The geologist working in a foreign country should arm himself first with equivalents in the language in current usage for such terms as white, (bleached?), red, (iron stained?), green, (copper stained?), the names of various metals, etc. After familiarizing himself with the history of the country, any other languages used by people, who previously populated or dominated the region, should be investigated and a similar set of equivalents obtained in that language.

One must keep in mind that languages change and different cultures often corrupt a pre-existing place name. A good example of this is the name of the town of Mazarrón, Spain. Mazarrón is a Spanish contraction of "Almazaroon" which, reportedly, means "place of the bitter red", an allusion to the red, alum, waste dumps left by the alunite mining in pre-Moorish times.

Madrid, 17th September, 1971.

EXPLORATION GUIDES FOR STRATIFORM DEPOSITS - SUMMARY

Stratiform base metal deposits (including Australian and Rhodesian deposits, Kupferschiefer Field, Maubach-Mechernich Lead-Zinc Deposits, Sullivan Mine, B.C., Tri-State Zinc-Lead Field, Southeast Missouri Lead Field, Upper Mississippi Valley Zinc-Lead Field) containing zinc, lead, silver and copper contribute to well over 25% of the free world's production of these individual commodities. The major stratiform deposits in Australia (Broken Hill, Mt. Isa, McArthur) not only contain reserves exceeding 100-200 million tons, but contain metal values of extremely uniform grades which tend to minimize production uncertainties. Continued exploration for partially concealed and concealed deposits of the stratiform type, which represent sizable exploration targets, is urgently recommended and should comprise no less than 50% of Asarco effort.

The stratiform deposits of Rhodesia and eastern Australia appear to have several geologic environment characteristics in common. Many of these features are obscure and not widely recognized but, when applied, will assist in selecting priority areas and serve as prospecting guides ranking targets. Notable broad characteristics are:

1. The deposits are contained in post Archean argillaceous sediments which are comprised of fine, silty, dark, laminated shale constituents and their metamorphic equivalents. The deposits are developed in and/or near continental shelf positions which during sedimentation are of flat submarine relief, in pockets, basins and channels, all pointing to and perhaps indicative of a euxinic environment.

2. Penecontemporaneous faulting during sedimentation not only suggests a loci of fumarolic activity but indicates weak volcanism causing a favorable depositional environment and structural setting. This is evidenced by turbidity currents, slump breccias and brecciated dolomites and metamorphosed and remobilized equivalents associated with the deposits.

3. Carbonaceous sediments, (perhaps indicative of the presence of kerogen) collina, (stromatolites) and the ubiquitous presence of pyrite are traceable beyond the ore areas and provide exploration clues.

Asarco does have within its ranks a decisive exploration advantage over competitors. Two major deposits are indirectly controlled by Asarco (Mt. Isa and Northern Leases, and McArthur River). Genetic concepts and exploration guides developed by Mt. Isa geologists have assisted not only in developing contiguous and substantial reserves, but have led to the discovery of new (McArthur deposits) reserves. I recommend that Messrs. E.M. Bennett, W.J. Murray and W.D. Smith attend the exploration conference in December 1971, and present papers along the following lines:

a) Mr. Bennett - Geology of Mt. Isa and Hilton Mines - emphasizing ore development guides in relation to geologic criteria.

b) Mr. Murray - Geology of McArthur River Deposits - stressing exploration guides.

c) Mr. Smith - Significance of Penecontemporaneous Faulting to Mineraliation at Mt. Isa, McArthur and Northern Rhodesian Deposits (if possible) and exploration criteria selecting favorable environments.

These individuals are geological experts on stratiform deposits and it is expected their discussions will not only stimulate the continued search for stratiform deposits but will lay the groundwork for successful exploration guidelines which have been demonstrated to lead to discovery of substantial economic reserves.

(19)

ASARCO (AUSTRALIA) PTY. LTD.

MEMORANDUM

FROM: M. KRIEWALDT

DATE: 28th September 1971

TO: MR. J. J. COLLINS
MR. J. H. COURTRIGHT

REFERENCE: Submission for Exploratior Conference.

ATTENTION:

SUBJECT: December 1971.

"FLUID SCIENCE CAN HELP FIND ORE"

Most ore bodies are formed from metalliferous fluids.

Knowledge of the nature and histories of ore-forming fluids and their environment leads to the discovery of further ore.

Investigation of the history of fluids in a sedimentary basin since inception is one step in looking for fluid-formed ore in that environment. Again, in some volcanic environments a study of the patterns and history of volcanic events, including the accession of metalliferous fluids, can lead to the discovery of fluid-formed ore.

This approach is not new, but I think that fluid science can help find ore; and I stress the need for well-informed investigations solidly founded on physics and chemistry, making full use of field work and historical geology by geologists of various talents extending to each other mutual aid and motivation.

Two aspects of fluid science suggested for critical examination are:-

1. The evolution and migration of formation waters in sedimentary basins,

and

2. The role of colloid-bearing fluids in the formation of ore bodies.

M Kriewaldt

c.c. D. M. Fletcher.

ASARCO (AUSTRALIA) PTY. LTD.
323 WAKEFIELD ST., ADELAIDE
SOUTH AUSTRALIA 5000

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ASARCO (AUSTRALIA) PTY. LTD.

MEMORANDUM

FROM: R. BARKER

DATE: 27th September 1971

TO: MR. J. J. COLLINS
MR. J. H. COURTRIGHT

REFERENCE: Submission for Exploration Conference.

ATTENTION:

SUBJECT: December 1971.

" REGIONAL STRATIGRAPHIC STUDY AS AN EXPLORATION METHOD FOR STRATIFORM MINERAL DEPOSITS"

A regional stratigraphic study is at present being carried out by the Company in an effort to find base metal deposits in the Lower Cambrian Hawker Group sediments of the Flinders Ranges, South Australia. This stratigraphic interval was selected because it is known to contain a number of possibly stratiform base metal deposits. The method involves measuring a number of stratigraphic sections (about twenty in this case). Samples of the rocks are taken from known portions in the sequence and analysed for base metals. Most of the Hawker Group rocks are carbonates and these are also analysed for major elements (calcium and magnesium in particular) to determine whether anomalous base metal values are related to calcite-dolomite transitions, or other changes in major element composition. Published information on previous mineral exploration, and on geology generally, will be combined with the data from the sections to give a regional picture of the geological conditions at the time these rocks were deposited. The base metal values should show in which areas the sediments are most likely to be mineralised.

I feel this method could be applied to other areas where stratiform mineralisation is likely, though it would need to be adapted to suit the region concerned.

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The application of plate tectonics theory in the search for ore.

The search for metals remains basically a quest for patterns or blueprints of occurrence. The establishment of such patterns enables exploration targets to be predicted with greater reliability. In combination with seafloor spreading and continental drift phenomena, the plate tectonics model represents the most substantial advance that has been made in recent years to an understanding of the nature of the relationship which exists between ore deposits and their tectonic settings. Many different types of ore deposit can be related to the theory. Patterns can thus be established and then utilized in the search for new orebodies.

Fundamental to the theory and its application to ore search are the following

1. Orogenic processes must be considered on a global scale
2. The positions of orogenic belts are controlled by the basically elongate contact zones of converging plates
3. Virtually every type of tectonic feature known to exist within orogenic belts can be related to the relative movements of lithospheric plates.

The history of plates throughout the last 100 million years is now well established as a result of the mapping of submarine magnetic anomaly patterns, earthquake data and deep sea drilling. It is in this age span, which incorporates many ore deposits of major significance, that the most reliable predictions of metal occurrence can be made. Difficulties do arise when attempting to reinterpret earlier events in geologic history in the light of plate tectonics. In these cases, data obtained from the recent sea floor cannot be utilized. However, as the theory undergoes continual refinement and as factual data increases, greater certainty can be expected.

It is envisaged that a research program could be established which would incorporate the following.

1. The continual refinement of knowledge of present plate boundaries and their motions. The analysis of smaller plates in particular seems to be of prime importance to an understanding of present tectonic patterns in many areas of high exploration potential e.g. Indonesia, Melanesia, Andean region. Researching the available world literature would be an integral part of such refinement.
2. The utilization of satellite photography to compile tectonic maps of areas suggested by the theoretical considerations of 1 above.
3. The study of broad scale gravity and seismic data and the assessment of any pronounced regional contrasts.

It is considered that the procedure above would outline areas of high exploration potential.

A. J. Hosking

The search for copper in arenites

This particular suggestion is prompted largely by the local situation. However, the case outlined is considered to be applicable to other similar environments and to other metals.

In the Northern Territory of Australia, Proterozoic and Palaeozoic sedimentary basins, which are closely associated with crystalline basement rocks of Precambrian (and possibly Archaean) age, contain thick arenaceous units of great areal extent. Many of the arenites are glauconitic and this feature can be used as a prospecting guide since glauconite is considered to form in a restricted marine environment and is commonly associated with iron sulphide. Thus, its presence indicates the conditions under which the trapping of sulphide insoluble elements such as copper is favoured. The close association with the basement complex is important since the older crystalline rocks presumably were the copper source.

The search for economic concentrations of copper, once the glauconitic members of the arenaceous sequence have been delineated, can best be pursued by the application of roll front theory and techniques in conjunction with the standard procedures of basin analysis. The absence of glauconite can be used to eliminate areas of low potential. The great lateral and vertical extents of the arenites make such initial assessments and eliminations essential.

Any program should utilize to a great extent data which has already been obtained by oil exploration companies and by Governmental organizations (the latter largely in connection with water and stratigraphic bores). On the local scene, a vast amount of such information exists. Bore logs plus drill cuttings and cores are available for examination. It is highly probable too that the upper sections of exploratory oil and gas bores have received but cursory attention from oil geologists in the past. Detailed study might well be rewarding.

N.J. Hosking

6th September, 1971. (23)

Selection of Areas Favourable for McArthur-type Sedimentary Base Metal Ores.

The McArthur River deposit is a type example of a very important group of sedimentary base metal deposits which include Mt. Isa, Broken Hill, Sullivan, Balmat and Edwards and possibly the Zambian copper belt. Because McArthur is unmetamorphosed and relatively undisturbed, it is easier to work out the criteria required for its formation.

At McArthur, pyrite, galena, sphalerite and chalcopyrite have been deposited as sedimentary layers in a shallow marine near-shore environment. These metal-bearing sediments show a definite relationship to a strong fault which forms the eastern margin of the McArthur basin. Evidence of penecontemporaneous activity along the fault is present in the form of slump breccias, interbedded acidic tuffs and acid intrusions along the fault zone. The base metal source appears to be fumarolic exhalations associated with igneous activity along the fault zone. Organic activity in algal reefs and black shales may have played a role in precipitation of sulphides.

Criteria which emerge from a study of this deposit, and which may help to select other areas favourable for this type of deposit are as follows:

1. Age of Rocks: Middle Proterozoic
2. Environment: Shallow marine, near-shore, lagoonal or reef-type sediments.
3. Rock types: Dolomitic shales, black shales, and algal dolomite, preferably with evidence of syngenetic pyrite mineralization.
4. Structure: Strong faulting, with evidence of movement contemporaneous with sedimentation.
5. Igneous Activity: Preferably acid volcanism, usually indicated by the presence of acidic tuffs.
6. Mineralization: Widespread disseminated pyrite and evidence of at least minor base metal occurrences.

Reasons for selection of these criteria will be presented in the paper, along with examples of how they can be applied in exploration.

A favourable environment forms a much larger and more easily recognizeable target than an ore deposit. However determination of what is considered favourable depends on a theory of ore genesis, which is only an idea and not a proven fact. Such a theory is only useful in as much as it helps to find ore, and must continually be reviewed critically to insure that it fits all the known facts.

R.S. Gray

Geochemical Indicators for W.A. Nickel Sulphide Deposits

(24)

Geochemical values for nickel, by themselves, are of little use in detecting nickel sulphide deposits. Not only does serpentinite contain a high Ni background, but erratic nickel enrichments occur within the weathering profile. Nickel sulphide gossans are usually severely depleted in Ni near surface.

Copper is a more reliable indicator because background Cu content in ultramafics is low, and Cu becomes enriched in the weathered zone.

Wallrocks in contact with the ultramafics frequently contain higher Cu backgrounds, or erratic Cu concentrations. Experience in W.A. indicates that these Cu concentrations are usually accompanied by relatively high Zn, whereas Zn values in ultramafics are very low. Thus, high Cu associated with low Zn is favourable for Ni, but high Cu Zn is unfavourable.

Cobalt is another sorting element, useful for two main reasons: (a) lateritic Ni concentrations are accompanied by high Co values, and (b) Mn scavenging is more readily indicated by Co than by Cu or Ni. Although anomalous Co can be expected with material derived from Ni sulphides, Cu values are usually several times higher than Co. High Co Ni with low Cu usually represents lateritic concentration. High Cu Co Ni, with Co higher than Cu requires additional checking for Mn.

Se, Pt, Pd, S and Bi can also be used as indicators, but are not normally required for routine work.

The above criteria may be applied to soil, rock-chip, or possible gossan samples, and with minor limitations to auger or percussion drill samples. Absolute values are less important than metal ratios, because background values vary from area to area.

In summary, the most favourable conditions are represented by (a) coincident high Cu Ni values, (b) low Zn values, and (c) anomalous Co, but with Co much lower than Cu.

R.S. Gray

A Giesecke

The Application of Nappe-Tectonics to the Arizona-Sonora Copper Province.

Many interpretations about the structure within the Arizona-Sonora Copper Province have consciously, or unconsciously, been based on the concept of the autochthonous nature of the ore deposits. Under this concept, however, no universally valid theory about the regional structure and the distributional pattern of the ore deposits seems to emerge, even after many decades of intense efforts. To the author, this indicates that one of the underlying principles may not be correct

Tentatively, another approach is offered here : allochthonous geology. Under this concept, nothing remained at its original place, but has travelled from far away. Such large and long-range transport is well known from many places of the world. The movements take place in the form of sheet-like Nappes which are tectonic rather than stratigraphic units. Often, such Nappes occur together in overlapping positions. Generally, they originate from the same source area, and their movements are uni-directional. The result of Nappism is a highly complicated structural situation which cannot be explained by "Lineaments", "Trends", or fault patterns.

The application of Nappism to the Arizona-Sonora Copper Province holds the promise to permit hitherto impossible insights into the regional structure which might prove of great value to locate additional ore deposits.

With respect to the source area of the nappes, considerations about the Laramide orogeny, its volcanism, and the age and genesis of the Copper deposits of Arizona-Sonora point to a specific belt : the batholiths of Baja California and California. Possibly, the Nappes represent the original roof of these batholiths. Then, the "Unroofing" would have been the work of Nappe tectonics, i.e. the removal of large sheets of roof via lateral sliding. In such a way, the Laramide metal concentrations which had collected in the roof of the batholiths, was carried away more or less intact, - and did not fall victim to the normal process of erosion which would have destroyed these metal concentrations. In other words : Nappism might have been the salvation of the Laramide ore deposits, removing them to a distant safe place of rest. The price, though, was high : the ore deposits might have been sliced many times, and spread thruout the area of nappe movement.

The distance of lateral movement would be about 200 miles, and the direction of movement from SW to NE.

In order to arrive at an undisturbed picture of the nappes, any "Post-Nappe" tectonics must be refitted, e.g. the San Andreas fault and its southerly extensions.

Recommendations :

1. Try a fresh approach. It might get us unstuck.
2. Apply Nappism. Try to identify each nappe(tectonic unit). Carry out mapping of nappe borders. Try to establish mineralization patterns for each nappe ("Puncture Pattern"). Correlate patterns from one nappe to the next, either upwards, or downwards.
3. Carry out exploration in the source areas : the batholiths. Try stack the nappes back again. Try to project features of nappes down into the batholith, - and vice versa.

The Role of Gypsum in Formation of Base Metal Deposits

Gypsum or anhydrite react readily with methane gas to form calcite, hydrogen sulphide and water ($CaSO_4 + CH_4 \longrightarrow CaCO_3 + H_2S + H_2O$). A relatively thin gypsum layer could easily be completely destroyed in this manner, leaving behind a porous collapse breccia heavily charged with H_2S. The breccia would provide a permeable channelway for connate waters squeezed out of a thick sedimentary pile migrating up a hydraulic gradient. Base metals dissolved in the connate waters would be precipitated upon contact with H_2S.

Many base metal deposits are located in restricted basins which contain evidence of evaporites. The German Kupferschiefer and Polish Zechstein deposits are examples. Even the HYC deposit at McArthur contains mud casts after halite and anhydrite.

Numerous Appalachian and Mississippi Valley-type deposits are associated with breccias for which no satisfactory explanation has been given. Perhaps these breccias could be related to thin gypsum layers which have been completely destroyed by this process.

R.S. Gray

To: J.H. Courtright

From: D.P. Cadwell

Exploration Suggestion.

The following suggestion is not strictly geological in nature, but one which involves ASARCO's initial attitude toward exploration.

I believe it can be shown that, in the case of the recent notable discoveries, the discovery is a natural conclusion to a well directed and integrated exploration program over large land holdings. The ability to hold or control large land areas is a point which has been neglected by ASARCO.

The foreign field still offers a reasonable success ratio to those organizations who are willing to apply for large exploration grants and spend commensurate amounts of risk money. ASARCO is well equipped with talent and technology to undertake this type of exploration, but appears to lack the foresight to commit itself.

It is then suggested that a study group be set up to evaluate potential mineral districts, by country or political entity, on a world-wide basis. In addition to basic geologic data, the group must evaluate the political, economic and legal requirements which must be met prior to ASARCO's participation.

In order to place these studies in the proper perspective, it would be important for the researchers to be indoctrinated into ASARCO's investment and profit objectives, particularly where U.S. Income Tax Law is concerned.

Careful study of local mining laws and personal communication with officials in charge can reveal points which over-ride local political tendencies which, in the past, have excluded us from participating in large scale exploration. The ability to maintain 100% control over prospective areas is past history over a large portion of the globe and so it may be necessary to re-evaluate our stance. Mixed companies, including local private and/or government participation must be considered.

The ability to obtain, under reasonable conditions, large exploration grants is of primary importance and should be fully investigated. Once a grant is obtained, the talent and manpower available within the ASARCO structure should be mobilized.

David P. Cadwell

To: J.H. Courtright

From: D.P. Cadwell

Exploration Suggestion
Oceanographic Studies.

In view of the fact that 70% of the earth is covered with water in the form of oceans, seas and polar ice caps and that certain mineral trends and tectonic belts are often stoped at the shore-line, it would appear that exploratory efforts will eventually be turned toward the sea bottom.

Recent studies and research grants have become more and more practical (from an economic point of view) and benefits are now being derived from undersea mining of manganese and phosphates.

It is also important to realize that roughly 40×10^9 tons of dissolved and particulate matter finds its way into the oceans each year. Considering the geochemical balance, this means 1.8×10^6T Cu; 0.6×10^6T Pb; 2.6×10^6T Zn; 4×10^3T Ag etc: (the above figures are rough approximations).

Another important aspect of under sea exploration would be the fact that island arcs and isostatic hinge lines are for the most part submerged and where exposed have proven to be prominent loci of economic mineral emplacement.

While this type of exploration is not economically feasible at present, we should make an attempt to keep abreast of developments through literature research and communication with institutes such as Lamont, Woods Hole and La Joya, and possibly through financial backing of selected research programs.

David P. Cadwell

To: J.H. Courtright
J.J. Collins
From: J.A. Staargaard
On: "Ore-finding" ideas,
first suggestion.

(28)

PUT THE ACCENT ON REGIONAL MAPPING

If one looks what became of one's colleagues, it is not possible to miss noticing that most of these men, who should by now be the best and most experienced geologists in the field, are not really involved in geology anymore. They are running offices, collect and pass on existing information, deal with lawyers, negotiate for property etc. There are only very few who could remain faithful to geology, by continuously exercising their abbilities, which can only be accomplished by own geologic work in the field.

The collecting of information on activities of competitors, the acquisition of property, the study of other peoples hypotheses published in litterature etc. all undoubtedly have their uses, but they do not help to develop the own abbilities of a geologist as such, on the contrary. These are all side-issues which distract from what is and remains the main object for a geologist to concentrate on, i.e. the earth itself.

The company that manages to keep all its geologists in the field, not only for the cursory examination of single prospects but also on regional mapping, in particular their senior men, will have the following advantages over its competitors:

1/ Rejuvenation of geologic abbilities in every geologist, including men in "key"-positions, who are asked to take decisions on geologic issues.

2/ Obtaining own, up to date geologic maps of major ore-districts, based on firsthand data and ideas, instead of using data collected and interpreted by others, for other purposes.

3/ Observation of mineral occurrences in their general geologic background, revealing relations and patterns which otherwise would escape notice.

4/ Discovering what of their knowledge in fact only is mere opinion and what penetrates to principles.

5/ A better evaluation of mining properties to be selected for negotiations.

6/ Creating geologic insight, the only thing that can guide us to mineral deposits not yet known to the mining community.

One could go on pointing out more advantages, but space is limited.

My first reply to the request for "ore-finding" ideas is the suggestion:

PUT THE ACCENT ON REGIONAL GEOLOGIC MAPPING

It is an invaluable exercise in developing allround geologic talent. And tomorrow's ore-bodies will only be discovered by geologists who can give the right interpretation of data collected today.

(29)

To: J.H. Courtright
J.J. Collins
From: J.A. Staargaard
On: "Ore-finding" ideas, second suggestion.

FORM A SPECIAL (TEMPORARY) GROUP OF FIELD-GEOLOGISTS TO HELP STIMULATING REGIONAL GEOLIGICAL MAPPING

Regional geologic mapping can be done nowadays in most areas in a minimum of time by means of the aerial photograph, which shows forms and relations of geologic entities, otherwise not directly perceivable and mappable. Complemented with a minimum amount of petrology and stratigraphy, which every all-round geologist should be capable to do himself, accurate maps can in this way be produced in months, which only a few decades ago would have taken years of footwork to accomplish.

To stimulate a regional mapping program, having the advantages outlined in my first suggestion, an independent group of field-geologists, not placed under supervision of a regional exploration division, could start mapping potential ore-districts.

This group should be dissolved the moment regional exploration divisions are handling the regional geologic mapping satisfactory in their own rayons.

(30) JJC read JUL 26 1971

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

July 12, 1971

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T. C. O.
JUL 14 1971

Mr. J. H. Courtright
Tucson Office

ANNUAL MEETING

Dear Sir:

JUL 19 1971
J. V. D.

I have been very impressed by the rapid development of new concepts resulting from the theory of Plate Tectonics. Since this theory is only six years old, new supporting evidence is being published at an ever increasing rate, triggering collateral studies. At present, the bulk of work is attempting to fit old concepts and geologic knowledge into the new frame work. In the future, however, the theory will be used to extrapolate into new areas of thought. One such area is the world wide search for ore. The concept of plate tectonics will probably not lead directly to a drill target but could lead to new and presently unknown districts. If, as is suggested, all mountain belts, plutons, and volcanics are the direct result of tectonics at plate boundaries, a knowledge of present and past boundaries is essential.

Only recently have the characteristics of plate boundaries been recognized and listed so that old boundaries could be recognized. Certain workers in the field such as Dr. W. R. Dickinson believe that ore deposits are intimately associated with certain features of plate tectonics. Therefor a knowledge of the details of previous episodes would lead to new fields of exploration.

My suggestion, though not new with this letter, is that ASARCO stay abreast of all developments in this rapidly expanding theory and put on retainer a few of the most knowledgeable academic people in the field. By grants of funds, their work could be directed in part toward a greater knowledge of how, when, and where ore deposits were formed in reference to the boundaries of present and past plates. Certain trends are already being recognized as being possible guides to exploration within this general concept.

Very truly yours,

B. C. MORRISON

BCM:am

cc: J. J. Collins
R. J. Lacy

OPTIMIZING STREAM SEDIMENT SURVEYS THROUGH USE OF A BROAD-SPACED SAMPLE INTERVAL AND SPECIAL SAMPLE COLLECTION TECHNIQUE

by

B.E.KILPATRICK

Stream sediment surveys are a proven ore-finding technique, but can be costly when large numbers of samples are necessary to cover an area. Broad-spaced sample intervals can be used to adequately "screen" a large area rapidly and thus gain a considerable competitive advantage both in time of initial evaluation and increased time available for follow-up work. A system is outlined below to optimize the sample spacing during a stream-sediment survey of a given area and thus reduce the total number of samples (and collection time) to a minimum.

This sampling system involves a broad-spaced sample interval based on measuring cumulative drainage lengths (rather than linear distances along a given tributary), a special sampling technique (to ensure a representative sample), and a simple graphical technique for analyzing sample data.

If possible, the optimum sample spacing should be determined by an orientation survey around a known mineral deposit in the area in which the survey is to be conducted. Sample spacing is measured as shown on Figure 1 and the sample sites are marked on base maps prior to going into the field. Surveys in northwest Montana and in Arizona have shown that a 12-mile sample interval is adequate to indicate major sources of mineralization. (Closer-spaced sample intervals are used to follow up and define the anomalies found in the original survey).

Broad-spaced sampling makes representative samples imperative. Stream-sediment samples are collected by a nested series of three or four nested plastic buckets with graduated sieve sizes for bottoms. Sediment (preferably from the center of the stream channel, where mixing is greatest and dilution the least) is sieved through the buckets to obtain a final-80 mesh sample. The individual samples are collected as a series of 16 or 32 sub-samples, each taken as one scoop of sediment at consecutive 10-ft. intervals along the stream channel, as shown on Figure 2. The sample is sieved in the field, retaining the -80 mesh portion, which results in a small

final sample that represents a large volume of sediment collected along a distance of 160 to 320 ft. (depending upon the number of sub-samples). Selected portions of the coarse fraction can also be saved for further study. Although this technique may seem cumbersome, the additional time required for sample collection in comparison to the conventional "grab" method is more than compensated for by the greatly reduced number of samples required in this sampling system.

The sample data are amenable to all the usual statistical treatments. A particularly effective method of analysis that requires no sophisticated treatment is to plot the cumulative frequency percentage of the sample values on log probability paper and use the results to interpret the sample data. Each straight-line segment of the log probability plot represents a separate sample population that may be treated separately with different background and anomalous values for each population. Various combinations of metal values and ratios can be used to enhance the anomalies. Once geochemical anomalies are defined, further follow-up sampling can be done to evaluate these anomalies. At this point, subsidiary tributaries not directly sampled in the original survey can be sampled, but only the local tributaries around the anomalies need be sampled. The sampling system eliminates the need to sample all tributaries, the majority of which will prove to contain only background values.

BEK/wj
6 August,1971

MINERAL ZONING AND TRACE ELEMENT HALOS AS EXPLORATION GUIDES

by

B. E. KILPATRICK

The chances of finding economic mineral deposits exposed at the surface are decreasing as the available land surface is increasingly more intensively scoured by mineral exploration teams. Large deposits discovered in the future will be concealed and will be found by indirect means. Other than looking for previously exposed deposits under post-mineral cover, concealed deposits will have to be found by recognizing mineral assemblages (combined with favourable geology) characteristic of the peripheral zones of ore deposits. This technique requires the study of mineral zoning patterns around known ore deposits to develop model zoning patterns that can be applied to exploration.

Recent publications have emphasized models of mineral zoning around porphyry copper deposits. Recognition of a symmetrical mineral zoning pattern around the truncated San Manuel deposit led to the discovery of the "missing" Kalamazoo deposit through deep drilling. The development of a concept of mineral zoning at the Climax molybdenum deposit was applied at Urad and led to the discovery of the Henderson deposit through deep drilling. Another application of alteration mineral zoning, combined with geochemistry, was Amax's discovery of the Bald Butte molybdenum porphyry in Montana.

Mineral zoning studies should be combined with studies of the trace metal content around ore deposits, for it has been demonstrated that distinct aureoles of metals occur in trace amounts around large ore deposits. "Leakage" anomalies may also exist around ore deposits.

Mineral zoning patterns and trace element halos around porphyry deposits have been well documented, as cited above; however, it has also been shown that stratiform deposits, such as White Pine, also have distinct mineral zoning patterns and periferal trace element halos that should prove useful in exploration for similar deposits. Certain massive sulphide deposits have also been shown to have characteristic trace element halos around them which could be used in the search for concealed massive sulphide deposits.

Mineral Zoning and Trace Element Halos as Exploration Guides

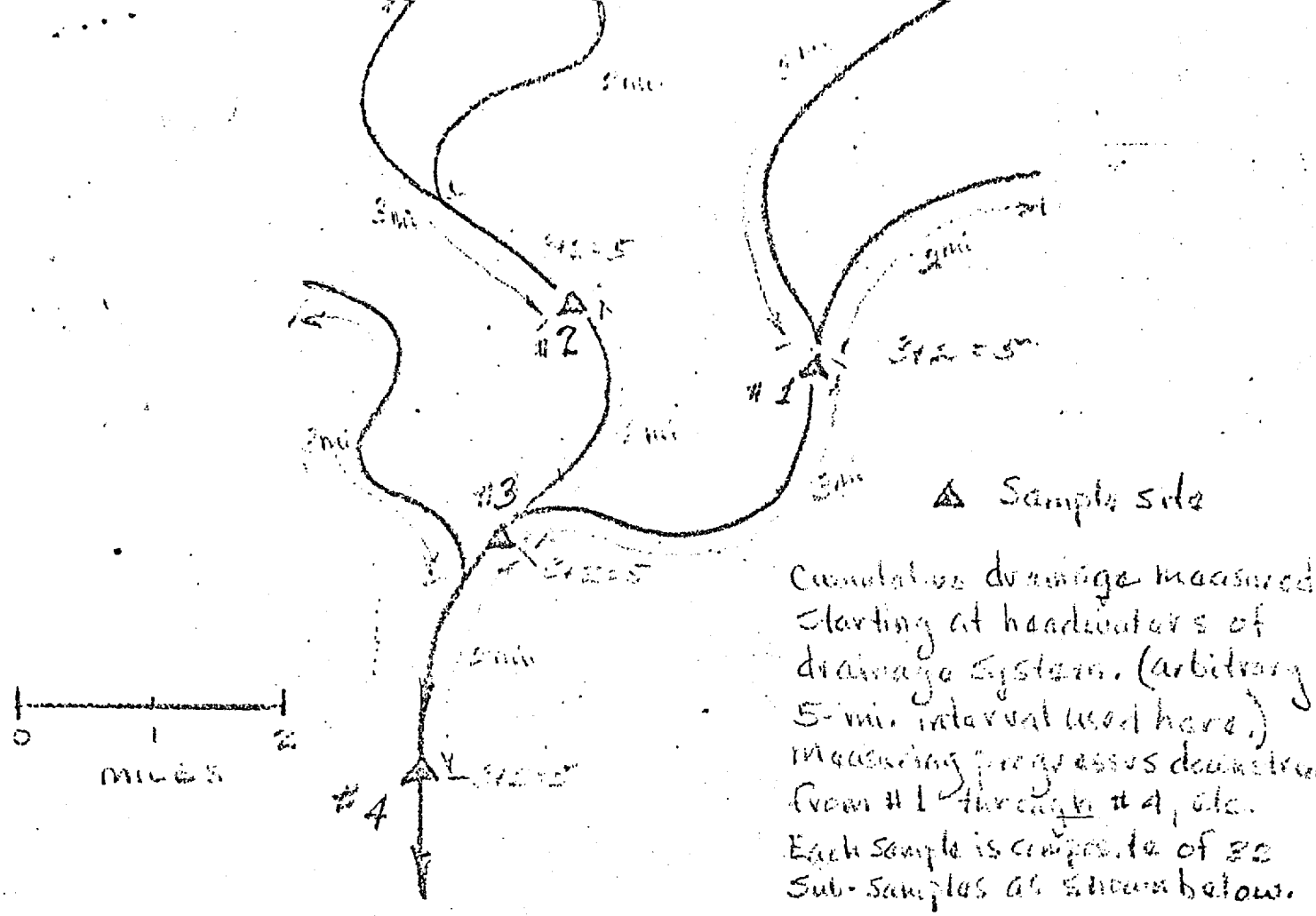
To utilize the mineral zoning (and trace element halo) concept the following steps should be taken:

1. Familiarize exploration personnel with mineral zoning models and the recognition of peripheral assemblages.

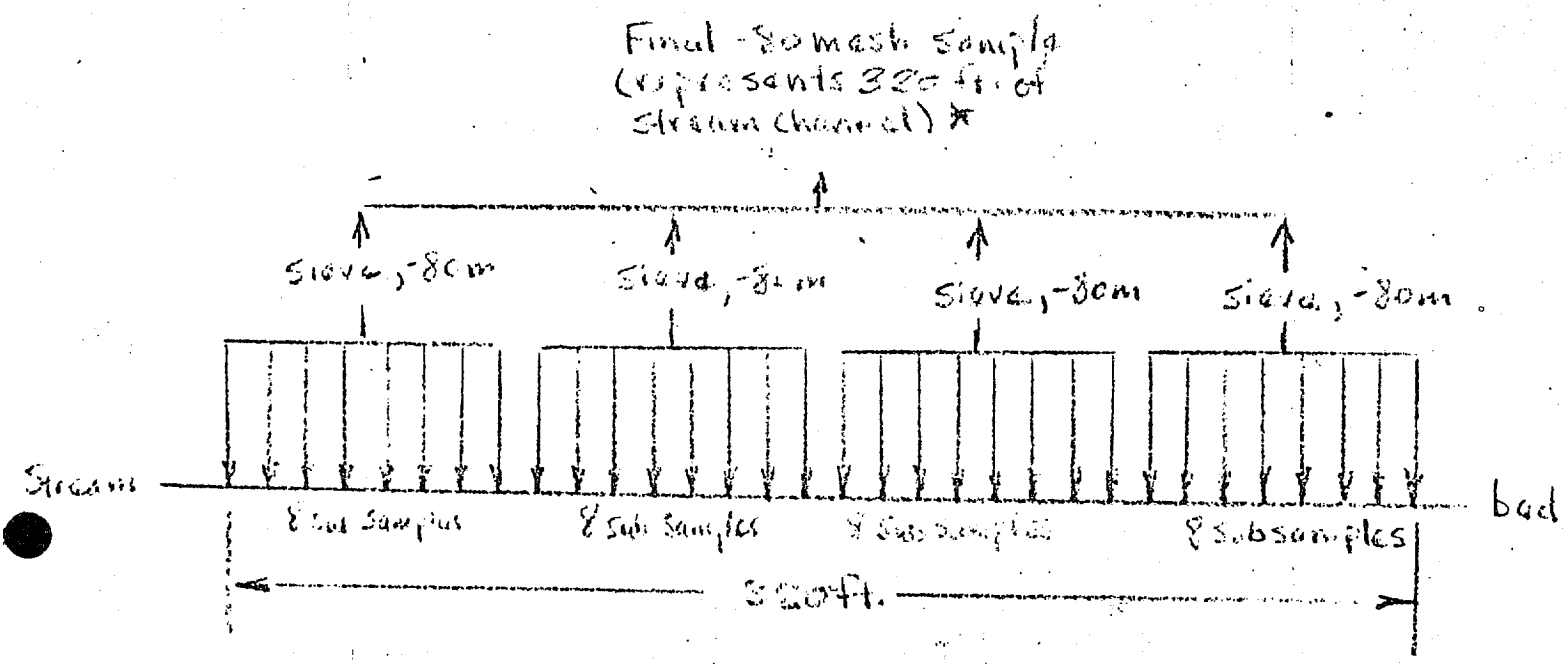
2. Coordinate geologic mapping and geochemical sampling to emphasize possible anomalous mineral assemblages. (Geophysics may aid in defining concealed orebodies indicated by mapping and sampling.)

3. Test anomalous areas by drilling - deep, if necessary.

BEK/wj
6 August,1971



— Fig. 1 —



* Can substitute other size fractions if desired.

— Fig. 2 —

PERIPHERAL ZONES OF SEDIMENTARY DEPOSITS

by

CECIL von HAHN

Most mineral exploration is carried out in more or less defined "metallogenetic provinces" by searching for new orebodies with characteristics similar to those of known ore concentrations. A more or less careful study of the known deposits is made; a set of factors are determined which, together, are thought to have enabled the development of the given deposit; and other localities, where similar factors occur together, are searched for. The study of orebodies most often concentrates on the more heavily mineralized zones of these.

The search for sulphide orebodies, of synsedimentary origin, could be greatly enhanced by the study of the peripheral portions of orebodies known, or suspected, to belong to this group. Such a study would, except in cases of very highly metamorphosed ores, enable one to determine if a deposit is in fact synsedimentary or a replacement. This is possible as here those original sedimentary relationships can be recognized which tend to be destroyed in the more sulphide-rich portions. (Very low grade metamorphism, or even diagenesis, will remobilize most sulphides, giving rise to cross cutting, and replacement textures, and obscuring the original sedimentary features. This has led to the epigenetic interpretation of ores such as those of Rammelsberg).

The fact that one is looking for a syngenetic or an epigenetic will obviously be invaluable in prospecting for further deposits. Similarly, knowledge of the facies, associated with the periphery of sedimentary orebodies, will be similarly of value as the appreciation of zones of hydrothermal alteration is, when in the search for non-exposed epigenetic ore concentrations.

Madrid, 29th September, 1971.
CvH/wj

CORE LOGS OF OIL COMPANIES

by

CECIL von HAHN

Several, if not all, Canadian provinces require that detailed core logs be submitted for all diamond drilling carried out in their territory. I believe that Alberta also requires specimens of all cores to be kept available.

The study of such records could lead to some interesting targets in Mississippi Valley-type environments. Furthermore, arrangements might be made to inspect drill logs and/or core logs of companies searching for oil, coal, or evaporite deposits.

Madrid, 29th September, 1971.
CvH/wj

ASARCO (AUSTRALIA) PTY. LTD.

35

MEMORANDUM

FROM: R. DINGWALL

DATE: 29th September 1971

TO: MR. J. J. COLLINS
MR. J. H. COURTRIGHT

ATTENTION:

REFERENCE: Submission for Exploration Conference.

SUBJECT: December 1971.

"PLATE TECTONICS AND GEOBOTANY"

1. PLATE TECTONICS

Australia is a continent where the thickness of weathering is a major problem in mineral exploration.

However, large portions of the continental shelves have been explored by the various oil companies and a great deal of information about the structure of this area is available from the Bureau of Mineral Resources. In addition to this data published marine seismic, gravity and magnetic academic work has resulted in the theory of plate tectonics.

It has been found that parts of the Australian continental shelf consists of a series of major basement fracture zones. The trend of these zones differs in various parts of the shelf. This trend pattern is probably a reflection of the rotational history of the Australian -New Guinea plate in relation to the Asian and Antarctican plates.

The onshore extension of one of these major fractures contains the Wallaroo-Moonta-Burra Copper province. It is suggested that a more detailed analysis of the known major offshore fault patterns, when linked to the major onshore fault patterns could result in more specific onshore exploration targets. This analysis may also account for the areas distribution of mineralisation in Australia.

To locate the possible ore bodies along such onshore extension and to help eliminate the overburden problem infra-red photography and radar imagery could be used.

Another instance where similar studies could be undertaken is along the western seaboard of North America.

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36

MEMORANDUM

FROM: R. DINGWALL

DATE: 29th September 1971

TO: MR. J. J. COLLINS
MR. J. H. COURTRIGHT

REFERENCE: Submission for Exploration Conference.

SUBJECT: December 1971

ATTENTION:

"PLATE TECTONICS AND GEOBOTANY"

2. GEOBOTANY

Because of the depth of weathering, difficulties in using the usual geophysical techniques have been experienced in Australia. An approach from the geobotanical-geochemical direction is therefore suggested.

It would appear that apart from European, Prussian and North American workers, geochemists and geologists in Australia have paid little attention to the mineral-soil-vegetation-agricultural complex. Exceptions to this are in Queensland where Polycarpaea spirostylis is known to indicate copper-bearing regions and in south-west Western Australia where pastures deficient in copper have probably been the major contributing factor to "falling disease" in cattle.

It is therefore suggested that an exploration programme using this mineral-soil-vegetation-agricultural complex be commenced.

A general programme using the widespread native vegetation such as the Eucalypts and the Mulga may well result in more specific target areas.

Another approach would be for a sampling programme to be carried out over all the known Cu-Pb-Zn deposits in Australia to find specific indication, plants, bushes and trees on each particular rock type. This would result in a rock type-indicator type map. Future exploration areas from government published soil and vegetation maps could then be chosen.

A final approach would be to study the association of particular vegetation types with particular rocks and soils, an example of this being the low spread-out bush Beclia. This is a characteristic plant found on volcanic soils underlain by rocks similar to those found at Captain's Flat and Woodlawn, New South Wales, Australia.

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RECENT ADVANCES IN THE IDENTIFICATION OF LEACHED OUTCROPS

The appraisal of leached outcrops has in the past been largely dependent on macroscopic examination and field work (as per Blanchard & Richards) and the recognition of secondary minerals formed from metal sulfides.

In Western Australia, widespread and intense surface oxidation, leaching and laterization have resulted in a preponderance of leached outcrops. These conditions hamper mapping and the recognition of leached outcrops due to sulfides. Local geologists are developing three techniques to improve their ability to recognise leached outcrops especially over base metal sulfides. The three techniques are:

Geochemistry
Microscopic examination of polished and thin sections
The study of polished sections by the electron probe.

The application of these methods has played a paramount role in the recent discoveries of Kambalda, Poseidon and other deposits in Western Australia.

The further development and the use of these techniques together with the ones already used by Asarco geologists will enable us to regain "the decisive exploration advantage over our competitors". The three methods are briefly outlined below:

The advent of AAS methods for the determination of the presence of trace amounts of elements has enabled the identification of very low concentrations of metals in leached rocks and gossans. Thus Woodall was able to establish the presence of anomalous quantities of Te (of the order of 1 ppm Te) in the Kambalda gossans by a method developed by the CSIRO for use in Te halo studies of Kalgoorlie goldmines. (D.E.S. Davis et al, 1969.) The presence of this quantity of Te in Kambalda gossans was evidence to Woodall that the gossans were derived from Magmatic base metal sulfides. The geochemical analysis of leached rock chips will often determine the rock type sampled. Example: Ni and Cr results from a leached ultramafic.

A microscopic study of polished surfaces of Western Australian gossans by Travis in 1968 showed that many of the characteristic textures of the supergene sulfides are preserved in surface gossans. Thus in the case of the Kambalda, St. Ives and Poseidon gossans the characteristic feature of the supergene sulfide assemblages of violarite-pyrite-siderite is preserved especially where silification has fixed the indigenous limonite. In the case of cellular gossans, impregnation with suitable plastics will enable a polished slide to be made. Many of the oxidised rocks in W.A. are silicified, or they can be impregnated with plastic so that a thin section of the rock can be made for microscopic examination of their texture and mineralogy. Thus their identity is often confirmed by features not readily seen under the hand lens.

The third method of appraisal is to examine selected polished sections prepared for microscopic examination with the electron microprobe. The electron probe can locate the position of any anomalous element concentrations on the polished surface. If this work is related to micrographic study then the identity of the pseudomorph sulfide is often revealed. The method is being perfected by the CSIRO in Sydney and Perth on material supplied by Selection Trust and WMC. Other examples were noted by J.J. Collins (memo of June 4, 1971).

H.C. Williamson

H.C. Williamson

September 30, 1971.

W.L. KURTZ

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ASARCO (AUSTRALIA) PTY. LTD.
Perth, Western Australia.

ANNUAL EXPLORATION MEETING TOPIC:
RECENT ADVANCES IN THE IDENTIFICATION OF
LEACHED OUTCROPS - H.C. Williamson

REFERENCES

Blainey, G. The Rush that Never Ended
Melbourne University Press, 1963.

Blanchard, R. Interpretation of Leached Outcrops
Nevada Bureau of Mines Bulletin 66, 1968.

Brooks, C.C. Mineral Economics of the Pt Metals
Conference on Pt Metals, Melbourne, 1971.

Davis, C.E.S., Ewers, W.E. & Fletcher, A.B. Determination of Traces of Tellurium in Rocks by AAS after volatillization with Synthetic Pyrite
Aust. IMM Bulletin 233, p 67-72. 1969

Geology of Australian Ore Deposits, 2nd Edition. Edited by John McAndrew. Aust. IMM, 1965. Brown Prior Anderson, Melbourne.

Griffiths, J.C. Scientific Method in Analysis of Sediments
McGraw Hill, 1967.

Hawkes, H.E. & Webb, J.S. Geochemistry in Mineral Exploration
Harper International, Tokyo. 1965.

Keays, R.R. Precious Metal Fraction and Implication for Ore Genesis and Exploration for Ni Sulphide Ores
Conference on Pt Metals, Melbourne, 1971.

Loftus Hills, G. & Solomon Co, Ni and Se in Sulphides as Indicators of Ore Genesis
Mineralium Deposita 2, p 228-242. 1967.

Sindeeva Mineralogy and Types of Deposits of Se and Te
Interscience Publishers, 1964.

Ward, F.N. & Nakagawa, H.M. Atomic Absorption Technique in Geochemical Exploration - Problems and Progress
Quarterly of Colo. School of Mines, p 497-506.

Woodall, R. & Travis, G.A. The Kambalda Nickel Deposits
Proceedings of the Ninth Commonwealth Mining and Metallurgical Congress, London, 1969.

November 18, 1971.

(58)

RECEIVED
OCT 4 1971
EXPLORATION DEPT.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 1, 1971

TO: J. H. Courtright

FROM: F. T. Graybeal

ANNUAL EXPLORATION MEETING TOPIC:
The Partition of Cu, Zn, and Mn Between Coexisting Biotite, Hornblende, and Chlorite in Some Laramide Intrusive Rocks in Arizona

The partition (distribution) of Cu, Zn, and Mn between coexisting biotite and hornblende was investigated in the Patagonia granodiorite and the Cornelia pluton. Roozeboom diagrams show that Cu, Zn, and Mn obey the Nernst distribution law, and that Cu and Mn partitioning are sensitive to variations in temperatures of crystallization. In an igneous rock the major portion of trace element partitioning occurs between the mineral and the adjacent melt. Thus Cu, Zn, and Mn are actually distributed in equilibrium between biotite or hornblende and the coexisting magma. Trace element concentrations in the minerals are therefore governed by trace element distributions in the magma.

Analyses of chlorite, which occurs as a hydrothermal alteration product of biotite, show that Cu, Zn, and Mn maintain a constant distribution ratio between chlorite and biotite. This suggests that the Cu, Zn, and Mn contents of biotite were in equilibrium with the Cu, Zn, and Mn contents of the coexisting hydrothermal fluid at the instant the magma solidified.

The above conclusions, as well as the extreme variations of the copper content of biotites studied in this investigation, support work by Parry and Nackowski (1961) and Lovering et al (1970), that the copper content of biotite is a useful exploration tool. However, this study has revealed that low as well as high concentrations of copper in biotite can indicate a favorable exploration target, and that proper interpretation of the analytical results depends on a clear understanding of the geologic history of the intrusion. It is therefore suggested that if a biotite sampling program is initiated, it should be carried on as a supplement to related field work and not as an independent saturation-type survey.

F. T. Graybeal

F. T. Graybeal

FTG:lad

cc: JJCollins

JDSell

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

November 9, 1971

ANNUAL EXPLORATION MEETING TOPIC:

The partition of Cu, Zn, and Mn between coexisting biotite, hornblende, and chlorite in some Laramide intrusive rocks in Arizona.

References:

1) Al-Hashimi, A.R.K., and Brownlow, A.H., 1970, Copper content of biotites from the Boulder batholith, Montana: Econ. Geol., 65, 985-992.

2) Lovering, T.G., Cooper, J.R., Drewes, H., and Cone, G.C., 1970, Copper in biotite from igneous rocks in southern Arizona as an ore indicator: U.S. Geol. Survey Prof. Paper 700-B, p. B1-B8.

3) Parry, W.T., and Nackowski, M.P., 1963, Copper, lead, and zinc in biotites from Basin and Range quartz monzonites: Econ. Geol., 58, p. 1126-1144.

F. T. Graybeal
F. T. Graybeal lad

FTG:lad

(39)

ASARCO (AUSTRALIA) PTY. LTD.

MEMORANDUM

FROM: L. R. DODDS

DATE: 30th September 1971

TO: MR. J. J. COLLINS
MR. J. H. COURTRIGHT

REFERENCE: Submission to Exploration Conference

SUBJECT: December 1971.

ATTENTION:

A NEW APPROACH TO THE LOCALIZATION OF BASEMETAL SULPHIDES WITHIN ALTERED ACID EXTRUSIVES.

Investigations of the nature of fluid inclusions within minerals of hydrothermal origin has indicated that these solutions are generally rich in sodium chloride. Sphalerite, galena and chalcopyrite mineralization of geologically recent formation has been recovered during the drilling of thermally active areas of tuffs and rhyolites in New Zealand.(Browne Economic Geol. Vol.64, 1969, pp156-199). The base metal sulphides vary in grade from 0.5 to 5 percent and occur in small fissures within an altered rhyolite which is probably in equilibrium with the sodium chloride rich solution obtained from the same depth. This mineralization occurs within adularia bearing altered rhyolite adjacent to an albite bearing rhyolite (Keratophyre).

Recent attention has been given to roll fronts, these are boundaries between zones of varying oxidation states which act as sites for ore accumulation. In an analogous manner a "sodium front" could be considered within a series of acid volcanics subject to alteration by sodium chloride rich hydrothermal solutions. It would therefore become necessary to discover the limit of albite alteration in the rhyolites, a zone which should be the site of base metal localization.

A brief search of the Australian literature did not reveal many known mineral occurrences within known keratophyres. However the lead-silver ore bodies of north west Tasmania, although now occuring within rocks of several diffent types, are confined to the general area of the Mount Read Volcanic arc of keratophyres and other acidic effusive rocks.

It is therefore suggested that attention be directed to areas of altered acid effusives particularly areas where keratophyres and soda rich acid rocks are exposed. The detection of the pattern of albite alteration in these rocks may serve as a useful prospecting aid.

ASARCO (AUSTRALIA) PTY. LTD.
323 WAKEFIELD ST., ADELAIDE
SOUTH AUSTRALIA 5000

Thermal Infrared Imagery In Gold and Base Metal Exploration

Maximum advantage is being taken of the various remote sensing devices for geologic mapping in mineral exploration in Western Australia's Yilgarn Block.

Much more than half of the Yilgarn Block is today covered by residual or transported soils. Arid to semi-arid conditions with pronounced day/night temperature variations prevail and the water table is generally 120 feet below the surface. Under these conditions, Thermal Infrared Imagery produces greater contrast and resolution than the other conventional techniques. It is suggested that the application of this technique in conjunction with known data be investigated and exploited for exploration programmes in the gold fields.

A considerable amount of alluvial and lode gold has been recovered from the goldfields. The districts surrounding the Kalgoorlie townsite has produced more than 39.6 million oz. of lode and 0.182 million oz. of alluvial gold. However there are local districts where alluvial gold forms 12% of the gold produced. In areas where the alluvial gold production was high the question to be asked is whether these deposits are in consequence of (a) one stream one source (b) several streams one source or (c) several streams several sources. Much of the area is soil covered and the detail old drainage system obscured. The Thermal Capacities of river sands and conglomerates, dry or wet, is different from that of the surrounding country rock. The drainage systems associated with alluvial gold despoits should therefore be able to be plotted, and explored. Areas with high lode but poor alluvial gold production could mean one of two (a) unfavourable conditions for large alluvial deposits or (b) the wrong drainage tapped.

Another application of this technique is detection hot spots due to oxidation of sulphides. Water table and base of oxidation in the gold fields is quite low. Therefore if there is a sulphide body reasonably close to the surface some portion of it would be undergoing oxidation producing heat. Since desert conditions are experienced and the water table is low solar heat would be lost rapidly and any hot spots could be indicators of sulphide bodies.

J.J. Martins
ASARCO, PERTH, WESTERN AUSTRALIA

ORE-INTRUSIVE RELATIONSHIP

In Western Australia, most of the nickel finds to date are associated with ultramafic intrusives less than half a mile from granite. At Sudbury, nickel ore occurs not only at the base of the intrusive, but also as veinlets and breccia filling in the adjacent rocks. This indicates extensive distribution of the sulfide by hydrothermal solution, after the sulfide originally segregated within the intrusive.

These two concepts, taken together with the well-known tendency of ore-deposits to cluster near the borders of granitic intrusives, indicate that although the ore bodies are not genetically related to the adjacent granite, still the granites play a major part in controlling the location of mineralization, in a structural sense. Studying the present known ore bodies associated with mafic and ultramafic intrusives, together with the adjacent granites (ore host-rock, extent of alteration, presence of several varieties of granite within the same intrusive, whether the granite is mineralized or not, and type of mineralization) must give a clearer picture about this relationship. This might enable us to differentiate between barren and mineralized mafic and ultramafic intrusives.

Another point in dealing with mafic and ultramafic intrusives one must keep in mind is that enrichment or depletion of an intrusive in ore-metal content could be taken as evidence for considering the intrusive as favourable for prospecting.

S. El-Raghy
Asarco, Perth, Western Australia.

September 27, 1971.

The following is directed towards arid and semi-arid areas with some or all of the following characteristics:- A subdued relief; deep weathering zones with little fresh outcrop; widespread mantles of residual and/or transported material; streams that are often unco-ordinated, ephemeral and internally draining; and a relatively "natural" vegetation. In short, where "seeing through" the barren cover rock is a major problem, one often accentuated by lack of background information and map cover.

I propose that photogeological studies include a study of the geomorphology and linear patterns. Such investigation to be at two levels; a sub-continent integration of lineaments and known mineralized areas, and a more immediately applicable study of linears within the major pattern to current exploration areas.

Most surface material under the above conditions is older than Holocene so that the buried geology has had a considerable time to influence and create a surface expression. In the above climates this usually appears as drainage lines either surface or subsurface. This is also marked in air photos as flora association changes, perhaps 80% of all vegetation changes being related to soil water and soil variations, the rest to other ecological factors.

A trial investigation over areas with less than 50% outcrop not known to the writer and using non-stereo cover showed good correlation between linear features and known geology. Distribution diagrams of the linears changed with lithology and, although less pronounced, linear features on superficial deposits and deep soil reflected the nature of the buried bed-rock. Very pronounced was the influence of tectonic features, even when no solid geology was visible faulting and folding were suggested by linear orientation changes.

It is felt that a systematic plotting of linears, combined with the usual geomorphological analysis of drainage patterns and basin province boundaries, would materially assist the correlation of scattered anomalies in geochemistry and geophysics as well as supplementing ground surveys.

W.J. Lorimer
ASARCO, PERTH, WESTERN AUSTRALIA

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GEOLOGIC ENVIRONMENT OF MESOZOIC AND TERTIARY HYDROTHERMAL ORE DEPOSITS

Ore deposits of the subject category in western North America have been intensely studied for many years. They have been shown to be closely related to magmatism; principally intrusive but also extrusive. The zonal distribution of base and precious metals within many of the known districts is well documented though by no means universal. The question one must ask then: Are the known minor occurrences of base and/or precious metals which have been investigated in the past and found to be too small to be of economic interest a part of some larger district pattern that may have economic possibilities?

The geologic environment of the significantly large deposits of copper, moly, and other base and precious metals is usually along zones or in areas of structural deformation. The intensity of the structure is often directly related to the size and distribution of the ore bodies.

The total structural picture must be studied by geologic age at several different scales. They are: 1) Regional structure, hopefully related to deep seated tectonic trends along which magmatism is most likely to have occurred, measured in tens to hundreds of miles; 2) district wide structure measured in miles, and 3) local structure directly associated with mineralization.

The possibility most worthy of investigating is the likelihood that the small deposit lying along a favorable regional trend or in a favorable area is a part of a larger district yet unknown. This possibility may have a fair probability in regions of poor outcrop and heavy growth or under extensive shallow post mineral cover rock.

Investigation of such potential districts after detailed literature search can be accomplished by conventional reconnaissance mapping and geochem sampling. My experience has also demonstrated that careful mapping from aerial photos can be highly effective in indicating anomalous structural conditions and localities of high structural density. A study of stereo photography makes it possible to place the known mineralization in relationship to the district and regional structural setting. Structural details can seldom be resolved but anomalous conditions are often evident. Follow up by mapping and geochem sampling may then be warranted.

A case history concerning application of this concept is available and further studies have lent substance to these conclusions.

M. P. BARNES

(44)

AMERICAN SMELTING AND REFINING COMPANY
BUCHANS UNIT

MEMORANDUM TO: Mr. J. H. Courtright, Chief Geologist

PROPOSED EXPLORATION TECHNIQUE

The following ideas are expressed in relationship to base metal deposits and volcanic complexes within predominantly volcanic belts:-

Recent exploration results in the immediate area of the Buchans Mine and in two widely separated areas 30 and 45 miles from Buchans, have pointed to economic mineralization being deposited with or associated genetically with one rock unit. Mineralization does exist in other rock units but it is not of economic significance. Other geological factors have been closely associated with the processes of introduction , concentration and deposition of the mineral substances but the one factor of lithology or rock composition appears to be the overriding determining factor in the occurrence of the economic mineralization. It is impossible to ignore as the structural, plumbing and purely hydrothermal approach tends to do, the association between certain metals and certain rock types.

Our direction in exploration should be towards comprehensive geological investigations and assessments of the mineral potential of fairly large areas prior to any actual field work. It is important to produce a mineral distribution map on a geological base. A thorough investigation of the geological ideas and an evaluation of the mineral deposits in relationship to the geological environment is then necessary in the field. If possible, geological controls and more specifically the lithological control should be established. The choice of the geological controls is the most important and critical factor and becomes increasingly so as the mineral target becomes more specific.

Areas selected for evaluation of their geological and mineral potential can be divided into three types: 1. A new district with geology similar to an existing producing area. 2. Apply new geological concepts to an old productive area. 3. Area with weak, widespread but economically significant mineralization in a geological setting similar to a producing area.

Buchans, Nfld.
September 30, 1971

EAS:JG

RESURGENT VOLCANIC CENTRES AND THEIR ROLE IN PORPHYRY COPPER LOCALIZATION

(45)

Many of the world's great base metal deposits are directly associated with centres of volcanic activity, these deposits are of two general types: massive sulfide and disseminated sulfide. This paper deals with the disseminated sulfide deposits and is based on a number of characteristics that show that intrusives containing disseminated sulfides are related to a type of resurgent volcanic centre which can be identified by conventional geologic methods.

With the application of geologic mapping, tectonic interpretation, petrographic and mineralogic identification, volcanic areas can be screened and placed into three groups for further exploration. The groups are:

(1) Pyroclastic-granitic radial-ring complexes (Butte type). Very favourable for mineralization. The Butte type of resurgent volcanic centre has many similarities with the mineral districts of Santa Rita, Climax and Toquepala. This type of centre is developed through a series of volcanic and tectonic events which incorporate radial and concentric fracture development, pyroclastic eruptions, coherent crustal subsidence, resurgent doming and uplift and intrusive emplacement with or without extrusive equivalents.

(2) Pyroclastic-andesitic complexes (Bougainville type). Favourable for mineralization. The Bougainville type of volcanic centre resembles in many ways the volcanic environment in which the Kerwin, Poison Ridge and Atlas deposits are associated. The Bougainville type of centre is developed by a series of catastrophic events, which include violent eruptions of pyroclastic and andesitic flows, chaotic subsidence, resurgent doming and intrusive emplacement with or without extrusive equivalents.

(3) Mafic-shield complexes (Kilauea type). Not favourable for mineralization The Kilauea type complex is exemplified by violent eruptions of mafic flows, subsidence, rejuvenation of volcanism and extrusion of mafic flows, and intrusive emplacement with or without extrusive equivalents.

Upon completion of the initial screening, areas of interest can be further ranked on a basis of alteration along the following guidelines:

(a) Areas of secondary biotite with fringes of argillic and or propylitic alteration with possibly areas of secondary potassic alteration are most favourable indications of base metal deposition within the vent at a relatively shallow depth - less than 1,000 feet.

(b) Areas of alteration consisting mostly of montmorillonite and silica represent fumerolic sulfateric breakdown of the volcanic rocks and does not infer base metal deposition at shallow depths.

(c) Areas of volcanic sulfur deposits and active sulfateric areas are generally related to zones of pyroxine rich andesites, quartz andesites and dacites and are not favourable indicators of base metal deposition at depth.

The evaluation of volcanic provinces using the suggested criteria could improve the odds of discovery and at the same time open a new horizon in porphyry copper-molybdenum exploration.

B.J. Devere
Asarco, Perth, Western Australia.

September 27, 1971.

J d Lee

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12th November, 1971.

Memorandum For: W. Kurtz, F. Graybeal, J. Balla
(Tucson Office)

Attached is a list of references which were used in the preparation of the paper "Resurgent Volcanic Centers and Their Role in Porphyry Copper Localization".

Burton Devere

Burton Devere

c.c.: JJCollins, New York Office
TCOsborne, New York Office
JHCourtright, Tucson Office

J.D. Lowell & J.M. Guilbert: Lateral and Vertical Alteration - Mineralization Zoning in Porphyry Ore Deposits, Eco. Geol. Vol. 65, No. 4, Jun - Jul. 1970.

H. Williams: Calderas and their Origin, Univ. of Calif. Pubs., Geol. Sci, Vol. 25, No. 6, 1941.

R. Richard & J.H. Courtright: Some Cretaceous - Tertiary Relationships in Southern Arizona and New Mexico, Ariz. Geol. Soc. Dig. Vol. 3, 1960.

K. Richard & J.H. Courtright: The Geology of Toquepala, Peru, Min. Eng. Feb. 1958.

J.A.L. White: Native Sulfur Deposits Associated with Volcanic Activity, Min. Eng. Jun. 1968.

S.R. Wallace and Others: Multiple Intrusions and Mineralization at Climax, Colorado, in J.D. Ridge editor, Ore Deposits of the United States, 1933-1967 Vol. 1, AIME, 1968.

J.D. Ridge: Changes and Development in Concepts of Ore Genesis - 1933 to 1967, in J.D. Ridge editor, Ore Deposits of the United States 1933-1967, Vol. 2, AIME, 1968.

P.M. MacNamara: Rock types and Mineralization at Panguna Porphyry Copper Prospect, Upper Kaverong Valley, Bougainville Island, Proc. Aust. Inst. Min. Met. No. 228, Dec. 1968.

V.D. Perry: The Significance of Mineralized Breccia Pipes, Min. Eng. Apr. 1961.

M.R. Klepper and Others: On the Nature of the Boulder Batholith of Montana, Geol. Soc. Amer. Bull. Vol. 82 No. 6, Jun 1971.

D.M. Kinny and Others: The Poison Ridge Volcanic Center and Related Mineralization, Grand and Jackson Counties, Colorado, U.S. Geol. Surv. Circ. 594, 1968.

R.R. Coats (editor): Studies in Volcanology, Geol. Soc. Amer. Mem. 116, 1968.

T. Tatsumi (editor): Volcanism and Ore Genesis, Univ. of Tokyo Press, 1970.

J. Gilluly: The Ajo Mining District, Arizona, U.S. Geol. Surv. P.P. 209, 1946.

W.R. Jones and Others: General Geology of Santa Rita Quadrangle Grant County, New Mexico, U.S. Geol. Surv. P.P. 555, 1967.

MEMO TO J. H. COURTRIGHT

(46)

LOCALIZATION OF MAJOR STRATIFORM ORE BODIES

Comparison of the present active base metal sulphide depositing geothermal systems of the Red Sea and Salton Sea with known stratiform ore bodies gives rise to criteria which can be used to define areas of high potential for the occurrence of this type of orebody.

The Red Sea system is forming deposits more closely analagous to known orebodies, e.g. Mount Isa and McArthur River, than the Salton Sea, but the two systems show remarkable similarities. The Red Sea deposits occur in a localised basin in the median trough of the Red Sea trench, where a high density, hot, chloride brine occurs. The median trough represents a zone of crustal separation with a steep geothermal gradient in the crust providing the energy for the system. Both areas show steep geothermal gradients and brine solutions transporting the metals and depositing them in the case of the Red Sea in a restricted basin of deposition.

Fossil evidence of steep geothermal gradients and hot brines is difficult to detect but the tectonic setting, chemical and mineralogical changes in sedimen and the environment of deposition for this type of deposit can be recognised. The Red Sea sediments show alteration of calcite to dolomite, formation of chloite a nd a high iron content occurring as pyrite in the sulphide horizons and as haematite and goethite at other horizons. The sediments are dominantly chemical precipitates.

Both Mount Isa and McArthur River deposits occur at the margins of narrow troughs and are in dominantly chemically deposited sediments, principally dolomites and dolomitic shales, which, at McArthur River at least, were deposited in a restricted basin. They both occur adjacent to major faults bordering the trough and these appear to be zones of presistent crustal fracturing.

Exploration for major stratiform deposits should be focused on fossil structual troughs and rift structures, particularly where there is dominant chemical and/or biochemical sedimentation adjacent to thebordering major faults. Dolomitic and ferruginous (both hematitic and pyritic) sediments, particularly when deposited in a restricted basin, (e.g. back reef basins) constitute favourable zones. The faults appear to provide the major plumbing for the circulating metal rich brines.

As the metals appear to be derived from country rock, no abnormal metal source is required, so deposits need not occur in major metal provinces, but due to the mobility of base metals in chloride brines, some clustering of minor showings of Pb, Zn or Cu can be expected near a major deposit.

The Proterozoic appears most favourable for this type of deposit, possibly dur to the incipient breakup of a proto-continent and greater prevalence of anerobic conditions permitting formation and preservation of the deposits.

P. N. Walker

c.c. J. J. Collins

P. N. WALKER
1.10.71

Geochimica et Cosmochimica Acta, 1971, Vol. 35, pp. 643 to 659. Pergamon Press. Printed in Northern Ireland

The source of ore metals*

KONRAD B. KRAUSKOPF
School of Earth Sciences, Stanford University, Stanford, California 94305

(*Received* 9 *December* 1970)

THE CLASSICAL goal of geochemistry, in the words of V. M. GOLDSCHMIDT (1954), is "to discover the laws which control the distribution of the individual elements". For many of the rare metallic elements the most striking fact of distribution is their local concentration into the rocks that we call ores. The laws controlling this extreme concentration are most elusive, as economic geologists discovered long ago. In the pursuit of these laws, where geochemistry and economic geology have a common purpose, the contributions of geochemists have been illuminating but hardly definitive.

Why do ore deposits form? There are many kinds of ores and many ways in which they can form, so that the question obviously admits of no simple answer. Pick a single deposit, and focus the question on it. The query is still complex, for it is an amalgam of subsidiary questions: Where did the metals come from? By what agent were they moved? In what form did they move? By what process were they deposited? Some of these part-questions are more readily attacked geochemically than others. We have learned a great deal in recent years, for example, about the nature of the fluids that transport the common ore metals and about the forms in which the metals may be carried. But about the source of the metals in most deposits we are still limited largely to guessing.

STATEMENT OF THE PROBLEM

It is this question of source, the most stubborn of the queries into which the problem of origin can be divided, that I have chosen for a speculative discussion. Whence come the metals of an ore deposit? There are many easy answers, with which I am sure you are all familiar. Metals come from magma, cooling and differentiating beneath the surface; metals are a by-product of volcanic activity; metals are liberated during metamorphism; metals are concentrated by the weathering and leaching of pre-existing rock, either by surface water or by groundwater. For almost any of the world's large ore deposits all of these guesses have at one time or another been proposed, singly or in combination, and the acrimonious debates that still go on are a measure of the difficulty of the question I have asked. Why should this question be so peculiarly unyielding?

The trouble here is a kind of trouble that arises very often in geology: the scarcity of clear-cut evidence to evaluate the relative importance of many variables. For some geologic problems we get hints by observing processes going on in the world around us, but here such guidance is largely lacking. Places where ore deposits

* Presidential Address delivered to the Geochemical Society, November 12, 1970 at Milwaukee, Wisconsin, U.S.A.

are demonstrably forming today are very few, so for the most part we must rely on subjective reconstructions from fragmentary post-mortem evidence. Always there are a myriad of possibilities, a myriad of variables that we can control or evaluate only in the most rudimentary fashion. Small wonder that the question of ultimate source of metals is often by-passed. Small wonder, too, that recent progress in the geochemistry of ore deposits has come not from speculations about such matters but from work on more limited and tractable problems that can be handled in the laboratory. Still it is useful now and then to meditate on the broader questions, for only so can we fit separate fragments of geologic inquiry into our evolving picture of how the planet functions.

The sources of metal, from one point of view, are not far to seek. All the common ore metals are present in ordinary igneous and sedimentary rocks, in amounts ranging from a few parts per billion to several tens of parts per million. We need only find a suitable method of concentration, and *any* large block of ordinary rock would be a possible source for major ore accumulations. It is a simple exercise in arithmetic to discover that the amount of rock needed is not prohibitively large—a few cubic kilometers or tens of cubic kilometers, depending on what sort of efficiency we imagine for the concentration process. There is no question about the adequacy of very ordinary earth materials to supply all the metal needed for even the largest ore deposits.

But the process of concentration—this is the prime difficulty. By and large, geologic processes lead in the wrong direction, toward further dispersal of trace elements rather than toward concentration. To solve the problem of source for a given deposit, we must look not only for the material from which its metals might have come, but also for a reasonable process or combination of processes which can reverse the usual trend toward homogenization.

To formulate the problem explicitly, we imagine a large mass of granitic magma of average composition, with the usual complement of trace elements. Let it undergo any normal geologic process or sequence of processes—crystallization, differentiation, weathering and erosion, metamorphism, partial re-melting and re-solidification. Are these processes *by themselves* capable of concentrating some of the trace metals into large ore deposits, or must we postulate something unusual—perhaps a peculiarity of composition in the original magma? We could ask similar questions about heterogeneous masses of sedimentary or volcanic rocks. I restrict the query to *large* ore deposits, because irregularities in the operation of normal processes can manifestly lead to minor occurrences of ore metals—occasional crystals of ore minerals in otherwise barren pegmatites, small pockets of sulfides in limestones, coatings of oxides and sulfides at the mouths of fumaroles. Such occurrences can be written off as chance deviations in a general progression toward homogenization of crustal materials, but large accumulations of ore cannot be dismissed so easily. *If* large deposits result merely from random variations in normal processes acting on normal materials, then at least we should be able to reconstruct the kind of local variation that made a given deposit possible. If, on the contrary, the formation of an ore deposit requires some abnormality in original material, then our search for a source must go farther back into geologic history.

The question is a fundamental one, but it is seldom brought out in the open.

Behind most discussions of ore genesis for individual deposits, it seems to me, is the tacit assumption that only normal materials and normal processes are involved. When we study a lead–zinc deposit in or near a granite stock, for example, and after weighing various hypotheses decide that the metals were concentrated in hydrothermal solutions resulting from magmatic differentiation, we are saying by implication that *any* normal granitic magma, given the requisite water content and suitable conditions of cooling, is capable of concentrating some of its contained lead and zinc into ores. Is this a tenable hypothesis, when we know that very similar granites elsewhere may be associated with copper deposits, or gold deposits, or tungsten deposits, or with no deposits at all? Those who have approached the problem from a different point of view, looking at the regional distribution of ore deposits over a large area (for example, SPURR, 1923; SCHMITT, 1966; JEROME and COOK, 1967; NOBLE, 1970) have almost unanimously reached the opposite conclusion—that ore formation generally requires original material somehow different from run-of-the-mill rocks. Here is the issue: what sort of evidence can we use to decide it?

FIRST EXAMPLE: SIERRA NEVADA SCHEELITE

We look first at two specific examples. I start with a kind of ore with which I happen to be familiar, the tungsten deposits of the southern Sierra Nevada in California. These deposits have been described in great detail by BATEMAN (1965); the following brief summary is based on his description supplemented by my own observations.

Tungsten here occurs almost exclusively in the calcium tungstate mineral scheelite, as crystals scattered through tactite developed at granite–marble contacts. The granitic rocks, ranging in composition from diorite to quartz monzonite, form plutons that make up the composite Sierra Nevada batholith. The marble is a fairly minor part of a one-time sedimentary sequence now converted chiefly to hornfelses and mica schists, accompanied by considerable material of volcanic ancestry. The scheelite-bearing tactite occurs irregularly at intrusive contacts with wall rocks, with roof pendants, and with isolated xenoliths. It contains a highly variable assortment of the usual tactite minerals: brown garnet, pyroxene, epidote, idocrase, with locally abundant plagioclase, quartz, and calcite. Scheelite is the chief exotic mineral, but many others appear in small amounts locally: pyrite, pyrrhotite, molybdenite, chalcopyrite, sphalerite, galena. The geologic relations and mineral assemblages are typical of contact-metasomatic tungsten deposits in many parts of the world.

One looks for relations that might give clues about the source of tungsten, but as so often happens the relations are baffling. The scheelite deposits are in large measure limited to the southern part of this one range (plus adjacent hills immediately east and southeast); farther north in the Sierra Nevada, to the east across Owens Valley in the White Mountains, in the Peninsular Ranges of southern California, are found similar granites and marbles but only a few small tungsten deposits. Within the tungsten-rich area the occurrence of scheelite is erratic: some marble contacts have much tactite but no scheelite, and others are devoid even of tactite; in a general way scheelite is more abundant where the original contact rock was

pure limestone rather than shaly limestone, at discordant contacts than at concordant contacts, and in iron-rich garnet–pyroxene tactite than in other kinds, but these rules have many exceptions. Most of the tungsten occurrences are small, but the enormous accumulation at Pine Creek is a major supplier of this country's tungsten—although the geologic relations here are not discernibly different from those at other contacts that are barren or nearly so. Scheelite is not limited to contacts of a particular pluton or a particular kind of granitic rock, although it does show a preference for the more siliceous varieties. This kind of situation is all too familiar to geologists: one can make a broad generalization, here the simple statement that scheelite is restricted to granite–marble contacts, and one can see some hint of further regularities, but beyond this the details of occurrence seem discouragingly erratic.

One negative detail gives a possible lead. Clear evidence of "feeder channels" along which tungsten-bearing fluids might have moved to the tactite bodies—evidence in the form of veins, dikes, or fractures—is conspicuous by its scarcity. Even in good three-dimensional exposures or in small mines where exploration has been carried below the mineralized zone, considerable imagination is needed to reconstruct pathways along which the tungsten might have moved. Particularly striking are small xenoliths of tactite, no more than a few meters in diameter, completely isolated in granite and far from a major contact, yet sometimes abundantly flecked with scheelite.

This observation at least narrows the possibilities for a source of metal. Almost certainly the tungsten came from the surrounding granite rather than from sediments or from a mysterious source far below. This conclusion is by no means novel, for tungsten is one metal that even ardent sedimentary syngeneticists accept as usually concentrated by igneous processes.

The metal was evidently part of an aqueous fluid that moved from the granite into tactite, and the high-temperature chemistry of tungsten is sufficiently permissive that various plausible mechanisms can be set up to accomplish this. One can argue at length about details of the mechanisms—where and when the fluid was formed, what sort of tungsten compounds existed in the fluid, whether diffusion or fluid movement was the chief mode of transport—but such arguments would serve no purpose here. In seeking the source of tungsten, our only pertinent query would be: How did the metal get into the fluid? From the original silicate melt, the textbooks would tell us, as a result of crystallization differentiation which concentrated both water and tungsten in residual solutions. The textbooks are probably right, but they are not very satisfying. A skeptic would immediately wonder, "Why, then, do we not find tungsten minerals associated with *every* granite that comes in contact with limestone?" The Sierran granitic rocks, let it be emphasized, are in no way unique, and the marble in contact with them is like marble anywhere. If our guess about the source of tungsten is to be more than an *ad hoc* hypothesis, it must explain not only why tungsten deposits are abundant in the southern Sierra but why they are scarce or nonexistent in geologically similar situations elsewhere.

This is a concrete example of the question we phrased in general terms earlier. Is Sierra tungsten a product of the *normal* differentiation of a *normal* granitic magma, or must a granitic melt that produces tungsten deposits contain abnormal amounts of

the metal to start with? If the first guess is correct, the scarcity of tungsten deposits elsewhere demands an explanation; if the second guess is correct, the question about the ultimate source of tungsten remains to plague us.

The first position is the one commonly taken, at least by implication. If we were called upon to defend it, to explain why tungsten is abundant as a product of normal differentiation in one area and scarce or absent where similar differentiation has occurred in similar material elsewhere, we could list the usual possibilities. Perhaps to concentrate this particular metal requires a certain fugacity of water in the original magma, or a certain ratio of water to other volatiles; perhaps a certain pressure-temperature combination is essential, or a certain rate of cooling; perhaps extensive fracturing is needed, or fracturing at a particular time during cooling; perhaps tungsten is concentrated only at a certain level in a plutonic body, and this level just happens to be exposed by erosion in the Sierra batholith. We know so little about magmatic processes that these variables cannot be evaluated, hence all remain as possibilities.

Building a case on such possibilities for Sierra tungsten, however, is at least open to serious question. To the argument that depth in an intrusive may be critical for the formation of tungsten ores, one can reply that the Sierra deposits are exposed over a vertical range of at least 3000 m; it would seem odd if some part of this enormous range were not duplicated in the magnificent vertical exposures of batholiths in the northern Sierra, the White Mountains, and the Peninsular ranges, where tungsten deposits are scarce or lacking. If an unusual amount of water supposedly aided the formation of tungsten deposits in the southern Sierra, one can point out that pegmatites, quartz veins, and coarsely porphyritic rocks are no less abundant in the adjacent tungsten-poor areas. For a comparison of temperatures, pressures, and rates of cooling between the southern Sierra and nearby areas one can urge the strong similarities in composition and texture of the igneous rocks and the similarities in degree of metamorphism of the adjacent rocks. The case is far from holeproof, but it seems at least unlikely that minor variations of the differentiation process in similar normal magmas can account for the abundance of tungsten deposits in this one area and their scarcity in geologically similar situations nearby.

We try, then, the alternative explanation that the original magma of the southern Sierra was at least slightly enriched in tungsten, and that the function of differentiation was to concentrate the *excess* metal into late residual solutions. The question of source now appears in a new guise, for here "source" must refer to the reason for the original excess of tungsten in the magma. Such a query takes us back to the origin of the magma itself, which is a sticky problem in its own right. The magma may be a differentiate of more mafic material in the lower crust or upper mantle, or a product of partial melting of deeply buried sedimentary and volcanic layers, or perhaps a mixture of material from both sources. Current thinking inclines to the last of the three guesses, although the relative contribution from each source remains a matter of dispute (Bateman and Dodge, 1970). Whatever the resolution of this problem may be, the important thing here is simply the conclusion that before the batholith existed there was a slight regional enrichment of tungsten, either in igneous material near the base of the crust, or in a sequence of sediments and lavas, or perhaps in both.

The result of this long discussion, that the existence of tungsten deposits in the southern Sierra requires a pre-intrusive enrichment of the metal in the lower crust or upper mantle of a large region, can be generalized to other metals and other areas where ore deposits are clearly associated with granitic rocks. A similar conclusion was drawn long ago by SPURR (1923) regarding the copper-rich province of southern Arizona, and statements of the same sort are commonly made about the tin deposits of southeast Asia and Bolivia (for example, SCHUILING, 1967; SAINSBURY and HAMILTON, 1967). How far the conclusion can be extended we will consider in a moment, but first we look at a second example of a very different sort—an ore deposit formed by sedimentary processes.

SECOND EXAMPLE: THE KUPFERSCHIEFER

The hypothesis that ores may form directly by sedimentary activity—generally called the "syngenetic" hypothesis—is well illustrated by a Permian formation that can be followed from England across northern Germany into Poland, and that in Germany goes by the name of Kupferschiefer. The evidence for a sedimentary origin of the metals in this formation has been ably presented by WEDEPOHL (1964, 1971), drawing on both his own detailed studies and the extensive work of previous authors.

The Kupferschiefer is a finely laminated, dark bituminous marl only a few tens of centimeters thick, remarkably uniform over distances of hundreds of kilometers. Sedimentary characteristics establish it as a transgressive, shallow-water marine deposit. Sulfides of copper, lead, and zinc, locally abundant enough for exploitation, show marked lateral and vertical zoning, with copper generally most concentrated in the lower layers and in parts of the formation near the Permian shoreline. There are no igneous rocks nearby, no veins, no hydrothermal alteration. In most other deposits for which a syngenetic origin has been proposed one finds enough deviation from strict stratigraphic control, enough places where the ore minerals have followed channels from one layer to another, so that an opposing case can be made at least plausible; but in the Kupferschiefer such evidence is scanty and is readily explained by minor later migration of the metals. To maintain an origin other than sedimentary for this deposit requires considerable temerity.

Now what is the source of the metals? Copper, lead, and zinc are easily detectable in seawater today, and were almost certainly present at similar concentrations in the Permian ocean; hence an obvious first guess is simply precipitation out of seawater. Chemically this is entirely reasonable. The concentrations of the metals, although small, are still sufficient for precipitation in the sulfide-rich environment of an organic-rich black mud; and by juggling equilibria one can account nicely for the successive precipitation of the three metals, hence for the observed zoning. The only difficulty, as Wedepohl emphasizes, is the *amount* of metal. No geologically reasonable conditions would permit anywhere near the observed quantities to be deposited from a shallow basin of normal seawater during the time-span of Kupferschiefer sedimentation. The chemistry of formation of the Kupferschiefer ore is straightforward, but geologically a source of metal other than seawater is required.

Reconstruction of the Permian landscape of northern Germany permits some guesses about possible sources. Another Permian formation underlying much of the

Kupferschiefer, a red sandstone called the Rotliegendes, was exposed to erosion in adjacent areas while the black marl was being deposited. The Rotliegendes is a desert formation consisting largely of sand grains cemented by hematite; the formation as a whole does not have unusual concentrations of trace metals, but Wedepohl and his students (HARTMANN, 1963) have shown that some heavy metals are locally enriched in the hematite cement and in shale lenses where hematite is abundant. The lack of widespread present concentration in the hematite is a weakness in Wedepohl's argument, but at least there is a fair presumption that heavy metals once were more generally abundant and were supplied to the Kupferschiefer sea by surface water or groundwater draining the Rotliegendes. The juxtaposition of a stagnant marine basin and a desert sandstone undergoing erosion, surely not a common situation in the geologic record, accounts for the near-uniqueness of this metal-rich marl.

Speculatively one can look behind the red cement of the Rotliegendes and suggest that its metals in turn may have come from underlying Carboniferous graywacke, or perhaps from erosion of metalliferous veins in the Harz and Erzgebirge to the south. Details of the longer history need not concern us. The important point is the demonstration, which seems convincing in Wedepohl's work, that an ore deposit whose sedimentary origin is well established requires for its formation some sort of previous slight regional enrichment of the metals it contains.

There is nothing new or startling, or course, about this conclusion. Those who have postulated a syngenetic origin for other stratiform deposits in recent years, so far as I know without exception, have envisioned a supply of greater than usual amounts of heavy metals to the sedimentary agent involved. For the Kupferschiefer the previous enrichment is ascribed to another sedimentary process, adsorption on iron oxide cement formed in an arid environment. More commonly the agent of enrichment is assumed to be igneous, particularly volcanic emanations supplied to the basin of deposition—the currently popular "sedimentary-exhalative" hypothesis (for example, STANTON, 1966). Whatever the agent may be, it seems widely agreed that sedimentary processes by themselves, acting on ordinary materials under ordinary circumstances, do not form ore deposits of heavy metals, but may do so if the metals have undergone previous enrichment in the materials being furnished to the sedimentary agents.

MULTISTAGE ORE FORMATION

We have looked at two ore deposits, chosen as particularly clear examples of two commonly assumed processes of ore formation. For both it seems necessary to postulate pre-ore enrichment of the metals they contain. Can we guess, then, that most large ore deposits form in a multistage process—an early slight concentration of metal in a large volume of rock, followed by much more drastic local concentration into the actual ores?

An affirmative reply is equivalent to stating that ordinary geologic processes acting on ordinary materials are generally incapable of forming large ore deposits. For this generalization, analytical data provide a good deal of support.

In igneous rocks the concentrations of trace elements show much variation from one kind of rock to another, a variation that follows well known rules, but in rocks of

similar silica content or similar differentiation index the range of analytical values for a given element is seldom greater than a factor of three or four. The most potent igneous mechanism for sorting out minor elements is the separation of fluid phases in late stages of crystallization, but the general ineffectiveness of this process when initial concentrations are small is indicated by the barrenness of most quartz veins and pegmatite dikes and by the uniformity of composition of granite near them. Surely if segregation of minor elements were a normal part of igneous activity, one would expect to find modest degrees of enrichment and impoverishment more commonly.

Analyses of sedimentary rocks are likewise disappointingly monotonous. By far the largest quantities of minor elements in sedimentary material are reported in shales, and the ranges in most shales are within a factor of three or four for most elements. Occasionally much higher concentrations appear, especially in organic-rich shales, but marked enrichment even here is less common than is generally thought (VINE and TOURTELOT, 1970). Nor is there any indication from compositions of most natural waters, either hot or cold, that trace metals in quantity are likely to be carried to sites of deposition.

The heavy metal content of igneous rocks, sediments, and surface waters seems nicely adjusted, in a sort of large-scale equilibrium, and ordinary geologic processes tend to smooth out local abnormalities of concentration rather than build them up. Details of how the equilibrium is maintained are uncertain, but the general tendency toward uniform distribution of trace elements seems clear from analytical data.

It is equally clear that the equilibrium is far from perfect, that occasionally large volumes of rock acquire slight enrichments of a metal or metals in apparently very ordinary geologic circumstances. This is probably most common during sedimentation: one thinks of the vanadium, nickel, copper, and molybdenum sometimes enriched in black shales, the uranium enriched in black shales and phosphorites, the copper concentrated with red beds, the many metals unusually abundant in some manganese oxide sediments. Igneous rocks seldom show as striking or as widespread enrichment as do some of the less common sediments, but slightly enhanced concentrations in tuffs are often cited as a source of metals in groundwater.

Perhaps it is from such large-scale but fairly minor enrichments—say by factors of at most a few tens of times over average values—that ore deposits can be formed. Various geologic processes, although tending as always toward overall dispersion of trace-metal accumulations, should nevertheless be capable of local intense concentrations of metals from previously enriched material.

EXCEPTIONS

A statement that the metals of large ore deposits commonly have a multiple source requires hedging, for some obvious exceptions come quickly to mind. One is represented by deposits intimately associated with mafic and ultramafic rocks. The nickel ores of Sudbury, the chromium of Turkey, the platinum of the Bushveld complex, the copper of Cyprus—to require for these a pre-enrichment stage would complicate the story needlessly. The source of metal is clearly in the magma itself, and the concentration is adequately explained by differentiation. One can argue

happily about details of the differentiation process, but there seems no need to postulate several stages.

These deposits differ from those associated with more felsic rocks in that the metals they contain are characteristically abundant as minor elements in the igneous rocks with which the ores occur, and that the metals even show preferences for particular kinds of mafic and ultramafic materials. Such intimate and regular association contrasts sharply with the apparently haphazard occurrence of metals like zinc, lead, tungsten, gold, and silver with felsic rocks of different compositions. Mafic and ultramafic magmas, more primitive in the sense that they are immediate derivatives of the mantle, can evidently differentiate so as to concentrate their more abundant minor elements directly, and the distribution of ore deposits in such rocks must be explained by local differences in the extent of differentiation or possibly by regional differences in upper-mantle composition. For granitic rocks the relation of ore deposits to trace-element content is so much more erratic, and the evidence for differentiation as a sole agent of metal concentration is so much more ambiguous, that a different and more complex process of ore formation seems required. Perhaps the multistage process just described, with a sedimentary step usually involved, can provide the necessary complexity.

Another possible exception to the multistage hypothesis is lead–zinc ores of the Mississippi Valley type. If HEYL (1968) is correct in assuming that these ores result from a convectional circulation of groundwater in carbonate rocks, the heat coming from an igneous body somewhere in the hidden basement and the fluid being a mixture of connate and meteoric water with minor magmatic additions, the source of at least part of the metal may be assigned to the minor zinc and lead content of the carbonate rocks. HEYL maintains that this source is quantitatively far from adequate, so that much of the metal must have been brought in by the magmatic fluids, but this conclusion is not universally accepted. Insofar as the metals are derived from the carbonate strata their accumulation would be clearly a single-stage process. One might quibble that lead and zinc are more abundant than most trace elements in limestone, hence that some pre-enrichment occurred before the final concentration by warm water, but this would lead only to a futile semantic argument about the meaning of "enrichment" and "ordinary rock." Far better, I think, to let such ores stand as a possible example of direct concentration of metals from common rocks by an unusual set of geologic conditions.

The sandstone uranium–vanadium ores of the Colorado Plateau (FISCHER, 1968), and the very similar lead–zinc ores in sandstones along the south-east margin of the Massif Central in France (SAMAMA, 1968), might also be cited as possible exceptions, because according to some reconstructions the metals were supplied by groundwater and surface water draining very ordinary rock material. In each case the "ordinariness" of the material is open to question, however. Certainly most students of the Colorado Plateau have tried to show that pre-existing rocks with greater than normal concentrations of uranium and vanadium were available to the solutions that formed the ores (for example, KELLEY *et al.*, 1968). The most reasonable conclusion about such deposits, it seems to me, is that metal accumulation by a single-stage sedimentary process cannot be ruled out, but that some degree of pre-enrichment of the metals is a more plausible assumption.

SEDIMENTARY VERSUS IGNEOUS EFFICIENCY

If the formation of most large ore accumulations requires more than one step of metal concentration, can any generalization be made about the nature of the successive steps? In particular, are igneous processes or sedimentary processes more effective in the preliminary regional enrichment? And which of the two kinds is more efficient for the stage of final concentration? For questions as broad as this, one can hardly expect more than very general answers.

To accomplish the early enrichment of metals in large volumes of material, I would hazard a guess that sedimentary agents are the more effective. In comparison with igneous activity, the processes of erosion and sedimentation have greater variety. The most conspicuous sorting of metals by sedimentation takes place during the formation of organic-rich black muds, and here the particular metals that undergo slight enrichment depend on many variables—the degree and persistence of anerobic conditions, the availability of sulfur, the pH, the kinds of organisms present. The diversity of metals that sometimes are considerably enriched in such environments is well documented in VINE and TOURTELOT's (1970) compilation of black shale analyses. Other opportunities for large-scale enrichment of particular elements are provided by differences in metal behavior during weathering and by differential adsorption on clay minerals and hydroxide sediments. Igneous activity, by contrast, concentrates metals chiefly by the single process of magmatic differentiation, which may lead to slight differential enrichment of metals from low concentrations because of variations in temperature, pressure, and kinds of volatiles, but which can hardly offer as much variety as the wide spectrum of sedimentary possibilities.

For the later stages of ore formation, the step or steps that lead to the final concentration of metals into deposits that can be mined, I would guess that igneous processes are generally more efficient. The nearly complete separation of heavy metals from a slightly enriched silicate melt into residual aqueous fluids has been abundantly demonstrated with both field and laboratory observations, and the process is fast enough for ore formation in geologically reasonable times. Another process resulting from igneous activity, the circulation of groundwater heated and set in motion by a nearby intrusive, is also effective for the rapid local concentration of metals from pre-enriched material. Sedimentary separations, on the other hand, are usually much less clean-cut, and to be effective in ore formation require that a delicate balance of conditions be maintained for such long periods that they can hardly be frequent in the geologic record.

Although it seems likely that early steps in ore formation are most commonly sedimentary and later steps igneous, for some deposits the sequence may be reversed and for others the successive steps may be entirely igneous or entirely sedimentary. A stratiform ore body deposited by sedimentary agents supplied with metals from a volcanic source, for example, would clearly involve preliminary igneous enrichment followed by final sedimentary concentration; the igneous enrichment might have been preceded by a step of sedimentary concentration in the materials from which the magma was derived, but all trace of this earlier history would be lost. An example of an ore deposit formed entirely by successive sedimentary concentrations is provided by the Kupferschiefer—unless part of the metal is traced far back to igneous processes accompanying the Variscan orogeny.

To find a convincing illustration of ores formed exclusively by a succession of igneous processes is more difficult, but some of the large copper deposits may have this origin. Copper is an element of extraordinary geochemical versatility: it is an abundant minor element of mafic rocks and often forms minor concentrations in them, probably by single-stage differentiation; many important copper deposits are associated with felsic igneous rocks of a great variety of compositions; and copper can also be enriched by sedimentary processes, as is shown by local high concentrations in red beds and in black shales. Where copper forms ores associated with felsic igneous rocks its concentration may be reasonably ascribed to differentiation; and the magma undergoing differentiation may have formed either by anatexis of sedimentary rocks slightly enriched in the metal, or alternatively by earlier differentiation of a more mafic magma. Choosing between these alternatives is impossible for most such deposits, but a porphyry copper on Bougainville described by BURNHAM (personal communication) has almost certainly an entirely igneous history because it is only a few million years old and far from the nearest area of continental crust.

Thus a very general argument about the efficiency of geologic processes suggests that successive concentrations of metal may take place in many ways, but that a common sequence for large ore deposits is early enrichment by dominantly sedimentary processes and later concentration by igneous processes.

BROADER PERSPECTIVES

This kind of free-wheeling speculation does not bring us much closer to answers for specific questions about source—for example, why is there so much tungsten in the southern Sierra Nevada, and so much copper in southeastern Arizona? We suggest vaguely, "Because at some time in the past the metals may have been somewhat enriched in regionally extensive volumes of sediment, and then igneous processes caused later local concentration of some of the excess metal." But a skeptic would immediately demand, "What sediments? When were they deposited, and what has become of them?" One can only reply, even more vaguely, that the enriched sediments must date from the distant past, perhaps in both cases from the Precambrian—and this is most unsatisfactory, because it falls back on the old geological dodge of putting events so far in the past and so far underground that no evidence pro or con can possibly be adduced.

By carrying our speculations one step further we can perhaps make the picture a little less vague. We turn for a moment to conditions on the primitive earth. Somehow, on general philosophical grounds, we imagine things in the remote past to have been simpler, more uniform, more homogeneous than they are today. So we think of the earth at one time as having had a uniform crust of generally basaltic composition, similar to the present oceanic crust, formed by differentiation from the mantle. Presumably parts of the crust were in motion, impelled by currents in the mantle beneath, just as the oceanic crust is in motion today. Some areas would be exposed to weathering and erosion, so that sediment would accumulate locally. Part of the sediment would be dragged down with the moving crust into the upper mantle, and the familiar cycle from sedimentary to metamorphic to igneous rock would get under way. At some time in the early cycles the first masses of granite

would form. It is interesting to wonder whether granite in large amounts could have formed at all without sedimentation, without some preliminary sorting out of the basaltic raw material by air and water, but this is another story.

For a time all the new-formed sedimentary and granitic rocks would be recycled through the upper mantle, but eventually a day would come when patches of the siliceous scum would accumulate in amounts too great to be dragged down in their entirety by the suberustal currents. So the continents would be born, and new possibilities of sedimentation would be opened up. With the appearance of life the variety of sedimentary environments would be enormously increased, for now reducing conditions on a large scale could persist for long periods. All the possibilities that we find in the modern world for minor enrichment of elements in large volumes of material would exist from that time forward.

In the early days the continents would still be undergoing fragmentation and partial engulfment by the restless mantle beneath, probably on a scale much greater than at present. Large volumes of sedimentary rock, in some areas slightly enriched in one metal or another, would be carried down in subduction zones and subjected to partial melting, and the excess metal might be added to either the lower crust or upper mantle. Thus the sedimentary origin of the enrichment would be erased, and some part of the material above the asthenosphere would acquire more than its average metallic content. The same process of enrichment has presumably gone on at a decreasing rate down to the present day.

When I say, then, that Sierra Nevada tungsten or Arizona copper might have been enriched orginally by sedimentary agents, I do not imply that a super-drill which could penetrate many kilometers beneath these areas would necessarily bring up cores of metal-rich sedimentary rock. The drill should indeed encounter somewhere above the asthenosphere a layer containing tungsten or copper at concentrations a few tens of times greater than the average for the earth's crust, but the layer might or might not retain signs that would betray its sedimentary origin. Magma originating in such a layer would have an abnormal metal content which could be locally concentrated into ore deposits. Successive episodes of magma generation might produce deposits of the same metal at different geologic periods, as has happened in Arizona. A specific layer must be assumed rather than an enhanced metal content through the entire crust and mantle below eastern California and southern Arizona, because in each area some igneous rocks are found which are not accompanied by ore deposits or by any sign of metal concentration, and which therefore presumably originated at levels having no enrichment in copper or tungsten.

To avoid wordiness I have suggested only sedimentary processes as the agents of preliminary metal enrichment. For Sierra tungsten I think this restriction is justified, but for Arizona copper an original enrichment by differentiation of mafic magma on a regional scale is just as plausible as the sedimentary hypothesis.

What all this says in effect is not very different from the conclusion reached by many students of ore distribution in the western United States, that the extraordinary abundance of particular metals in particular areas, with little apparent pattern and little regard to structure or to kinds of igneous rocks, can be reasonably explained only by assuming metal concentrations in the material somewhere beneath. The most comprehensive study of this sort is NOBLE's (1970) recent paper, in which

he argues that the metals must have had a "primitive heterogeneous distribution in the upper mantle." I differ with Noble only in trying to be more specific about the location and origin of the heterogeneity. To assign metal concentrations to "primitive" inhomogeneities in the mantle implies a perpetually static mantle that is hard to reconcile with current ideas about the mobility of the outer part of our planet. I have tried simply to find in ancient sedimentary and igneous processes, coupled with movement in subduction zones, a mechanism for explaining how metal concentrations in particular areas and in restricted layers of the material above the asthenosphere might have come about.

Possible Tests

Where can one look for evidence to support or discredit so nebulous an hypothesis? Really convincing tests are hard to find.

Seemingly analytical data should help. If intrusive rocks with associated ore deposits represent magmas originally enriched in the ore metals, one might expect to find higher than average amounts of the metals remaining in the rocks. The Sierra Nevada granite, for example, should contain more than the usual 1–2 ppm of tungsten. Analyses in general do not bear out this expectation. With the single exception of tin, metals show no consistent relation between trace amounts in an intrusive and the nature of associated ores (Krauskopf, 1967). Some intrusives are enriched in the metals of adjacent ore deposits, others are depleted, and many show no change from average values. For tungsten as an example, although data are not available for the Sierra Nevada, extensive analytical work on Siberian intrusives has convinced Ivanova (1963) that trace amounts of tungsten in the granites of mineralized areas may show wide variation, but cannot be correlated with the presence or absence of tungsten deposits. Analytical data at best are ambiguous, because an excess or deficiency of metal in the exposed parts of a granite may just as well be due to permeation by later ore-forming solutions as to an original characteristic of the rock. The most reasonable interpretation of the fragmentary available data is that any excess of metal which may once have existed in a slightly enriched magma is largely removed during ore formation.

Better support for the hypothesis lies in the observation that ore deposits are lacking or nearly so on oceanic islands, in areas of plateau basalts, and in other places where material directly derived from the mantle is exposed at the earth's surface. An immediate exception, of course, is deposits of the metals characteristic of mafic and ultramafic rocks—copper, nickel, chromium, platinum. For the other common ore metals, large accumulations are restricted to areas of continental crust, to places where a combination of igneous and sedimentary activity may be confidently assumed. A skeptic might counter with Bostrom and Peterson's (1966) observation that sediments at the summit of the East Pacific Rise are abnormally rich in lead as well as nickel and chromium, presumably added by fluids rising directly from mantle material; a possible reply is that local concentrations of a few hundred parts per million can arise by chance variations anywhere, and that such concentrations do not constitute ore deposits. A more serious objection can be based on the presence of huge quantities of zinc-rich sediment in basins of the Red Sea, in a situation where movement of adjacent lands is opening a rift that might

function as a channel for fluids from the mantle (MILLER *et al.*, 1966); a reasonable reply here is that other plausible sources of zinc are available in nearby sedimentary and volcanic materials. Except for these possible anomalies, the restriction of ore-metal concentrations to the continents is striking. If *all* ore metals are supposed to rise haphazardly from the deep mantle, or to be concentrated by direct differentiation of mantle material, their near-absence from oceanic islands is hard to explain.

A second observation of possible significance is the scarcity of ore deposits near the Pacific coast of the United States, in contrast to the abundance of deposits farther inland. In California and southern Oregon the basement rock underlying much of the Coast Ranges is the Franciscan formation, a supposedly eugeosynclinal assemblage of sedimentary and volcanic material resting directly on oceanic crust (PAGE, 1970), containing an abundance of rocks like limestone and mafic tuffs and lavas which elsewhere are frequently hosts for ore deposits. Why should mineralization be so meager here? A possible answer is that the Franciscan rocks are too immature, too little worked over by sedimentary and igneous processes. They are all, so to speak, first-generation material, derived by differentiation or by rapid erosion and sedimentation directly from the mantle or mantle products. Give them a few more tens of millions of years, a few cycles of sedimentation and anatexis, and prospectors may yet find good hunting in the Franciscan.

Ores are scarce in the Franciscan but not completely absent, and the kinds of deposits that do exist are worth noting. In serpentinized peridotite that intrudes the formation widely and forms at least part of its basement there are many small chromite deposits, a few places where nickel is abundant enough so that lateritic weathering in the Tertiary has produced minor concentrations, and enough platinum to furnish a few grains to beach and stream placers. Chalcopyrite forms a few small concentrations in the mafic and ultramafic rocks, some of them rich enough for exploitation in the past. Then there are small manganese accumulations, commonly associated with chert and greenstone, probably formed when hot lava moved into shallow sea water; in a sense this process would telescope the sedimentary-igneous cycle, for the reaction of hot salt water with lava resembles chemically an enormously speeded-up process of weathering. Most famous of the ores associated with the formation are the mercury deposits, which are not restricted to Franciscan rocks but are commonly not far distant from them. The source of the mercury has long been a puzzle, but it is often thought to have been sweated out of Franciscan sediments by heat from pockets of Cenozoic magma that fed adjacent volcanic piles. In such a mechanism mercury would represent simply the first metal to be slightly enriched during sedimentation and then locally concentrated by igneous activity. Thus the metal concentrations of the Franciscan are what might be expected in first-generation mantle-derived material: random minor concentrations of metals characteristic of mafic and ultramafic rocks, local enrichment of manganese by violent lava-seawater interaction, and local concentration by much later volcanic activity of the most volatile of all ore metals.

Parenthetically, this picture of the Franciscan formation helps to explain a fact that has long puzzled me. The San Andreas fault along much of its course cuts Franciscan rocks or separates them from others, and some of the Franciscan rocks should be easy prey to replacement by metal-bearing solutions; yet nowhere along

the huge rift, with the possible exception of the brine wells near the Salton Sea, is there any sign of ore-forming activity or even of hydrothermal alteration. Like major structures elsewhere, the San Andreas fault seems strangely dead with respect to fluid movement. If ore formation were simply a matter of fluids rising out of the mantle wherever access to the upper crust is easy, surely the San Andreas would be lined with major deposits. But if metal concentration generally requires an interplay of sedimentary processes that take place near the surface and igneous processes in the lower crust and uppermost mantle, then a rift like the San Andreas, no matter how deeply it may penetrate, is simply irrelevant to ore formation.

Recapitulation

By way of summary, I have been trying to reconcile two points of view about the source of metals in large ore deposits: the widely assumed, strictly uniformitarian idea that ordinary rocks are a sufficient source, given the right combination of ordinary geologic processes, and the opposing conclusion generally reached by those who meditate on the large-scale geographic distribution of ore deposits that metals must come largely out of the mantle.

The observation that geologic processes in the present world only rarely lead to even minor concentrations of ore metals, coupled with the fact that ores of many different metals can occur indiscriminately with similar kinds of rocks and in similar geologic situations, suggests that ore accumulation is often a multistage process. Ordinary rock material may well be the ultimate source, and ordinary processes the agents of metal concentration, but the history of a deposit must generally involve more than one step. Guesses about relative efficiencies of various processes suggest that a common sequence is slight enrichment in large volumes by sedimentary agents, followed by strong local concentration during igneous activity. Early steps in multistage concentration may date from the distant past, and may now be evident only in slight regional enrichments in layers of the lower crust and upper mantle. Hence the immediate source of metal may lie well below parts of the crust now exposed to view, but a source in the deeper mantle is excluded by the evidence for differential movement between rocks above the asthenosphere and rocks below. Thus the opposed points of view about source are reconciled by deriving ore metals ultimately from ordinary rock materials, but adding the postulate that these materials have undergone a sequence of igneous and sedimentary processes, and in considerable part have been carried down in subduction zones to become part of the lower crust and upper mantle.

If ore formation is a long-continued, multistage process of this sort, and if particular ore metals are regionally enriched in discrete layers below the upper crust, it follows that ore deposits should be most numerous in regions that have undergone much orogenic and igneous disturbance, that the geographic distribution of metals is largely determined by events of the remote past and may now seem almost entirely random, and that a given metal may form ore deposits of different ages in a single region. These consequences accord with observation, but the agreement is hardly cause for rejoicing. The points of agreement are much too vague and general to constitute a rigorous check. One can suggest further that the hypothesis would predict the limitation of most ore deposits to continents, the scarcity of ores

in geosynclinal strata lying directly on oceanic crust, and the seemingly anomalous lack of ore deposits along major structures like the San Andreas fault. But again these are general observations that could be explained in other ways. What one needs is a specific prediction about where deposits of a specific metal will be found, and of course for such predictions this hypothesis is not suited. Far from helping in the practical search for ores, the hypothesis tends in the opposite direction by giving theoretical support to the old despairing conclusion that "gold is where you find it."

So at the end of all this rumination I find that I have merely added another to the long list of not-very-useful hypotheses that have punctuated the history of economic geology. One can never be comfortable proposing an idea that fails to satisfy the most elementary criterion of a good scientific hypothesis—the possibility of formulating an experiment or imagining an observation that would clearly disprove it. Only one such possibility for the future has occurred to me: if a mission to the moon should discover huge deposits of gold and silver, I will forthwith abandon this notion and start looking for some other way to attack Goldschmidt's problem of the distribution of ore metals in the earth's materials.

Acknowledgments—Many of the ideas expressed herein I owe to conversations with colleagues and students, and to articles and books I have read over a long period of time. How some of the ideas entered my thinking I have long since forgotten, and proper acknowledgments are impossible. The list of references, in particular, is less complete than it should be, not through intention but simply from gaps in my memory. I am especially indebted to my colleagues CHARLES F. PARK, JR. and FRANK DICKSON, who kindly read the manuscript and made valuable suggestions.

REFERENCES

BATEMAN P. C. (1965) Geology and tungsten mineralization of the Bishop District, California. *U.S. Geol. Surv. Prof. Paper* **470**, 208 pp.

BATEMAN P. C. and DODGE F. C. W. (1970) Variations of major chemical constituents across the central Sierra Nevada batholith. *Geol. Soc. Amer. Bull.* **81**, 409–420.

BOSTROM K. and PETERSON M. N. A. (1966) Precipitates from hydrothermal exhalations on the East Pacific Rise. *Econ. Geol.* **61**, 1258–1265.

FISCHER R. P. (1968) The uranium and vanadium deposits of the Colorado Plateau region. In *Ore Deposits in the United States 1933/1967*, Vol. 1, (editor J. D. Ridge), pp. 735–746. Amer. Inst. Min. Metal. Petrol. Engineers.

GOLDSCHMIDT V. M. (1954) *Geochemistry*, (editor A. Muir). Oxford University Press.

HARTMANN M. (1963) Einige geochemische Untersuchungen an Sandsteinen aus Perm und Trias. *Geochim. Cosmochim. Acta* **27**, 459–499.

HEYL A. V. (1968) The Upper Mississippi Valley base-metal district. In *Ore Deposits in the United States 1933/1967*, (editor J. D. Ridge), Vol. 1, pp. 431–459. Amer. Inst. Min. Metal. Petrol. Engineers.

IVANOVA G. F. (1963) Content of tin, tungsten, and molybdenum in granites enclosing tin-tungsten deposits. *Geochemistry* **1963**, 492–500.

JEROME S. E. and COOK D. R. (1967) Relation of some metal mining districts in the western United States to regional tectonic environments and igneous activity. *Nevada Bureau of Mines Bull.* **69**, 35 pp.

KELLEY V. C., KITTEL D. F. and MELANCON P. E. (1968). Uranium deposits of the Grants region. In *Ore Deposits in the United States 1933/1967*, (editor J. D. Ridge), Vol. 1, pp. 747–769. Amer. Inst. Min. Metal. Petrol. Engineers.

KRAUSKOPF K. B. (1967) Source rocks for metal-bearing fluids. In *Geochemistry of Hydrothermal Ore Deposits*, (editor H. L. Barnes), pp. 1–33. Holt, Rinehart & Winston.

MILLER A. R. *et al.* (1966) Hot brines and recent iron deposits in the deeps of the Red Sea. *Geochim. Cosmochim. Acta* **30**, 341–360.

NOBLE J. A. (1970) Metal provinces of the western United States. *Geol. Soc. Amer. Bull.* **81**, 1607–1624.

PAGE B. M. (1970) Oceanic crust remnant on land near San Luis Obispo, California. *Geol. Soc. Amer. Abstracts with Programs*, Vol. 2, No. 7, 643–644.

SAINSBURY C. L. and HAMILTON J. C. (1967) Geology of lode tin deposits. Technical Conference on Tin of the International Tin Council, March 1967, 35 pp.

SAMAMA J. C. (1968) Contrôle et modèle génétique de minéralisation en galène de type "red beds". *Mineralium Deposita* **3**, 261–271.

SCHMITT H. A. (1966) The porphyry copper deposits in their regional setting. In *Geology of the Porphyry Copper Deposits, Southwestern North America*, (editors S. R. Titley and C. L. Hicks), pp. 17–33. University of Arizona Press.

SCHUILING R. D. (1967) Tin belts on the continents around the Atlantic Ocean. *Econ. Geol.* **62**, 540–550.

SPURR J. E. (1923) *The Ore Magmas*, Vol. 2. McGraw-Hill.

STANTON R. L. (1966) Compositions of stratiform ores as evidence of depositional processes. *Inst. Mining and Metallurgy (London) Trans.*, Sec. B, Vol. 75, pp. B75–B84.

VINE J. D. and TOURTELOT E. B. (1970) Geochemistry of black shale deposits—a summary report. *Econ. Geol.* **65**, 253–272.

WEDEPOHL K. H. (1964) Untersuchungen am Kupferschiefer in Nordwestdeutschland. *Geochim. Cosmochim. Acta* **28**, 305–364.

WEDEPOHL K. H. (1971) "Kupferschiefer" as a prototype of syngenetic sedimentary ore deposits. Reports of Meeting of Internat. Assoc. on Genesis of Ore Deposits, Japan, Aug.–Sep. 1970 (in press).

(47)

AMERICAN SMELTING AND REFINING COMPANY
EXPLORATION DEPARTMENT
EASTERN UNITED STATES DIVISION
2640 BROADWAY, N. E.
KNOXVILLE, TENN. 37917

J. V. DESVAUX
EXPLORATION SUPERVISOR

RECEIVED
OCT 5 1971
EXPLORATION DEPT.

October 4, 1971

Mr. J. H. Courtright, Chief Geologist
American Smelting and Refining Company
P. O. Box 5747
Tucson, Arizona 85703

ANNUAL EXPLORATION MEETING
An Exploration Technique--
Possible "Roll-Front" Color
Changes in Overlying Shales and
Clastic Portions of Carbonate
Host Rocks in Mississippi Valley
Type Deposits

Dear Mr. Courtright:

With reference to Mississippi Valley Type Deposits in their report on "Roll Fronts" (October 8, 1970), Von Fay and Hoskins suggest "that very careful study of any color change in all beds through the dolomite front is warranted". In the hope that such color changes might be physically located closer to ore deposits than limestone dolomite facies, or that they might at places exhibit an angular relationship with dolomite-limestone fronts, or that they might be more abrupt and regular than carbonate fronts, literature research was instigated on several Mississippi Valley Type Mining Districts. Although detailed data is not everywhere available, it was learned that in several districts minor amounts of shale or siltstone within host carbonate units or portions of overlying shaley units exhibit color changes that might be ascribed to "roll-front" activity and that, in places, exhibit a closer physical relationship with ore than do dolomite-limestone fronts. Although the exact nature and genesis of these color changes is not well known, future exploration for Mississippi Valley Type Deposits should pay special attention to such changes.

Very truly yours,

Jerry N. Biery

Jerry N. Biery

JNB:ad

cc: JJCollins ✓

W. L. K. 48

OCT 4 1971

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OCT 7 1971

EXPLORATION DEPT.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 4, 1971

TO: W. L. Kurtz

FROM: J. C. Balla

Annual Exploration Meeting

Subject: Relative position of porphyry copper deposits to barren Laramide stocks.

Mapping along the northeast trending lineament between Casa Grande and Miami has shown that there are a number of barren, Laramide granitic stocks in this zone, and that these stocks are internally zoned. These barren stocks are aligned such that the long axis of the stock is parallel with the regional structure. The ends of these stocks are zones of strong cross fracturing, and it is in these zones that porphyry copper deposits are most likely to occur.

This setting, which occurs elsewhere in Arizona (see attached sheet as an example) can be used as a guide to looking for buried porphyry copper deposits. If part of a barren stock is exposed in a mountain range, the orientation of the barren stock will give a clue as to the direction of the regional structure, and hence the direction along which to look for a buried porphyry copper deposit.

John

J. C. Balla

JCB:lad
Attach.

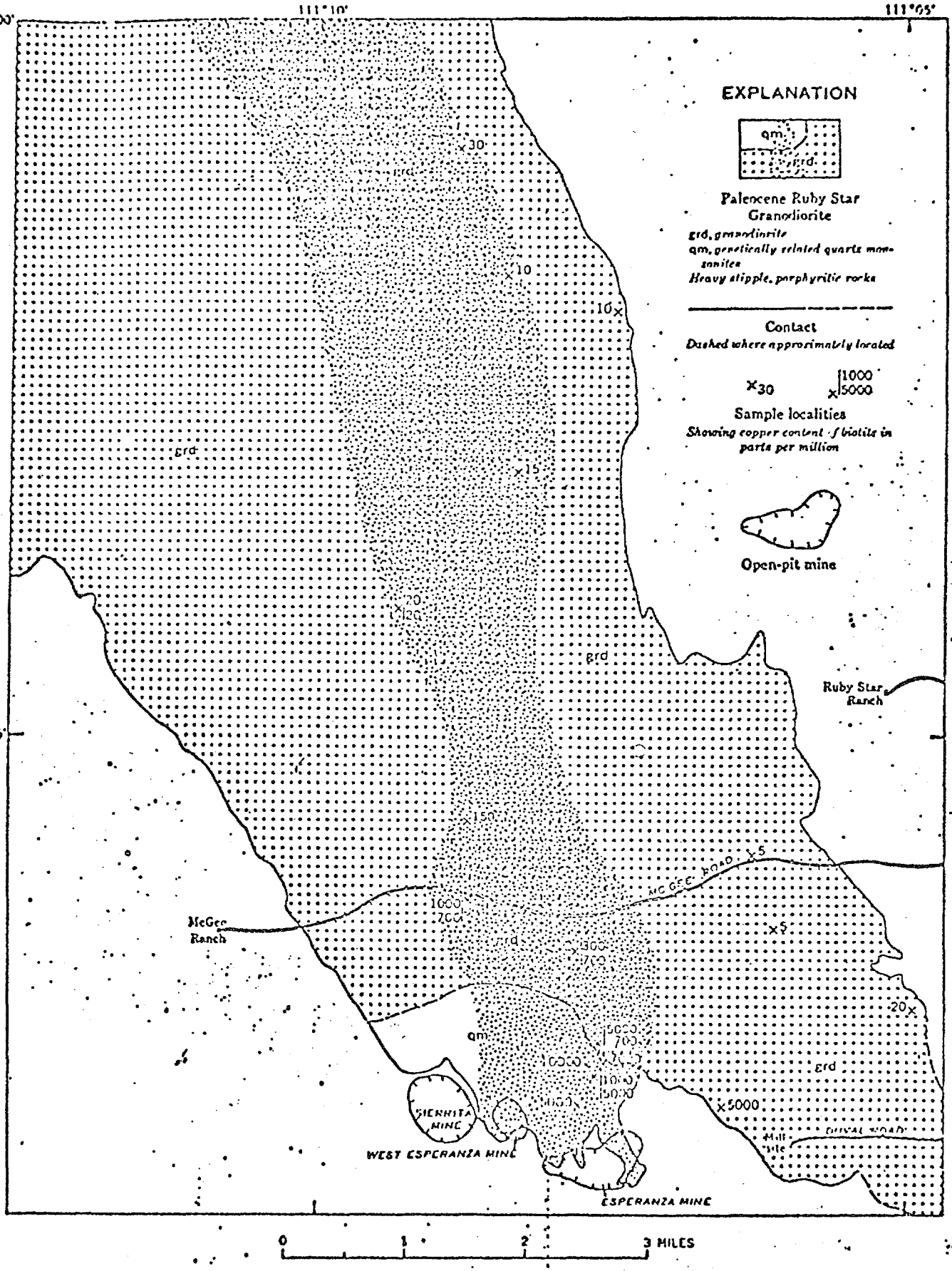


FIGURE 2.—Generalized map of composite stock and associated ore deposits in the southwestern part of the Pima mining district, east of the Sierrita Mountains, showing sample localities and copper content of biotite.

JDSell

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

November 10, 1971

Annual Exploration Meeting Topic:

Relative position of porphyry copper deposits to barren Laramide stocks.

References:

1. Emmons, W.H., On the Mechanism of the Deposition of Certain Metalliferous Lode Systems Associated with Granitic Batholiths, in Ore Deposits of the Western States, Lindgren Volume, 1933. This paper is concerned with large batholiths (Sierra Nevada type), but the basic concept is probably applicable to barren Laramide stocks. Much of the specific comments in the volume are, of course, out of date.

2. Ettlinger, I.A., Ore Deposits support hypothesis of a central Arizona batholith, AIME Tech. Pub. 63, 1928. An old, obscure paper concerned with the Globe-Miami district.

3. Lovering, T.G., Cooper, J.R., Drewes, H., and Cone, G.C., 1970, Copper in biotite from igneous rocks in southern Arizona as an ore indicator: U.S. Geol. Survey Prof. Paper 700-B pp. B1-B8, particularly pages B5-B8. One of the few recent papers explicitly stating that a porphyry copper deposit is related to a barren Laramide stock.

John

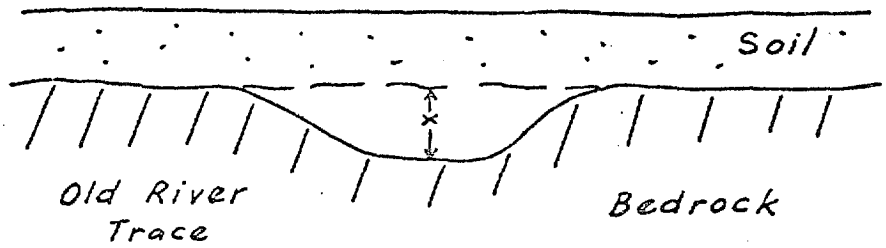
John C. Balla

JCB:lad

cc: All participants

Uses of Infra-Red photography coupled with Magnetometer Surveys

Infra red photographs of the area to be explored should be taken and due to the distance x (see diagram below) a difference should show,



This method might be applied to possible erroneous magnetic anomalies over soil covered areas in the search for say nickel. That is, the anomalous magnetic results might be due to heavy minerals concentrating in that part of the buried river where the energy of the water was low.

Conversely, where it is desired to know the location of old river traces for the purpose of finding gold or diamonds, Infra-Red photographs could be used to detect the old river trace, followed by a magnetometer survey to pick up the anomalous area, which would be the equivalent of a low energy area: The place where the gold or diamonds are most likely to be.

Arnold Franks
ASARCO, PERTH, WESTERN AUSTRALIA

Kimberlite Pipes and Carbonotite

Kimberlite pipes and Carbonotites have definite relationships to each other, therefore the detection of either one will help in the search for the other.

Before an area is to be stream sampled for base metals etc., it should be noted if the regional setting perhaps conforms to an ideal geological setting for Kimberlite pipes or Carbonotites.

Rift valleys have a definite relationship to Carbonotite and Kimberlite pipes, and are indicated by abnormally low gravity anomalies.

The regional area for Kimberlite pipes is a shield area flat that has escaped strong horizontal compression since Precambrian times.

Stream samples coming from areas as mentioned above should have additional work done on them. The samples should be panned to detect garnets, analysed for high concentrations of titanium, phosphorous and boron. In addition to, the establishing of background values for the following ratios:

$$\frac{Ni}{Co}, \frac{Al}{Ga}, \frac{K}{Rb}, \frac{Ca}{Sr}, \frac{Nb}{Ta}, \text{ and especially } \frac{Cl3}{Cl2}$$

These ratios help to delineate streams draining ultrabasic areas, as opposed to those draining Kimberlite and Carbonotite areas.

Arnold Franks
ASARCO, PERTH, WESTERN AUSTRALIA

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AMERICAN SMELTING AND REFINING COMPANY
2640 Broadway, N. E.
Knoxville, Tennessee 37917
October 5, 1971

51

MEMORANDUM TO MR. J. H. COURTRIGHT

Possible Exploration Guides for
Massive Sulfide Deposits in Sediments

Many massive sulfide deposits in sedimentary rocks rank among the largest producers of non-ferrous base metals in the world. In spite of this, little exploration effort has been expended on them, because the geophysical techniques used in exploring for massive sulfides in volcanic rocks do not have enough resolution for use in sediments. A need exists to develop geological ideas for use in an exploration program for these large deposits.

From a review of the literature on Mt. Isa and Sullivan, it appears that the sulfide bodies:

1) are in black argillaceous shales

2) are grossly conformable but locally disconcordant

3) consist mainly of pyrite and pyrrohotite with varying amounts of chalcopyrite, sphalerite, galena and other minor sulfides

In addition to the above characteristics, the massive sulfides appear to be surrounded by anomalous amounts of iron sulfide. Possibly this is a reflection of their fumerolic origin and may serve as an exploration guide in exploration for them.

The following criteria appear to be useful as geological guides in exploration for these deposits:

1) An area should be in a province which is rich in non-ferrous base metal deposits. Attention should be paid to black argillaceous shales in sediment accumulations overlying earlier volcanic belts of the same orogenic cycle. Since massive sulfide deposits are often associated with the volcanics in the Archean greenstone belts in the Superior Province of the Canadian Shield, the later sediments overlying these greenstone belts deserve special emphasis in exploration.

2) Pyrite and/or pyrrohotite distribution should be mapped in order to choose an area to concentrate in since these deposits seem to be surrounded by halos of anomalous iron sulfide content.

3) Geologic field mapping should be used to pick out features such as faulting and folding which appear to be related to or reflected by ore localization.

Once an area has been chosen for detailed work some of the traditional methods such as geochemical and geophysical surveys will probably be useful.

John C. Rishel

John C. Rishel

JCR:ad
cc: JJCollins

(52)

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 6, 1971

TO: W. L. Kurtz

FROM: R. B. Cummings

Ore Fluid Chemistry as a Guide
to Porphyry Copper Mineralization

To date, guides to porphyry copper mineralization have been concerned with examination and interpretation of various products or resultants of the mineralization. A more direct approach would be an interpretation of one of the basic constituents which produced the mineralization. Interpretation of the chemical and physical properties of the ore solution through fluid inclusion studies is one means of accomplishing this end.

Recent fluid inclusion studies by the USGS near Battle Mountain, Nevada may have applications in interpretation of porphyry copper type mineralization. It was found that fluid inclusions, associated with copper mineralization (in primary and secondary quartz) were dense, strongly saline, and sometimes CO_2-rich. Some inclusions contain daughter salt minerals which can be identified by standard petrographic methods. The above occurrence in the fluid inclusion represents a salinity of greater than 30 weight percent in the ore solution. Edwin Roedder (in Geochemistry of Hydrothermal Ore Deposits, ed. Barnes) states that this type of inclusion is common in some porphyry copper deposits (and some epithermal deposits), but absent in most hydrothermal ore deposits. Roedder postulates that near-surface boiling of the saline ore fluids might have produced this type of inclusion.

It is suggested that strong salinity and other properties of a hydrothermal solution (such as density, temperature, and pressure) might be utilized to distinguish barren from economic mineralization in the porphyry copper environment.

R. B. Cummings lad
R. B. Cummings

RBC:lad

cc: JJCollins

Mr. Kurtz

JDS

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NOV 1 1971
S. W. U. S. EXPL. DIV.

New York, October 29, 1971

MEMORANDUM FOR: Division Supervisors
Exploration Department

Annual Meeting

Herewith are six more "idea" suggestions for the Annual Meeting. Numbers 55, 58, 59* have been chosen for their value as subjects for discussion. Participants should study these topics and prepare to discuss them, as well as the papers previously distributed.

Wherever possible speakers should circulate copies of their references early enough for other participants to check their bibliographic sources.

Please bring this to the attention of your staff.

John J. Collins

Attachments

* Place up front with others.

(53)

AMERICAN SMELTING AND REFINING COMPANY
Denver Colorado

October 5, 1971

HYDROGEOCHEMICAL EXAMINATION OF GROUND-WATER AS A METHOD FOR BASE METALS EXPLORATION

Abstract

Through geological time, not only surface waters but also ground waters are considered as a major transportation medium.

However, chemical reactions in supergene environments and in weakly concentrated solutions, heavily depend on time for direct contact with mineral and chemical components. Chemical and physical characteristics of ground water also depend on mineralogic and lithologic type of permeable rocks. Even barely soluble elements, if in sufficient contact with moving ground water, can be extracted from one place and deposited in another.

Using the known pattern of distribution of fresh and brackish waters occurring along sea coasts, it is thought that similar vertical and lateral zonation should exist in the vicinity of ore bodies.

Based on the above mentioned empirical assumptions, a hydrogeochemical exploration method for base metals is proposed. It is specifically recommended to precisely examine water samples collected from different depths of existing abandoned or temporarily not exploited water wells. Water samples could be examined in ASARCO'S geochemical laboratory and the following parameters should be determined: Eh and pH, SO_4 and CO_3 content, and cationic concentration of major and minor trace elements.

It is recommended that in the first stage, hydrogeochemical exploration methods should be tested on three different base metal deposits. One proposed area for testing this method is a stratibound copper deposit located in Baca County, SE Colorado, and its near vicinity in New Mexico and in Oklahoma.

If the test exploration stage is successful, technical specifications for a further program will be made. Perhaps for more efficient exploration, a field laboratory, and special drill holes would also be benifical.

I should mention that by applying hydrogeochemical exploration methods, Russian investigators claim great success, such as the discovery of the huge Dzazkhazgan copper ore body.

Jan Krason

(54)

AMERICAN SMELTING AND REFINING COMPANY
Denver Colorado

October 5, 1971

HYDROGEOCHEMICAL EXAMINATION OF GROUND-WATER AS A METHOD FOR BASE METALS EXPLORATION

Abstract

Through geologic time, in subsurface natural environments, ground-water is the most significant transportation medium. Its chemical load depends on chemical and physical conditions of permeable rocks.

If ground water moves relatively rapidly through porous and permeable strata, or if normal supergene environments are disturbed, only the easiest disolved solids and suspended particles can be transported. It is also well known that even so called impermeable rocks transmit great amount of ground water. But in this case, water moves very slowly, and all fine grained rock particles and disseminated minerals are accessible to water. There is obviously enough time for chemical reactions in weakly mineralized media. In such environments even very difficultly disolved solids may be mobilized. Mobilized solids will move with ground water, and they will precipitate in adequate geochemical and physical environments.

It is also known that in certain physical conditions precipitation depends on saturation and solubility of particular chemical and mineralogical components. For most of the sulfides the solubility ratios and sequence of solubility is known, so that if we determin the chemical concentration of only some of them, and if any hydrogeochemical trend is noticed, the location of other sulfides may be predicted.

An almost similar process is involved when weakly mineralized ground water penetrates through a highly concentrated ore body. Only in this case, at distances from ore reserve, the total metal amount in ground water will decrease.

In both cases, if chemical and physical characteristics are precisely determined, ground water should be a direct guide to ore.

Considering the fact that in relatively uniform permeable rocks, ground water moves also in a laminar form, and per analogy with contamination of ground water by saltier and heavier brackish water occurring usually below the zone of lighter fresh water along sea coasts, it is thought that a similar vertical and lateral zonation should occur in ground water containing abnormal amounts of disolved metal solids.

I acknowledge many publications expressing considerable work on the examination of surface and ground waters for base metals exploration, but it appears that in most of the cases, water samples were taken by pumping. There was an insufficient effort make to examine base metals concentrations in ground water horizons, particularly in their vertical and lateral zones.

When suggesting hydrogeochemical exploration methods for ASARCO, I was informed by Mr. C.K. Moss that generally similar proposals were prepared by Mr. Peter Solomon, from Carpenteria Exploration Company Ltd, Brisbane, Australia, and a copy of the technical report, dated October, 1965 (No. GEO-82) was also submitted to Mr. C. Pollock.

Mr. P. Solomon draws attention to the fact that "recently Russian geochemists, working in the black soil plains of Central Kazakhstan have published a series of papers giving brief descriptions of methods of hydrogeochemistry developed to cover areas where conventional methods do not apply."

Now, especially after discovery of a huge copper ore body in Dzazkhazgan and some others in Siberia, it is known that their hydrogeochemical exploration methods were very successful. It is recommended that we utilize hydrogeochemical methods.

This exploration method could be applicable anywhere, but particularly in areas with thick overburden and existing deep water wells.

Probably an ideal area for testing the suggested exploration methods would be Baca County, Colorado, and its vicinity in New Mexico, and in Oklahoma. Copper occurrences are reported from many localities of this area, and in several driller's logs of water wells native copper was noted. Significant copper showings and geological structures in this area indicate ore potential, but for location of drill holes, ground water sampling and their physico-chemical examination should be very helpful.

Similar hydrogeochemical exploration methods should be tested in other areas, including porphyry types, and Mississippi Valley types of base metal deposits.

It is recommended that in the testing-exploration stage, water samples should be taken from different depths of existing water wells. For sampling a special water sampler should be used.

Water samples could be examined in ASARCO'S geochemical laboratory and the following parameters should be determined: Eh and pH, SO_4 and CO_3 content and cationic concentration of major and minor trace elements.

If these simple proposals are accepted, cost and detailed technical specifications including required instruments, instruction in selection of water wells, and additional field observations and measurements will be proposed.

If the test of the suggested hydrogeochemical exploration technique is successful, a further program for utilization of ground water geochemistry for base metals exploration can be made. Perhaps for more efficient exploration achievements, a field laboratory and special drill holes may be also benifically utilized.

Jan Krason

COMMON FACTORS IN STRATIFORM COPPER BODIES AND THEIR SIGNIFICANCE AS EXPLORATION GUIDES

A porphyry copper specialist, J.D. Lowell, in a recently published estimate of copper in the upper mile of the earth's crust, states that at grades better than .25% Cu, there may be 4×10^9 tons as porphyry copper, magmatic segregation and massive magnetite copper deposits; and 3×10^9 tons of copper as "stratabound and red-bed deposits." Porphyry coppers are cylindrical, with a narrow cross section (1 mile or less) and a longer vertical axis. Stratiform copper deposits have very large lateral dimensions, of many square miles. This geometry should render stratiform deposits easier to locate with vertical probing. Grades of primary porphyry coppers are commonly less than .4% Cu, while stratiform coppers are much higher grade. If it is feasible to search for laterally limited porphyry coppers (or their characteristic haloes) below thick post mineral cover, it is also feasible to search for stratiform coppers (or their characteristic alteration haloes) below younger sediments.

Stratiform coppers occur in rocks ranging in age from Middle Precambrian to Cretaceous, and from highly metamorphosed to essentially unconsolidated. Commercial ore bodies occur in Asia, Africa, Europe, and North America. These deposits either outcropped or the suboutcrop was close to the surface. Good exploration potential exists for unrecognized ore bodies.

Regardless of genetic theory, known stratiform copper ore bodies occur: in sedimentary basins known to contain sub-ore grade copper bearing beds; are generally in an oscillating (cyclic) sedimentary sequence with copper at an interface between water lain and continental beds, or beds of two different permeabilities; are generally in permeable clastic rocks such as arkoses and quartzite; or in somewhat less permeable rocks such as shales at the contact with the permeable beds; are commonly localized in areas of younger structural events; commonly are associated with disseminated organic material; may show a spatial relationship to uranium, vanadium, molybdenum, zinc, and lead in the same beds; and show many other similarities.

Regardless of the method of introduction of the copper ion from water into sediment (marine water or ground water), copper mineralogy is exactly controlled by solubility products, and the copper minerals can be read to define the oxidation-reduction state of the copper bearing beds.

It follows that to find stratabound copper ore the exploration geologist should determine that host rocks are known to contain copper and have enough volume to bear ore in sufficient tonnages; determine structural pattern, amount, and variation of carbon, permeability, etc; test by drilling to locate the position of the oxidation-reduction interface, and/or determine location within the reduced zone; and test laterally along or within this zone for favorable mineralized lithology and structure.

Garlick, a premier proponent of sygenetic origin of stratiform coppers in Africa, in his paper states that beyond the ore, the ore bed has detrital iron oxide in one direction and pyrite in the other. "The ore body occurs in the same horizon between the barren (iron oxide) and the pyritic facies, and therefore discovery of a pyritic facies of a thick arenite may be the first step toward discovery of an orebody." Garlick's thesis is exactly as the last two steps above. One apparently searches for ore bodies in Africa in a manner similar to the search for copper in the Permian, in the U.S.

Algal Growths.

Recently Malan (1964) discovered well preserved stromatolitic structures at the western fringe of the 'B' orebody at Mufulira. He described the close association between algal growths, bioherms, and copper-iron sulphides, which Garlick (1964) compared with that in the Katanga and with the Mt. Isa silica dolomite bodies, in which stromatolites have subsequently been discovered (A. Bennett, in Press). The disseminated copper mineralization at Matsitamma in Botswana, discovered by RST in 1963, is in calcareous arenites and argillites flanking an algal bioherm.

Fig. 23 shows the relations at Mufulira of a bioherm with stromatolitic structures and meagre copper, adjacent to well bedded lagoonal sediments rich in copper sulphide.

In all the known associations, stromatolite structures are rare or absent within bodies of rich disseminated copper mineralization. Bioherms with stromatolites in situ are nearly barren or very low grade, but silica dolomite breccias and detrital carbonate muds flanking the bioherm may be extremely rich in copper or other sulphides, and sufficiently extensive to justify recognition as a special sedimentary facies.

Classification of sedimentary facies.

Under the heading 'Special Features' mineralization has been described in rocks of various lithological types, some with characteristic features recognized in modern sediments. The various lithological types are just as much facts of observation, but in discussing such rocks it is desirable to relate them to their depositional environment, and in some cases this may introduce controversial interpretations.

The Zambian arenaceous orebodies, contrary to impressions given in much of the literature, do not occur in ortho-quartzite and rarely in quartzite. The meta-sediments of aeolian origin are nearest to the definition of felspathic quartzite, but they are significantly barren. Ore occurs in aqueous sediments with considerable range in content of felspar and argillaceous material - the latter now altered to sericite or biotite. The meta-sediments of the ore horizon form a gradational series of lithological types, each of which represents a sedimentary facies. They are:-

1. Arkose
2. Felspathic arenite or subarkose
3. Sericitic arenite
4. Arenaceous slump breccia
5. Carbonaceous graywacke

Any of these five sedimentary facies may lie side by side in one horizon with gradational or inter-fingering contacts. Minor beds of pebbly grit, argillite, and dolomite may be inter-bedded, and under or over lie the various facies of the ore horizon. These are also mineralized in places.

Beyond the orebody fringe, the ore horizon is either a barren felspathic arenite or arkose, commonly crossbedded and containing a little detrital iron-oxide, or alternatively a pyritic arenite which may or may not be argillaceous. An orebody commonly occurs in the same horizon between the barren and the pyritic facies, and therefore discovery of a pyritic facies of a thick arenite may be the first step towards discovery of an orebody.

A few thin beds of dolomite in the Lower Roan succession appear to be excellent chrono-stratigraphic markers, for unlike the ore horizons, they show practically no

JDlell

AMERICAN SMELTING AND REFINING COMPANY
Denver Colorado

November 16, 1971

To: Exploration Supervisors
From: Stephen Von Fay

Memorandum: Bibliography for annual meeting subject: "Common Factors in Stratiform Copper Bodies and Their Significance as Exploration Guides."

The listed bibliography is pertinent to this subject.

Very truly yours,

Stephen Von Fay

SVF/pn
cc: JJCollins
TCOsborne
JHCourtright
RJLacy
WLKurtz ✓
RKKirkpatrick
JVDesvaux
KWhiting
SAAnzalone
RLBrown
RBSprague
JJMerz
AGiesecke
LPEntwistle
RSGray
MKriewaldt
DPCadwell

BIBLIOGRAPHY

1. Perel'man, Aleksandr Il'ich, "Geochemistry of Epigenesis," Academy of Sciences, USSR, Nedra, Moscow, 1965. Translated, N.N. Kohanowski, Dept. of Geol, Univ. of N. Dak.; Plenum Press, N.Y., N.Y., 1967.

2. Ridge, John D., Editor, "Ore Deposits of the United States, Vol I and Vol II, AIME, New York, 1968.

3. Brown, J.S., Editor, Monograph 3, "Genesis of Stratiform Lead-Zinc-Barite-Fluorite Deposits," Economic Geology, 1967, Lancaster Press, Lancaster, Penn.

4. James, Clifford J., Editor, "Sedimentary Ores, Ancient and Modern (Revised)," Spec, Pub. #1, Dept. of Geol., Univ. of Leicester, 1969.

5. Nicolini, P. and Lombard, J., Editor, "Stratiform Copper Deposits in Africa," Vol 1 and Vol 2, Lithology, Sedimentology, and tectonics, Symposium, Association of African Geological Surveys, Paris, 1963.

6. Memoir 15, "Geology and Technology of the Grants Uranium Region." State Bureau of Mines and Mineral Resources, 1963, Socorro, New Mexico.

7. Economic Geology, Vol 66, #5, August, 1971, Symposium. "A Paleoaquifer and its Relation to Economic Mineral Deposits. The Lower Ordivician Kingsport Formation and Mascot Dolomite," 1971, Lancaster Press, Lancaster, Penn.

8. Emmons, W.H. "The Principles of Economic Geology," 2nd Edition, McGraw-Hill, New York, 1940, pp. 324-325; 335-342.

9. Bateman, A.M., Editor, "Fiftieth Anniversary Volume, Economic Geology," 1955, Lancaster Press, Lancaster Penn.

   Part I. Anderson, Charles A., "Oxidation of Copper Sulphides and Secondary Sulphide Enrichment," pp. 324-340.

   Krauskopf, Konrad B., "Sedimentary Deposits of Rare Metals," pp. 411-436.

   Part II. Levorsen, A.I., "Time of Petroleum Accumulation," pp. 748-746.

   Ellison, Samuel P. "Economic Applications of Paleoecology."

10. Panel Proceedings, "Uranium Exploration Geology," IAEA, Vienna, 1970.

11. Lindgren, W., and others. "The Ore Deposits of New Mexico," PP 68, 1910.

12. Butler, B.S., and others. "The Ore Deposits of Utah," PP III, 1920.

Geochimica et Cosmochimica Acta, 1954, Vol. 5, pp. 153 to 168. Pergamon Press Ltd., London

J. D. SELL

Mineral species as functions of pH and oxidation-reduction potentials, with special reference to the zone of oxidation and secondary enrichment of sulphide ore deposits

ROBERT M. GARRELS*

Contribution from Northwestern University

British

N.W.I

1

AMERICAN SMELTING AND REFINING COMPANY
Denver Colorado

October 13, 1971

The Relationship of Organically Derived Material to Stratabound Ore Deposits

Organically derived material has long been known as a major precipitating agent in stratabound ore deposits.

Extensive study of uranium deposits over the past 20 years has documented this importance. All major districts of Mesozoic and Tertiary Age are associated with organically derived material. These major districts are located in or adjacent to oil fields, either dead or producing, and capable of furnishing H_2S to metal bearing waters.

Many of the base metal stratabound deposits, including White Pine, Zechstein, and the Missouri Lead District, are associated with hydrocarbons and are positioned around domes or flanks of basins.

Emphasis has been placed on carbonaceous material with cell structures and finely disseminated organically derived material solid, liquid, or gas, has been disregarded. Carbonaceous substances are found in sedimentary rocks as hard, black impregnations, rounded black pellets and colloidals. Organic substances of this nature are capable of collecting and transporting metals.

A search of oil field data, including subsurface structure in favorable base metal environments, should help define and specify mineral targets.

W.G. Hoskins

WGH/pn

(57)

RECEIVED

OCT 12 1971

EXPLORATION DEPT.

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 8, 1971

T.C.O.

OCT 12 1971

To: J.H. Courtright

From: S.R. Davis

ANNUAL EXPLORATION MEETING

Mapping in the Safford area has detected a number of unique features about the Phelps Dodge copper deposit. All of these features deserve further study as possible exploration devices; however, at least two appear to have significant potential.

A secondary biotite halo surrounds the deposit and corresponds closely to a definite but very subtle doming of the older volcanic lithology (Silver Bell type). The biotites occasionally occur as blotchy irregular masses and are rarely oriented along fractures and veins. The majority, however, occur as microscopic flooding of an aphanitic rock, and are extremely difficult to recognize. Propylitic alteration has been superimposed on the biotites and could help explain their being overlooked in earlier exploration.

Aside from the small geochemical anomaly, no other typical porphyry copper features are exposed. The deposit is a closed system, is very low in total sulfides and does not exhibit an acid intrusive or porphyry. The dominant copper mineral is bornite and molybdenite appears to be a significant by-product. Data we have suggests that the mineralization occurs in the older volcanics. The Safford deposit is therefore a porphyry copper only in the economic definition thereof.

In conversations with Phelps Dodge personnel, they have asserted a definite exploration edge based on information acquired at Safford. They also claim to be able to determine proximity of ore-grade mineralization by potassium analysis of drill core.

In view of the fact that this type of surface can overlie a relatively high grade deposit, such as at Safford (200 million tons @ 0.9% Cu), it therefore may have potential similar to leached outcrop interpretation.

I would recommend additional research on this data and familiarization of our personnel with this type of occurrence. We could also instigate a file search and field reconnaissance directed at extensive areas of known or interpreted pre-mineral VOLCANICS.

S.R. Davis

S.R. Davis

cc: J.J. Collins

xc JJC/JHC - Madrid

(58)

GEOPHYSICAL DIVISION

3422 South 700 West
SALT LAKE CITY, UTAH 84119

October 13, 1971

T.C.O.
OCT 18 1971

MEMORANDUM to J. H. COURTRIGHT:

GEOCHEMISTRY AND THE EXPLORATION DEPARTMENT

Geochemical exploration techniques constitute an important part of many of the exploration programs undertaken by the Exploration Department. In the future the relative importance of these techniques will likely become even greater as exploration programs become increasingly concerned with the search for buried deposits. However, maximum benefit cannot be obtained from these techniques unless they are applied with adequate regard to relevant geochemical and geological factors. In my opinion this is most likely to occur if a competent geologist/geochemist with knowledge of the local geological and geochemical environment is able to participate at all stages (i.e. from planning through to final interpretation) of every program involving use of geochemical techniques. Such a service can only be provided by a locally based man. It cannot be adequately provided by the field geologists involved in a particular project as they generally do not have either the requisite training or time to give sufficient attention to geochemical aspects. Neither can it be achieved by use of a centralized service, particularly in view of the widespread nature of Asarco's exploration activities.

I am not proposing that a geologist/geochemist be located in each exploration office! Initially, a suitably competent man in each major region would probably be adequate. This would amount to, say, four men, one each in U.S.A., Canada, Australia and Europe. The men should not be narrow specialists but rather exploration geologists with post-graduate training in exploration geochemistry. Their background and experience should generally be such that they need not be confined to the geochemical aspects of exploration as their careers progress. They would come under the general control of the exploration supervisor of the region in which they are located.

There will continue to be a need for a central geochemical laboratory able to provide routine and research analytical service to the regional offices. This laboratory also provides a suitable location for limited research programs in exploration geochemistry. These should generally be related to new techniques and on specific problems encountered by the regional geochemists. Adequate standard of research does, I think, require the services of a research geochemist without routine exploration responsibilities. Although he would obviously need to have a basic geological background, he also should have a strong chemical background (particularly in physical chemistry) in fact far stronger than would the average exploration geochemist. The research geochemist would report to the chief geochemist.

/

The research responsibility would only form a part of the chief geochemist's duties. His main function should be to act as geochemical consultant to the individual exploration offices---aiding the regional geochemists as necessary. He should keep abreast of developments in the geochemical field and ensure the regional men are aware of them. Periodic visits to Exploration Divisions and field areas would help ensure the geochemical service provided is maintained at an optimum level and standard.

L. D. James

L. D. JAMES

LDJ:db

cc:J.J.Collins

(59)

EXPLORATION SERVICES DIVISION
3422 SOUTH 700 WEST
SALT LAKE CITY, UTAH 84119

October 13, 1971

RECEIVED
OCT 15 1971
EXPLORATION DEPT.

T.C.O.
OCT 15 1971

OCT 21 1971
J.V.D.

Mr. J. J. Collins
New York Office

EXPLORATION IDEAS
ANNUAL MEETING

Dear John:

I apologize for not replying previously on the above subject, but I have been preoccupied in recent weeks with the problem of keeping alive the geophysical follow-up of our aeromagnetic work in Arizona.

In this particular case I would justify my actions on the grounds that I have been trying to implement a "new exploration approach" which evolved out of yester-years' work, in place of submitting a newer suggestion.

I consider the follow-up of magnetics in Arizona to be a more important idea than any other new idea which I might bring into the exploration picture at the moment. (The large amount of magnetic data which we have accumulated in Arizona gives us a temporary advantage over our competitors in that area.)

I am sorry that we do not have a formal proposal to submit this year. Jerry Montgomery was considering an idea on gravity for presentation, but later decided he would not be able to acquire sufficient data this year to support it.

Ralph Falconer, likewise, decided that he was unable to develop a suitable topic.

In a general comment on new geophysical ideas, I believe the most important point which I could offer concerns the value of fitting geophysicists directly into the exploration picture at regional offices. Innovation

requires intimate familiarity with specific problems which need to be solved, as well as the technical ability to solve them. Such intimacy can only be gained through multiple seasons of direct exposure to exploration conditions.

Attached is an article which Barry Nichols recently sent me. I believe it is quite appropriate.

Yours very truly,

Cal Moss

C. K. MOSS

CKM:am
Enc.

Cal — I think you might appreciate this.
Berry

DIGEST

PROSPECTORS AND DEVELOPERS ASSOCIATION

TORONTO 1, ONTARIO — 362-1969
SUITE 406 • 25 ADELAIDE ST. WEST

Vol. 1 September, 1971 No. 10

Cal – Think you might appreciate this.
Benny

DIGEST

PROSPECTORS AND DEVELOPERS ASSOCIATION

TORONTO 1, ONTARIO — EM-1-9939
SUITE 400 - 25 ADELAIDE ST. WEST

Vol. 1 September, 1977 No. 10

Nov 30 - '71

JIC — 35 mil — no disc.

Dick Brown — metallogeny — mineral dep in space-time diagram
- Grouping? on mineralogy? origin? age?
- assume plate tectonic proven
— Ordovician — py-cpy — lower mafic volcanism
Dsb. - Quebec - not explained —
Devonian — variety of deposits — Au Sn WO_3 etc
— Mt Pleasant NB — Cu - Sn - Bi — 40 m tons
Rift thru mass - move S. N.F. — fossil evidence

Bob Gale — zoning in mineral Belts — {a mineral dist / g mineral dist
" mining districts
" " individual ore bodies

Gibraltar — mineralized schists zone
300 m .4 Cu equiv — 1:1 strip
high cpy — lower py —
low gr EP intrusive as core
Zone 1 — 3 diff Cu comp
Central barren zone — no py — ?

Nov 30

(3)

John Balla —

Cavanaugh 10 km long 3½ wide
Barren Cavanaugh Gr on NW

Bishop — Juniper Flat Barren gr
slightly older than Sacramento Stock

Pine

Ruby Star grd — cse gr porphyry
and equi gran phase

Globe Mini

deposits on roof of Schultz Gr
assoc with gp intrusion

---

average — dip up to 3 mi away
from stock —

Sacaton

zoned stocks (coolidge Gr)

Florence

Walker Butte gran
Ammiral Butte ?

Fred Graybeal —
Cornelia pluton — grd-to porphy center
transitional & core, - same as ore zone
now looking at "root zone"

Patagonia — Four metals
pod phase of granodior.

Core — cop content of biotite magnetically
controlled — ~~co~~ cop content direct -
semi quantitive measure —
~~se~~ The contrast bet backgr —
Tyrone — bio-cu anom extend 3 miles
size of ore body — whole rock
samples do not provide good load in —
8 X cu in biot as comp to whole rk
Schultze Gr — ~~mea~~
from 10 ppm to 360
no outstanding leads — many
be root zone ore ? for 1300 ppm
Esperanza — extend out 3 mi to 40 ppm

Ajo — silt over Then drop to 7 ppm —
in core phase

Devere –
magic shield eruption –
contrast – Krakatoa group
– Resurgent types – – volumin
eruptions of pyroclastic material

Butte type – volumin pyroclastic erupt –
Bonneville resurg center

Geisik – Napper – giant landslides
– may explain anomalous stratigraphic
problems .. age Near Laramide
trend of pos cap – The direction of movement
of napper – ± 140 miles W to E

Dec 1, 1971 (5

A13 Sprague —

Stratabound — definition — metallic elements introduced contemp — not after rock indurated
metal elements been rock forming minerals.
over 50% of metal mined in Europe
Avoid classif as to origin —
types (1) fossil placers — Witwater & Blind River
(2) Related to volcanism — Iberian py belt.
deposited in shallow geosyncline
(3) "Synquetic" — hydrothermal — fault channel
metals introduced — Meggen + Rammelsberg
Silverwine Keel — Tyrgnah —
dep in reef ls — piled up sulphides
against fault zones. — Keel
normal hydrother vein — plus pb zn
in bed horizons. Keel mainly py —
Meggen — worked for 300 yrs — 4 sq mi
basin — grade laterally from barite
into Ls — some earlier mining in
veins of cpy — remobilized —
confined within a turbidity channel —
— transport of metals by brines — rather
than volcanic — exhalative —

pb zn on fund basin inside reef outside → iron dep

(4) metals related to organic shale — Kupferschiefer
— african copper belt — organic shale —
shoreline facies — arenite — not all
in organic shales. — Dev. ss of Ireland
— arid conditions in tropical climate —

Kuper schifer — cold sea water comes to surface — (winds) — causes rapid growth of plankton — (cold up welling current) — plankton rapid growth (red tide) use up oxygen — fish die. causes evol of H_2S — precipitates metallic sulphides —

upwelling of deep waters rich in metals

Cu in arenites — similar conditions but more rapid sedimentation

world-wide — geochem marker horizons — one example — W Hg Sb — Almaden same horiz

Same horiz in state of Utah — (ordovician?)

certain metals — v. certain geologic ages — deep seated sol chemistry? arising along fissures — could easily be over-looked in field —

most flourite in Europe — regarded sedimentary

travel from Turkey into Spain — amphibolite and silica sand — derived from basic volcanics.

Steve Von Fay —
"Long mounds" over 1 mile —
copper in ss — probab epigenetic
Permian → Zechstein — ½ Km × 10 Km 3 m Thick
— 3 bill tons 3% Cu —
+ Vanadium
no U. Cop. — extremely amenable —
Southern Africa Cu in arkose
" northern " " Shales
— Shale " a ε-1- ser rock —
chuibosi —
mufulira — feldpathic ss — —
Carbonaceous ss by far most favorable
Boleo prod 600,000 tons Cu
ore at contact underlying congl.
(3 beds)
deposited on volcanics — 4 horizons
one bed on volc.
White Pine — zoning, cc, bn, cpy — py —
~~White~~ ↑ most insoluble — in Sulph
limited system — 2 white Cu beds in
cop harb cg — below none such —

Regard Cu in outcrop as unfavorable
Zechst — some.
Exploration guides — 1st find bed
thick enough & continuous — with Cu
— leached outcrops — Cu up dip from
sed aspect in ls
evaporites — Graybeal — copper in Nicolai
Alaska — Kennecott deposit — 300 mile belt.

Mt Isa Low proterozoic - very first carbonates formed -

Bob Gray - McArthur Type -
lower to mid Proterozoic Mt Isa Broken Hill - Zambian Belts -
how Prot first ~~shallow~~ marine life
Archean 1% O in air -
increased - to 1% - During Prot
to mid Prot Then increased -
changing to oxid condition -
Early Prot - energy of shallow marine life
could provide prec (agent) -
First major 1s dep in mid prot
Confirm -

Mt Isa - sil dol related to algal reef
near shore facies change

reef Cu

Pb Zn

Mt Isa - major sed in fault trough,
McArthur - sulphides present when turbidity
breccia formed - gouge out fragments
of sulphides - reefs grow on fault scarps
Cu in algal reef - on east - later mx1
- ore beds above + below turb bx - rules
out ground water origin -
fumarolic acting - origin -
1. Examine are - mid Prot -
- Same criteria could be applied in N. Am

High Density Brines
Reservoir Rocks

Dec 1 — (9)

Peter Walker —
Red Sea — sulphides similar size
range as mac Arthur Riv —
Seds — 7 Km on side — 1 K in trough
positive grav — in trough — , Atlantis basin
Enna fault — pencentrop'
uranium deposits at Hilton — pyritic shale
Potash rich brine may have dep not Isa
ores — similar to Salton Sea Brine
Major crustal structures at not Isa
— Red Sea — Salt Sea — mc Arthur
avoid chl brine — high heat flow
main pt — major structural feature
Red Sea "banded iron" — similar to Broken
Hill banded iron —
Lady Annie —
mc Arthur — 8 mile radius of metal deg —
volcanic material not found bin Red Sea dep
Expl — look for major trough —
Lady Annie — 20 mil tons 20 — 30
% comb — Placer Dev — tuff bands
in core —

Bill Hoskins –

— 1.5 % organic matter – overall av. —

Bob Gray – The Role of Gypsum –

Dec 2 '71 (11)

Cay Williamson —

Bob Gray — Geochem Indicators —

Ni Cr Co — subst higher in ultra mafics
— geochem soil can outline ultrams

		Ni	Cu	Co
Fresh rock sulphide	Barren ultram —	600	26	44
	Ore "	1800	400	84
	Threshold	1.780	100	158

surface
kinetic crust
mottled zone
clay with limon stain

5000 ppm — up to 1% in

Cu 50–100 ppm

o o
saprolite

water table

fresh rock
geochem on joints

— primary .2% Ni

over 100 ppm Cu favorable

Windsina " 285 — Zn low in ultram;

Zn useful in . < than 100 ppm in ultram

Cu anom with low Zn more far than high Zn

	Ni	Cr
bleached serp	55	7000
fresh "	2000	—

Selic nonclam pseudo gos

pinnacle —

	Ni	Cu	Z
Queen Victoria rock.	5000	500	high
Gurdi gos	13500	500	

general rule — ni cu anom with cu higher than co

Anzalone Sal —

Lizardite — serpentine —

textural zoning — related to region of economic asb. —

Big Cat — asb fib in drainages — 4 to 5 miles from outcrop — and 6 miles most in 20-40 mesh —

— large sample — 2 hrs looking, thru bin oc

3 lb silt sample —

— check of gravel made on barren ultram — no asb found

picrolite — may be an indicator —

K Whiting — How to find Asbestos

Chrysotile only — 90% of market —

— origin — related to later intrusion? — diorite etc —

30 occurs. tabulated in Shasta region —

Shasta asb — boulders over 3 mi from source

Bl Lake — in mining after breaking — fines contain 50% of fiber — a prospecting factor — evaluating float

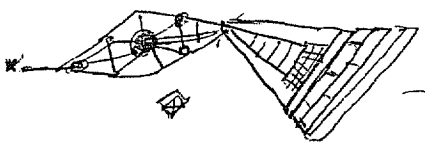
Picrolite — transition serp to asb Pic an indicator min

Color anom in Cangaua — new ash corp deposit ← observed by Rod

Chem comp of ash - vist same as host rock. Weathering tends to make fiber more brittle

Loyd James

Geol - geochemist in each Division — only thru long term exposure — can problem be fully appreciated



3. Tuc
Spok.
Sac.
Denver
Knoxv
Van.
Tow.
Lond.
Perth.
NY

Dec 3, 71

14

Peter Walker - mt Isa computer System —
— applied to mine inf. and to GEC data —
drill data - geochem — etc —
— ultimately planned visual display unit ——

Dick Brown — main thrust — massive sulph in Archean
Blind spots — glacial cover is such that
still possib. of discov. of major sizes such as
White Pine — Rocky Antelope etc —
depos in red ~~sl~~ sandstone and other types —
Two facts — (1) Sand beds with a
(2) They are big —
— Asb - partic. rapid soil erosion in west — not in shield
(Saco paper)
"Gravity slides of today could be nappes of tomorrow"

Sal Anzalone
apply plate tect in western cordil. —
Geological drill — can be applied &
nappism — can possib be applied —
dep east of Coast Range may have moved
down to their pres position —
— laphrogeosynclin — Sullivan in such environment.

Steve Von Fay

Bill Kurtz —— shales in new geochem values — possible
stratiform dep

Bob Gray — western coast fault zone 500 miles long
— persists to lower crust - forming at time
of continental drift —

R Whiting —

Dick Brown — Nicholls - Gravity — no idea of validity — or cause of error —

15

← 15 compass — depth 3 miles — continuous plastic cable dredge modules — $50,000 each.

ASARCO MEXICANA, S. A.

BAJA CALIFORNIA 200

MEXICO 7, D. F.

RECEIVED
SEP 8 1971
EXPLORATION DEPT.

APARTADO POSTAL 38-BIS
MEXICO 7, D. F.

Mexico City, September 2, 1971

J. H. C.
SEP 13 1971

DR. D. F. COOLBAUGH
DIRECTOR GENERAL DE EXPLORACIONES

T. C.

Mr. John J. Collins,
Director,
American Smelting and Refining Company,
120 Broadway, New York, N.Y. 10005,
U.S.A.

Dear John:

Thank you for your letter of July 1, 1971 regarding your annual exploration meeting.

I certainly wish that we could participate in this meeting with new ideas or techniques. We have some good young thinkers coming along and we certainly do hope -in the future- to develop new ideas or techniques or better application of known methods.

Since I came with Asarco Mexicana, S.A., four years ago, I have been pleased to see the development of a few high-class exploration engineers. Our work, however, has been to apply the known techniques.

Asarco Mexicana has the only company geochemical section in Mexico and there are no reliable commercial laboratories. We are slowly building up geochemical data (background etc) in various areas of the country.

We operate the only company I.P. crew in Mexico. Although there are two contract companies, their service is suspect and it is difficult to maintain control. We also are beginning to do other geophysical surveys.

We have developed an excellent petrographer. I know of no other company in Mexico with such an individual.

XC – J H Coolbaugh 9-9

As you see, we are doing pretty well, but we must walk before we run and the walking has sometimes been difficult.

I certainly do want to thank you and especially your geophysical Division under Bob Lacy and to your Southwestern Division under Harold Courtright and Bill Saegart (sorry you lost him) for the great assistance they have given us which has allowed us to walk rather than crawl.

Atentamente,

Dave

D.F. Coolbaugh,
Director General de Exploraciones

DFC/mfb.

J. P. Entwistle

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

January 24, 1972

Dec 71

To: Division Supervisors

DECEMBER MEETING PAPERS

At the December, 1971 Exploration Meeting, Mr. Collins asked that the authors of papers presented send copies to my office for reproduction and distribution to the various Exploration Divisions.

I have so far a total of 10 papers. Those not as yet received are listed below:

1. R.L. Brown - Metallogeny in the Northeastern Appalachians
2. R.B. Sprague - An Exploration Project in North America Based on European Ideas of Ore Genesis
3. P.H. Walker - Localization of Major Stratiform Ore Bodies
4. S. Von Fay - Common Factors in Stratiform Copper Bodies and Their Significance as Exploration Guides
5. R.S. Gray - (1) Geochemical Indicators for W.A. Nickel Sulphide Deposits; (2) McArthur Type Ores; (3) Role of Gypsum
6. W.L. Kurtz - Drilling for Geologic Information
7. W.G. Hoskins - Organic Black Shales - Strat. Ore Deposits

J. H. Courtright
J.H. COURTRIGHT

JHC:kre

cc: J.J. Collins

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ASARCO EXPLORATION RECORD SHEET
FOR COMPUTER INDEX AND STORAGE

☐ FIELD EXAMINATION ☐ LITERATURE SEARCH ☐ ASARCO FILE SEARCH ☐ _____

Section I General Indexing

(1) Name of Property or Project		(2) Country	(3) State		(4) County
			(8) Examined by:	Field Days	Date
(5) Latitude ± Deg Min Min. Max.	(6) Longitude ± Deg Min Min. Max.	(7) Meridian	Twn / Rng / Sec	(9) Searched by:	Date
		(11) Office	(12) File No.	(10) Reference:	

Section II Appraisal

(13) Recommended Company Interest Classification
1. ☐ Priority
2. ☐ Secondary
3. ☐ Future
4. ☐ None
5. ☐ Technical

(14) Stage of Development
1. ☐ Past Producer
2. ☐ Producer
3. ☐ Undeveloped Ore Body
4. ☐ Prospect
5. ☐ Alteration Zone
6. ☐ Geophysical Anomoly
7. ☐ Geochemical Anomoly
8. ☐ Geologic Concept

(15) Production

Commodity	Tons	Grade

(16) Reserves ☐ Estimated ☐ Measured

Commodity	Tons	Grade

Section III Documents Available

(17) Maps
1. ☐ Topographic
2. ☐ Photographs
3. ☐ Photogeology
4. ☐ Areal Geology
5. ☐ Underground Geology
6. ☐ Sketch

(18) Geochem Samples Approx. No.
1. ☐ Steam Sed. _____
2. ☐ Soil _____
3. ☐ Rock Chip _____
4. ☐ Water _____
5. ☐ _____
☐ Maps

(19) Geophysics
1. ☐ Airborne
2. ☐ Magnetics
3. ☐ IP & Resistivity
4. ☐ Gravity
5. ☐ Radiometric
6. ☐ Electromagnetic
7. ☐ In Hole Method
8. ☐ _____
☐ Maps

(20) Drill Holes
Number _____

(21) Assays Approx. No.
1. ☐ Surface _____
2. ☐ Underground _____
3. ☐ Drill Hole _____
☐ Maps

Section IV Geologic Environment

(22) Type of Deposit
1. ☐ Vein
2. ☐ Disseminated
3. ☐ Mass. Sulphide
4. ☐ Replacement
5. ☐ Porphyry Copper
6. ☐ Stratiform-
7. ☐
8. ☐

(23) Mineral Zone
Length _____
Width _____
Thickness _____
Age of Mineral _____

(24) Evidence of Mineral Zone (Use code letter)
1. ☐ Leached
2. ☐ Enriched
3. ☐ Recrystallized
4. ☐ Color (Code number - see column to right)

W = Weak
M = Mod.
S = Strong

(25) Regional Structural Setting
1. ☐ Major Fault Zone
2. ☐ Intrusive Environment
3. ☐ Sedimentary Trap

(26) Local Structure (Use code designation)
1. ☐ Structure Density
2. ☐ Porosity – Permeability
3. ☐ Dip of Bedding
4. ☐ Type of Bedding

-CODES-

Colors	Structure Density	Dip of Beds
1 = White	1 = Few Faults	1 = 0-5°
2 = Gray	2 = Many Faults	2 = 5°-10°
3 = Dark	3 = Shear Zone	3 = 10°-20°
4 = Black	4 = Intense Shearing	4 = 20°-40°
5 = Red	5 = Breccia	5 = 40°-60°
6 = Green	6 = Crackle Breccia	6 = >60°
7 = Brown		
8 = Yellow		
9 = Orange		

Porosity-Perm	Type of Bedding
G = Good	T = Thick Bdd
M = Mod	N = Thin Bdd.
P = Poor	L = Laminated
	C = Cross Bedded

Section V Rocks and Minerals

(27) Host Rock
1. _____
2. _____
3. _____
4. _____
5. _____

(28) Alteration and Weathering (Enter Code For Intensity)
1. ☐ Qtz-Silica
2. ☐ K-Spar
3. ☐ Py-Sericite
4. ☐ Argillic
5. ☐ Propylitic
6. ☐ Pyritization
7. ☐ Dolomitization
8. ☐ Kaolinization
9. ☐ Chemical weathering
10. ☐ _____

W = Weak M = Moderate S = Strong

(29) Minerals (Enter by order of abundance)
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

Section VI Analysis

(30) Contained Metals
☐ Au-Ag ☐ Cu ☐ Pb ☐ Zn ☐ Ni ☐ Mo ☐ U-Th ☐ Asb ☐ ☐

(31) Spectrographic Analysis – Attach analytical report

Section VII Comments - Use back of sheet

Explain features that are not well represented by the above indexing system and in particular give your opinions and recommendations.

Asbestos
Coking Coal
Fluorspar

Ti sands
Pb Zn
Au Ag

Mo
Tungsten
U
Pt

THE SALTON-MEXICALI GEOTHERMAL PROVINCE

By James B. Koenig

Figure 1. Index map to Salton-Mexicali geothermal trough, with details of geothermal field at Niland, Imperial County, California.

Jhc

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

March 3, 1967

Mr. K. E. Richard, Chief Geologist
American Smelting and Refining Company
120 Broadway
New York, N. Y. 10005

HYDROTHERMAL BRINES
SALTON SEA, CALIFORNIA

Dear Sir:

Reference is made to my letters to you of January 24 and February 14 transmitting data on metal-bearing hydrothermal brine wells controlled by Magma Power and Earth Energy Inc., the latter a subsidiary of Union Oil.

During the recent AIME meeting in Los Angeles, Mr. Saegart, Mr. Watson and I talked with Mr. McCabe of Magma Power and Dr. Carel Ott of Earth Energy. We also attended a lecture on the hydrothermal brines of the Salton Sea Basin by Donald E. White, author of the paper dated March 8, 1963, on the first deep well drilled near the Salton Sea.

Earth Energy later drilled 3 wells ranging from 5000' to 8000' in depth over a distance of 3 miles and conducted extensive tests to determine the power potential of the Basin. One of the 3 was allowed to discharge over a period of 12 months, producing brine at the rate of 500,000 pounds per hour and steam equivalent to 12,000 kilowatts of power. No drop in pressure (300 lbs. per square inch at well head) was noted, nor was there any effect observed on adjacent wells, indicating a reliable reserve of steam for power production.

Due to the corrosive nature of the brine (pH 2) and other problems involved in the production of the contained salts and metals, Earth Energy decided to defer development of the Salton Sea Basin in favor of other areas with essentially pure water accompanying the steam, such as the big geysers 80 miles north of San Francisco, California. McCabe of Magma is not satisfied with this delay and has been attempting to interest other companies, including ASARCO, in making a deal with Earth Energy and Magma Power to invest in research and development of processes to recover salts and other marketable elements, including metals, from the Salton Sea Basin.

The major constituents of the deep well brines of the Salton Sea are NaCl, CaCl, and KCl, totalling 35 per cent. Water makes up 60 per cent and the remaining 5 per cent is composed of numerous metallic and non-metallic elements --- Fe, Cu, Pb, Zn, Ag, Mn, Li, Ba, Sr, S, etc.

McCabe stated that for production of power, 10 wells (at $150,000 each) would be required for a 120,000 kw plant. Cost of a plant for production of salts was estimated at $15 million; no estimate was given as to the cost of the power plant. From 10 wells, the total brine production would amount

to 5 million pounds per hour, or 1,800,000 tons per month. According to the latest analyses given by Dr. White, a month's brine production would contain approximately:

		Short Tons	PPM
KCl	----	72,000	40,000
Li	----	540	300*
Sr	----	1,080	600
Zn	----	1,530	850
Pb	----	160	90
Cu	----	16	9
Ag	----	1.8	1 (52,400 ounces)

* Lithium content from White's March 8, 1963 paper

Obviously, these brines are a potentially important source of both metals and salts, providing economic recovery processes can be developed. Dr. White estimated that the Salton Sea Basin contains at least 5 cubic kilometers of brine.

Dr. Ott stated that the salts (NaCl, CaCl, KCl) were recoverable by solar evaporation, but the sodium chloride contained too much Pb to be marketable except for certain industrial uses. According to news reports, Morton Salt (holding adjacent ground) is proceeding with plans to spend up to $30 million on plants to produce sodium and calcium chloride, also potash and anhydrous ammonia.

So far the only reported metal recovery from the brines is that which was precipitated on crushed glass in discharge pipes. A sample of this material sent to Mr. Reed Welch assayed 435 ounces of silver and 9.6% copper.

The brine also may become an important source of lithium, as the demand for this metal could increase greatly if development of the lithium chloride battery is successful. Several companies are engaged in research and one reported during the past year the development of a lithium battery which produces 230 watt-hours per pound --- over 11 times the lead-acid battery (see attachments).

Dr. Ott implied that they did have some research going which might produce important results within 3 or 4 months, but in the meantime they would be willing to listen to any major company's proposal for participation.

Other saline basins may contain metal-bearing brines at depths so far not reached in drill exploration. The Salton Sea Basin contains 20,000' (seismic and gravity data) of Pleistocene, or Recent alluvium interbedded with evaporities. The upper 4000' to 5000' is relatively impermeable, and

the hot saline brines were not encountered in early shallow wells. Of note is the fact that the brine field encompasses an area of hot springs directly over a projection of the San Andreas Fault.

We believe the possibilities of metal and non-metal production from brines merits serious consideration and recommend that a consultant be engaged to assess the risk involved in financing research and development to acquire an interest in the Earth Energy-Magma Power leases in the Salton Sea Basin.

Ralph Parsons, Los Angeles, and Jacobs, Pasadena, are consulting firms specializing in brine production and processing. Stearns Rogers also provides services in this field, but reportedly is now working for Morton in the Salton Sea area.

Yours very truly,

J. H. Courtright

J. H. COURTRIGHT

Attachments
JHC/kw
cc: KERichard, lx
RFWelch
WESaegart - All w/atts.
SIBowditch
BNWatson

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requires intimate familiarity with specific problems which need to be solved, as well as the technical ability to solve them. Such intimacy can only be gained through multiple seasons of direct exposure to exploration conditions.

Attached is an article which Barry Nichols recently sent me. I believe it is quite appropriate.

Yours very truly,

Cal Moss

C. K. MOSS

CKM:am
Enc.