CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
416 W. Congress St., Suite 100
Tucson, Arizona 85701
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

Detach here before depositing check

No. 109795

COST CENTER NUMBER	ACCOUNT NUMBER	AMOUNT		PAYEE AND OPTIONAL DESCRIPTION	IRS	INCURRED DATE	COMMIT-MENT NUMBER	P/F	COMM
2584-050	541-01	395	11	Mulchay Red Mt 7/24-25/85		072585			
	Dep. T.C. check 8/20/85								

CHECK DRAWN FOR 395 11

VENDOR NUMBER OR DESCRIPTION
Travel

SHOULD YOU HAVE ANY QUESTIONS REGARDING THIS PAYMENT, PLEASE REFERENCE OUR CHECK NUMBER WHEN INQUIRING.

NATIONAL ACADEMY OF SCIENCES
Washington, D.C. 20418
(202) 334-3573

ORIGINAL

Misc	Date	Br.	L.	Dinner	Tel	Lodging	Tips	Total	Taxi
.35	7/23	—	—	8.47		51.34	3.00 ~~4.25~~	49.31	14.00
								129.60	
	7/24	5.60	6.00	7.62		34.56 (adj)		178.91	
.35	7/25	6.06	3.12 (2.07)	7.00		43.20			3.00
.35	7/26	5.44			1.20		~~1.00~~		17.00
1.05		17.10	9.19	23.09	1.20	129.60			TIPS

HOTEL 7/23 - 26

	B	L	D	Tip	ROOM	TEL.
7/23	—	—	7.22 8.[illegible]7	1.35	48.00 3.84 51.84	
7/24					32.00 Adj. 2.56 34.56	
7/25	5.06 + 1.00 6.06				40.00 3.20	
7/26	4.44 + 1.00 5.44				43.20	1.20 ✓

5.60
6.00
7.62
19.22

6.06
3.12
7.00
16.18

8.47
51.84
60.31

19.22
34.56
53.78

16.18
43.20
59.38

17.10
9.12
23.09
129.60
178.91

198.00
17.00
178.91
1.20
395.11

INSTRUCTIONS FOR PREPARING TRAVEL VOUCHER

After "NAS Committee or Office" enter CSDC

After "Purpose of Travel" use the following statement:

Participation in meeting of CSDC Task Group on Red Mountain, 24-25 June 1985, Tucson, AZ

PLEASE NOTE

(1) Attach hotel receipt(s) and passenger coupon from air travel (please use economy class). They must be originals.
(2) If use of rental vehicle is necessary, explain on voucher.
(3) See back of the voucher for other instructions.
(4) Sign the voucher.

Retain the pink copy of the voucher for your records. The completed and signed white original voucher and the yellow copy, along with receipts, should be sent to:

Robert S. Andrews, CSDC, JH-840
National Academy of Sciences
2101 Constitution Ave., N.W.
Washington, DC 20418

Please call me at (202) 334-3350 if you have any questions.

Rolana B. Mulahay

Rolana B. Mulahay

NOTE 8/1/85

THE EXPENSE FORM GIVEN ME HAD A SCRIBBLED SIGNATURE ALREADY ON IT. AS IT IS THE ONLY FORM AVAILABLE, IT HAS BEEN COMPLETED, AND MY SIGNATURE PLACED ABOVE.

THE HOTEL RATE WAS ADJUSTED TO THE GROUP RATE AFTER THE FIRST DAY.

1176
JULY, 1984

NATIONAL ACADEMY OF SCIENCES

2101 Constitution Avenue, N.W., Washington, D.C. 20418

TRAVELERS COPY

TRAVEL VOUCHER

SEE INSTRUCTIONS ON REVERSE OF TRAVELER'S COPY

PLEASE PRINT OR TYPE

MAKE CHECK PAYABLE TO: ROLAND B. MULCHAY
(Limit 27 Characters)

DATE THIS VOUCHER SUBMITTED: Aug. 1, 1985

NAS COMMITTEE OR OFFICE: CSDC

☐ MAIL CHECK TO: (Address) 2732 WREN ROAD
— OR — SALT LAKE CITY, UTAH
84117

PURPOSE OF TRAVEL: INCLUDE NAMES OF PERSONS OR ORGANIZATIONS VISITED, DATE AND LOCATION OF MEETING(S).
Participation in meeting of CDSC
Task Group on Red Mountain,
24 - 25 June, 1985, Tucson, Ariz.

☐ DELIVER CHECK TO: (Name) ______

BLDG. ______ RM. NO. ______

DATE AND HOUR OF DEPARTURE (PAR 1) ______

DATE AND HOUR OF RETURN (PAR 1) ______

TRANSPORTATION: ATTACH ORIGINAL PASSENGER COUPON; ECONOMY CLASS AIR FARE AND TRAVEL BY U.S. CARRIER ARE REQUIRED.

ITINERARY FROM CITY AND STATE/COUNTRY	ITINERARY TO CITY AND STATE/COUNTRY	CARRIER* (PAR 2)	CLASS OF SERVICE* (PAR 3)	PRIVATE AUTO MILEAGE (PAR 4)	AMOUNT OR SOURCE OF PAYMENT (PAR 5)
July 23,1985					$
Salt Lake City,Ut.	Tucson, Ariz.	Amer.West	Economy		198.00
And Return 7/26/85			(30 day pre-		
			pay rate)		

*ATTACH WRITTEN JUSTIFICATION IF AIR TRAVEL NOT BY ECONOMY CLASS OR IF FOREIGN CARRIER USED.

RENTAL CAR: ATTACH ORIGINAL INVOICE AND REASON WHY PUBLIC TRANSPORTATION COULD NOT BE USED (PAR 6) $

TAXI FARES AND PARKING: ENTER CITIES, AMOUNTS, TOTAL Tucson, Ariz. $ 17.00

SUBSISTENCE AND OTHER EXPENSE: COMPLETE BLOCKS BELOW AND ATTACH ORIGINAL LODGING RECEIPTS (PAR 7)

DATE	MEALS AND TIPS B	L	D	TOTAL	LODGING	DAILY TOTAL
7/23			8.47	8.47	51.84	60.31
7/24	5.60	6.00	7.62	19.22	34.56(adj)	53.78
7/25	6.06	3.12	7.00	16.18	43.20	59.38
7/26	5.44			5.44		5.44

IF ADDITIONAL SPACE IS NEEDED, USE "CONTINUATION SHEET FOR SUBSISTENCE EXPENSE" TOTALS $ 49.31 $ 129.60

TOTAL MEALS & LODGING $ 178.91

OTHER EXPENSE (PAR 8) SPECIFY: ______ $

TELEPHONE CALLS ON NAS BUSINESS $ 1.20

TOTAL TELEPHONE & OTHER $ 1.20

I CERTIFY THAT THE ABOVE CLAIM IS CORRECT AND PROPER AND THAT PAYMENT THEREFOR HAS NOT BEEN RECEIVED.

CLAIMANT'S SIGNATURE [signature] DATE 8/1/85

CHECK ONE: ☐ EMPLOYEE ☐ CONSULTANT ☒ COMMITTEE MEMBER ☐ OTHER ______

TOTAL EXPENSE $ 395.11

LESS ADVANCE (PAR 9)

BALANCE DUE $ 395.11

CLAIMANT NOT TO WRITE BELOW THIS LINE

APPROVAL: I CERTIFY THAT THE ABOVE EXPENDITURE WAS DULY AUTHORIZED AND I APPROVE CLAIM FOR PAYMENT.

NAME OF OFFICE SUBMITTING VOUCHER ______ PHONE EXTENSION ______

SIGNATURE ______ SIGNATURE ______

FOR ACCOUNTING OFFICE USE ONLY

COST CENTER NUMBER	ACCOUNT NUMBER	AMOUNT	PAYEE AND OPTIONAL DESCRIPTION (Limit 27 Characters)	IRS	INCURRED DATE	COMMITMENT NUMBER	P/F	COMM
—	—	.						
—	—	.						
—	—	.						

INSTRUCTIONS FOR COMPLETING TRAVEL VOUCHERS

This form is to be used by all persons traveling on business for the National Academy of Sciences when requesting reimbursement for travel expense or accounting for travel performed. The completed form should be sent to the NAS committee or office authorizing the travel within 30 days after travel has been completed.

Cost limitations and other related provisions concerning domestic and foreign travel are specified by federal government contracting regulations as well as NAS policies. Essential information is provided in the instructions below and the traveler's cooperation is requested in complying with stated policies. More detailed information and samples of completed vouchers are contained in the NAS *Guide* which may be referred to for additional assistance. Please review the instructions carefully before completing the form.

All transportation should be accounted for on this form even if payment will be made to or by another firm or agency. Subsistence and other expense should be listed only when reimbursement is requested or an advance is to be accounted for. When appropriate, claims should be adjusted equitably with an explanatory note to account for activities performed for organizations other than NAS.

1. Enter the date and hour of departure from and return to home, office or other place at which official travel begins and ends. The dates and hours should be those in effect within the time zone at the place of departure and return.

2. Enter name of the airline or rail company in the column marked "Carrier." Federal law, which is incorporated into U.S. government contracts and audit procedures, provides that U.S. air carriers must be used for foreign and domestic travel if the cost is to be allowable as a contract expense. U.S. air carriers must therefore be used by all travelers from the airport of origin to the furthest practicable interchange point on a usually traveled route. This is required to the extent such service, including appropriate connections (with layovers of less than six hours), is available. Whenever use of a foreign air carrier is unavoidable, a statement must be furnished with the Travel Voucher justifying such use. Please contact the committee office or see the NAS *Guide* if additional information is required. Cost of travel by foreign flag air carriers is subject to disallowance if it is not justified and in accordance with the above regulations.

3. Air travel must be by economy class or at equivalent rates. First class rail or bus fare is permitted. Air travel costs in excess of economy class are subject to disallowance. In instances when reimbursement for first class air fare is claimed it must be supported by a statement of explanation furnished with the Travel Voucher. Travelers should be aware that a desire for working space is not an allowable reason for using first class accommodations. Whenever possible, reservations should be made far enough in advance to insure that economy class space is available.

4. Expense for transportation by privately owned auto will be reimbursed on a mileage basis at a rate of 20 cents per mile plus toll charges and necessary parking fees when travel by auto is for the convenience of the Academy or when public transportation is more expensive or not practical. Costs associated with the use of a privately owned auto will be reimbursed at the above rate to the extent that the cost of automobile expense claimed plus related subsistence expense do not exceed the cost of travel by common carrier plus related subsistence expense.

5. Enter the amount claimed for air, rail or auto transportation supported by originals (i.e., the traveler's copy) of air or rail coupons. If no expense is claimed because no out-of-pocket costs were incurred by the traveler, complete the itinerary section in full but enter in the amount column the source of payment such as the name (or abbreviation) of the travel agency or credit card company to whom separate payment will be made by NAS. If the traveler makes no claim because payment for travel will be made by a government agency, private firm or other source, please indicate "No claim" where appropriate. If furnished to the traveler, the passenger's copy of the invoice/itinerary supplied with the ticket should be attached to the Travel Voucher.

6. Enter the amount claimed for auto rental supported by the original invoice. The use of rented cars is discouraged in favor of public transportation (including taxis) provided public transportation is more economical. Whenever a rented automobile is used due to circumstances which make it impossible, impractical or more costly to use other transportation, the traveler should submit an explanation (the Remarks section below on this form may be used). Efforts should be made to obtain economical rates in terms of smaller car size and all available discounts.

7. DOMESTIC TRAVEL subsistence costs (food and lodging) are reimbursed on an itemized, actual expense basis with costs recorded daily. Lodging should be reserved far enough in advance, whenever possible, to obtain standard single rooms in national chain hotels and motels where available, and in Washington, D.C. and Woods Hole, MA, at hotels and motels which give NAS travelers special rates. Reasonable lodging costs for the period of travel are reimbursable when supported by the original paid hotel statement submitted with the Travel Voucher. Meal receipts are not required but per-meal costs should be entered on the voucher with maximum reimbursement limited to $28.00 per day. FOREIGN TRAVEL subsistence costs are reimbursed on a per diem basis in accordance with current U.S. Department of State guidelines with rates intended to cover hotel and meal costs including tips, and necessary laundry. Current applicable rates, instructions and a worksheet to be attached to the Travel Voucher are available from the NAS committee office or Accounting Office. Commitments for foreign travel (which may be defined for approval purposes as travel outside the United States and Canada) must be approved in advance by the NAS Office of Contracts and Grants.

8. Other reimbursable costs (in addition to transportation, meals and lodging) include telephone calls necessitated by NAS business or travel schedules, laundry service necessitated by domestic travel, baggage handling tips or fees and, occasionally, extraordinary items which should be explained in the Remarks section below. Receipts may be required for expensive or unusual items. For foreign travel, passport costs and other similar, necessary costs as listed in the NAS *Guide* are reimbursable. Certain costs such as travel insurance, entertainment, alcoholic beverages, gifts, membership dues to organizations and personal items are not allowable as reimbursable travel expense.

9. If a travel advance has been issued, it should be accounted for on the Travel Voucher in the space provided. Travel costs in excess of advances will be reimbursed. If the advance is greater than the travel costs, a check payable to the National Academy of Sciences for the remaining advance should accompany the voucher. Advances should be accounted for within 30 days after completing travel.

10. *CHECKLIST* — The Travel Voucher should be filled out completely, signed by the traveler, and submitted to the NAS office which authorized the travel.
    The following should be attached as appropriate:
    (a) Original transportation coupon (and travel agency invoice/itinerary when available).
    (b) Original car rental statement and justification.
    (c) Original hotel statement.
    (d) Foreign travel authorization and per diem worksheet.
    (e) Explanation of any unusual items.

    NOTE: If you need help in completing this form or have any questions, please contact the NAS office authorizing travel or the Accounting Office. If additional space is needed for the daily subsistence record, itinerary or remarks, please attach separate sheet(s).

AMERICA WEST AIRLINES — PASSENGER TICKET AND BAGGAGE CHECK

ISSUED BY: AMERICA WEST AIRLINES
SOLD SUBJECT TO CONDITIONS OF CONTRACT ON PASSENGER'S COUPON — NOT TRANSFERABLE

PASSENGER'S COUPON

Airline / Form / Serial Number: 401:4400:096:054

Name of Passenger: Mulchay, Ronald
Restrictions/Endorsements (Carbon): Mine Order
Date of Issue: 6 22 85
Not Valid Before: 1 — 2 23 3 Jul 4 85
Not Valid After: 1 2 3 4

X/O	NOT GOOD FOR PASSAGE	FARE BASIS	CARRIER	FLIGHT/CLASS	DATE	TIME	STATUS	ALLOW
	FROM Salt Lake City	K$30	HP	[illegible] K	7/23	[illegible]	OK	
O	TO Tucson	K$30	HP	[illegible] K	7/28	[illegible]	OK	
X	TO Phoenix	K$30	HP	[illegible] K	7/28	[illegible]	OK	
	TO Salt Lake City	—	—	VOID				
	TO — VOID							

Fare: 183 33
Tax: 14 67
Total: 198 00

Form of Payment: Mulchay, Ronald B. 3739-641-432 [illegible] 801-277-2724 Ex 12 85

PRINTED IN U.S.A. BY RAND McNALLY REV 10-84

REV 1-83

27956

Sheraton Pueblo Inn
SHERATON HOTELS, INNS & RESORTS WORLDWIDE
350 S. FREEWAY, TUCSON AZ
85745 602/622-6611

Room: 131 — Name: Mulchay Ronald — Rate: 48 (CSD) 43 — Out: 7/28 — In: 7/23
Guests: 1 — Street: — City: — State: — Zip: — Address ☐ Home ☐ Bus
Clerk: MAH — Company: — Travel Agent ☐

Please notify the room clerk if there are any errors above.

OTHER — CLOSING / OPENING / DIFFERENCE — CHANGE ☐ ROOM ☐ RATE — ROOM NO. — RATE — TAX

DATE	REFERENCE	CHARGES	CREDITS	BAL. DUE	PICK-UP
					.00
JUL 23B	GARAGE 131	[illegible]		3.00	3.00
JUL 23B	[illegible] 131	[illegible]		10.22	10.22
JUL 23B	ROOM 131	[illegible]			
JUL 23B	TAX 131	[illegible]		62.06	62.06
JUL 24B	ROOM 131	[illegible]			
JUL 24B	TAX 131	[illegible]		96.62	96.62
[illegible]	[illegible] RESTR 131	[illegible]		101.68	101.68
JUL 25B	ROOM 131	[illegible]			
JUL 25B	TAX 131	[illegible]		144.88	144.88
[illegible]	[illegible] RESTR 131	[illegible]		149.32	149.32
JUL 26B	EPHONE 131	[illegible]			
JUL 26B ADJ	E 131		[illegible]	147.52	

GUEST'S SIGNATURE
CHARGE TO
ADDRESS
CITY STATE ZIP

APPROVED

▲ LAST BALANCE IS AMOUNT DUE UNLESS OTHERWISE INDICATED. BILLS ARE PAYABLE WHEN PRESENTED. RETAIN THIS RECEIPT.

REMARKS:

REGARDLESS OF INSTRUCTIONS, GUEST IS ALSO LIABLE UNTIL BALANCE HAS BEEN PAID.

PASSENGER'S RECEIPT, TAXICAB FARE

Date 7-23-85

Amount of Fare $ 14 00

Other Charges $______

Total. . . . . $______

Driver's Name [illegible]

Cab Number Cochise 318

TRAY BUSINESS SYSTEMS INC Severna Park Md 21146/(301) 647 7747/ Washington Office (301) 261-1647

AOAP-02-1176
JULY, 1984

NATIONAL ACADEMY OF SCIENCES

2101 Constitution Avenue, N.W., Washington, D.C. 20418

ORIGINAL

TRAVEL VOUCHER

SEE INSTRUCTIONS ON REVERSE OF TRAVELER'S COPY

SUBMIT TO NAS OFFICE AUTHORIZING TRAVEL

PLEASE PRINT OR TYPE

MAKE CHECK PAYABLE TO: ROLAND B. MULCHAY (Limit 27 Characters)

DATE THIS VOUCHER SUBMITTED: AUG 1, 1985

☑ MAIL CHECK TO: (Address) 2732 WREN ROAD
– OR – SALT LAKE CITY, UTAH
84117

NAS COMMITTEE OR OFFICE ______

PURPOSE OF TRAVEL: INCLUDE NAMES OF PERSONS OR ORGANIZATIONS VISITED, DATE AND LOCATION OF MEETING(S).

☐ DELIVER CHECK TO: (Name) ______
BLDG. ______ RM. NO. ______

DATE AND HOUR OF DEPARTURE (PAR 1) 7/23/85 1:30 PM
DATE AND HOUR OF RETURN (PAR 1) 7/26/85 4:00 PM.

TRANSPORTATION: ATTACH ORIGINAL PASSENGER COUPON; ECONOMY CLASS AIR FARE AND TRAVEL BY U.S. CARRIER ARE REQUIRED.

ITINERARY FROM CITY AND STATE/COUNTRY	ITINERARY TO CITY AND STATE/COUNTRY	CARRIER* (PAR 2)	CLASS OF SERVICE* (PAR 3)	PRIVATE AUTO MILEAGE (PAR 4)	AMOUNT OR SOURCE OF PAYMENT (PAR 5)
SALT LAKE CITY, UT. U.S.	TUCSON, ARIZ US	AMERICA WEST	ECONOMY		$ 198.00
AND RETURN		"	(30 day pre-pay)		

*ATTACH WRITTEN JUSTIFICATION IF AIR TRAVEL NOT BY ECONOMY CLASS OR IF FOREIGN CARRIER USED.

RENTAL CAR: ATTACH ORIGINAL INVOICE AND REASON WHY PUBLIC TRANSPORTATION COULD NOT BE USED (PAR 6) $

TAXI FARES AND PARKING: ENTER CITIES, AMOUNTS, TOTAL TUCSON, ARIZ. $ 17.00

SUBSISTENCE AND OTHER EXPENSE: COMPLETE BLOCKS BELOW AND ATTACH ORIGINAL LODGING RECEIPTS (PAR 7)

DATE	MEALS AND TIPS B	L	D	TOTAL	LODGING	DAILY TOTAL
7/23			8.47	8.47	51.84	60.31
7/24	5.60	6.00	7.62	19.22	34.56 (Adjust)	53.78
7/25	6.06	3.12	7.00	16.18	43.20	59.38
7/26	5.44			5.44		5.44
	17.10	9.12	23.09	49.31	129.60	178.91

IF ADDITIONAL SPACE IS NEEDED, USE "CONTINUATION SHEET FOR SUBSISTENCE EXPENSE" TOTALS $ 49.31 $ 129.60

TOTAL MEALS & LODGING $ 178.91

OTHER EXPENSE (PAR 8) SPECIFY: ______ $

TELEPHONE CALLS ON NAS BUSINESS $ 1.20

TOTAL TELEPHONE & OTHER $ 1.20

I CERTIFY THAT THE ABOVE CLAIM IS CORRECT AND PROPER AND THAT PAYMENT THEREFOR HAS NOT BEEN RECEIVED.

CLAIMANT'S SIGNATURE [signature] DATE 8/1/85

CHECK ONE: ☐ EMPLOYEE ☐ CONSULTANT ☑ COMMITTEE MEMBER ☐ OTHER ______

TOTAL EXPENSE $ 395.11
LESS ADVANCE (PAR 9)
BALANCE DUE $ 395.11

CLAIMANT NOT TO WRITE BELOW THIS LINE

APPROVAL: I CERTIFY THAT THE ABOVE EXPENDITURE WAS DULY AUTHORIZED AND I APPROVE CLAIM FOR PAYMENT.

NAME OF OFFICE SUBMITTING VOUCHER ______ PHONE EXTENSION ______

SIGNATURE ______ SIGNATURE ______

FOR ACCOUNTING OFFICE USE ONLY

COST CENTER NUMBER	ACCOUNT NUMBER	AMOUNT	PAYEE AND OPTIONAL DESCRIPTION (Limit 27 Characters)	IRS	INCURRED DATE	COMMIT-MENT NUMBER	P/F	COMM
–	–	.						
–	–	.						
–	–	.						

FOR ACCOUNTING OFFICE USE ONLY

AUDITED ______ DATE ______
APPROVED ______ DATE ______
SPECIAL APPROVAL ______ DATE ______ REFERENCE NO. ______ DATE ______

Roland B. Mulchay
Consulting Geologist
2732 Wren Road
Salt Lake City, Utah 84117

April 16, 1981

Mr. J. J. Quinlan
Senior Geologist
Kerr-McGee Resources Corporation
P. O. Box 25861
Oklahome City, Okla. 73125

Dear Jim:

Thanks very much for sending me your AGS paper on the Red Mountain deposit. Now that my struggle with the numerous IRS forms has been completed, for better or for worse, I'm looking forward with great interest to review the report. There aren't many breccias which do not outcrop that have been recognized outside of Cananea, so there is a good chance you have an important "first".

If I get any bright ideas from the paper, I'll drop you a few lines of discussion. In any case some one of these days I'll hope to visit the property when you are there and we can speculate on origins of breccias and sources of minerals - "ore tectonics" on a small scale without the necessity to push continents around globally !

With best regards and very best wishes for your continued success in search of these elusive ore deposits,

Sincerely,

Roland B. Mulchay

RBM:m

J. J. QUINLAN

SENIOR STAFF GEOLOGIST

MINERAL EXPLORATION AND JOINT VENTURES

KERR-McGEE RESOURCES CORPORATION

POST OFFICE BOX 25861

OKLAHOMA CITY, OKLAHOMA 73125

KERR-McGEE TOWER, ROOM 2603

BUS: 405/270-~~8859~~ 3975 RES: 405/364-9895

3/30/81

Roland:

Red Stevens introduced and stimulated my early interest in breccia pipes. Sure wish I could have shown him this one.

Trust you enjoy the paper and would be interested in your comments.

Best regards,

Jim

JIM QUINLAN

CONTINENTAL SCIENTIFIC DRILLING PROGRAM
CONFIDENTIALITY AND LIABILITY AGREEMENT
WITH THE KERR-McGEE CORPORATION

Red Mountain
Santa Cruz County, Arizona

The Kerr-McGee Corporation has granted to the Continental Scientific Drilling Committee (CSDC) permission to use its Red Mountain, Arizona property as a study and possible drill site. In addition, the company has agreed to make available to the project basic geologic data and cores resulting from previous drilling. As with all outside studies of this nature, the company does not warrant any of the material or data furnished.

In consideration of the above, and to protect Kerr-McGee's interest in the property and the company from any contingent liability resulting from the project, Kerr-McGee requires all representatives or members of CSDC participating in the Red Mountain project to agree to the following:

1. Analyses and geologic information provided by Kerr-McGee or developed under the study will be treated as proprietary information. It will be restricted in distribution within the project group to those directly involved and none released to the public prior to approval by the Ad Hoc Task Group for the Red Mountain Project and Kerr-McGee.

2. Kerr-McGee has no objection to the public release of general geologic and scientific data resulting from the project. However, prior to public release, including the publishing or placement of theses resulting from project work in university libraries, Kerr-McGee reserves the right to review and comment on data, papers, manuscripts or proposed publications pertaining to the finds, descriptions or determinations resulting from the project.

3. All unused materials, including samples, rock chips, petrographic slides and work documents will be returned to Kerr-McGee upon completion or termination of the project. This shall not preclude arrangements with Kerr-McGee to place special samples or materials in repositories or archives.

4. The undersigned, as a representative or member of the Continental Scientific Drilling Committee, by acceptance of the terms and conditions of this Agreement does indemnify and save harmless Kerr-McGee Corporation of and from any and all liability for injuries to or death of the undersigned, or for loss or damage to his or her property, and further, the undersigned shall and hereby save harmless from any and all liabilities, claims, demands, suits, actions, losses, damages recoveries, judgments, costs or expenses in any manner arising out of or in connection with your activities on the Kerr-McGee premises.

ACCEPTED THIS 25 day of JUNE, 1985

by Roland B. Mulchay

Title____________________

CONTINENTAL SCIENTIFIC DRILLING COMMITTEE
PANEL ON MINERAL RESOURCES
AD HOC TASK GROUP MEETING
Red Mountain, Arizona

July 24, 1985

☑ I plan to attend the Ad Hock Task Group Meeting for Red Mountain on July 24, 1985.

☐ I will be unable to attend the Ad Hock Task Group Meeting for Red Mountain on July 24, 1984.

☑ I would like you to reserve a room at the Sheraton Pueblo Inn in Tucson for July 23 and 24, 1985 (date or dates).

Rilana B. Mulchay
Signature

Return to: J. J. Quinlan
Kerr-McGee Corporation
P.O. Box 25861
Oklahoma City, Oklahoma 73125

KERR-McGEE CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

June 21, 1985

Roland B. Mulchay
2732 Wren Road
Salt Lake City, Utah 84117

Dear Roland:

Maurice Chaffee and I wish to thank you for agreeing to serve as a member on the Continental Scientific Drilling Committee Ad Hoc Task Group for Red Mountain. A directory of Task Group members and observers is attached.

The first meeting of the Task Group is to be held at Red Mountain on July 24. At that time we plan to tour the mountain, introduce the group to the core storage facility, and outline a program of study for Red Mountain.

The tour on July 24 will start from the Sheraton Pueblo Inn at 350 S. Freeway in Tucson at 8:00 a.m. To help with planning we would appreciate it if you would complete and return the attached form at your convenience. We also need your signature on the attached confidentiality agreement and liability release.

Again, thanks and I am looking forward to seeing you on July 24.

Sincerely yours,

Jim

James J. Quinlan
Senior Staff Geologist
Minerals Exploration Division

JJQ:bw

Attachments

TUES., 5/21/85
3:30 PM

CALL FROM JIM QUINLAN, KERR-McGEE, TUCSON.

INVITED RBM TO BE MEMBER OF COMMITTEE TO CONSIDER DEEP DRILL HOLE AT RED MT., PATAGONIA DIST., ARIZ. WILL BE PART OF DEEP DRILLING PROGRAM OF NATL. SCI., HEADED BY BARBER.
KERR-McGEE WILL COOPERATE FULLY.
SEVERAL COMMITTEE MEMBERS, INCLUDING CHUCK MEYER, GRAYBEAL (ASARCO), AND GEOPHYSIST,

PRELIMINARY MEETING ABOUT JULY 24TH TO VISIT RED MT., REVIEW CORE.

PROF. TO BE ADVISORY AND HAVE STUDENTS DO WORK ON PROJECT; MENTIONED BURNHAM, TITLEY, OTHERS.

RBM ACCEPTED; HE WILL GET OUT LETTER AFTER HE HAS CONTACTED ALL CONCERNED

Journal of Geochemical Exploration, 14 (1981) 135—153
Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

REGIONAL GEOCHEMICAL STUDIES IN THE PATAGONIA MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

M.A. CHAFFEE, R.H. HILL, S.J. SUTLEY and J.R. WATTERSON

U.S. Geological Survey, Box 25046, Denver Federal Center, Denver, CO 80225 (U.S.A.)

(Received April 9, 1980; revised and accepted July 16, 1980)

ABSTRACT

Chaffee, M.A., Hill, R.H., Sutley, S.J. and Watterson, J.R., 1981. Regional geochemical studies in the Patagonia Mountains, Santa Cruz County, Arizona. J. Geochem. Explor., 14: 135—153.

The Patagonia Mountains in southern Arizona contain the deeply buried porphyry copper system at Red Mountain as well as a number of other base- and precious-metal mines and prospects. The range contains complex Basin and Range geology with units ranging in age from Precambrian to Holocene. Rock types present include igneous intrusive and extrusive units as well as sedimentary and metamorphic units, most of which have been tectonically disturbed. A total of 264 stream-sediment samples were collected and analyzed for 32 elements. Geochemical maps for Sb, Ag, Pb, Te, B, Mn, Au, Zn, Cu (total), Cu (cold-extractable), and Mo, as well as for Cu (cold-extractable)/Cu (total) and Fe/Mn, are presented.

Anomaly patterns for these elements generally occur over the Red Mountain deposit and (or) along a north-northwest trend parallel to the major Harshaw Creek Fault. Much of the entire area sampled contains widespread anomalies for Pb, Te, and Cu; the other elements are only locally anomalous. Various plots of ratios of Cu (cold-extractable) to Cu (total) did not produce any new information not readily apparent on either one of the two copper maps. A plot of ratios of Fe to Mn delineated many areas of pyrite mineralization. Several of these areas may represent the pyritic halos around deeply buried porphyry copper systems.

The best ore guide for the Red Mountain porphyry system is the coincidence of positive anomalies of Mo, Pb, and Te and a negative anomaly of Mn. Other areas with anomalies of the same suite of elements are present within the Patagonia Mountains.

It is concluded that geochemical sampling, even in a highly contaminated area, can be useful in delineating major geologic features, such as porphyry copper belts and major faults. Multielement geochemical surveys on a regional scale can effectively locate large, deeply buried, zoned mineral systems such as that at Red Mountain. Plots of element ratios, where adequately understood, can provide geochemical information not readily discernible from plots of single elements alone.

INTRODUCTION

The U.S. Geological Survey is currently studying on a regional basis the geochemical characteristics of the porphyry copper belt or belts in southern

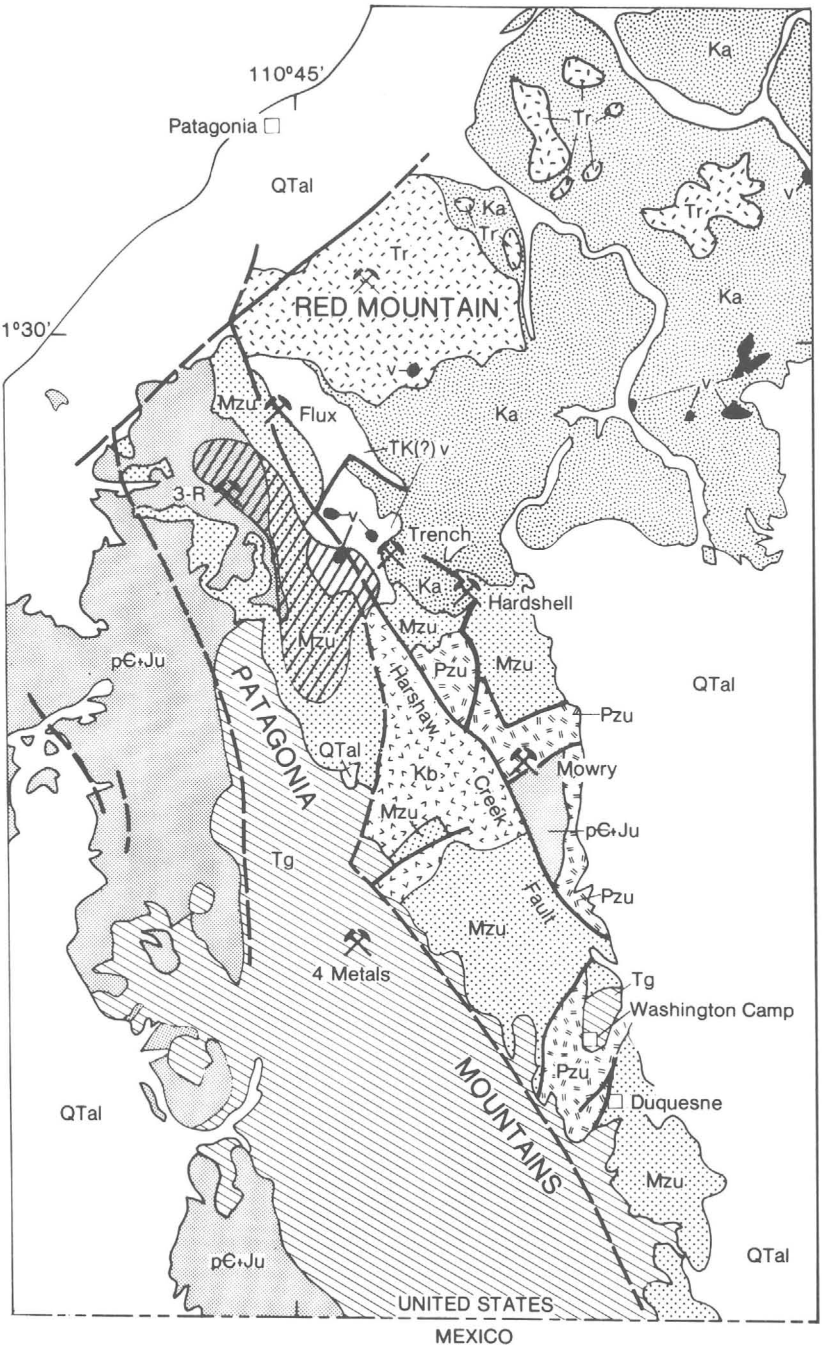

Fig. 1. Map of Arizona showing location of study area, and generalized geologic map of the Patagonia Mountains.

EXPLANATION

QTal — Unconsolidated and consolidated gravels and alluvium (Quaternary and Tertiary)--Locally contains tuffs and limestone

Tr, v — Volcanic rocks of Red Mountain (Tertiary); v, volcanic vent

Tg — Granodiorite stock (Tertiary)--Locally includes quartz monzonite and quartz diorite

TK(?)v, v — Silicic volcanic rocks (Tertiary and Cretaceous?)--May be related to volcanic rocks of Red Mountain; v, volcanic vent

Ka, v — Trachyandesite flows (Cretaceous); v, volcanic vent

Kb — Bisbee Formation (Lower Cretaceous)--Sedimentary rocks

Mzu — Intrusive and extrusive rocks undivided (Jurassic and Triassic)

Pzu — Sedimentary rocks, undivided (Paleozoic)

p€+Ju — Igneous intrusive rocks and metasedimentary or metavolcanic rocks (Precambrian)--Intruded by Jurassic granite, undivided

Fault--Dashed where inferred or covered

Intensely altered zone of Simons (1974)

0 1 2 3 4 5 MILES

0 1 2 3 4 5 KILOMETERS

Arizona and northern Sonora, Mexico. A part of this region obviously of considerable interest is the Patagonia Mountain range (Fig. 1), which contains the large, deeply buried porphyry deposit at Red Mountain, as well as a number of smaller base- and precious-metal mines and prospects.

The Patagonias lie within the Basin and Range province in Arizona, east of Nogales and just north of the Arizona—Sonora border. The area is semi-arid. All of the streams are intermittant, with water flowing only at times of heavy precipitation. Relief in the Patagonia Range is about 1000 m; consequently, erosion and subsequent mechanical dispersion of sediment along stream channels are relatively rapid, and the resulting sediment is very poorly sorted. As a result of the rapid rate of erosion, fresh pyrite is exposed in some of the canyons. Iron oxides are common in outcrops throughout much of the region; exposures containing manganese oxides are much more limited.

Portions of this paper were presented orally at the Association of Exploration Geochemists-sponsored Regional Symposium held in Tucson, Arizona, in April 1979.

GEOLOGY

The geology of much of the Basin and Range province is complex; the Patagonia area is no exception. Figure 1 shows the generalized geology of the range. We have drawn freely on the detailed mapping work of Simons (1974), Drewes (1971), and Corn (1975) in constructing this map. The oldest rocks in the area include Precambrian biotite quartz monzonite and hornblende diorite, on the east side of the range, along with biotite-hornblende quartz monzonite and hornblende gabbro along the west side.

Paleozoic sedimentary rocks are present in two areas on the east side of the range, where formations exposed include the Bolsa Quartzite, Abrigo Formation, Martin Formation, Escabrosa Limestone, Earp Formation, Colina Limestone, Epitaph Dolomite, Scherrer Formation, and Concha Limestone.

Mesozoic rocks are present mostly in a north-northwest-trending belt through the range and as Jurassic granite intruding the Precambrian rocks on the west flank of the range. These Mesozoic rocks are predominantly igneous and include intermediate to felsic volcanic tuffs and flows and intrusive monzonite, quartz monzonite, diorite, granodiorite, granite, and syenite. Clastic sedimentary rocks are also present locally.

The Bisbee Formation consists of both carbonate and clastic sedimentary rocks, and is also present within the north-northwest-trending zone. Trachyandesite flows are common in the northeastern part of the area.

A Laramide-age, predominantly granodioritic stock is present as the core of the central and southern part of the range. The volcanic rocks of Red Mountain include a layered sequence of volcanic units and hornfels that has been intruded by monzonite porphyry and quartz monzonite porphyry.

Silicic volcanic rocks have been mapped south of the volcanic rocks of Red Mountain. These silicic rocks may be a part of that volcanic complex. Numerous vents are present in the Cretaceous and Tertiary volcanic units.

Surrounding the older rocks is a thick sequence of Quaternary and Tertiary gravels. Minor tuffs and limestone are included in this unit. The Holocene alluvium that is present in the modern stream channels is also included in this latter unit.

Major faulting has occurred in the Patagonias, mainly along north-northwest and northeast directions (Fig. 1). The most prominent structure is the major north-northwest-trending Harshaw Creek Fault. An area of intense alteration that was mapped by Simons (1974), is outlined in Fig. 1. The area contains the minerals pyrophyllite, sericite, alunite, and (or) kaolinite. In outcrop, much of this area appears strongly bleached and iron-stained as a result of the breakdown of the dark rock-forming minerals and pyrite.

MINERAL DEPOSITS

Mining in the Patagonias goes well back into the Spanish missionary period (Schrader, 1915). The Patagonias contain many altered and mineralized outcrops as well as many old mines. Some of the more important mines and mining districts and the metals present in their ores (Fig. 1) include the 3-R (Cu-Au-Pb), Flux (Cu-Pb-Zn-Ag-Au-Mn), Trench (Pb-Ag-Mn), Hardshell (Pb-Ag-Mn), Mowry (Pb-Ag-Mn-Sb), and 4-Metals (Cu-Ag-Au-Pb) Mines, and the Washington Camp-Duquesne district (Cu-Pb-Zn-Ag-Au-As) (Schrader, 1915).

The Red Mountain porphyry copper deposit (Cu-Mo-Pb-Zn-Ag) (Fig. 1) is present near the north end of the Patagonia Mountains. This deposit consists of zoned, deeply buried copper-lead-zinc mineralization with ore-grade chalcopyrite present at depths of 1070 m (3500 ft.) or more below the present surface (Corn, 1975). Both fresh pyrite and a near-surface secondarily enriched copper zone crop out locally. Iron oxides, clay minerals, and silica are common in outcrops overlying the deposit.

GEOCHEMICAL SAMPLING AND ANALYSIS

For the Patagonia study we collected 264 stream-sediment samples. A given sample was composited from active alluvium present within a 15- to 20-m radius of the actual sample site. The sediment that passed through a screen with 0.25-mm openings (minus 60 mesh) was retained and pulverized for analysis. This material was analyzed for 32 elements[1]. Except for gold, tellurium, zinc, and antimony, all of the elements were determined using a six-step semiquantitative spectrographic method (Grimes and Marranzino, 1968). Analyzed by atomic-absorption methods were gold (second method,

[1]The 32 elements are: Ag, As, Au, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, La, Mg, Mn, Mo, Nb, Ni, Pb, Sb, Sc, Sn, Sr, Te, Th, Ti, V, W, Y, Zn, and Zr.

Ward et al., 1969), antimony (Welsch and Chao, 1975), tellurium (Chao et al., 1978), and zinc (Ward et al., 1969). Copper was also analyzed using a cold-extractable method (Ward et al., 1963).

Threshold values[1] for each element were selected somewhat arbitrarily, based on analytical distributions and visual inspections of plots of analyses.

GEOCHEMICAL MAPS

Figure 2A shows the distribution of antimony in the Patagonias. On this figure and on the succeeding figures, sample sites are shown and portions of given stream channels above given anomalous sample sites are indicated with heavy lines. We show antimony first to illustrate how upstream anomaly source areas were separated from anomalies farther downstream that were obviously the result of material moved downstream from such a source area. Therefore, where two or more adjacent stream channels exhibited anomalies, we drew contours only around those parts of the respective drainage basins above the uppermost anomalous site for each basin. Each of these shaded areas is here defined as an upper drainage basin anomaly. Considering the scale of this study, we feel that most isolated, generally single site anomalies probably do not represent significant anomalies; thus, most such anomalies have not been patterned on figures for this report.

As is true for many of the elements discussed in this report, antimony anomalies are present in host rocks of varying lithologies and ages. Clearly, many, if not all, of these shaded anomalies for antimony are related to old mine dumps. At the scale shown here, however, we are not particularly concerned with this fact. Our primary interest in this paper is to examine the broad regional geochemical trends and to try to relate them to the known geology and other parameters. The mineral residence of the antimony is not entirely known; tetrahedrite, pyrargyrite, bindheimite, and jamesonite have been reported from mines in the Patagonias (Schrader, 1915).

Silver (Fig. 2B) is widespread in the northern part of the range, generally in the area south of Red Mountain. Silver was an important metal recovered at mines in the Flux, Trench, and Hardshell areas. Not surprisingly, silver is also present in the vicinity of the Mowry, 4-Metals, and Washington Camp-Duquesne Mines, from which silver was also recovered in the ores. Silver, like antimony, is present in a variety of types of host rock. Most of the silver was found in galena, argentite, or horn silver (Schrader, 1915).

Lead (Fig. 3A) shows a pattern similar to silver, as might be expected in light of the fact that many of the mines were exploited for their lead-silver (galena) ores. The largest lead anomaly, however, extends considerably north of the largest silver anomaly and covers most of Red Mountain.

We have given two background ranges for lead in Fig. 3A. Our examination of lead values from many other areas of southern Arizona indicates that

[1]A threshold value is the highest background value for a positive anomaly and the lowest background value for a negative anomaly.

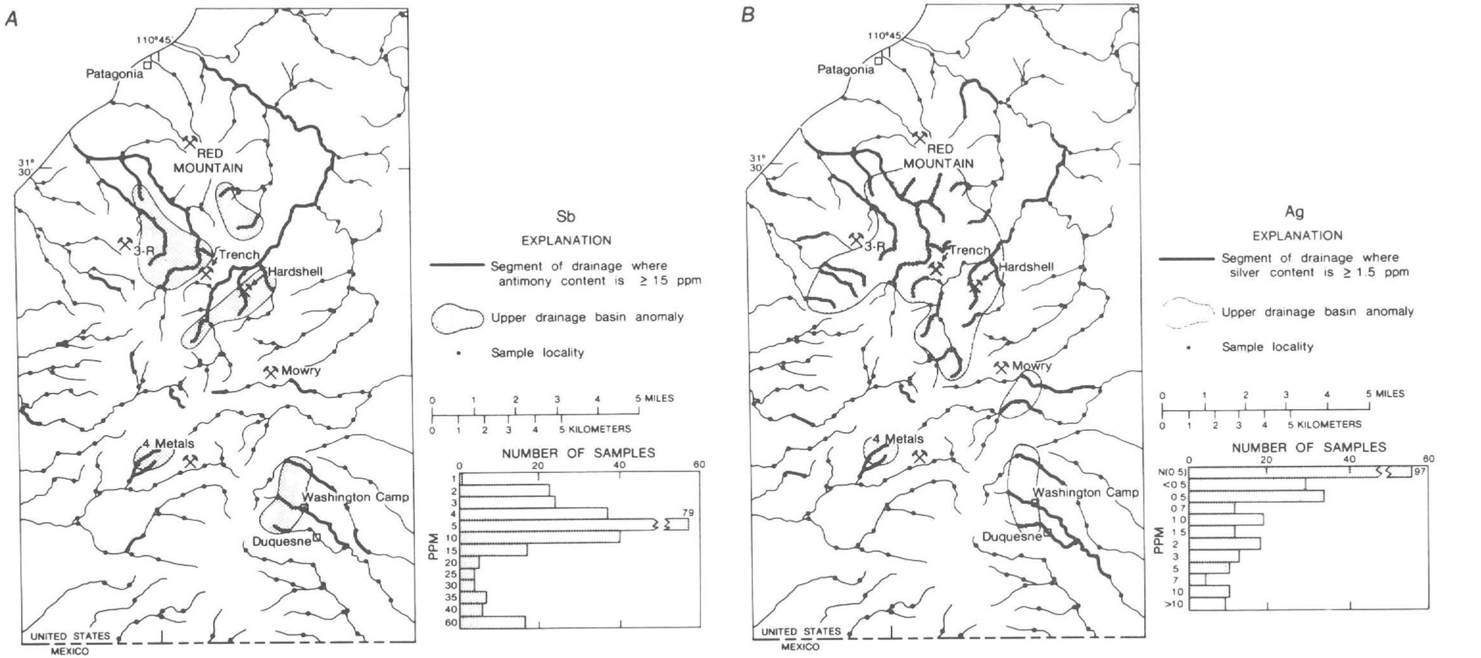

Fig. 2. Distributions of anomalies and concentrations of (A) antimony and (B) silver, Patagonia Mountains, Arizona. The ranges for background concentrations are 1—10 ppm (parts per million) Sb and N(0.5)—1.0 ppm Ag. N means looked for but not detected at the lower detection limit shown in parentheses.

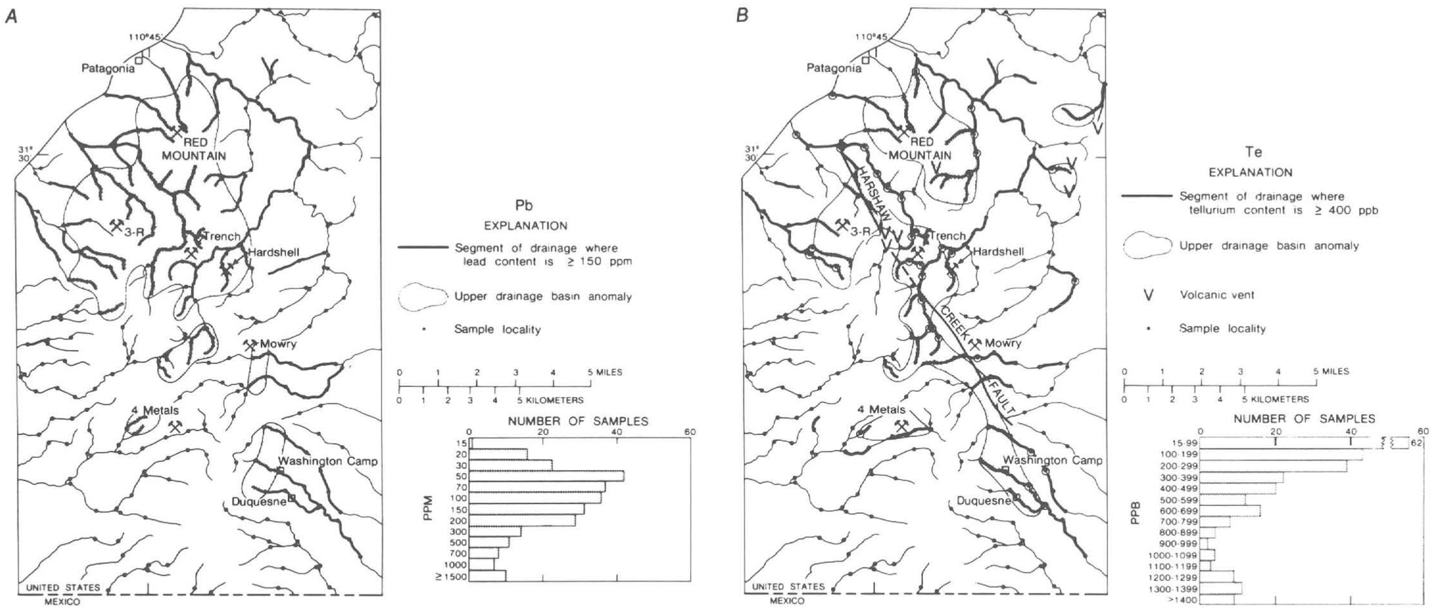

Fig. 3. Distributions of anomalies and concentrations of (A) lead and (B) tellurium, Patagonia Mountains, Arizona. The ranges for regional background concentrations are 15—30 ppm Pb and 15—99 ppb (parts per billion) Te. The ranges for local background concentrations are 50—100 ppm Pb and 100—399 ppb Te. Samples with tellurium concentrations ⩾ 1000 ppb are located by circled dots.

regardless of local lithology, this element has widespread anomalies (termed local background here) in the range of 50 to 100 ppm, whereas a true regional background seems to be in the range of 15 to 30 ppm.

Tellurium distributions are shown in Fig. 3B. Like lead, samples from much of the area shown contain tellurium in concentrations in the local background range or higher. A true regional background seems to be in the range of about 15 to 99 ppb, whereas local background is in the range of 100 to 399 ppb. A number of samples contained tellurium in concentrations of 1000 ppb or more (Fig. 3B). The source for the high tellurium is not entirely understood, but clearly some is related to volcanic vents, such as the ones labelled on the northern part of the map (Fig. 3B). The areal distribution of tellurium shows a general high over Red Mountain plus a linear high extending north-northwest through the range, a feature seen for several other elements. This linear high correlates spatially mostly with the various Mesozoic units, including the Jurassic granite, the Mesozoic undivided unit, and the Bisbee Formation, all in the vicinity of the Harshaw Creek Fault. The north-northwest spatial distribution of tellurium anomalies, including many of the sites with values that are >1000 ppb, also suggests an association with the major Harshaw Creek Fault. If one assumes an association of tellurium with late-stage mineralizing fluids, then the proximity of the sites of these high tellurium concentrations to the location of the Harshaw Creek Fault suggests that this fault may be an important regional source of mineralizing solutions.

We did not find any direct correlation between samples high in tellurium and those high in gold. Studies we did with different types of sample material collected at different locations in the Patagonias suggest that tellurium is mostly concentrated in pyrite or in the iron oxides or clay minerals resulting from the weathering of pyritized rock.

Figure 4A shows the distribution of boron. Note the general north-northwest trend again. As was the case for tellurium, the distribution of the highest boron values, shown by circled dots, suggests a linear pattern that roughly follows the Harshaw Creek Fault. The presence of higher concentrations of both tellurium and boron near this fault strongly suggests that this fault has been associated with mineralizing solutions. The mineralogical residence of the boron is not known.

Figure 4B shows the distribution of manganese. The north-northwest linear pattern shows up here again, but note that for manganese, this anomaly is a *negative* anomaly. Much of this anomaly is west of the boron and tellurium north-northwest anomalies and is spatially associated both with the Mesozoic units and the eastern part of the Tertiary granodiorite stock (Fig. 1). The cluster of very lowest manganese values (upper drainage basin anomaly ⩽200 ppm) seems to coincide closely with the area of most intense hydrothermal alteration outlined by Simons (1974) (Fig. 1). Examination of outcrops in this area suggests to us that this manganese low is related to the destruction of the dark minerals, a process that probably includes the leaching of elements such as manganese.

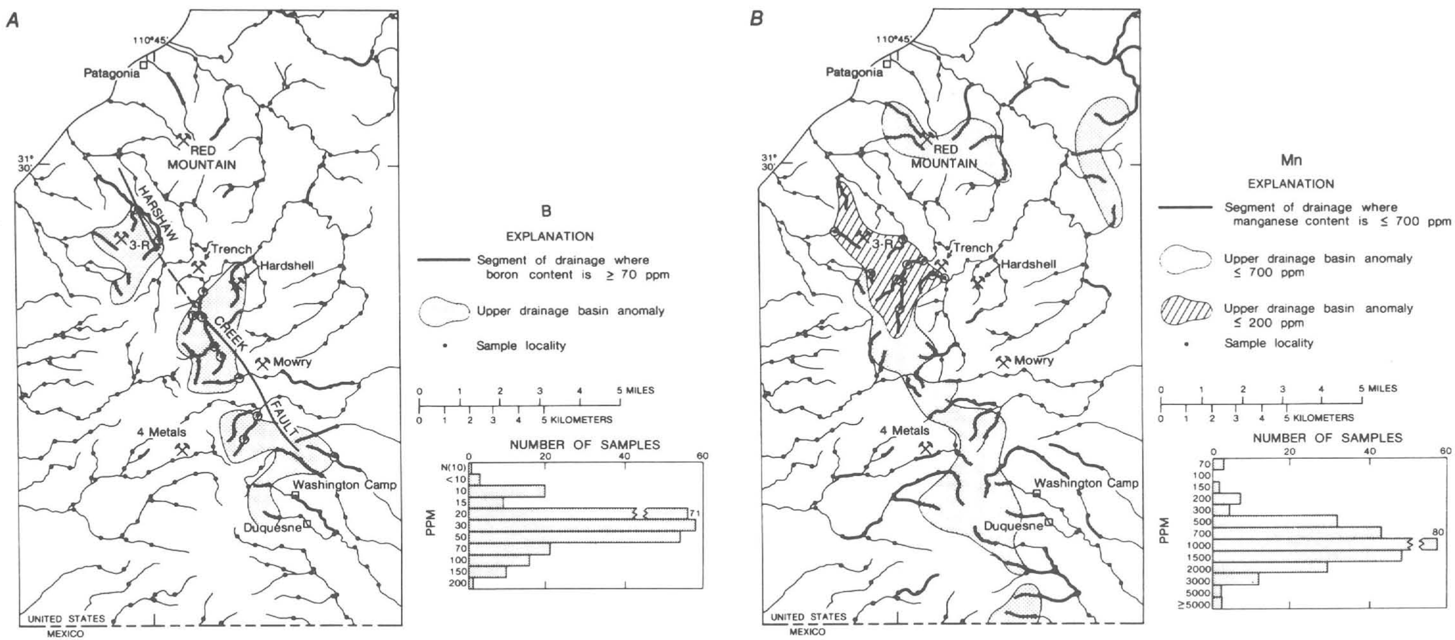

Fig. 4. Distribution of anomalies and concentrations of (A) boron and (B) manganese, Patagonia Mountains, Arizona. The ranges for background concentrations are N(10)—50 ppm B and 1000—2000 ppm Mn. N means looked for but not detected at the lower detection limit shown in parentheses. Samples with boron concentrations ⩾ 150 ppm and manganese concentrations ⩽ 200 ppm are located by circled dots.

The low manganese values present in the northeastern part of the area are probably related to a low manganese content of the Cretaceous trachyandesite flow rock. A manganese low also seems to be present over parts of Red Mountain. This low and some other manganese lows are especially significant in light of the fact that many of the ores mined in the Patagonias were enriched in manganese (mostly manganese oxides), and therefore many of the sediments in the stream channels are enriched in manganese derived from mine dumps.

Anomalous gold (Fig. 5A) also seems to follow the north-northwest trend; like manganese, the largest gold anomaly seems to be generally offset to the west of the boron-tellurium trend. The relatively limited gold anomalies probably reflect the generally limited distribution of gold in the ores of the region and the generally low gold tenor of the ores. Only a few of our samples contained gold at or in excess of 0.06 ppm. The gold anomalies generally agree with the locations of mines that are known to have shipped gold (Schrader, 1915) and are mostly confined to the Mesozoic units and the Tertiary granodiorite stock (Fig. 1). The mineral residence of the gold is not known.

Zinc anomalies (Fig. 5B) show two features. Positive zinc anomalies clearly delineate many of the old sphalerite-rich mines and are not related to any one lithology. The *negative* zinc anomalies are not as easily explained. The large low to the north is to some extent coincident with Simons' (1974) altered area (Fig. 1) suggesting a leaching of zinc, as well as manganese, as part of the alteration process. The large low to the south is wholly within the Tertiary granodiorite stock (Fig. 1) and may relate to chemical zoning within the stock.

Copper, occurring mainly as chalcopyrite, chalcocite, and enargite, was analyzed by two different methods for this report. The spectrographic copper method essentially determines the total copper content in a sample, including both ore-related and non-ore-related copper. In contrast to the spectrographic method, the cold-extractable analytical method measures primarily the weakly bound, mostly ore-related secondary forms of copper. Our study of analyses of samples from the Patagonia Mountains as well as from other areas in southern Arizona indicates that copper is another element that exhibits both regional and local background ranges. Considerable areas of the Patagonias have copper concentrations (by either analytical method) in the local background range or higher.

The distribution of total copper is shown in Fig. 6A. The shaded anomalies coincide spatially only locally with any of the elements previously discussed. Known copper-producing areas, such as the 3-R Mine, the 4-Metals Mine, and the Washington Camp-Duquesne areas, are delineated; however, when one considers the extent of copper in outcrop at Red Mountain, the copper anomaly there is not as extensive as one would hope to see. Copper anomalies do not correlate well spatially with any particular rock unit.

Anomalies for cold-extractable copper are shown in Fig. 6B. All of the old

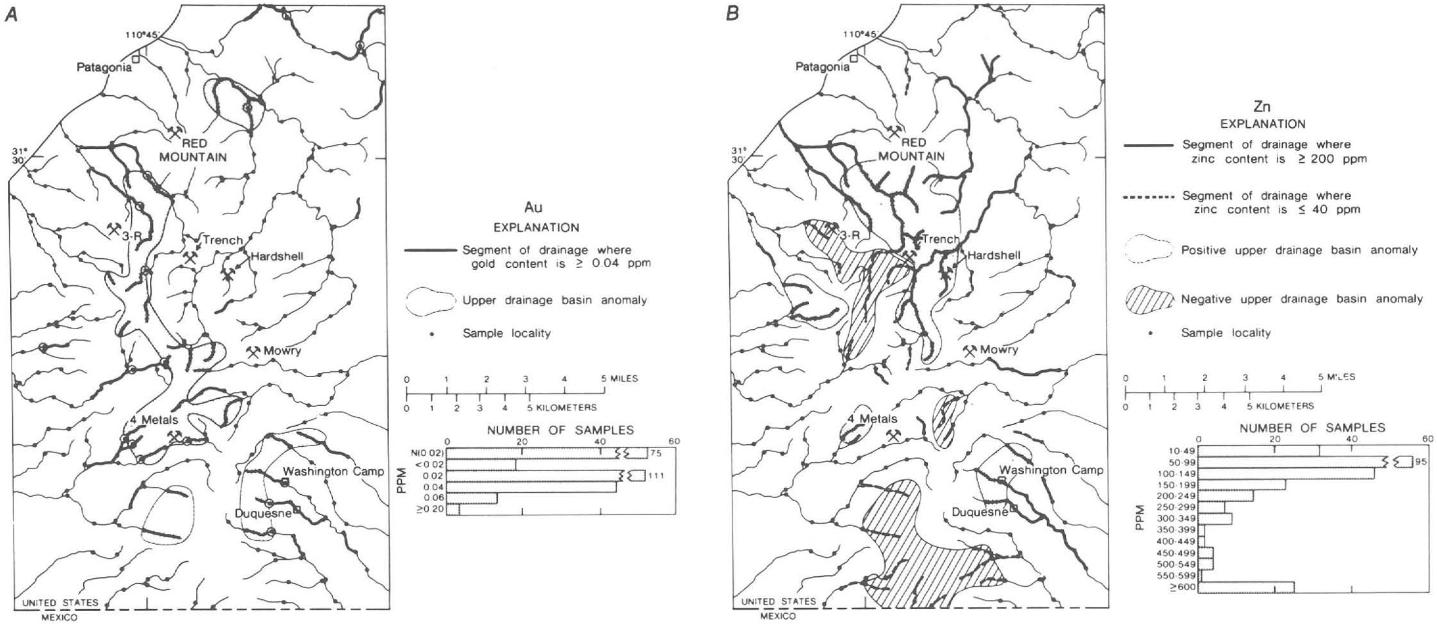

Fig. 5. Distributions of anomalies and concentrations of (A) gold and (B) zinc, Patagonia Mountains, Arizona. The ranges for background concentrations are N(0.02)—0.02 ppm Au and 10—100 ppm Zn. N means looked for but not detected at the lower detection limit shown in parentheses. Samples with gold concentrations ⩾0.06 ppm are located by circled dots.

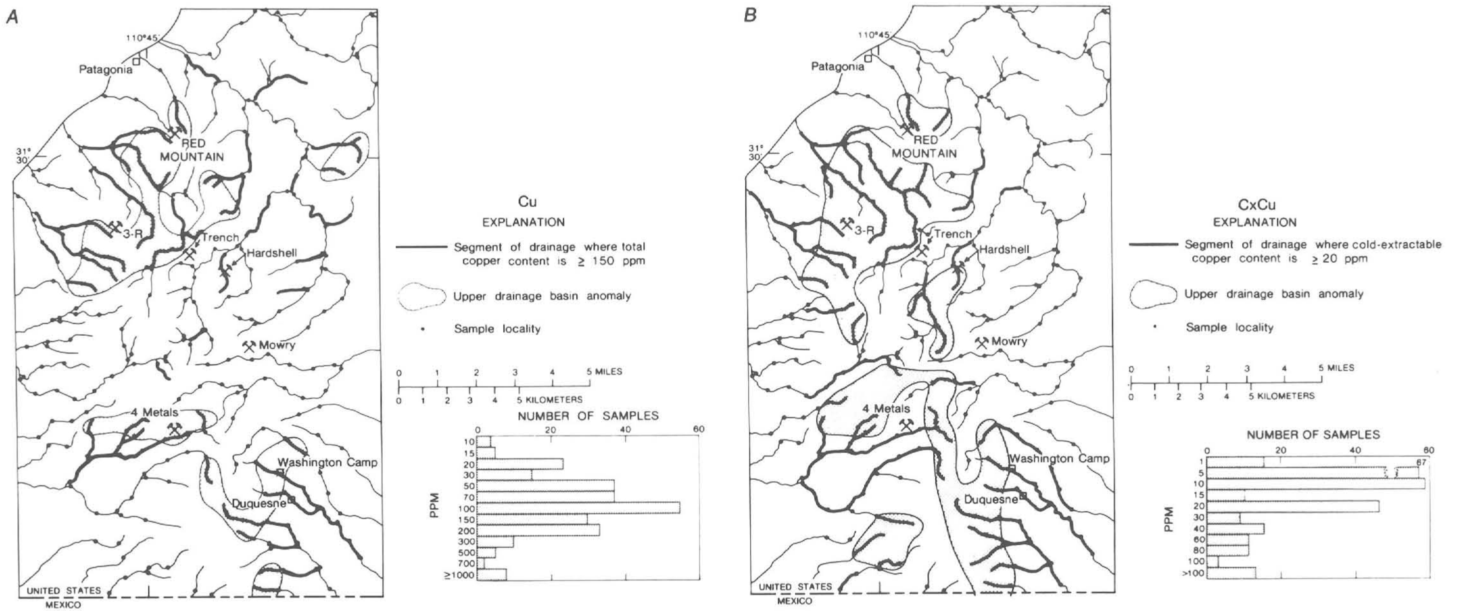

Fig. 6. Distributions of anomalies and concentrations of (A) total copper (Cu) and (B) cold-extractable copper (CxCu), Patagonia Mountains, Arizona. The ranges for regional background concentrations are 10—50 ppm Cu and 1—5 ppm CxCu. The ranges for local background concentrations are 70—100 ppm Cu and 10—15 ppm CxCu.

mining areas are reflected by cold-extractable copper anomalies except for the area of the Mowry Mine. Schrader (1915) did note the presence of copper in the ores from the deepest levels of the Mowry Mine; apparently copper minerals are volumetrically insignificant on the Mowry dumps and (or) have not moved into the stream channels below the dumps.

The anomalies for cold-extractable copper are more extensive than those for total (spectrographic) copper (Fig. 6A), at least in part because of the higher anomaly contrast values[1] present in the cold-extractable copper data set as compared to the total copper data set.

It is evident that neither total nor cold-extractable copper anomalies taken alone isolated as a favorable area the deeply buried porphyry system at Red Mountain, in spite of the fact that copper is present locally in outcrops in that area. Further, the anomaly patterns for these two copper methods do not coincide well spatially with any of the other elements discussed to this point. For purposes of this study, neither copper method was found to be clearly superior to the other in terms of showing all types of copper source areas.

The ratio of cold-extractable copper to total (spectrographic) copper has been used as a means of interpreting the type of copper anomaly present in an area. A high value for this ratio commonly indicates the presence of hydromorphic or biogenic copper, whereas a low value indicates the presence of mechanically transported copper (Levinson, 1974, p. 360). In the presence of oxidizing pyrite, however, areas that should produce high ratio values may actually yield low values because the oxidizing pyrite creates an acidic environment that lowers the pH in any waters present. Acidic waters in turn tend to mobilize any easily soluble copper, and thus produce low ratio values in spite of the presence of significant copper enrichment (Coope and Webb, 1963).

The ratio values obtained from our two copper data sets ranged from 1 to 100%. We plotted a number of different copper-ratio maps, varying the threshold values for each type of copper and also varying the lower cutoff value for the ratio. An example of one such plot is shown in Fig. 7A. We were unable to find any combination of these three parameters (copper ratio, total copper threshold, and cold-extractable copper threshold) that would provide any information that could not be readily obtained using either copper method alone. No consistent correlation of sites of low ratio values to areas of known pyrite was evident. We conclude, as noted by Levinson (1974), that the copper ratioing technique does not seem to provide meaningful information in an arid environment.

Molybdenum anomalies (Fig. 7B) partly reflect the north-northwest trend seen earlier and give a much better indication of the Red Mountain porphyry copper system than do those of copper. The highest molybdenum concentra-

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[1]An anomaly contrast value is the ratio of the element concentration for a given sample to an assigned single background value for that same element in a given data set.

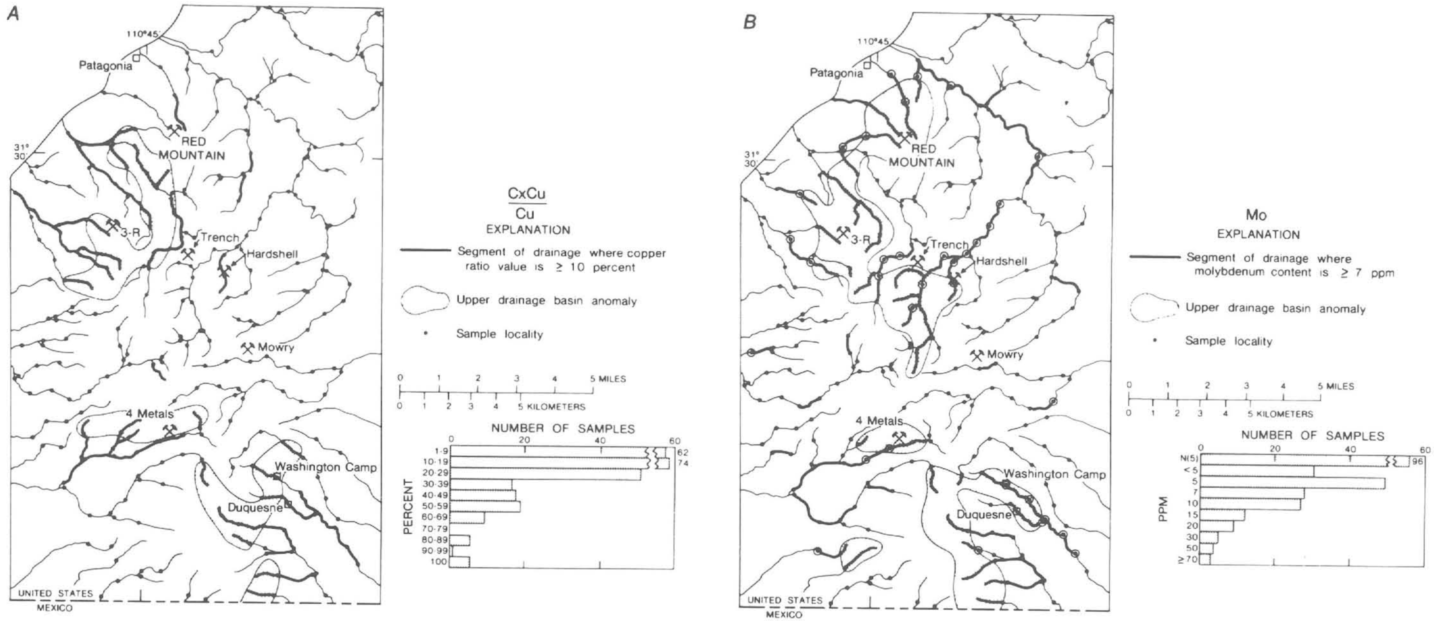

Fig. 7. Distributions of (A) anomalies and values for the ratio [ppm cold-extractable copper/ppm total (spectrographic) copper] × 100 [(C× Cu/Cu) × 100] and (B) anomalies and concentrations of molybdenum, Patagonia Mountains, Arizona. Note that for A, only those sites with a combination of cold-extractable copper concentrations ⩾20 ppm, total copper concentrations ⩾150 ppm, and ratio values ⩾10% are considered anomalous. For B, the range for background concentrations is N(5)—5 ppm Mo. N means looked for but not detected at the lower detection limit shown in parentheses. Samples with molybdenum concentrations ⩾20 ppm are located by circled dots.

tions are found on the west side of Red Mountain and are also apparently associated with ores from the Washington Camp-Duquesne areas, the Red Hill area, and also the American Peak-Hermosa Hill and other areas south of the Trench and Hardshell Mines.

An earlier study of element ratios at the Kalamazoo porphyry copper deposit north of Tucson (Chaffee, 1976) suggested that a high value for the ratio of iron to manganese might delineate those areas containing high concentrations of pyrite that might represent the pyrite halo in a porphyry system. A similar plot for the Patagonias (Fig. 8A) seems to confirm, at least locally, this relationship between high Fe-Mn ratio values and pyritized rock. The shaded area on the northwest side of Red Mountain locally contains fresh to oxidized pyrite in outcrop that probably represents part of the pyritic halo around the deeply buried porphyry copper deposit. The altered area extending southeast from the 3-R Mine and the altered area of oxidized pyrite around the 4-Metals Mine are also clearly delineated. The pyrite, or iron oxide after pyrite, that crops out in these two areas could, therefore, represent portions of the pyritic halos above buried, zoned porphyry systems. Sparse pyrite was also seen in outcrop in the small shaded area near the Mexican border; however, surface exposures in this area do not exhibit anywhere near the intensity of alteration seen in the other three areas.

Many of the areas of *low* iron-to-manganese ratios, such as the Washington Camp-Duquesne area (Fig. 8A), also contain significant pyrite; however, these areas also contain manganese-rich ores. Thus, high iron-manganese ratios can define potential pyrite halos only where manganese minerals do not form a significant part of the ore mineral suite.

One of the obvious questions we asked ourselves as part of this study was: "Is it possible that there is another deeply buried system in the Patagonias, like that at Red Mountain, that might be revealed geochemically?" If one assumes that a level of erosion comparable to that present at Red Mountain exists elsewhere, then the coincidence of anomalies of several elements found over the Red Mountain deposit may delineate favorable ground elsewhere. Figure 8B shows the results of this study. The shaded areas outline the upper drainage basins above sites that contained anomalies for high molybdenum, lead, and tellurium values and low manganese values. Clearly, the Red Mountain deposit area is identified. Because of the presence in some areas of manganese-enriched ores, Fig. 8B also shows those areas that contained coincident anomalies for molybdenum, lead, and tellurium only. It is possible that these areas are geochemically comparable to the shaded areas; no simple method has been devised to remove the effects of manganese contamination. The larger anomaly on Fig. 8B, which surrounds shaded areas B and C and is based on only three elements, suggests a broad area that might be of potential interest in the search for outcrops that are geochemically similar to those over the Red Mountain porphyry copper deposit.

Much of the ground in areas A, B, C, and D of Fig. 8B also has high Fe/Mn ratios (Fig. 8A). If one assumes that the Fe/Mn ratio map is an accurate mea-

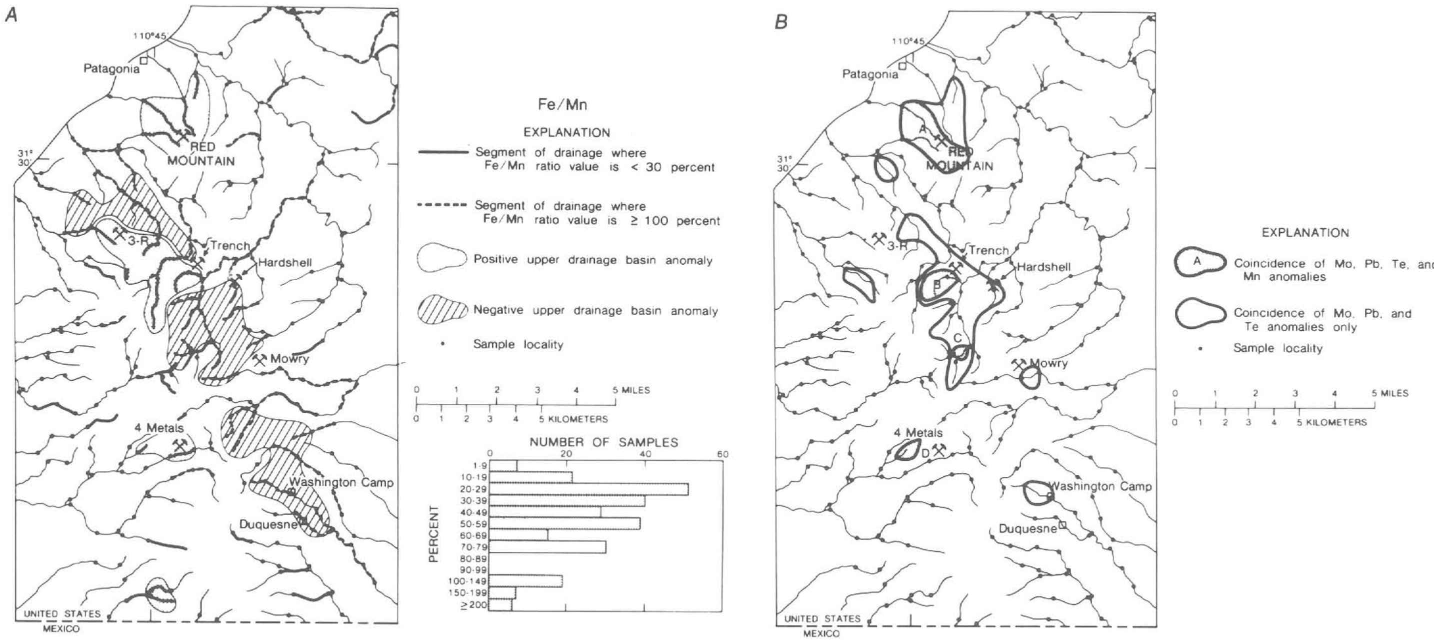

Fig. 8. A. Distributions of anomalies and values for the ratio ppm Fe/ppm Mn, Patagonia Mountains, Arizona. B. Distribution of anomalies for sites with a combination of molybdenum ⩾7 ppm, lead ⩾150 ppm, tellurium ⩾400 ppb, and manganese ⩽700 ppm, and for sites with anomalous combinations of molybdenum, tellurium, and lead only. Shaded area *A* is in the vicinity of the Red Mountain porphyry copper deposit. Area *B* is in a small drainage basin with no obvious mines. Area *C* is near the Endless Chain Mine. Area *D* is in the vicinity of the 4-Metals Mine.

sure of the location of possible pyrite halos associated with buried, zoned copper porphyry systems — as seems to be the case for the Red Mountain deposit — then the ground in the vicinity of shaded areas B, C, and D seems to be even more significant.

CONCLUSIONS

Geochemical surveys, even in a highly contaminated area, can be useful in delineating major geologic features. The geochemical survey conducted for this report used stream sediment exclusively as the sample medium. Most of the geochemical anomalies shown here are probably related to previous mining and prospecting activity; consequently, many of the geochemical patterns seen here probably would not exist, at least at the concentrations seen, had prospecting and mining not occurred in the past. Although one might expect to duplicate, in a gross way, the anomaly patterns shown here by using only representative samples collected from existing mine dumps, enough of the sample sites (both anomalous and non-anomalous) were located where no known mining activity had occurred to suggest that the use of sediment samples is to be preferred to the use of dump samples, even in a regional study.

Regional anomalies of as-yet unknown extent have been identified in the Patagonia Mountains for copper, lead, and tellurium. Such anomalies, when fully defined, may represent geochemical expressions of large areas of favorable ground, such as porphyry copper belts or metallogenic provinces. Within the Patagonia Mountains tellurium and boron seem to be closely associated with the major Harshaw Creek Fault, suggesting that this fault may be associated with undiscovered mineralization. Many elements are enriched in the Mesozoic-age block of ground located between the Harshaw Creek Fault and the Tertiary granodiorite stock (Fig. 1), suggesting that the units in this large block may be a more important mineral deposit host than has been previously recognized.

A north-northwest trend is apparent for anomalies of some of the elements studied, with a crude zoning pattern exemplified by gold and manganese anomalies on the west and tellurium and boron anomalies on the east. The general parallelism of these anomalies to the Harshaw Creek Fault and to the Mesozoic fault block west of that fault suggests that structural and (or) lithologic controls for these elements are the most likely cause for the patterns observed.

Multielement geochemical surveys are clearly more useful than those based on only one, or perhaps two, elements. Such surveys may be useful in locating large, deeply buried, zoned porphyry systems or other types of deposits. Plots of element ratios, when adequately understood, can provide geochemical information not readily discernible from plots of single-element analyses alone.

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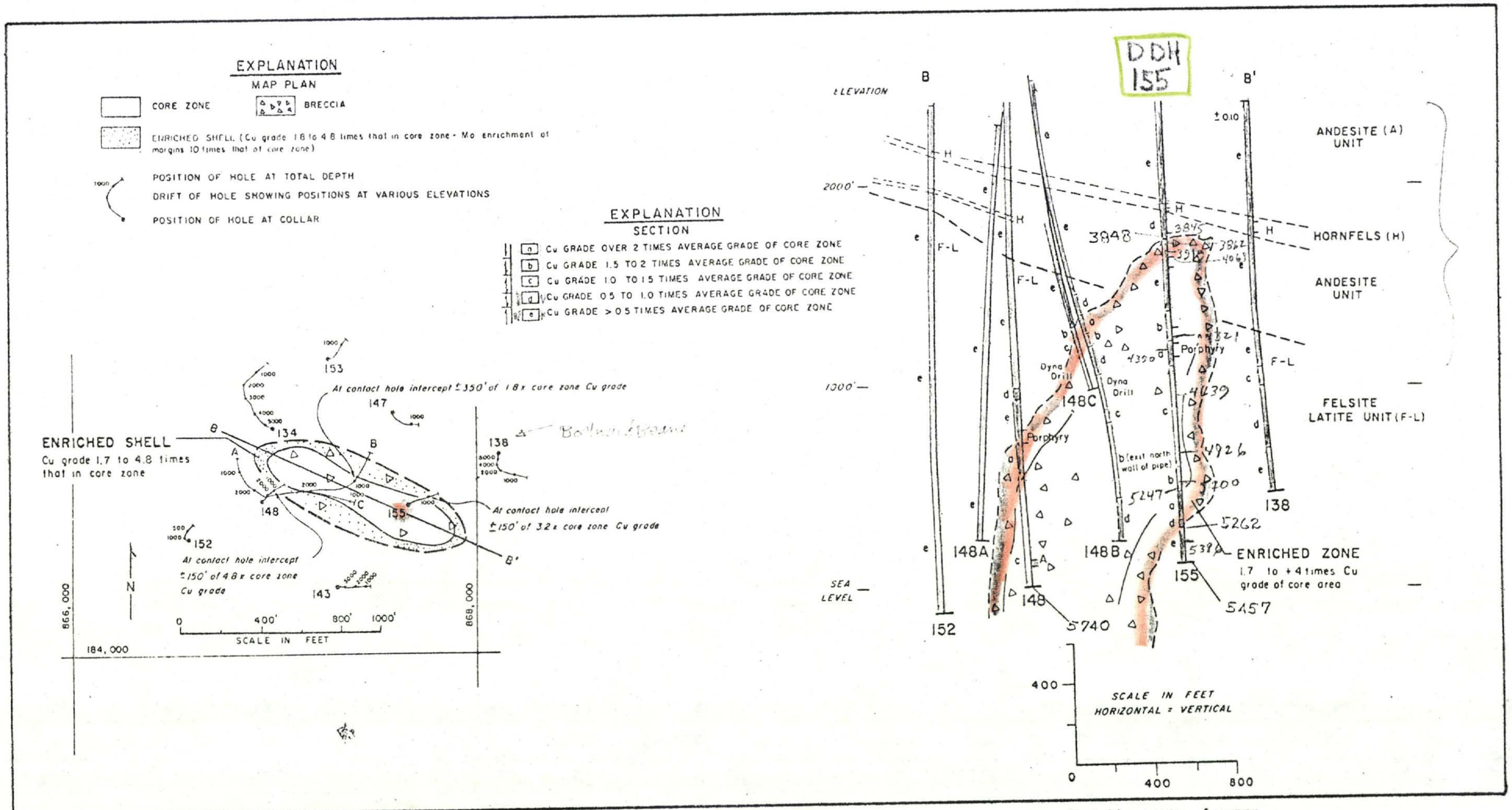


Fig. 12. Plan map and diagramatic cross section, looking northeasterly 148-155 breccia pipe at Red Mountain, Arizona

PETROGRAPHIC DESCRIPTION OF LOWER HALF OF DDH 155
BIOTITE DISTRIBUTION G. BRIMHALL AND J. AGUE

"ANDESITE" UNIT:

SLIDE #	HOLE DEPTH (FEET)	FIELD WIDTH	DESCRIPTION:
1	2897	7MM	VOLCANIC TEXTURE, PERVASIVE BIOT., MINOR ANHYD.
2	2897	1.5MM	CLOTTY BIOT., MINOR MAGNETITE (REFLECTED LIGHT)
3	2897	1.5MM	QTZ-VEIN CONTROLLED CHLORITE-ANHYD. VEIN
4	3414	1.5MM	WEAKER BIOT. THAN # 1
5	3414	7MM	QTZ-ANHYD-CARB. VEINLET
6	3845	7MM	PALE GREEN BIOT.-ANHYD.-QTZ VEIN IN "ANDESITE" WITH BIOT. GRDMASS.
7	3845	1.5MM	COARSE GRAINED BIOT. CO-EXISTING WITH ANHYD.

BRECCIA UNIT:

8	4321	1.5MM	TOP OF BRECCIA UNIT: COARSE-GRAINED ANHYD. AND CARBONATE WITH SERICITE WITH QTZ
9	4321	7MM	HIGH GRADE CHALCOPYRITE WITH MAGNETITE
10	4639	1.5MM	BLADED MUSCOVITE AND ANHYD.
11	4929	7MM	OVERGROWTHS ON EUHEDRAL QTZ.
12	5247-5396		HAND SPECIMENS OF LOWEST BRECCIA AND FELSITE-LATITE UNIT

"FELSITE-LATITE" BENEATH BRECCIA UNIT

13	5396	1.5MM	BROWN AND GREEN BIOTITE
14	5396	1.5MM	GREEN CHLORITE (PLANE LIGHT)
15	5396	1.5MM	GREEN CHLORITE (CROSSED POLS)
	5457	BOTTOM OF DDH	

16 LOG(XF/XOH) VS. LOG(XMG/XFE) IN BIOTITES
17 LOG(XF/XCL) VS. LOG(XMG/XFE) IN BIOTITES

RED MOUNTAIN, ARIZONA
CORE SPECIMENS

Sent to George Brimhall
for CSD Program Study

May 24, 1985

Specimens From Hole 155	Remarks
Above Pipe Intercept	All specimens above pipe are from Andesite Unit.
155 - 2897	
3319	
3414	
3544	
3769	
3818	
3845	
Pipe Intercept	From 3848 to 5262
155 - 3862	
3919	
4063	
4321	
4390	"Unbrecciated" Porphyry Dike
4639	
4926	
5200	
5247	
Below Pipe Intercept	Specimen from Latite Unit
155 - 5396	
Specimen From Hole 148	
Pipe Intercept	
148 - 5729	11 ft. from bottom of hole.

KERR-McGEE CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

May 24, 1985

Dr. George Brimhall
Division of Geological and Planetary Sciences
California Institute of Technology
Pasadena, California 91125

Re: Continental Scientific
Drilling Program
Red Mountain, Arizona

Dear George:

As promised during our phone conversation of May 21, I am sending under separate cover a suite of 18 specimens from and near the deep level breccia pipe at Red Mountain, Arizona. The specimens are for study prior to the proposed meeting of the Red Mountain Task Group of the CSDC in late July.

The specimens are labeled by hole number and distance where taken from the drill hole collars. To assist you in locating the specimen with reference to the pipe, I am enclosing a copy of the interpretive sketch of the pipe from the University of Arizona-Arizona Geological Society 1982 field guide to Red Mountain. I have penciled on the sketch the depth location of certain features so as to correlate the sketch and drill hole collar elevations. Trust this will help.

The specimens are shown on the attached list. Except for one, all are from Hole 155 and represent material from above, within and marginal to the pipe. The one exception is the specimen from Hole 148. This is to provide you with material from near the bottom of the deepest pipe penetration to date.

I trust that the microprobe and other work you intend prior to the July meeting will be of interest and help the group. As discussed, the material is furnished in confidence and with the understanding that it will be governed by the terms of a confidentiality agreement now being drawn to protect Kerr-McGee from the release of Company confidential information by CSDC.

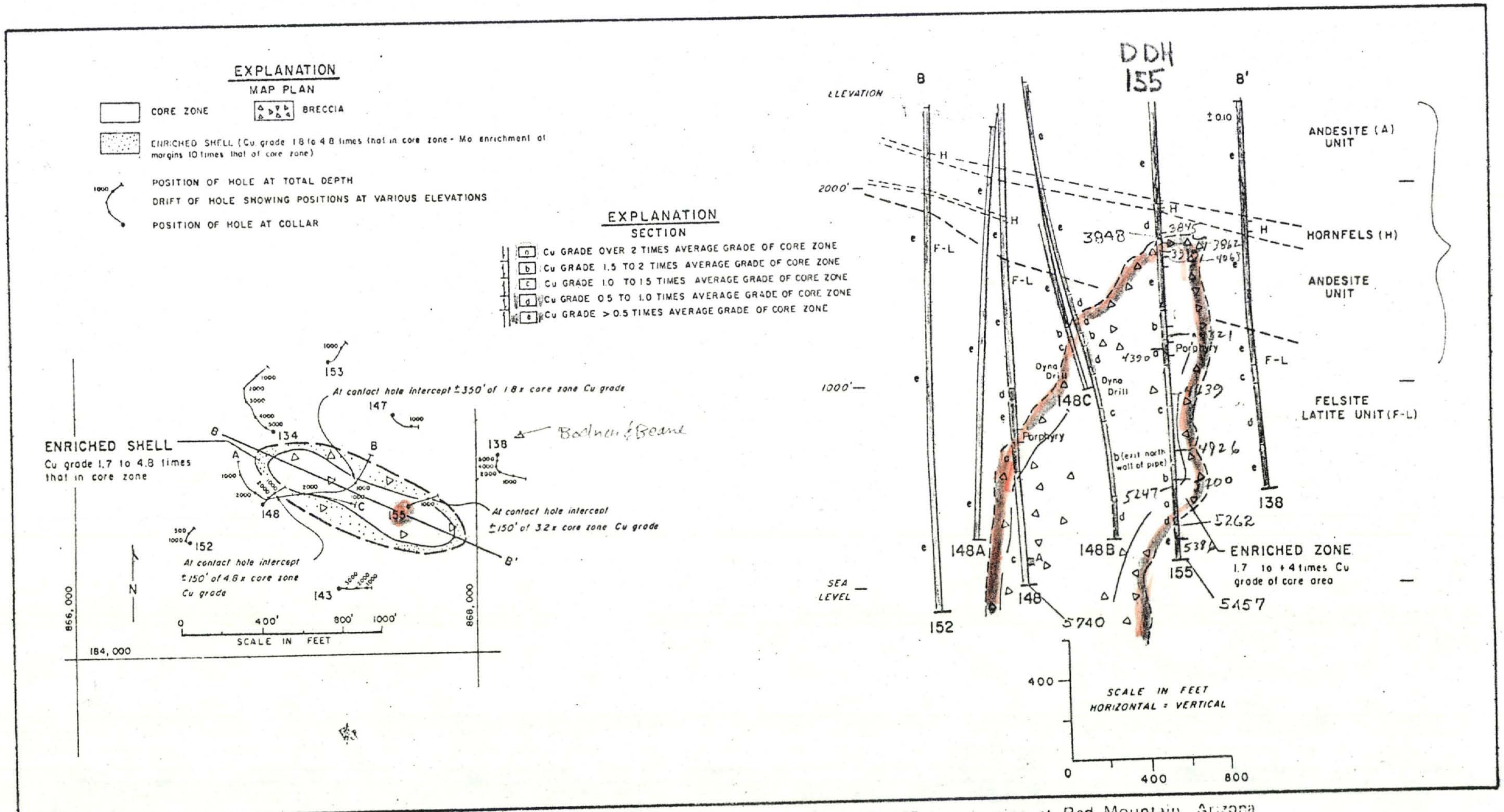
I am looking forward to the July meeting, and thank you for your support and interest.

Sincerely yours,

Jim

James J. Quinlan
Senior Staff Geologist
Minerals Exploration Division

JJQ:bw
Attachments



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BIOTITE DISTRIBUTION   G. BRIMHALL AND J. AGUE

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	5457		BOTTOM OF DDH

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May 24, 1985

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	5247	
Below Pipe Intercept		Specimen from Latite Unit
155 -	5396	
Specimen From Hole 148		
Pipe Intercept		
148 -	5729	11 ft. from bottom of hole.

KERR-McGEE CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

May 24, 1985

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I am looking forward to the July meeting, and thank you for your support and interest.

Sincerely yours,

Jim

James J. Quinlan
Senior Staff Geologist
Minerals Exploration Division

JJQ:bw
Attachments

CONTINENTAL SCIENTIFIC DRILLING COMMITTEE
PANEL ON MINERAL RESOURCES
AD HOC TASK GROUP FOR
RED MOUNTAIN ARIZONA

	Address	Phone
Co-Chairmen		
James J. Quinlan ✓	Kerr-McGee Corporation P.O. Box 25861 Oklahoma City, OK 73125	(405) 270-3975
Maurice A. Chaffee ✓	US Geological Survey Box 25046 M.S. 973 Federal Center Denver, Colorado 80225	(303) 236-1855
Members		
George D. Christiansen	Kerr-McGee Corporation P.O. Box 25861 Oklahoma City, OK 73125	(405) 270-3971
Paul I. Eimon ✓	Pioneer Nuclear, Inc. P.O. Box 151 Amarillo, TX 79189	(806) 373-6054
Frederick T. Graybeal	Asarco, Inc. 180 Maiden Lane New York, NY 10038	(212) 510-2000
Richard H. Merkil	Arco Exploration P.O. Box 5540 Denver, CO 80217	(303) 293-1118
Charles Meyer ✓	P.O. Box 2607 Sedona, AZ 86336	(602) 282-2287
Roland B. Mulchay ✓	2732 Wren Road Salt Lake City, UT 84117	(801) 277-2722

	Address	Phone
Observers		
George H. Brimhall ✓	Department of Geology and Geophysics University of California Berkley, CA 94720	(415) 642-5868
Jay Ague	Grad. Stud. U.C. Berkeley	
C. Wayne Burnham ✓	Pennsylvania State University 207 Deike Building University Park, PA 16802	(814) 865-6711
George Davis ✓	Department of Geosciences University of Arizona Tucson, AZ 85721	(602) 621-6024
Fleetwood Koutz ✓	Asarco, Inc. P.O. Box 5747 Tucson, AZ 85703	(602) 792-3010
Albert S. Johnson	Anaconda Minerals 7805 Windfont Row Parker, CO 80134	(303) 841-0192
Spencer R. Titley ✓	Department of Geosciences University of Arizona Tucson, AZ 85721	(602) 621-6018 298-8025

James Eidel

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James Eidel ✓		

8/29/85

KERR-McGEE CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

August 26, 1985

Mr. Roland B. Mulchay
2732 Wren Road
Salt Lake City, Utah 84117

Dear Roland:

I very much appreciate you taking the time to set down your observations on Red Mountain. As a member of the Marlboro School of Geology, that is tear and compare, I value your observations because of the many and different breccias you have seen and studied. Your suggestion to construct plan maps from drill hole data at 400 foot vertical intervals is a good one.

Hopefully, the CSDC will favorably consider the program that has been recommended for Red Mountain. In any event, I certainly am grateful for your interest and support, and most of all that you could join us.

Best personal regards, and hope to see you again soon.

Sincerely yours,

Jim

James J. Quinlan
Senior Staff Geologist
Minerals Exploration Division

JJQ:bw

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MAY 24 '85
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RED MT.
LETTER &
REPORT

Roland B. Mulchay
2732 Wren Road
Salt Lake City, Utah 84117

Salt Lake City, Utah
Oct. 22, 1985

Dear Vin:

I had intended to send this Red Mt. data several weeks ago, but various things seemed to interfere - mostly connected to Alice's broken collarbone. She is getting along well, but isn't driving, so the various grocery shopping, dental appaointments, clubs, etc., have taken up a lot of time. She visits the doctor next Monday, and, hopefully, the X-rays will show a good juncture of the bone segments.

The papers by Quinlan and Corn are published, but the data in my letter and the two other inclusions are confidential, according to Kerr-McGee; so consider them for your own information. The list of participants has the attendance checked; Paul Eimaon was there the first day, and I spent the second day (AM) looking at core at Nogales rather than spending it writing up my impressions based on one half hour of core observation, and a trip over the surface which did not reach the intrusive outcrops; consequently, neither Eimon or myself signed such an opinion. The final report, summmarized by Quinlan, included the expense allocations as listed. It appears that everyone there, and some who weren't, were angling for a grant to pursue thier own interest. The expense allocations were sent out for comment; as my copy arrived late on a Friday afternoon, and the comments were due in Okla. City by Tuesday, I didn't bother to make any.

We were glad to know that Mary's eye operation went well, and I'm sure your journey to the homo capital of the world was enjoyable, at least the food there is still enjoyable. If you found any familiar faces at the convention, they must have been pretty ancient. A trip through the Mother Lode would be interesting - apparently a few outfits are brave enough to challengs the prevailing California atmosphere of "to hell with mining".

We've had several weeks of great fall weather, but three inches of snow dropped in last night. However, more nice days are forecast, and I hope they last through December ! We'll look forward to a visit with you in Tucson in February. Phil Chase called that they would be there briefly, and will hope to see you.

With best regards from Alice and myself,

Sincerely,

RBM

Inclusion
Red Mt. AGS paper - Quinlan
" " Econ Geol - Corn
" " CDSC partipants
" " Expense grants requested
" " RBM letter

Roland B. Mulchay
Consulting Geologist
2732 Wren Road
Salt Lake City, Utah 84117

August 20, 1985

Mr. James J. Quinlan
Kerr-McGee Corporation
P. O. Box 25861
Oklahoma City, Okla. 73125

Dear Jim:

I am sorry thia description of my observations at Red Mountain is so very late, but it can help clutter your files on that ~~enjoyable and~~ interesting informative visit there. A couple of small consulting jobs developed, and my writing efforts have suffered a number of revisions. It was very enjoyable to be with the geologists of the CDSC group, though I'm sure Wayne Burnham and others did not take my observations very seriously!

I am very grateful that you included me in the group, and the limited time spent on the core undoubtedly contributed to my ed~~e~~ucation. The deep Red Mountain mineral zone is, indeed, an important one, and the efforts of the academics to assess it ~~was~~ were most interesting !

With best personal regards,

Yours very truly,

Roland B. Mulchay

Roland B. Mulchay

Impressions Gained from Rapid Observations of Specimens in "Skeletonized" Core at the Red Mountain Property, Santa Cruz County, Arizona on July 24 and 25, 1985

As a member of the CDSC Group , about one hour was spent in rapid examination of"Skeletonized" core from DDH 155 in the late afternoon of July 24th; With Jay Ague, a graduate student at U. C. Berkeley, short sections of similar core from several drill holes in the vicinity of DDH 155 were reveiewed during two and one half hours on July 25th. Only very general impressions could be gained from this scant introduction to the Red Mountain mineral deposit. These are undoubtedly colored by my experience in very detailed geologic mapping of roughly similar zones in Mexico at Cananea and La Caridad (Santa Rosa Claim). Such mineralized contact zones have also been observed in the United States, South America and in the Philippines, though with less detailed mapping.

The general geology at Red Mountain, as noted by Kerr-McGee geologists and others, is described as a very large ~~thick~~-column of volcanic rocks, divided into three sections. The upper thick series, called tuff, has been laced with original pyritic seams over a wide area; ~~the~~ the middle extensive section is composed of andesites; the lowest series, exposed at surface and partly by drill holes, is made up of hornfels with thick andesitic sills. The volcanic sequence, in the western part of the Red Mountain mineral area, is intruded by an irregular stock, mapped as quartz monzonite porphyry and quartz porphyry. Similar intrusives have been mapped at surface in dikes and small masses in the eastern section of the main mineral zone.

In the drill hole specimens observed, it appears that the middle andesite horizon has been entirely flooded with fine biotite, and associated minor minerals, giving it a dark gray-black ~~appearance~~ color. Where later alteration has affected it, the andesite is bleached to a light gray.

There was no evidence, in the core examined, that the deep mineralized zone is a large collapse breccia. In these, rock fragments may have moved downward as much as several hundred feet with consequent development of large to small open cavities, with or without later mineral introduction. Likewise, there is no evidence that the area is a large injection breccia, (termed "intrusive breccia" by D. G. Bryant), where rock and mineral fragments have been forced into irregular positions following earlier fracturing or mineral channels.

The deep mineralized section appears to be contained largely in a contact ~~breccia~~ zone, - probably closely related to the intrusive stock mapped at surface. As viewed in the core, and visualized in three dimensions, fine fingers, dikes and masses of quartz porphyry and porphyry derivatives, which grade from irregular fingers of silica- feldspar rich material to definite quartz porphyry, invade and assimilate the volcanics; the ~~biotized~~ biotite-flooded andesite is bleached and altered at the gradational contacts with the intrusive material. One dike , several feet in width, which is probably the same at the quartz monzonite porphyry mapped at surface, was observed. It is not unlikely that, in common with many other "porphyry" copper districts, more than one age of closely related quartz porphyry ~~intrusions~~ intrusives may ~~occur~~ be present at Red Mountain.

The contact zone has been followed and invaded by slightly later, large amounts of glassy quartz, chalcopyrite, traces of bornite, molybdenite, little pyrite, anhydrite and minor minerals in short stringers, splotches and dissemin- ations. ~~The impressive mineral content in the contact zone~~ The mineral deposit extends over a considerable area, and its vertical ~~extent~~ range of over 1300 ft. may be unique for this type of deposit. Within the mineralized contact zone it would not be unusual to find relatively small, weakly ~~brecciated~~ fragmented breccia pipes which do not reach surface. Such pipes may have copper mineral concentrations at their domed apex, and may be obliterated at depth by later quartz porphyry.

The important deep ~~mineral zone~~ mineralized mass at Red Mountain has not been completely explored laterally or with depth by the present drilling. Its large lateral and vertical extent will demand close geologic study to determine a locus for deeper exploration. For such study, it is suggested that plan geologic ~~mpas~~ maps, at elevations of about 400 ft. intervals, be established from the drill hole data. Geology at drill hole intersections would be plotted, with projections to the level of important changes immediately above or below ~~the level~~. Similarly, assay averages for the principal minerals could be shown for about 25 ft. above and below the level with projections of important variations. Upon completion of the plan maps, a series of sections could be developed through the longer dimension of the ~~mass~~ deposit, with cross sections at right angles to these.

Essentially all of the available drill hole information could be shown on these sections.

It is believed that ~~from~~ these compilations ~~it~~ would ~~be~~ make it possible to determine a suitable location for one or more drill holes to test the deep continuation of this mineral deposit. With sufficient drilling expertise, directional drilling might be done at depth from an original hole to increase the data gained from that entry.

It seems doubtful that any other mineral district, suggested for deep drill hole tests, contains ~~an~~ the area and vertical extent of favorable mineralized igneous rocks such as that already known at considerable depth at Red Mountain. ~~at considerable depth~~. The possibility that a change in rock type, or a structural trap, might ~~cause~~ develop a major deep concentration of ~~at depth~~ the minerals alredy found adds an intiguing conception to such drilling. In any case, exploration of this mineral zone ~~at depth~~ below the presently prospected elevations should provide new and important scientific data about the formation of known orebodies nearer surface.

It is to be hoped that adequate consideration will be given to this deep drilling project to explore ~~an important~~ a significant primary mineral deposit. To this end, the necessary geologic preparation should be started in the near future to determine a suitable location for the drill holes.

ROLAND B. MULCHAY

August 20, 1985

Roland B. Mulchay
Consulting Geologist
2732 Wren Road
Salt Lake City, Utah 84117

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RBM/lh
Encl.

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There was no evidence, in the core examined, that the deep mineralized zone is a large collapse breccia. In these, rock fragments may have moved downward as much as several hundred feet with consequent development of large to small open cavities, with or without later mineral introduction. Likewise, there is no evidence that the area is a large injection breccia, (termed "intrusive breccia" by D. G. Bryant), where rock and mineral fragments have been forced into irregular positions following earlier fracturing or mineral channels.

The deep mineralized section appears to be contained largely in a contact zone, probably closely related to the intrusive stock mapped at surface. As viewed in the core, and visualized in three dimensions, fine fingers, dikes and masses of quartz porphyry and porphyry derivatives, which grade from irregular fingers of silica- feldspar rich material to definite quartz porphyry, invade and assimilate the volcanics; the biotite-flooded andesite is bleached and altered at the gradational contacts with the intrusive material. One dike, several feet in width, which is probably the same at the quartz monzonite porphyry mapped at surface, was observed. It is not unlikely that, in common with many other "porphyry" copper districts, more than one age of closely related quartz porphyry intrusives may be present at Red Mountain.

The contact zone has been followed and invaded by slightly later, large amounts of glassy quartz, chalcopyrite, traces of bornite, molybdenite, little pyrite, anhydrite and minor minerals in short stringers, splotches and disseminations. The mineral deposit extends over a considerable area, and its vertical range of over 1300 A. may be unique for this type of deposit. Within the mineralized contact zone it would not be unusual to find relatively small, weakly fragmented breccia pipes which do not reach surface. Such pipes may have copper mineral concentrations at their domed apex, and may be obliterated at depth by later quartz porphyry.

The important deep mineralized mass at Red Mountain has not been completely explored laterally or with depth by the present drilling. Its large lateral and vertical extent will demand close geologic study to determine a locus for deeper exploration. For such study, it is suggested that plan geologic maps, at elevations of about 400 ft. intervals, be established from the drill hole data. Geology at drill hole intersections would be plotted, with projections to the level of important changes immediately above or below. Similarly, assay averages for the principal minerals could be shown for about 25 ft. above and below the level with projections of important variations. Upon completion of the plan maps, a series of sections could be developed through the longer dimension of the deposit, with cross sections at right angles to these. Essentially all of the available drill hole information could be shown on these sections.

It is believed that these compilations would make it possible to determine a suitable location for one or more drill holes to test the deep continuation of this mineral deposit. With sufficient drilling expertise, directional drilling might be done at depth from an original hole to increase the data gained from that entry.

It seems doubtful that any other mineral district, suggested for deep drill hole tests, contains the area and vertical extent of favorable mineralized igneous rocks such as that already known at considerable depth at Red Mountain. The possibility that a change in rock type, or a structural trap, might develop a major deep concentration of the minerals already found adds an intriguing conception to such drilling. In any case, exploration of this mineral zone below the presently prospected elevations should provide new and important scientific data about the formation of known orebodies nearer surface.

It is to be hoped that adequate consideration will be given to this deep drilling project to explore a significant primary mineral deposit. To this end, the necessary geologic preparation should be started in the near future to determine a suitable location for the drill holes.

Roland B. Mulchay

Roland B. Mulchay

RBM/lh

August 20, 1985

Roland B. Mulchay
Consulting Geologist
2732 Wren Road
Salt Lake City, Utah 84117

August 20, 1985

Mr. James J. Quinlan
Kerr-McGee Corporation
P. O. Box 25861
Oklahoma City, Okla. 73125

Dear Jim:

I am sorry this description of my observations at Red Mountain is so very late, but it can help clutter your files on that informative visit there. A couple of small consulting jobs developed, and my writing efforts have suffered a number of revisions. It was very enjoyable to be with the geologists of the CDSC group, though I'm sure Wayne Burnham and others did not take my observations very seriously!

I am very grateful that you included me in the group, and the limited time spent on the core undoubtedly contributed to my education. The deep Red Mountain mineral zone is, indeed, an important one, and the efforts of the academics to assess it were most interesting!

With best personal regards,

Yours very truly,

Roland B. Mulchay

Roland B. Mulchay

RBM/lh
Encl.

Impressions Gained from Rapid Observations of Specimens in "Skeletonized" Core at the RED MOUNTAIN PROPERTY, SANTA CRUZ COUNTY, ARIZONA on July 24 and 25, 1985

As a member of the CDSC Group, about one hour was spent in rapid examination of "Skeletonized" core from DDH 155 in the late afternoon of July 24th; with Jay Ague, a graduate student at U. C. Berkeley, short sections of similar core from several drill holes in the vicinity of DDH 155 were reviewed during two and one half hours on July 25th. Only very general impressions could be gained from this scant introduction to the Red Mountain mineral deposit. These are undoubtedly colored by my experience in very detailed geologic mapping of roughly similar zones in Mexico at Cananea and La Caridad (Santa Rosa Claim). Such mineralized contact zones have also been observed in the United States, South America and in the Philippines, though with less detailed mapping.

The general geology at Red Mountain, as noted by Kerr-McGee geologists and others, is described as a very large column of volcanic rocks, divided into three sections. The upper thick series, called tuff, has been laced with original pyritic seams over a wide area; the middle extensive section is composed of andesites; the lowest series, exposed at surface and partly by drill holes, is made up of hornfels with thick andesitic sills. The volcanic sequence, in the western part of the Red Mountain mineral area, is intruded by an irregular stock, mapped as quartz monzonite porphyry and quartz porphyry. Similar intrusives have been mapped at surface in dikes and small masses in the eastern section of the main mineral zone.

In the drill hole specimens observed, it appears that the middle andesite horizon has been entirely flooded with fine biotite, and associated minor minerals, giving it a dark gray-black color. Where later alteration has affected it the andesite is bleached to a light gray.

There was no evidence, in the core examined, that the deep mineralized zone is a large collapse breccia. In these, rock fragments may have moved downward as much as several hundred feet with consequent development of large to small open cavities, with or without later mineral introduction. Likewise, there is no evidence that the area is a large injection breccia, (termed "intrusive breccia" by D. G. Bryant), where rock and mineral fragments have been forced into irregular positions following earlier fracturing or mineral channels.

The deep mineralized section appears to be contained largely in a contact zone, probably closely related to the intrusive stock mapped at surface. As viewed in the core, and visualized in three dimensions, fine fingers, dikes and masses of quartz porphyry and porphyry derivatives, which grade from irregular fingers of silica- feldspar rich material to definite quartz porphyry, invade and assimilate the volcanics; the biotite-flooded andesite is bleached and altered at the gradational contacts with the intrusive material. One dike, several feet in width, which is probably the same at the quartz monzonite porphyry mapped at surface, was observed. It is not unlikely that, in common with many other "porphyry" copper districts, more than one age of closely related quartz porphyry intrusives may be present at Red Mountain.

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The important deep mineralized mass at Red Mountain has not been completely explored laterally or with depth by the present drilling. Its large lateral and vertical extent will demand close geologic study to determine a locus for deeper exploration. For such study, it is suggested that plan geologic maps, at elevations of about 400 ft. intervals, be established from the drill hole data. Geology at drill hole intersections would be plotted, with projections to the level of important changes immediately above or below. Similarly, assay averages for the principal minerals could be shown for about 25 ft. above and below the level with projections of important variations. Upon completion of the plan maps, a series of sections could be developed through the longer dimension of the deposit, with cross sections at right angles to these. Essentially all of the available drill hole information could be shown on these sections.

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It is to be hoped that adequate consideration will be given to this deep drilling project to explore a significant primary mineral deposit. To this end, the necessary geologic preparation should be started in the near future to determine a suitable location for the drill holes.

Roland B. Mulchay

Roland B. Mulchay

RBM/lh

August 20, 1985

September 6, 1985

Rec'd 9/9/85

Roland:

Here it is! Trust that it will do the job.

Again, thanks for looking at the breccia. Most of all, I appreciate the report.

Best regards,

Jim

JIM QUINLAN

PRELIMINARY SCIENTIFIC INVESTIGATIONS FOR LOCATIONS OF DEEP DRILL HOLES

CONTINENTAL SCIENTIFIC DRILLING PROGRAM

RED MOUNTAIN, ARIZONA

by

R. J. Bodnar, G. H. Brimhall, Jr., C. W. Burnham, R. F. Butler,
M. A. Chaffee, J. D. Corbett, P. E. Damon, G. H. Davis, K. P. Furlong
C. Meyer, H. Ohmoto, J. J. Quinlan, S. R. Titley

September, 1985

TABLE OF CONTENTS

INTRODUCTION

The porphyry copper deposit at Red Mountain, Arizona was selected by the Panel on Mineral Resource (PMR) of the Continental Scientific Drilling Committee (CSDC) as the drilling target most likely to reveal scientific information about deep crustal processes attending emplacement of porphyry copper deposits (CSDC, 1984). It was recognized by PMR that the unmined deposit at Red Mountain has received less scientific attention than many better known and productive porphyry copper deposits. This deficiency, however, could be remedied by a detailed scientific investigation prior to siting of deep drill holes to study the deep portions of the system.

PMR approached the Kerr-McGee Corporation, owner of the deposit, regarding the availability of the property to the CSDC. Kerr-McGee agreed to make the property available for study and as a possible drill site. The Company has made available split core, assay pulps and basic geologic and assay data resulting from its investigation of the deposit which includes completion of 72 drill holes totaling 55 km (185,000 ft) of drilling. Twenty-five of the drill holes are deeper than 1.5 km (5,000 ft), the deepest being 1.75 km (5,790 ft).

An Ad Hoc Task Group for Red Mountain appointed by CSDC reviewed and inspected the materials made available by Kerr-McGee on July 24, 1985. This review confirmed PMR initial interest and the attractiveness of the proposed deep drilling target. A program to accomplish the initial scientific investigation and drill hole siting at Red Mountain was outlined. Principal investigators to accomplish the proposed program were identified. This report discusses the proposed Red Mountain project and contains proposals and cost estimates prepared by the principal investigators to target properly and site deep drilling at the study area.

RECOMMENDATIONS

The Panel of Geoscientists, charged by PMR of CSDC to evaluate and undertake scientific studies at Red Mountain, recommend that deep drilling to test the deep portions of the porphyry copper system at Red Mountain be given a high priority by the CSDC and DOSECC.

The Panel of Geoscientists also recognizes a need to refine and enlarge the geological, geochemical, and geophysical base of information at Red Mountain in preparation for locating the proposed deep drill holes. The following program to accomplish this objective is recommended:

1. Regional Studies including Paleomagnetic Studies
   Principal Investigators: G.H. Davis, University of Arizona (Regional Studies); R.F. Butler, University of Arizona (Paleomagnetic Studies)

   Time: 2 years — Cost: $48,000

2. Surface Mapping and Drill Core Fracture Studies
   Principal Investigator: S. R. Titley, University of Arizona

   Time: 2 years — Cost: $76,000

3. Geochronology Studies (25 dates)
   Principal Investigator: P.E. Damon, University of Arizona

   Time: 1 year — Cost: $18,000

4. Petrography, Petrology and Mineral Chemistry
   Principal Investigator: G. H. Brimhall, Jr., University of California, Berkeley

   Time: 2 years — Cost: $172,000

5. Fluid Inclusion Studies
   Principal Investigator: R. J. Bodnar, Virginia Polytechnic Institute

   Time: 2 Years — Cost: $80,000

6. Isotope Studies
   Principal Investigator: H. Ohmoto, Pennsylvania State University

   Time: 2 years — Cost: $238,000

7. Thermal Modeling
   Principal Investigator: K. P. Furlong, Pennsylvania State University

   Time: 2 years — Cost: $80,000

8. Applied Geochemistry
   Principal Investigator: M. A. Chaffee, USGS

   Time: 2 years — Cost: $140,000

9. Geophysics and Remote Sensing
   Principal Investigator: J.D. Corbett, University of Utah Research Institute

   Time: 2 years — Cost: $140,000

10. Management, Synthesis and Deep Hole Siting

    Principal Investigator: J.J. Quinlan, Kerr-McGee Corporation

    Time: 2 years — Cost: $ 70,000

TOTAL COST $1,062,000

LOCATION AND PROPERTY STATUS

The Red Mountain property is located in the Harshaw Mining District, Santa Cruz County, Arizona, Figure 1. The property lies at the north end of the Patagonia Mountains, 80 km (50 miles) south of Tucson, Arizona and 3 km (2 miles) south of Patagonia, Arizona.

The Kerr-McGee property consists of 36 patented and 524 unpatented lode mining claims. These claims cover an area of 3,625 hectares (14 square miles) and center on Red Mountain, Figure 2. The peak at Red Mountain is at an altitude of 1,942 m (6,371 ft) and lies in Section 20, T.22S., R.16E.

Other claim and land owners in the area include Asarco, Inc., and Commonwealth International. Representatives from these companies; i.e., Fred Graybeal and Fleetwood Koutz of Asarco; and Paul Eimon, Commonwealth International are members of, or observers for, the Ad Hoc Task Group for Red Mountain.

The Kerr-McGee property and others lie within an area managed by the U.S. Forest Service, pursuant to Forest Service Regulation 36 CFR. The regulation is reasonable and no problems have been encountered, nor are any anticipated in conducting scientific investigations or drilling operations at Red Mountain.

ENVIRONMENTAL CONSIDERATION

Scientific research or deep drilling at Red Mountain should present no unusual or significant environmental problems.

Mining in the area predates the Spanish conquest of Mexico in the sixteenth century (Schrader, 1915). Asarco operated the Trench mine as recently as 1960. Kerr-McGee has carried on drilling operations since 1961. In recent years numerous other companies have conducted drilling and geologic mapping programs in the region surrounding the deposit.

GEOLOGY

The geology and base-metal occurrences at Red Mountain have been intermittently studied since 1915 (Schrader, 1915; Drewes, 1971a,b, 1972a,b; Simons, 1971, 1974). More recent efforts have focused on data provided by the Kerr-McGee drilling program (Corn, 1975; Bodnar and Beane, 1980; Quinlan, 1981). Surface geochemical sampling by the U.S. Geological Survey surrounding Red Mountain was summarized by Chaffee et al. (1981). Copies of these papers are attached as Appendix A.

The Red Mountain deposit is part of the Harshaw district, which is a part of the greater Patagonia district and a part of the southwestern North America porphyry copper province. Its lateral and genetic position relative to nearby vein and replacement deposits can be studied.

The geological setting of Red Mountain includes an altered complex of flat-lying volcanic and intrusive rocks of Cretaceous and early Tertiary age. Three layered volcanic units are present. These include an upper rhyolite and dacite tuff unit of 730-m (2,400 ft) maximum thickness, a middle andesite as much as 900 m (3,000 ft) thick, and a basal felsite-latite unit that is at least 550 m (1,800) ft) thick. Porphyritic intrusive rocks ranging in composition from granodiorite to quartz monzonite cut the layered volcanic rocks.

Silicate alteration, described in detail by Quinlan (1981) and Corn (1975), varies with rock types and depth. Alteration assemblages (i.e., argillic, phyllic, and potassic) typical of porphyry copper deposits (Lowell and Guilbert, 1970; Rose, 1970) are present. The alteration zoning pattern can be explained by a deep ore-stage alteration system superimposed on an earlier, larger, and essentially copper-barren alteration system. Argillic and phyllic alteration at the surface are parts of the large, early stage system. Strong potassic and phyllic alteration at depth are parts of the deep-level porphyry copper emplacement.

Sulfide mineral zoning appears to be related to the deep-level porphyry copper-stage alteration. Lead and zinc generally occur in the upper portions of the deposit, and small amounts of molybdenum are present throughout. Chalcopyrite is the predominant copper mineral. Enargite occurs in the upper levels, and minor amounts of bornite are present at depth. Chalcocite occurs as a secondary mineral in the upper parts of the deposit.

Breccia pipes crop out at the surface and a "blind" pipe is recognized in several deep drill holes. This deep-level breccia pipe is within the potassic core of the main copper deposit and may be the deepest copper-molybdenum breccia pipe known in the world. Strong quartz-sericite-pyrite alteration is recognized at the top of this pipe, and to a lesser extent at its margins. This phyllic type alteration in the pipe clearly cuts strong biotite-magnetite-orthoclase alteration in the core area of the main deposit. A zone of copper, molybdenum, and silver enrichment is situated near the margins of the pipe. This pipe presents a unique environment permitting insight into vertically zoned mineral deposits in relation to other major elements of such deposits. It also provides an opportunity to compare high-level and deep-level breccia pipes in a porphyry copper environment.

Understanding of the structural evolution of this district could aid in the interpretation of other mineral deposits that represent single phases of the multi-staged process at Red Mountain.

RESEARCH OBJECTIVES

The Red Mountain district represents an unusual opportunity for increasing the scientific understanding of important criteria in hydrothermal mineral genesis, geochemistry, geophysics and paleohydrology.

The district presents a number of unique features that are scientifically attractive. The deposit does not appear to have been tilted, and neither has it been extensively faulted or deeply eroded. However, more work is needed to verify these conditions. The deposit seems to be of moderate size so its root system is likely to be within reach of present drill technology. Classic mineralogical and geochemical zoning can be studied at the well-exposed present surface and by means of the drill core resulting from 55 km of drilling by the Kerr-McGee Corporation. Thus, sampling and scientific study of a nearly complete vertical system is possible.

The combination of these and other desirable features were judged by the PMR of CSDC to make the Red Mountain deposit a unique opportunity to study the movement and chemical evolution of aqueous fluids in the deep continental crust as they interacted with a large localized source of heat and chemical components related to subvolcanic processes.

PROPOSED PROGRAM

Based on present information, the Ad Hoc Task Group and Panel of Geoscientists for Red Mountain are considering two deep drill holes. One hole should be located specifically to test the breccia pipe and its downward extension, and a second hole to test below the main porphyry copper sulfide body. Both holes may be drilled to a depth as great as 5 km (16,000 ft) to explore the bottom of the potassic alteration zone. These holes should penetrate the lower limit of fluid circulation and provide data on fluid transport, paleopermeability and temperatures. They should provide data regarding existing hypotheses on metal source and mobilization as well as alteration in the roots of the system. Preliminary estimates indicate that each hole would take about a year to drill and each would cost $3 million. An additional $2 million to $3.0 million would be needed to complete scientific studies of the core and add-on experiments in the proposed holes.

The Ad Hoc Task Group and the Panel of Geoscientists for Red Mountain recognize a need to refine and enlarge on the geologic, geochemical and geophysical base at Red Mountain in order to site properly the proposed deep drill holes. A program of geological, geochemical, and geophysical research is proposed to accomplish this objective. This preliminary scientific investigation as designed should also provide much new data on porphyry copper deposits in general and a better understanding of the processes of formation. Whereas the overall program as outlined in the section on Recommendations represents a consensus of the Ad Hoc Task Group and Panel of Geoscientists for Red Mountain, details and costs for individual parts of the program have been prepared by the principal investigator responsible for each area.

Regional Studies including Paleomagnetic Studies

Principal Investigators: G.H. Davis, University of Arizona (Regional)
R.F. Butler, University of Arizona (Paleomagnetic)

Time: 2 years — Cost: $48,000

The Red Mountain mineralized system is located within a part of Arizona where Laramide, mid-Tertiary, and younger Tertiary tilting and low-angle displacement have been reported (Davis, 1979, 1981; Dickinson, 1984). Although tilting and lateral transport at Red Mountain have not been recorded, except for studies of Pliocene tectonics and stratigraphy in the Sonoita Creek Basin (Menges, 1981), no evidence exists to indicate that such a possibility has been reviewed or studied. Except for strike dip plots shown in the volcanic rocks of Red Mountain (Huckins, 1976) there is little information available to assess the possible present attitude of the Red Mountain hydrothermal system. An investigation focused on this problem is of paramount importance. The siting of a drill hole based upon surface data with a purpose of testing a deep target (e.g., 5 km or 16,000 ft) will be strongly influenced by correct projections of that target. For example, a 6° inclination of the system will result in a 500 m (1,600 ft) lateral displacement at a 5 km depth, a 15° inclination will result in 1300 m (4,160 ft) of lateral displacement from the vertical.

Regional mapping and structural analysis of Mesozoic, Laramide, and younger Tertiary rocks are therefore a prerequisite to drilling. From such studies, which must be integrated with a thorough sampling of rocks for radiometric age-dating (See Geochronology section) and with a paleomagnetic study as a supplement, the faulting and tilting history of the system may be assessed. A sound basis of peripheral mapping and structural interpretation exists from which to build and extend. Further, paleomagnetic studies (Barnes and Butler, 1980; Kluth et al, 1982; Calderone and Butler, 1984) provide a working basis for additional studies in the Red Mountain system.

Surface Mapping and Drill Core Fracture Studies

Principal Investigator: S.R. Titley, University of Arizona
Time: 2 years Cost: $76,000

Distribution of flow in hydrothermal systems such as Red Mountain is chiefly controlled by an extensive interlocking network of fractures, evolved as a direct consequence of emplacement and cooling of igneous magmas. Thus the distribution of fractures is a guide to limits of fluid flow. The evolution and distribution of fractures has been detailed for a few hydrothermal porphyry-centered systems (e.g. Silver Bell: Kanbergs, 1980; Norris, 1981; Sierrita: Haynes and Titley, 1978; Titley et al., 1985, in press). Initial surface studies have been carried out over Red Mountain (Kistner, 1984).

A principal and necessary objective of the interim science project at Red Mountain is to extend the surface study of fracture distribution and abundance to the limits of fracture occurrence, and to integrate the surface information with abundance and distribution data from drill core. Such a study is a fundamental requirement for the more basic purpose of the drilling project. Information developed provides the only basis for determining the locus of most intense flow and the patterns of peripheral flow in any genetic interpretations advanced and provides an important basis for siting the drilling to be done. Further, as the study of the sequence of fractures is diagnostic of the evolution of alteration, the results will provide the only basis for understanding the chemical-thermal evolution of the system (Titley and Beane, 1980; Preece and Beane, 1982).

Fracture density data will be collected at the surface by techniques described elsewhere (Haynes and Titley, 1980; Titley et al, 1985, in press) and integrated with paragenetic studies and fluid inclusion data. Drill core fracture data will be collected by a fracture area/core volume technique in drill core and will be supplemented by petrographic studies of alteration mineralogy and fluid inclusions.

Geochronology

Principal Investigator: P.E. Damon, University of Arizona
Time: 2 years Cost: $18,000

The stratigraphic succession at Red Mountain is relatively well-established. However, the chronology of rocks and events is unknown except for scattered dates on region-wide units and a few plutonic rocks. A K-Ar or Rb-Sr chronology is required for volcanic and intrusive rocks as well as for mineralization-alteration events to verify the age, succession, and duration of thermal and geological events in this system. Such a study is especially critical to the regional tectonic analysis. It is important to establish the time of tilting of the Red Mountain system if such has occurred.

A minimum of twenty-five dates are projected as required to date the pre-, inter- and post-ore rocks and to date the hydrothermal event(s) as measurable in the alteration assemblages.

Petrography, Petrology, and Mineral Chemistry

Principal Investigator: G. H. Brimhall, Jr., University of California, Berkeley
Time: 2 years Cost: $172,000

Objectives of the petrologic study will be to define better the deep drilling target and the petrographic and compositional criteria for recognizing the parent intrusive to be penetrated during the deep drilling phase of the Red Mountain program. Identification of this source of heat, magmatic fluids, and metals is the most critical part remaining in completing the description and analysis of this magmatic-hydrothermal system. Compositions of hydrothermal and igneous biotite from core samples expressed in terms of OH, F, Cl, Mg, Fe, Ti, Al, Si, Mn, K, and Na mole fractions in specific crystallographic sites will provide a sound basis for comparison of biotite in the breccia and in potassic alteration zones of the volcanics with drilling samples of intrusives encountered at depth during the deep drilling phase. Such results can be interpreted in terms of magmatic fluid composition and temperature at the point of release of these aqueous fluids from the magma body. This mineral chemistry will be used to define the thermal and chemical evolution of magmatic fluids from purely igneous to hydrothermal processes during breccia formation, hydrofracturing, and alteration-mineralization. During the deep drilling phase, wall rocks can be analyzed using mass balance principles to assess the relative contributions of magmatic input of metals in relation to leaching these metals from adjacent protores.

It is proposed here to use a combination of mapping (core logging) and mineral chemistry to define the locus of early-stage mineral assemblages, and to deduce fluid composition and the temperature field during the initial stages of fluid circulation. The composition of biotite is ideally-suited for this purpose as its composition and petrographic relationships clearly reflect the thermal and chemical environments of formation, including transition from magmatic to hydrothermal conditions. Biotite crystallizes both during magmatic crystallization as well as during high-temperature hydrothermal processes, making its composition an ideal monitoring device over this range in physical and chemical processes, including breccia formation and fluid-rock interaction during alteration.

Fluid Inclusion Studies

Principal Investigator: R.J. Bodnar, Virginia Polytechnic Institute
Time: 2 years Cost: $80,000

The purpose of the fluid inclusion study at Red Mountain is to provide a data base on the thermal and chemical characteristics of hydrothermal fluids in the system in time and space. These data will be combined with other available information to generate a predictive model for fluid evolution in a magmatic-hydrothermal environment. The final product would be a set of criteria based on fluid inclusion characteristics that could be used to predict where one is in a particular hydrothermal system and, more importantly, the direction and distance to the center of activity.

The proposed study includes detail petrographic work to determine the temporal and spatial distribution of fluid inclusion types in the hydrothermal system, and correlation of various inclusion types with specific episodes of alteration and mineralization. During this stage of the investigation, the limits of immiscibility (boiling) in time and space and relationships between boiling and mineralization would be defined. Outlining the boiling zones may provide a relatively simple means of distinguishing the epithermal from the deeper magmatic environment.

The petrographic phase of the study would be followed by microthermometric analyses of fluid inclusions to determine the temperatures and bulk salinities of the fluids and, more importantly, how these properties vary in time and space within the hydrothermal system. Raman microprobe analyses of these same inclusions would be conducted to determine the types and amounts of volatile components in the fluids. Considerable emphasis will be placed on the volatile analyses because the gas content of inclusion could prove to be the best indication of where one is in the system and probably is one of the major controls in metal transport and deposition.

Isotope Studies

Principal Investigator: H. Ohmoto, Pennsylvania State University
Time: 2 Years Cost: $238,000

Three major mutually related problems on the genesis of porphyry copper deposits are: (1) the sources of various components of the ore-forming fluids, especially H_2O, metals and sulfur; (2) the hydrology of the ore-forming systems; and (3) the mechanisms of sulfide and sulfate deposition.

Oxygen and hydrogen isotope studies of minerals and fluid inclusions in porphyry copper deposits (e.g., Taylor, 1979) have revealed that two types of waters, magmatic and meteoric, were involved in the formation of most porphyry copper deposits. The sulfur isotopic data at hand also suggest that a significant proportion of sulfur in most porphyry copper deposits is magmatic in origin (e.g. Ohmoto and Rye, 1979).

Some of the major unresolved questions concern: the changes with respect to time and space in the relative importance of magmatic and meteoric waters; their effect on the mineralogical and elemental characteristics of porphyry copper deposits; and the exact nature of physical and chemical interaction between magmatic fluids and meteoric water. Specific questions include the following: Did the sulfide and sulfate minerals precipitate from magmatic fluids, and only locally redistributed by circulating meteoric water? Or, was a significant proportion of metals and sulfur derived from the surrounding country rocks by circulating meteoric water or magmatic water? How did the geometries of the two fluid systems (magmatic and meteoric) change with time? Did the two fluid systems operate independently, and the dominant system in the ore zone change from pure magmatic to pure meteoric at some state in the mineralization history? Or, was the magmatic fluid system diluted continuously by meteoric water through time? If fluid mixing was an important process for changing the chemical nature of the hydrothermal system, did the mixing take place at the site of sulfide deposition, or at the peripheral or deeper parts of the plumbing system?

If a significant proportion of metals and sulfur in these deposits is found to be magmatic in origin, a question that follows concerns the mechanism through which the magmas acquired these elements. Did the magmas acquire these elements through the partial melting of source rocks in the upper mantle or the lower crust, or did they acquire them through selective assimilation of the upper crustal rocks during magma emplacement?

The mechanism of hydrothermal mineral precipitation in porphyry copper deposits remains unresolved. The possible processes include: a simple decrease in P and T; an increase in the activity of H_2S and SO_4 (caused by the hydration of SO_2 during cooling); an increase in pH due to chemical reactions with wall rocks; mixing or unmixing of magmatic fluids; and mixing of magmatic fluids with meteoric water.

The main reason that the previous studies were unable to answer any of the above questions quantitatively was because essentially the previous isotopic studies on porphyry copper deposits were reconnaisance in nature. A detailed investigation of the temporal and spatial changes in the oxygen, hydrogen, carbon, and sulfur isotopic compositions of minerals and fluid inclusions in a well selected system can solve all of the above problems, if the isotopic study is coordinated with other geochemical studies (e.g., fluid inclusion, mineralogic, and major-and trace-element studies). The Red Mountain porphyry system seems to be one of the best localities to solve these problems on porphyry copper deposit genesis because the bottom and the sides as well as the top of a porphyry system can be sampled.

The research plan is to investigate systematically the oxygen, hydrogen, sulfur and carbon isotopic compositions of minerals and fluid inclusions from drill core samples, on which various other geochemical studies will be pursued by other members of the Red Mountain Research Panel. Approximately 200 to 500 samples, representing both mineralized and barren intrusive and country rocks, will be investigated. The study will be carried out by a post-doctoral fellow and graduate assistant under the direction of the principal investigator.

Thermal Modeling

Principal Investigator: F. P. Furlong, Pennsylvania State University
Time: 2 years Cost: $ 80,000

The thermal modeling part of the project is to develop constrained models of the detailed thermal evolution of the intrusive-hydrothermal system. At present, primarily as a consequence of a paucity of constraining data (and associated model simplications), models of the thermal evolution of such systems are relatively general in scope. The proposed work, in conjunction with the geological and geochemical data collected is intended to develop models which simulate the evolution of such systems, including the effects of conducted and advected heat, and heat produced via chemical reactions and phase changes (heat and crystallization). The modeling effort will be aimed at unraveling the thermal history of the system as a whole, and also at determining the local perturbations to the general pattern.

Currently, modeling algorithms allow for evaluation of the conductive aspect of the thermal evolution of intrusive systems. It is planned to adapt and improve these algorithms to allow for the evaluation of the effects of advected heat. Clearly, in systems such as Red Mountain, an important component of this advected heat is carried by fluids moving through fracture networks. Thus, to evaluate this aspect will require inclusion of data regarding the timing of formation of fracture systems, the volumes and rates of fluid flow, and the lifetime of any one fracture system, in addition to the density and geometry of the fractures. Only with the constraints provided by the geological and geochemical data gathered as a part of this project can these models be made to realistically simulate the thermal evolution of the system. This modeling will be conducted primarily on two scales. A large system-wide scale will be used to model the overall evolution, while a smaller, local-scale of modeling will be used to evaluate the variability in thermal history which can occur on such a small scale. The inclusion of these small-scale effects is a necessary component of models of the system in general.

Expected results of this work include numerical algorithms, constrained by the available data, which will allow us to simulate the thermal evolution of an intrusive-hydrothermal system. These models will provide a means of evaluating potential deep drilling sites with particular usefulness in determining the scale of local (near borehole) variability possible in the thermal history of upper crustal intrusive systems.

Applied Geochemical Studies

Principal Investigator: M.A. Chaffee, USGS
Time: 2 years Cost: $140,000

The purpose of the geochemical studies is to determine in conjunction with other geological studies, the zoning of selected elements and minerals in the Red Mountain system. This zoning will be a primary means of establishing the history and geometry of the presently drilled part of the overall mineralized system and will thus be a valuable method for locating drill sites and targets.

Samples of drill core, as well as outcrop, soil, and mine dumps, will be collected and analyzed for as many as 40 elements. Both single and multi-element plots of the raw analyses, as well as of derived parameters such as element ratios and values created by factor analysis and other statistical techniques, will be evaluated. Selected samples will be studied to determine the mineral residences of elements shown to be zoned in the study area.

The analyses will be used to establish the abundances and distributions of ore and lithologically-related elements. The analyses, and the parameters derived from the analyses, will be used to define the 3-dimensional zoning within the presently drilled out area as well as in the area immediately surrounding the known extent of the mineralized system. The analytical data will also be used to help correlate the structurally separated geologic units mapped during the project. The mineral residences of selected elements will be determined to identify those minerals that are diagnostic of specific lithologic and (or) hydrothermal zones within the system. The zoning model will help in determining the timing, location, and intensity of mineralizing pulses in the system and will therefore help to define the geometry of the system and thus suggest possible sites for deep drilling.

The distributions and abundances of the selected elements will also assist in determining the effects and extent of supergene alteration and the possible sources of the elements associated with the mineralizing processes.

Geophysics and Remote Sensing

Principal Investigator: J.D. Corbett, University of Utah Research Institute
Time: 2 years Cost: $140,000

Very little detailed geophysical data are know for the Red Mountain porphyry copper system. Geophysical studies, particularly aeromagnetic and gravity surveys, will provide a three-dimensional physical property model of the depth, lateral extent and transitional variations of both the intrusive rocks and the near-surface host-rock lithologies of the Red Mountain area. Susceptibility contrasts are known within the host rocks; densities and density contrasts between rock types can be determined from surface and drill core specimens. Geologic data and extrapolations from known outcrops or borehole intercepts will add significant control for geophysical interpretation of the third dimension of the Red Mountain deposit and siting of deep drill holes. A surface induced polarization test and borehole geophysical logging will provide additional physical property data to assist research study of the geological and mineralogical features of a hydrothermal porphyry copper system and its peripheral epithermal deposits.

A detailed helicopter-base aeromagnetic survey is proposed to cover the zone of alteration and peripheral mineralization with extensions well out into fresh unaltered rocks and background magnetic field values. A tight line spacing of about 250 m (800 ft) at a draped survey terrain clearance of 90 m (300 ft) is recommended. The survey should be completed early in the geologic mapping sequence for optimum utilization and could be completed in six months after a contract is approved.

Detail gravity across the rugged terrain of the Patagonia Mountains will require extensive surveying and terrain-effect corrections. A study of the density of the several types of surface rocks and diamond drill core is a necessary preliminary step to the survey.

Specific studies of the electrical properties (chargeability and resistivity) of the alteration zone will be undertaken. With large electrode separations this study would probe the limits of the deep sulfide mineralization to the west where erosion largely has removed the upper level sulfide zone. Short-spaced electode lines would determine the electrical parameters on the near-surface alteration zones of both Red Mountain and the peripheral mineralized environments. Selection of line placement would be based upon host-rock lithology, alteration type and extent, and culture interference.

Remote sensing data needs to be updated and integrated as a part of this study. The alteration halo associated with the Red Mountain deposit was delineated using spectral reflectance data, acquired by Landsat, a field spectrometer, and NASA's Bendix 24-channel Multispectral Scanner (MSDS) (Abrams and Siegal, 1977). These data should be recovered and integrated with the airborne geophysical data and detailed geologic mapping proposed in the preliminary investigation. Further ratioing and creation of additional contour maps and/or false-color ratio composites are recommended. The budget requirements to upgrade the previous data base should be minimal assuming the data and programs from JPL are available.

<u>Management, Synthesis and Hole Siting</u>

Principal Investigator: J.J. Quinlan, Kerr-McGee Corporation

Time: 2 years — Cost: $70,000

Provision is made here to manage and coordinate project work during the life of the project and to synthesize data at the end of the project so as to site the proposed deep drill holes.

TIME AND COST ESTIMATE

The following time and cost estimate has been prepared from details furnished by the principal investigators of individual studies. Proposed work will be accomplished using existing equipment and facilities at the institutions of the principal investigator or will be contracted. No funds are requested or allowed for the purchase of new equipment or facilities.

1.	Regional Studies including Paleomagnetic Studies	
	Regional Studies	
	2 years, with 1/2 time R.A. = 1 R.A. year @ $16,000/yr	$ 16,000
	Transportation and Field Expenses	2,500
	Indirect Costs	8,000
	Palemagnetic Studies	
	1 year with 1/2 time R.A. = 1/2 R.A.year at $16,000/yr	8,000
	1 month Faculty Expense	5,000
	Transportation and Field/Lab Expenses	2,500
	Indirect Costs	6,000
	Subtotal	$ 48,000
2.	Surface Mapping and Drill Core Fractures Studies	
	2 years with 1 1/4 times R.A.=2 1/2 R.A.yrs.@ $16,000/yr	40,000
	2 months Faculty Expense	10,000
	Transportation and Field/Lab Expenses	3,500
	Indirect Costs	22,500
	Subtotal	$ 76,000
3.	Geochronologic Studies	
	1 year with 1/4 time R.A. = 1/4 R.A.year @$16,000/yr	$ 4,000
	25 Age dates @ $500 ea., less $4,000	8,500
	Indirect Costs	5,500
	Subtotal	$ 18,000
4.	Petrography, Petrology and Mineral Chemistry	
	2 years with 2 R.A. = 4 R.A. years @$16,000/yr	$ 64,000
	+ part time technician at 20% of R.A. time	12,800
	2 months Faculty Expense	11,200
	Transportation and Field/Lab Expenses	32,000
	Indirect Costs	52,000
	Subtotal	$172,000
5.	Fluid Inclusion Studies	
	Time: 2 years with R.A. = 2 R.A. years @$16,000/yr	$ 32,000
	2 months Faculty Expense	10,000
	Transportation and Field/Lab Expense	15,000
	Indirect Costs	23,000
	Subtotal	$ 80,000

6. Isotope Studies

2 years with Proj. Assoc. = 2 P.A. years at $33,500/yr	$ 67,000
1/2 time R.A. = 1 R.A. year @ $16,000	16,000
Secrectary and Technician	18,000
3 months Faculty Expense	30,000
Transportation and Field/Lab Expense	36,000
Indirect Costs	71,000
Subtotal	$238,000

7. Thermal Modeling

2 years with 1 R.A. = 2 R.A. years @$15,000/yr	$ 30,000
2 months Faculty Expense	10,000
Transportation and Lab Expense	17,000
Indirect Costs	23,000
Subtotal	$ 80,000

8. Applied Geochemistry

2 years with 1-GS-5 = 2 GS-5 years @ $15,000/yr	$ 30,000
Analysis - 2500 samples @ $20 ea.	50,000
Transportation and Field Expense	20,000
Indirect Costs	40,000
Subtotal	$140,000

9. Geophysics and Remote Sensing

Aeromagnetic, includes interpretation	$ 50,000
Gravity	25,000
Electrical Method	20,000
Remote Sensing Update	5,000
Indirect Costs	40,000
Subtotal	$140,000

10. Management, Synthesis and Hole Siting

2 years Administration, etc.	50,000
Indirect Costs	20,000
Subtotal	$ 70,000

GRAND TOTAL	$1,062,000

SCHEDULE

Work can be scheduled so funds requirements are as follows:

	Year 1	Year 2	Total
1. Regional and Paleomagnetic Studies	$ 34,000	$ 14,000	$48,000
2. Surface Mapping and Drill Core Fracture Studies	38,000	38,000	76,000
3. Geochronologic Studies	18,000		18,000
4. Petrography, Petrology and Mineral Chemistry	86,000	86,000	172,000
5. Fluid Inclusion	40,000	40,000	80,000
6. Isotope Studies	114,000	124,000	238,000
7. Thermal Modeling	40,000	40,000	80,000
8. Applied Geochemistry	70,000	70,000	140,000
9. Geophysics & Remote Sensing	100,000	40,000	140,000
10. Management, Synthesis and Hole Siting	20,000	50,000	70,000
TOTAL	$560,000	$502,000	$1,062,000

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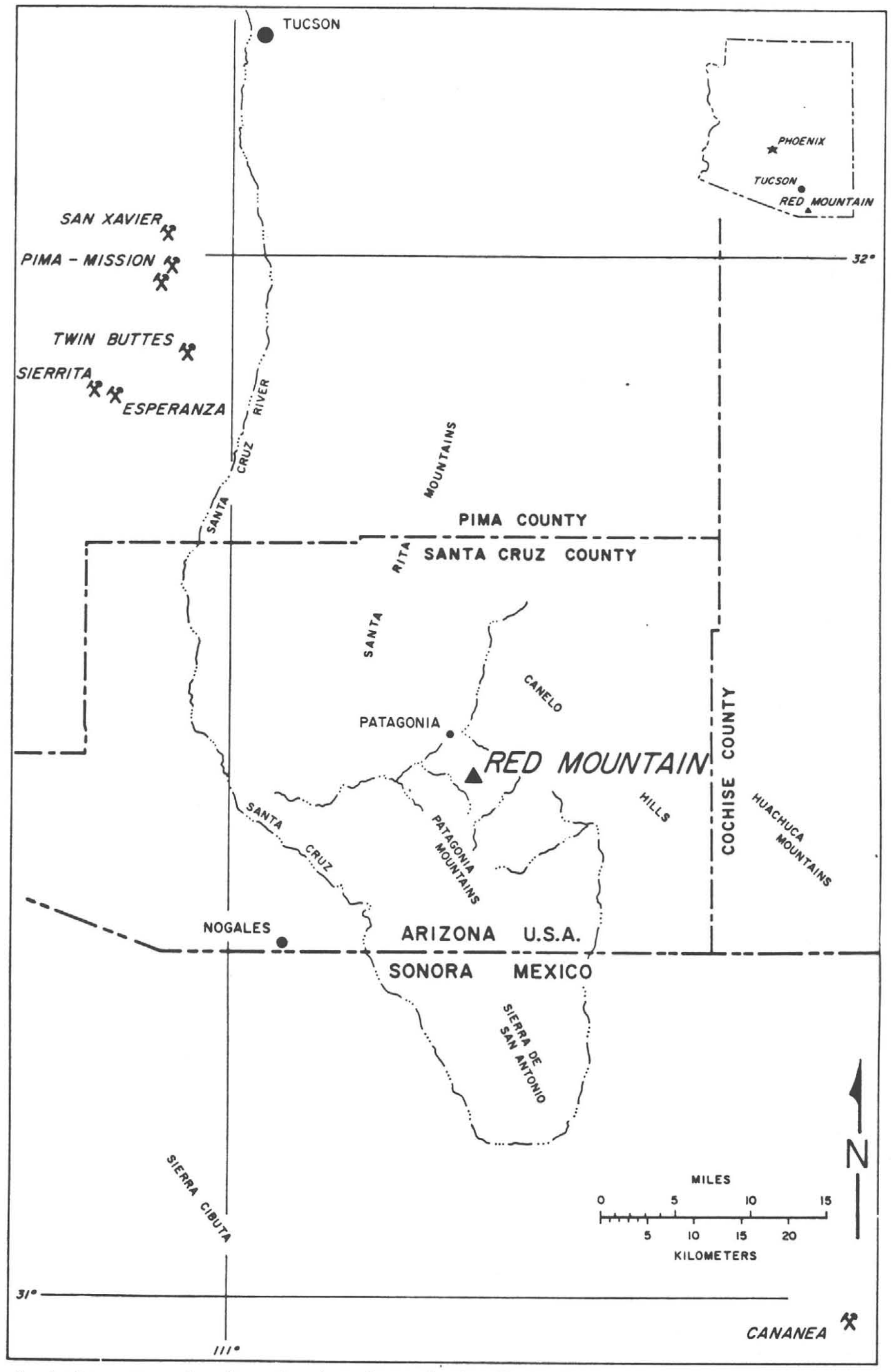
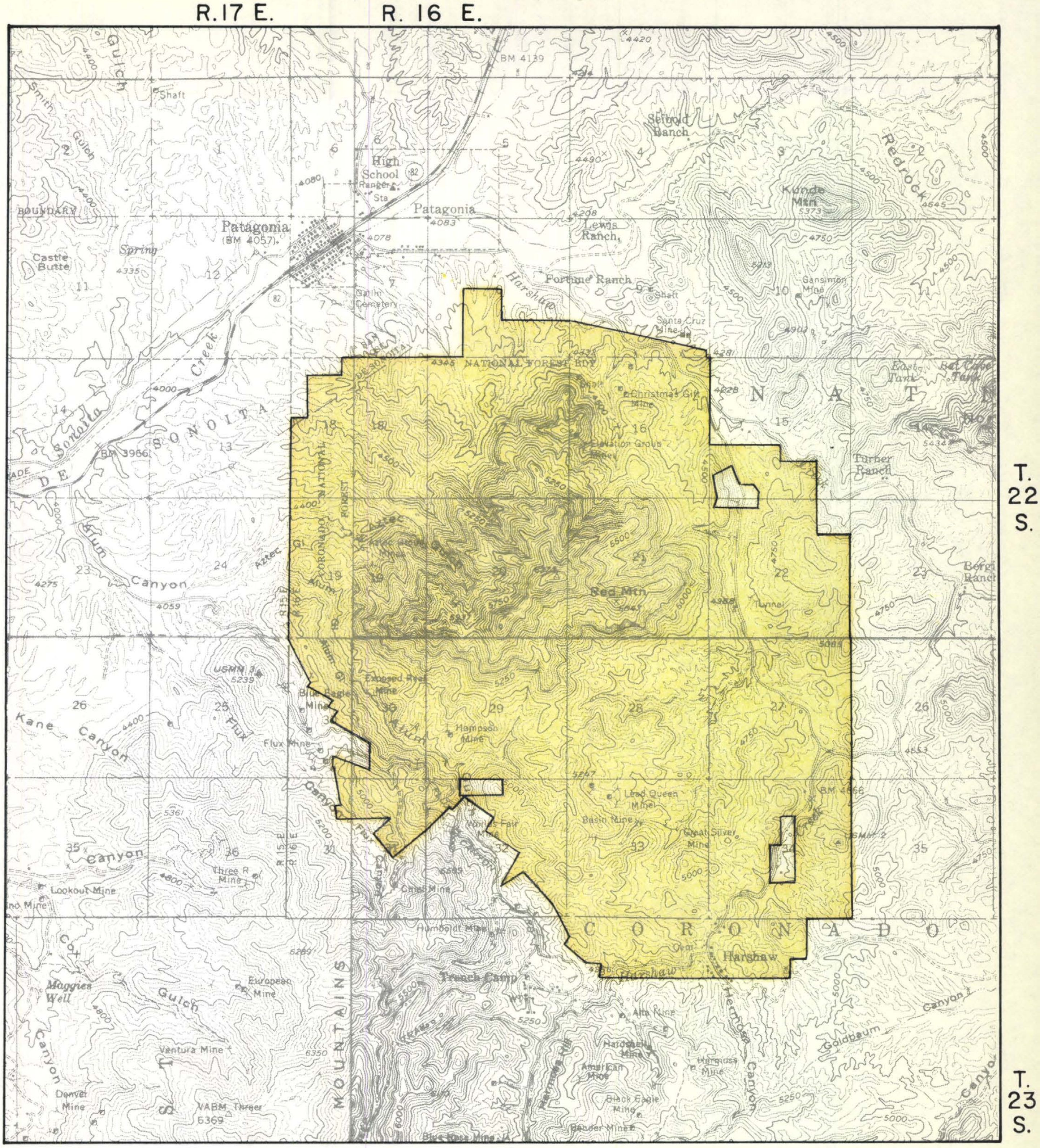


Fig. 1. Index map showing the location of the Red Mountain porphyry copper deposit. After R.M. Corn, Economic Geology, Vol. 70, No. 8, Dec. 75



EXPLANATION

KERR-McGEE PROPERTY

RED MOUNTAIN PROPERTY MAP

SANTA CRUZ COUNTY, ARIZONA

SCALE 1:62,500

TOPOGRAPHIC BASE FROM USGS 15' QUADRANGLE MAPS
ELGIN (1958), LOCHIEL (1958), NOGALES (1958), MT. WRIGHTSON (1958)

FIGURE 2

APPENDIX

PARTIAL REFERENCE SOURCE

GEOLOGY AND GEOCHEMICAL PAPERS

PERTINENT TO THE RED MOUNTAIN PORPHYRY COPPER DEPOSIT

APPENDIX A

PRELIMINARY SCIENTIFIC INVESTIGATIONS FOR LOCATIONS OF DEEP DRILL HOLES

CONTINENTAL SCIENTIFIC
DRILLING PROGRAM

RED MOUNTAIN, ARIZONA

by

R. J. Bodnar, G. Brimhall, C.W. Burnham, R.F. Butler,
J.D. Corbett, M.A. Chaffee, P.E. Damon, G.H. Davis, K.P. Furlong
C. Meyer, H. Ohmoto, J.J. Quinlan, S. R. Titley

September, 1985

TABLE OF CONTENTS

BODNAR, R.J. &
BEANE, R.E.

Temporal and Spatial Variations in Hydrothermal Fluid Characteristics during Vein Filling in Preore Cover Overlying Deeply Buried Porphyry Copper-Type Mineralization at Red Mountain, Arizona

R. J. Bodnar and R. E. Beane

Reprinted from Economic Geology, Vol. 75, No. 6, September–October 1980

Economic Geology
Vol. 75, 1980, pp. 876–893

Temporal and Spatial Variations in Hydrothermal Fluid Characteristics during Vein Filling in Preore Cover Overlying Deeply Buried Porphyry Copper-Type Mineralization at Red Mountain, Arizona

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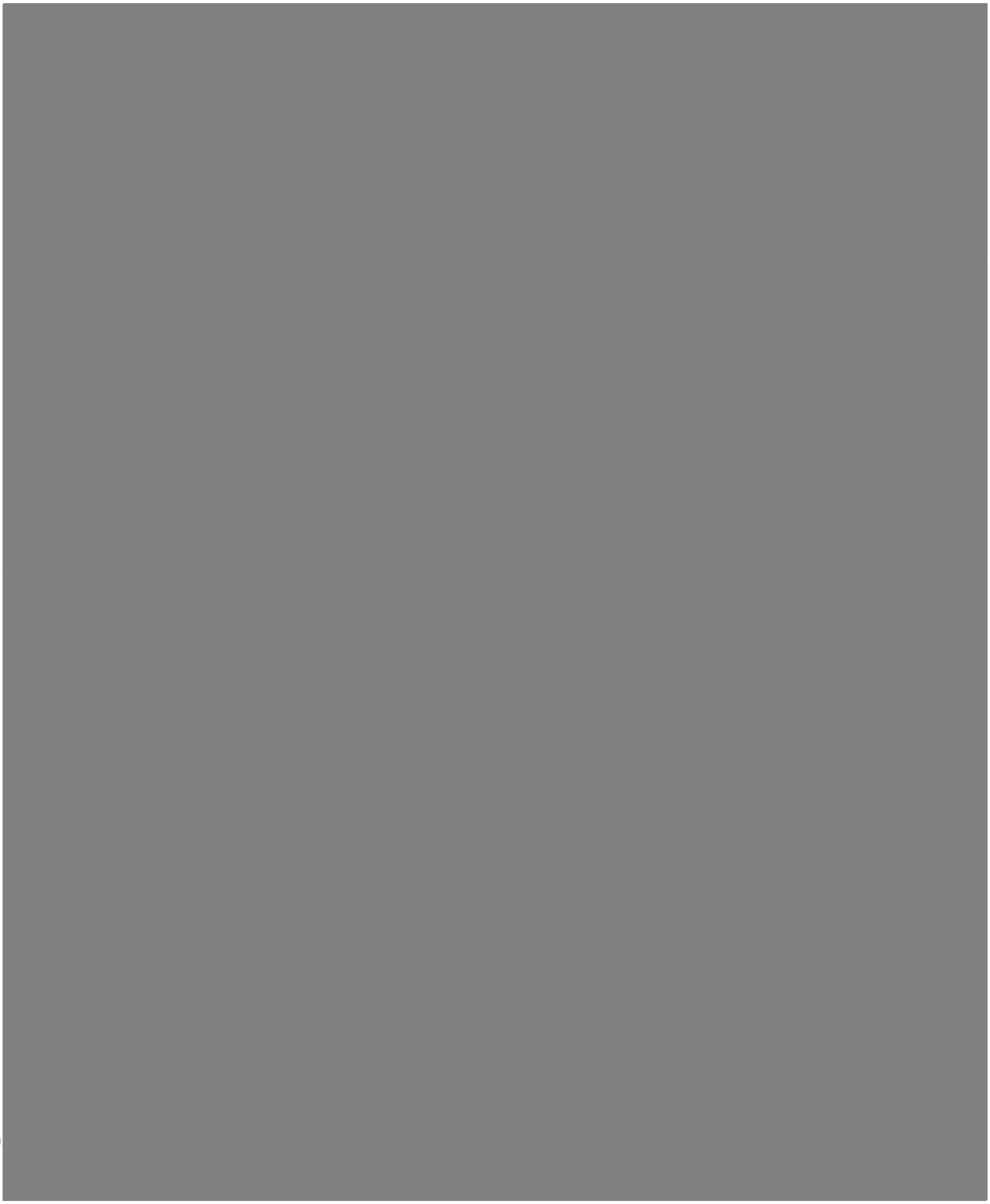

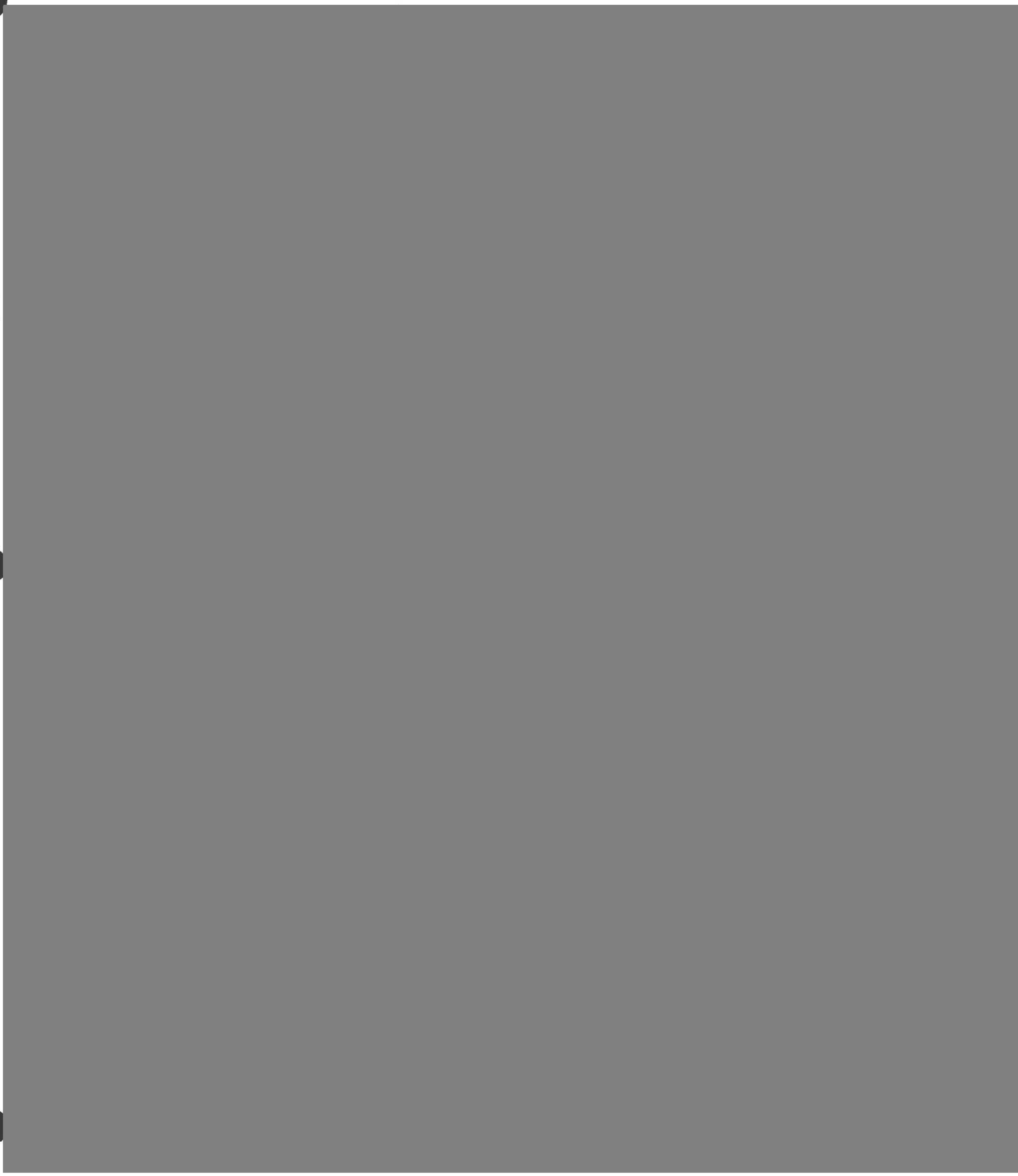

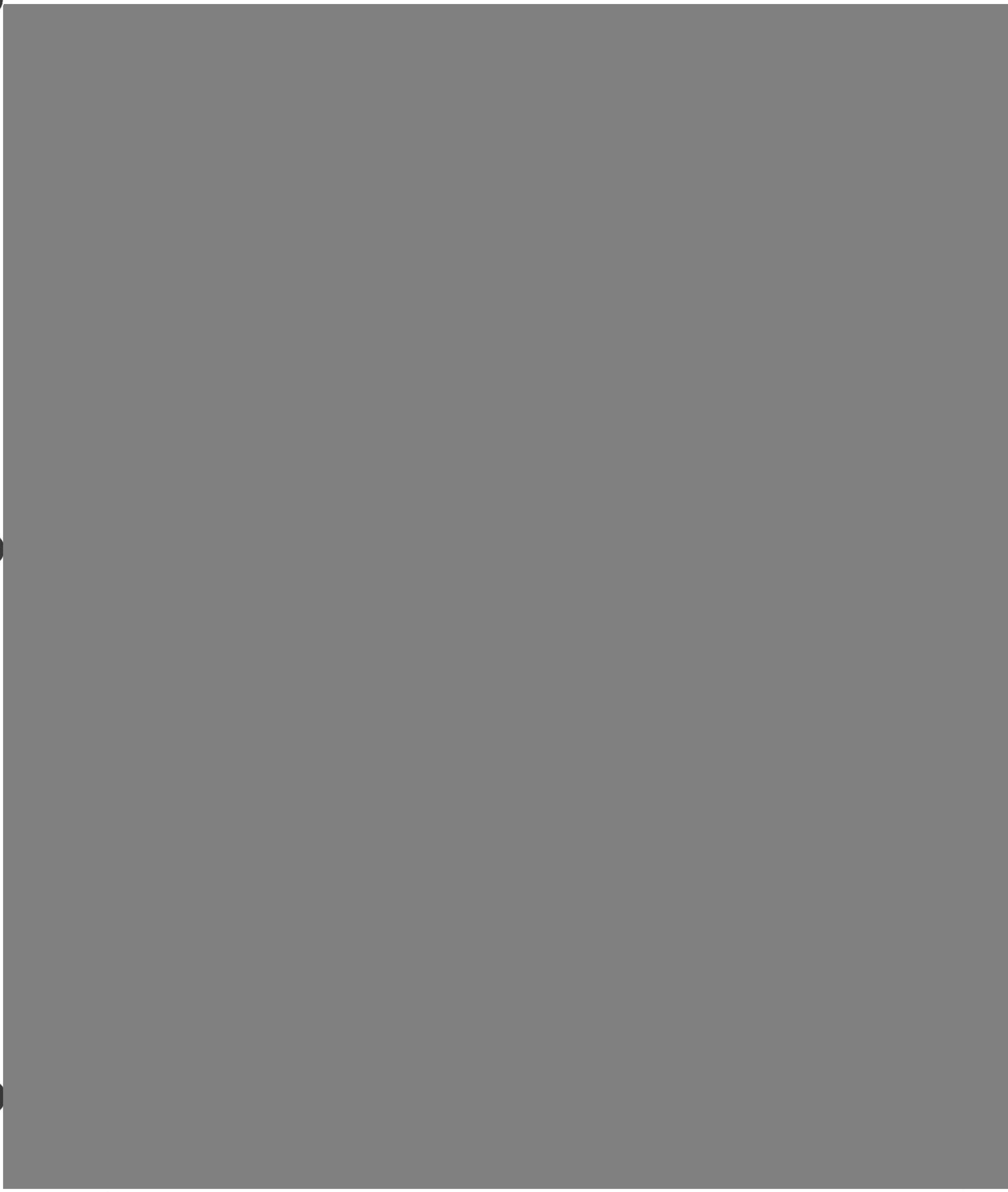

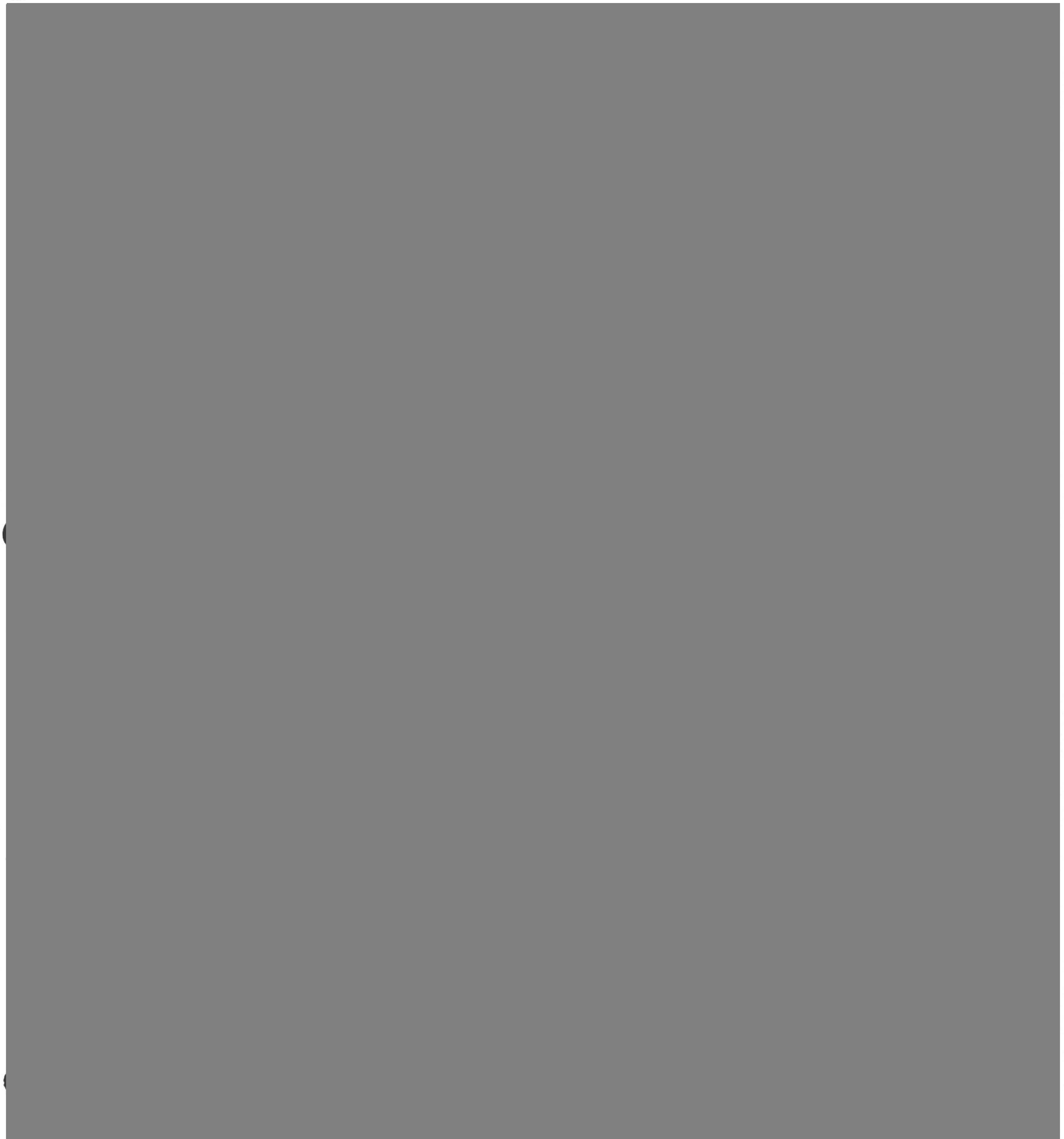

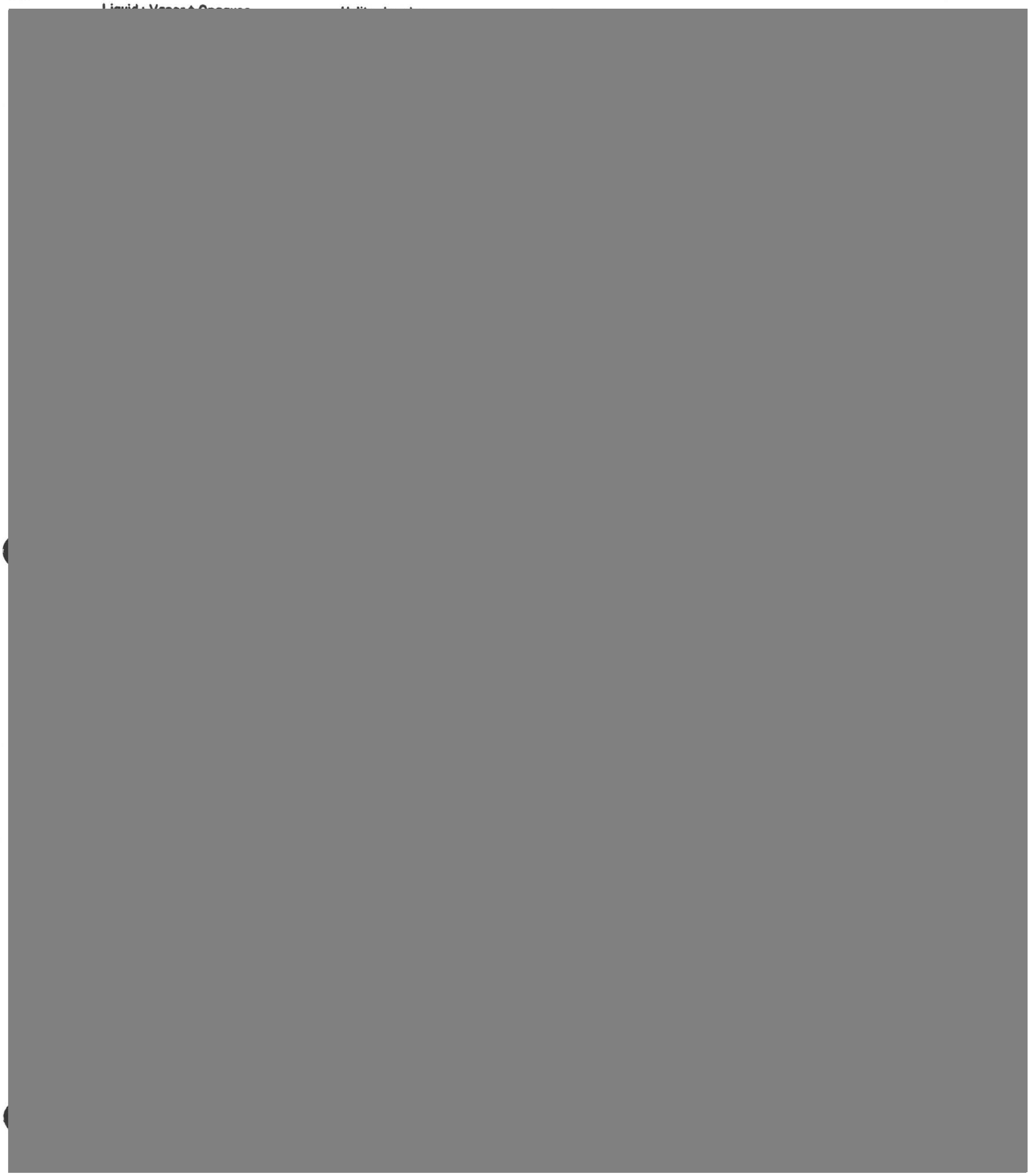

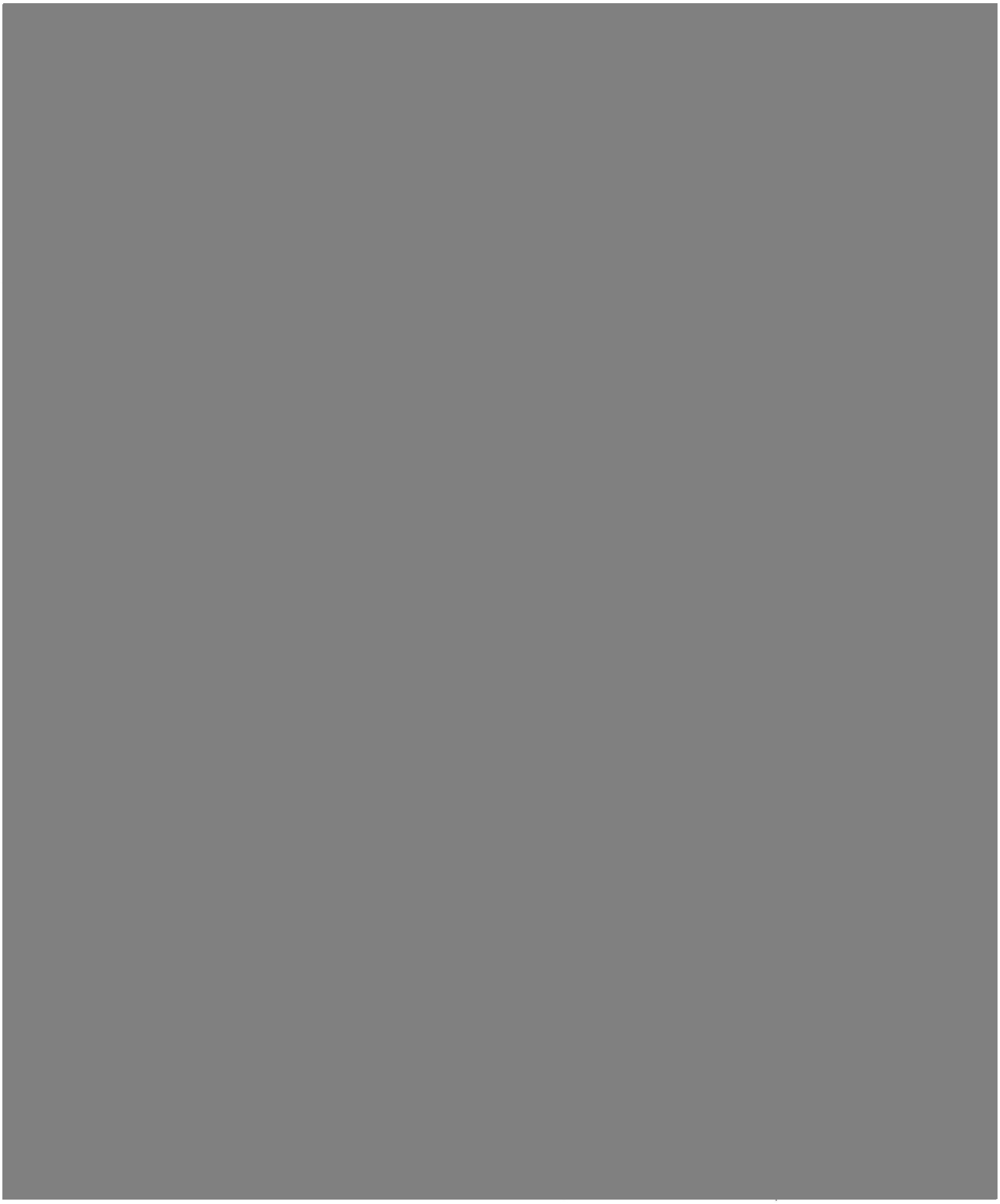

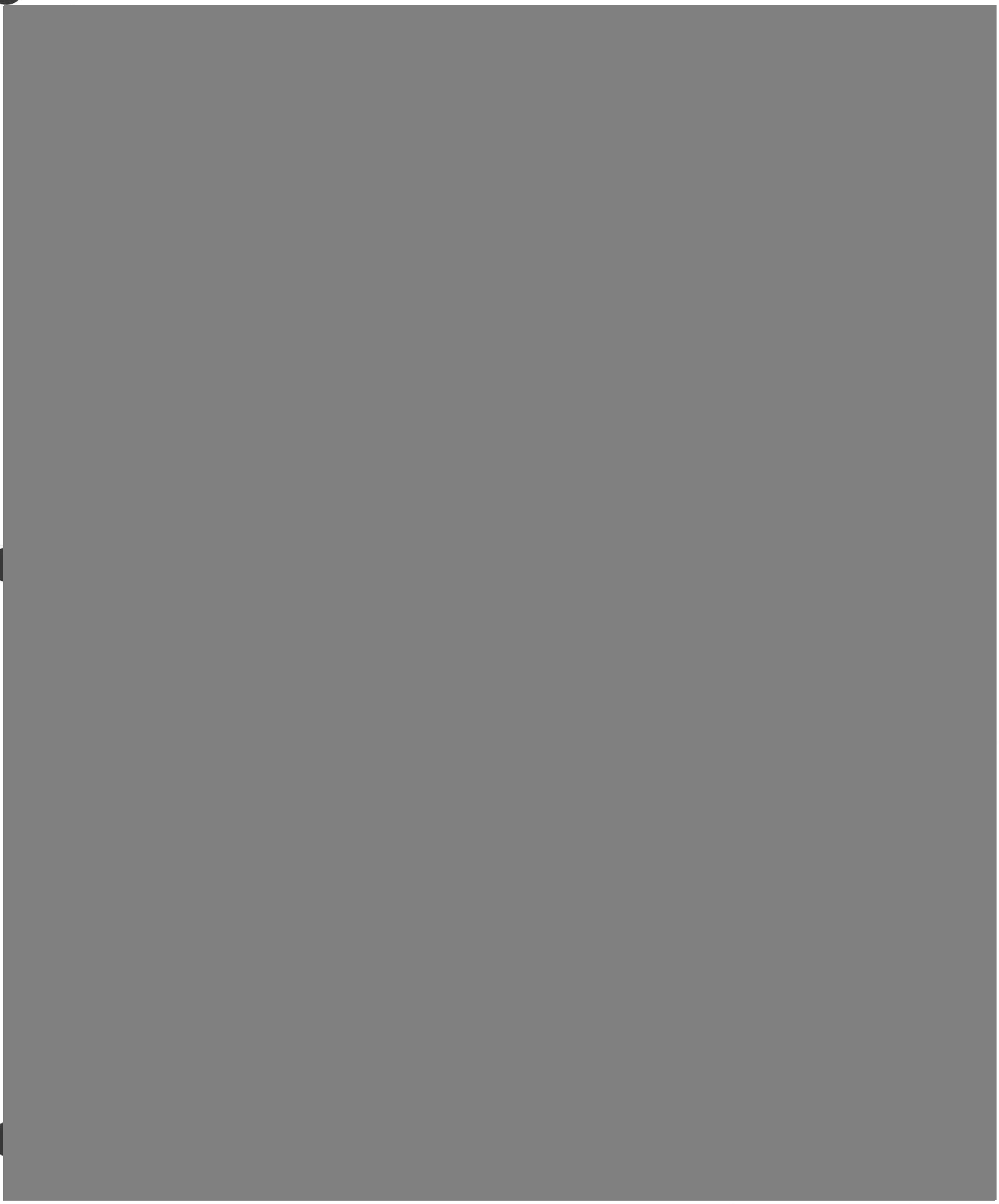

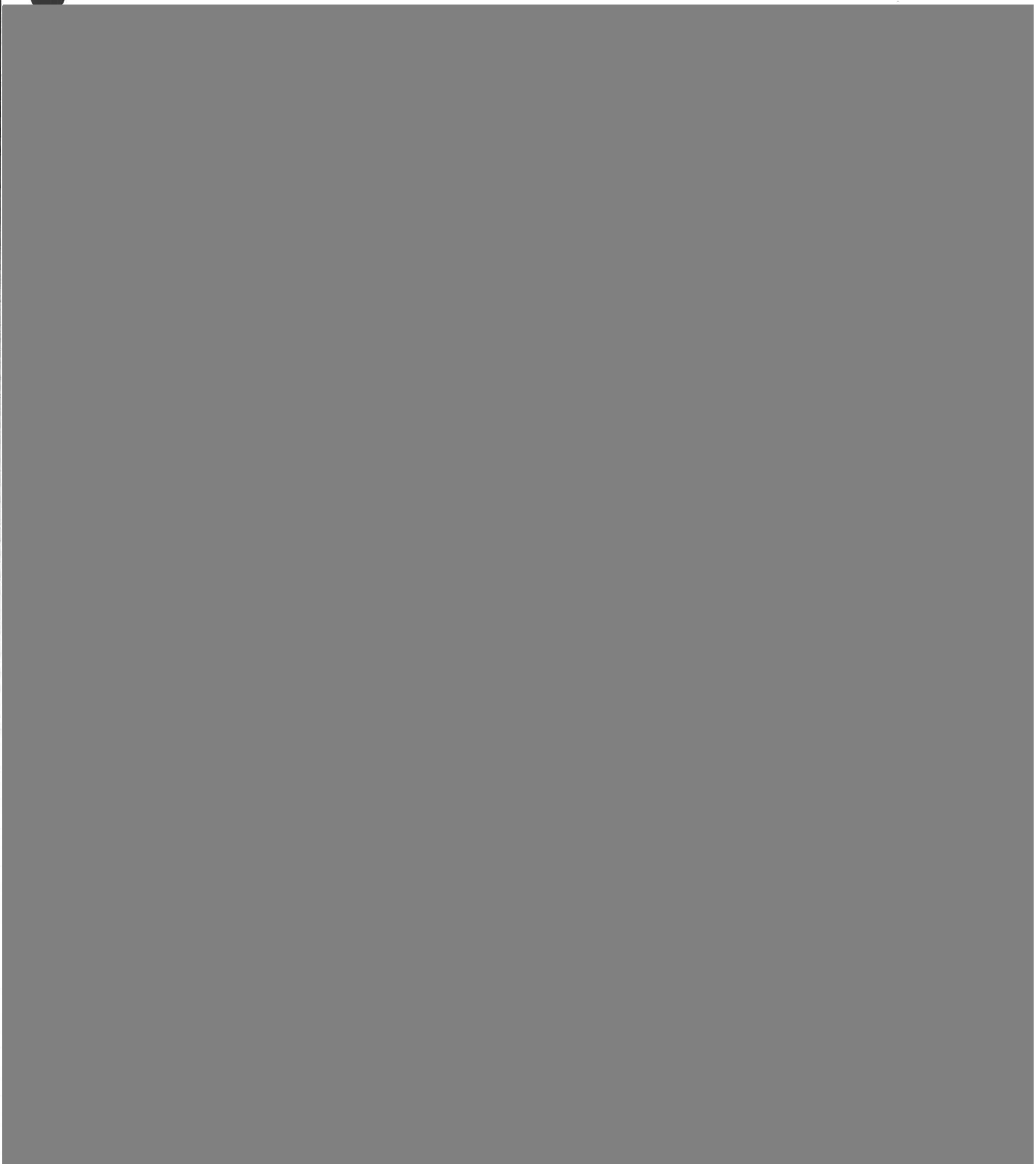

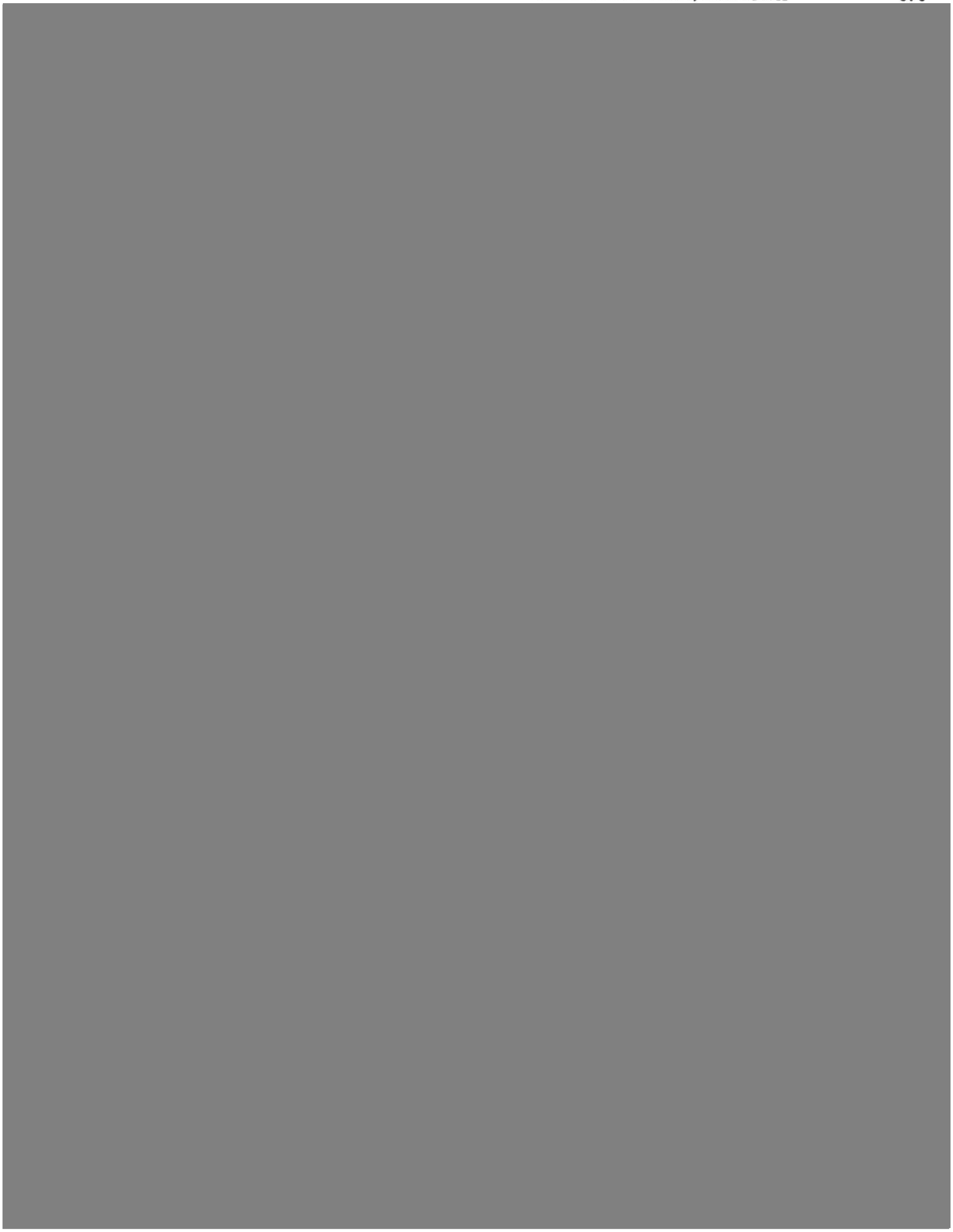

CHAFFEE, M.A.
et al

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REGIONAL GEOCHEMICAL STUDIES IN THE PATAGONIA MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

M.A. CHAFFEE, R.H. HILL, S.J. SUTLEY and J.R. WATTERSON

U.S. Geological Survey, Box 25046, Denver Federal Center, Denver, CO 80225 (U.S.A.)

(Received April 9, 1980; revised and accepted July 16, 1980)

ABSTRACT

Chaffee, M.A., Hill, R.H., Sutley, S.J. and Watterson, J.R., 1981. Regional geochemical studies in the Patagonia Mountains, Santa Cruz County, Arizona. J. Geochem. Explor., 14: 135—153.

The Patagonia Mountains in southern Arizona contain the deeply buried porphyry copper system at Red Mountain as well as a number of other base- and precious-metal mines and prospects. The range contains complex Basin and Range geology with units ranging in age from Precambrian to Holocene. Rock types present include igneous intrusive and extrusive units as well as sedimentary and metamorphic units, most of which have been tectonically disturbed. A total of 264 stream-sediment samples were collected and analyzed for 32 elements. Geochemical maps for Sb, Ag, Pb, Te, B, Mn, Au, Zn, Cu (total), Cu (cold-extractable), and Mo, as well as for Cu (cold-extractable)/Cu (total) and Fe/Mn, are presented.

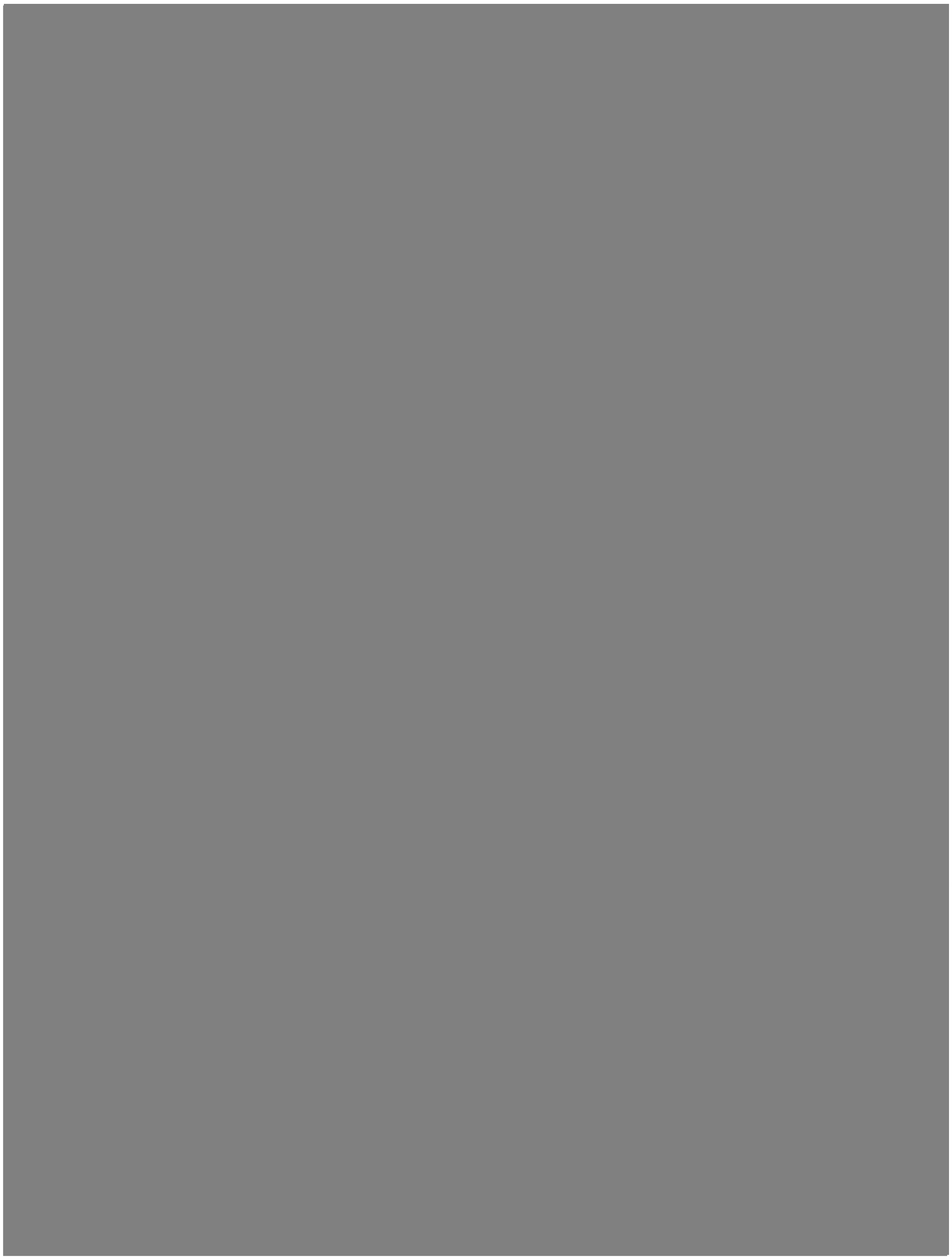
Anomaly patterns for these elements generally occur over the Red Mountain deposit and (or) along a north-northwest trend parallel to the major Harshaw Creek Fault. Much of the entire area sampled contains widespread anomalies for Pb, Te, and Cu; the other elements are only locally anomalous. Various plots of ratios of Cu (cold-extractable) to Cu (total) did not produce any new information not readily apparent on either one of the two copper maps. A plot of ratios of Fe to Mn delineated many areas of pyrite mineralization. Several of these areas may represent the pyritic halos around deeply buried porphyry copper systems.

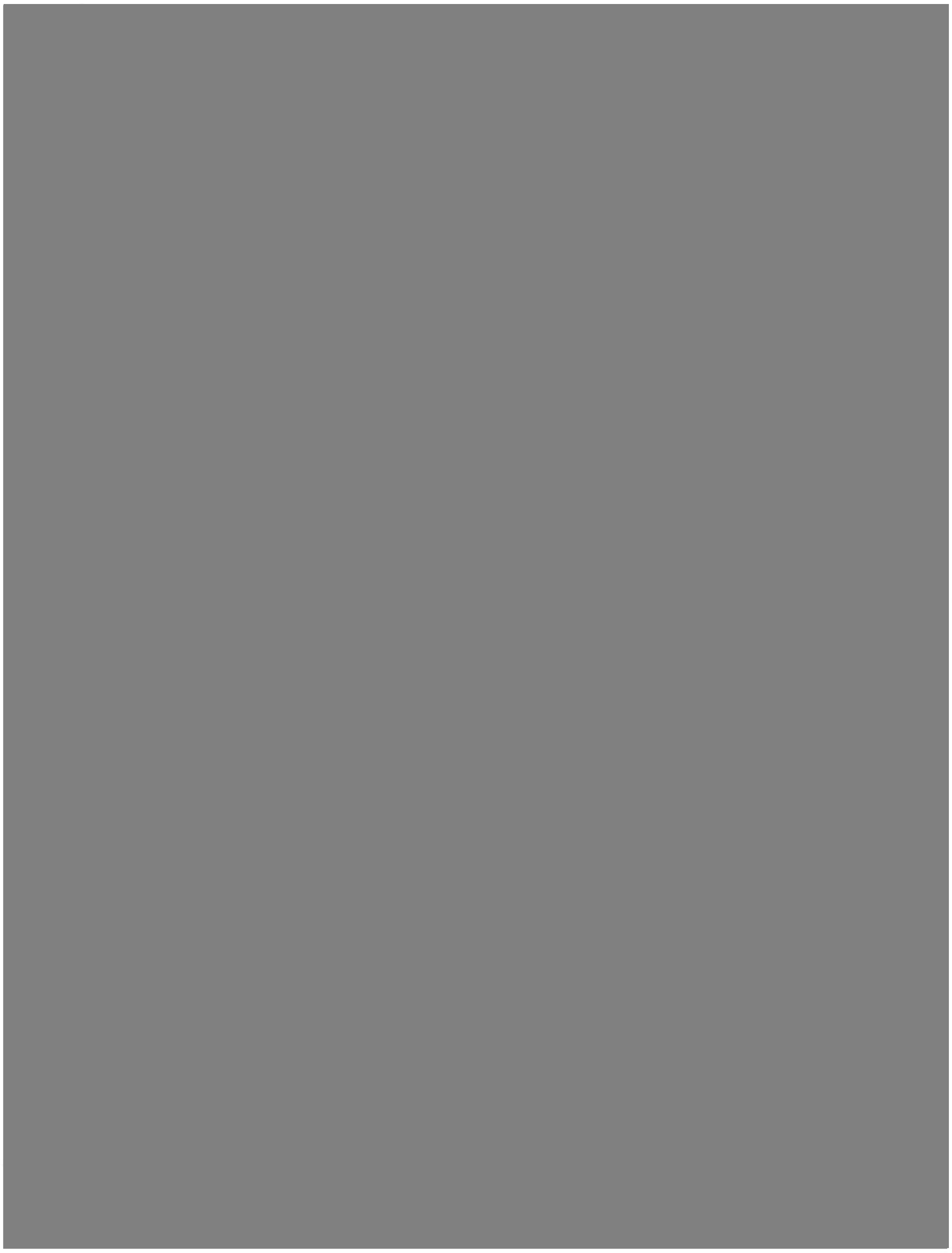
The best ore guide for the Red Mountain porphyry system is the coincidence of positive anomalies of Mo, Pb, and Te and a negative anomaly of Mn. Other areas with anomalies of the same suite of elements are present within the Patagonia Mountains.

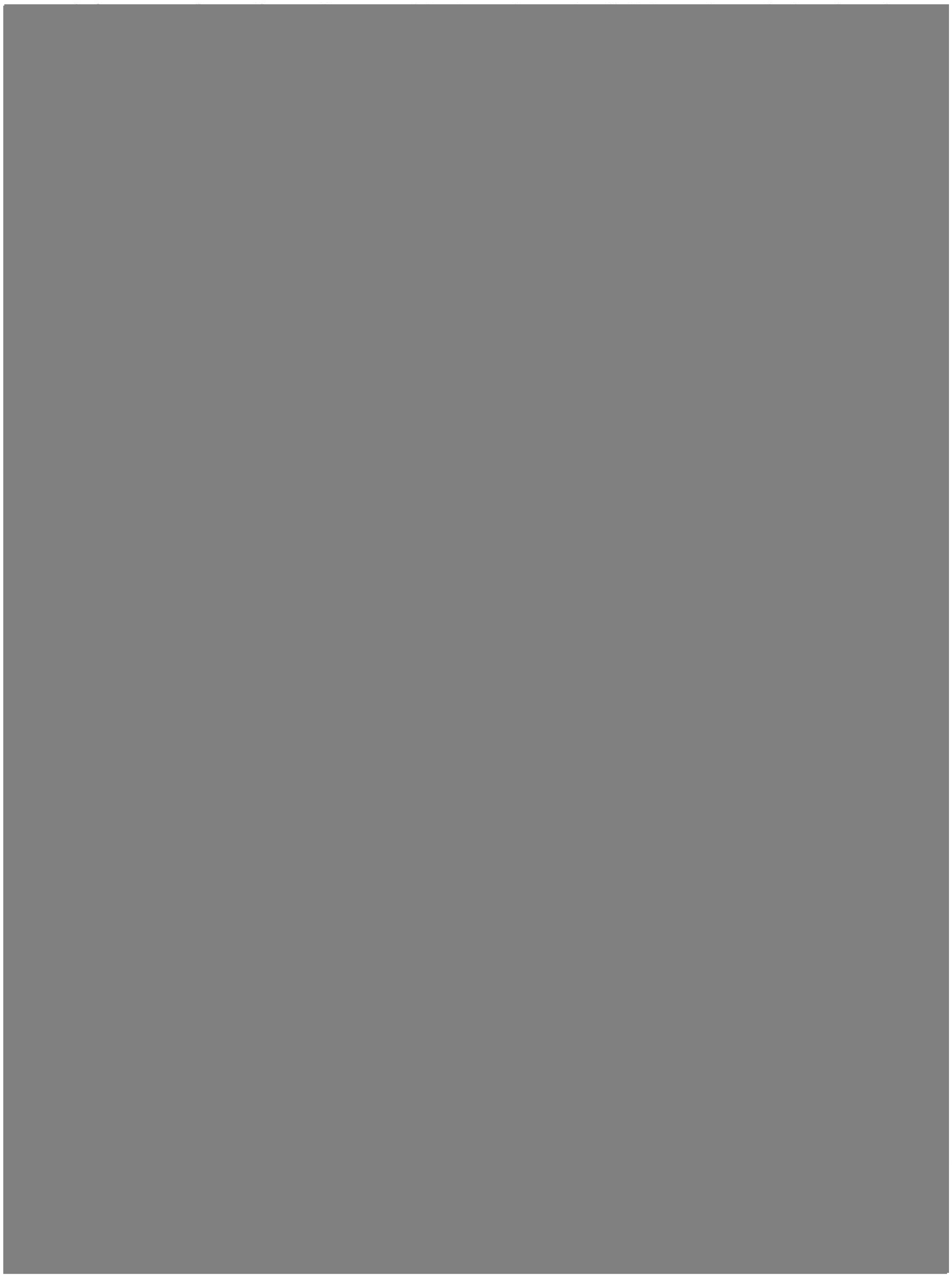
It is concluded that geochemical sampling, even in a highly contaminated area, can be useful in delineating major geologic features, such as porphyry copper belts and major faults. Multielement geochemical surveys on a regional scale can effectively locate large, deeply buried, zoned mineral systems such as that at Red Mountain. Plots of element ratios, where adequately understood, can provide geochemical information not readily discernible from plots of single elements alone.

INTRODUCTION

The U.S. Geological Survey is currently studying on a regional basis the geochemical characteristics of the porphyry copper belt or belts in southern







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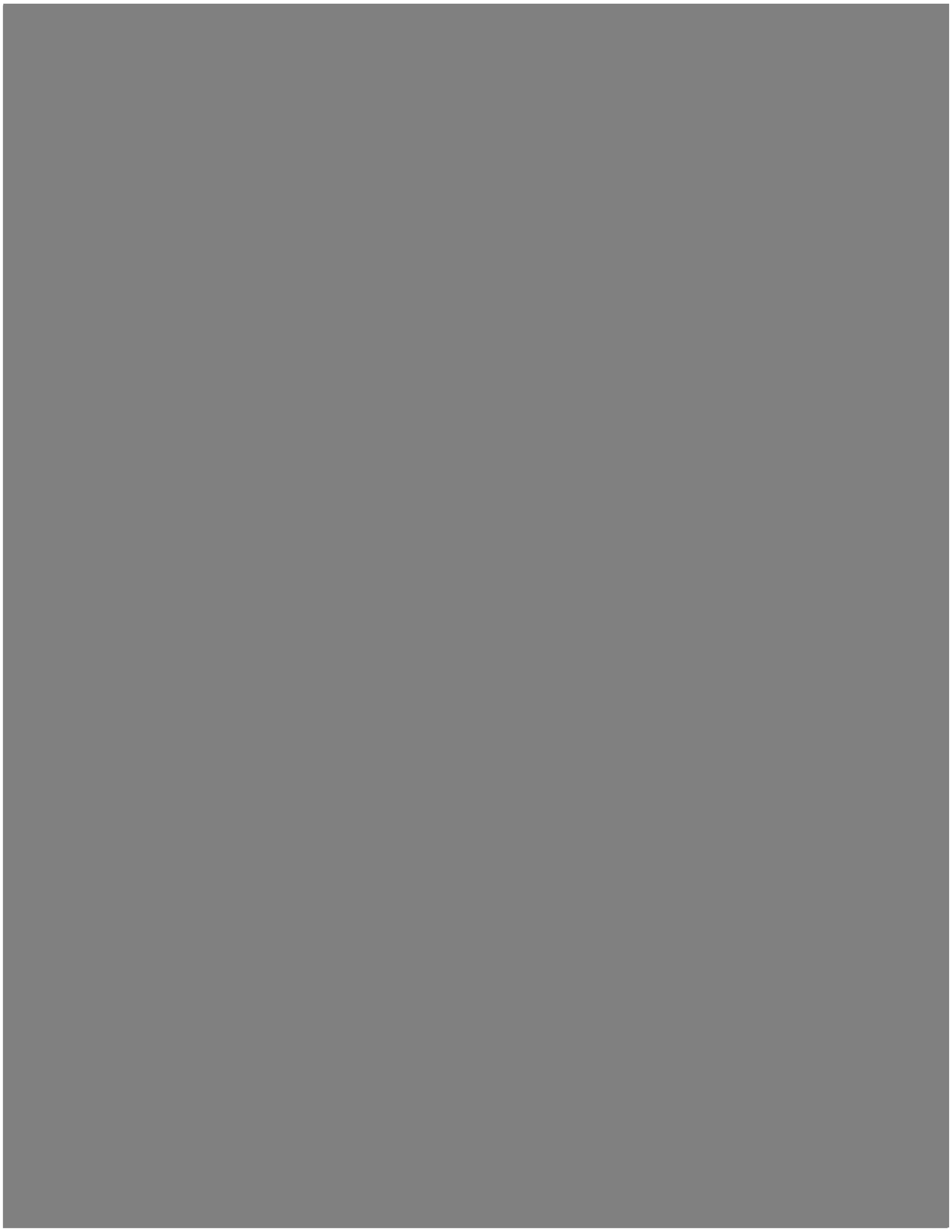

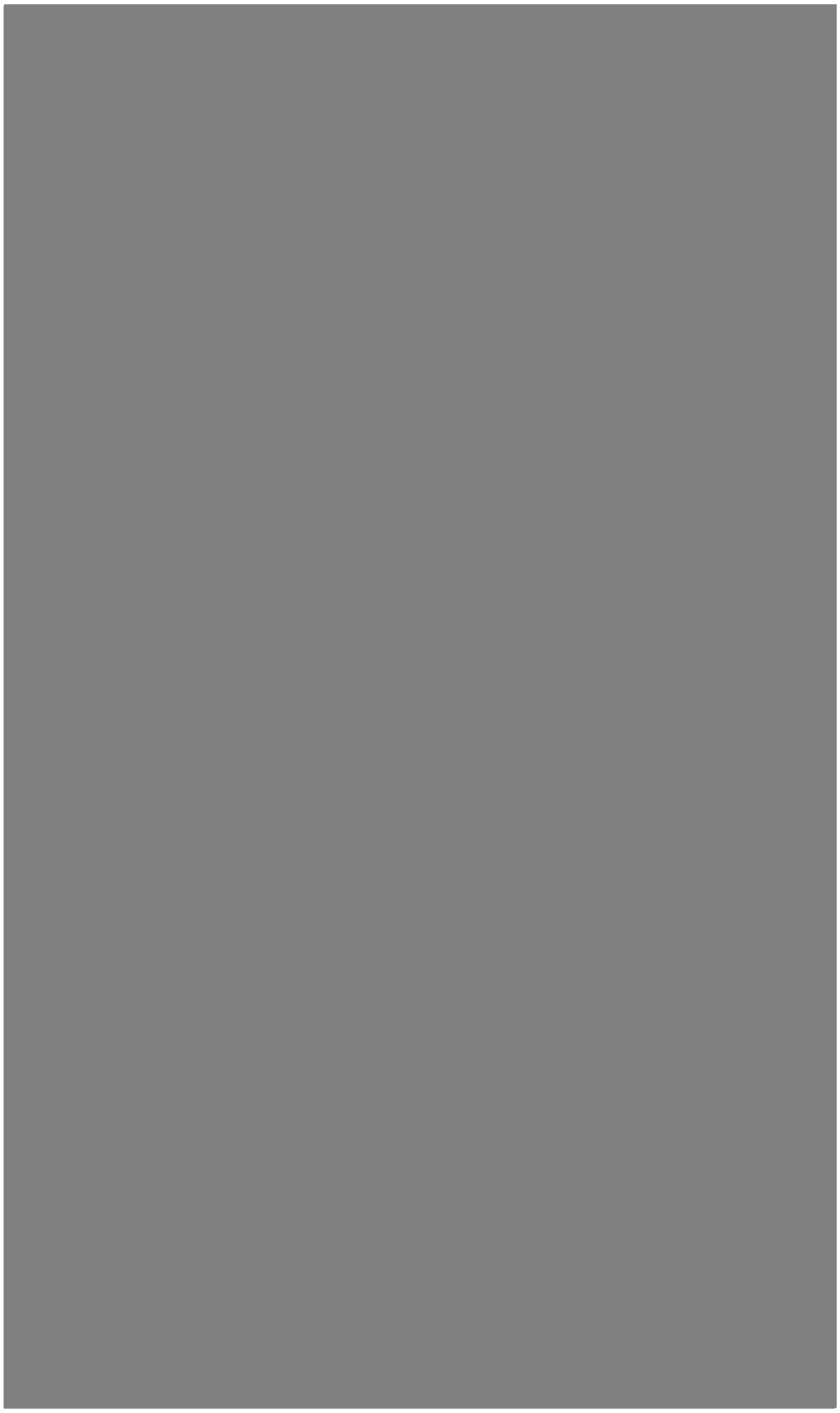

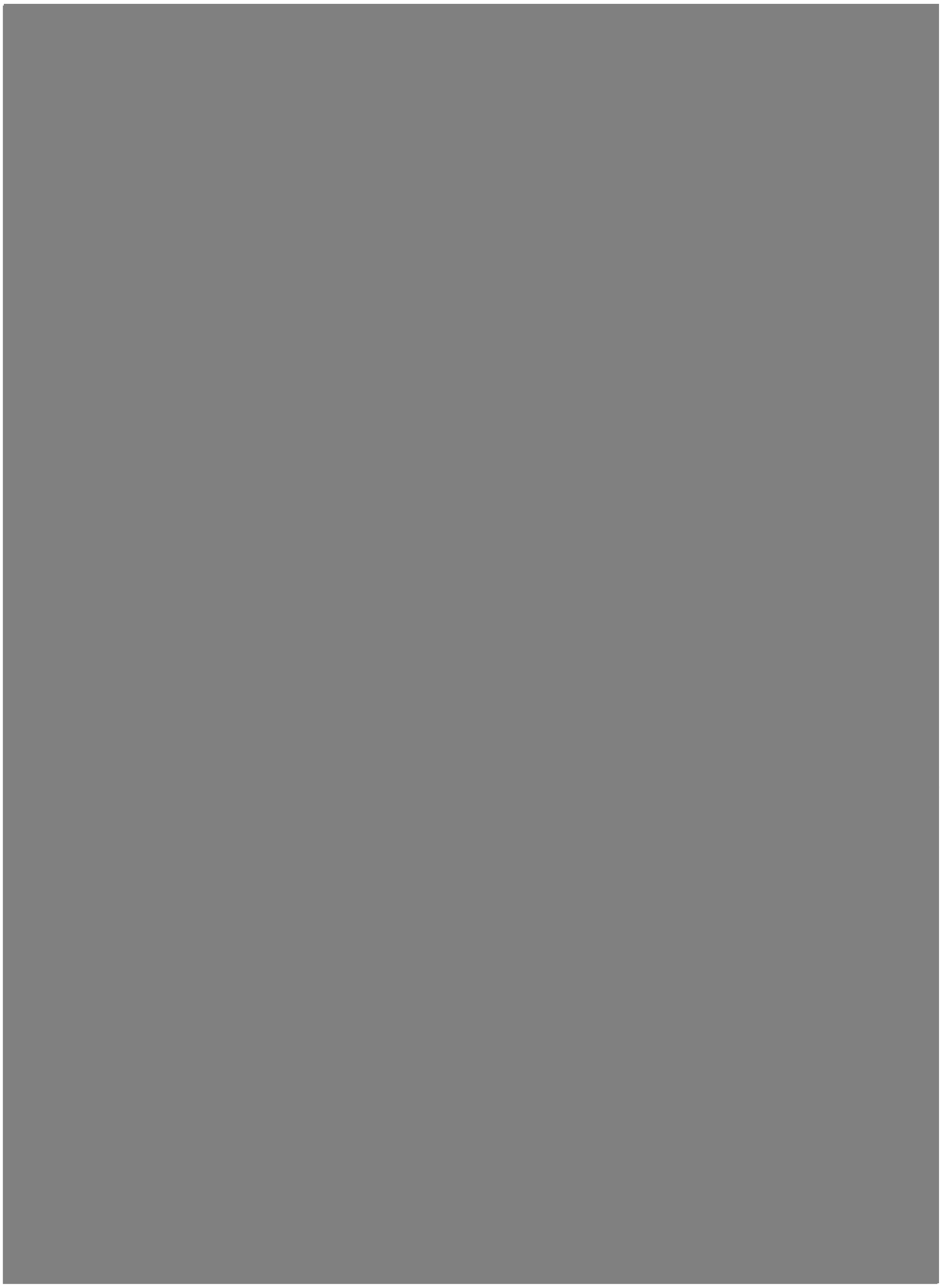

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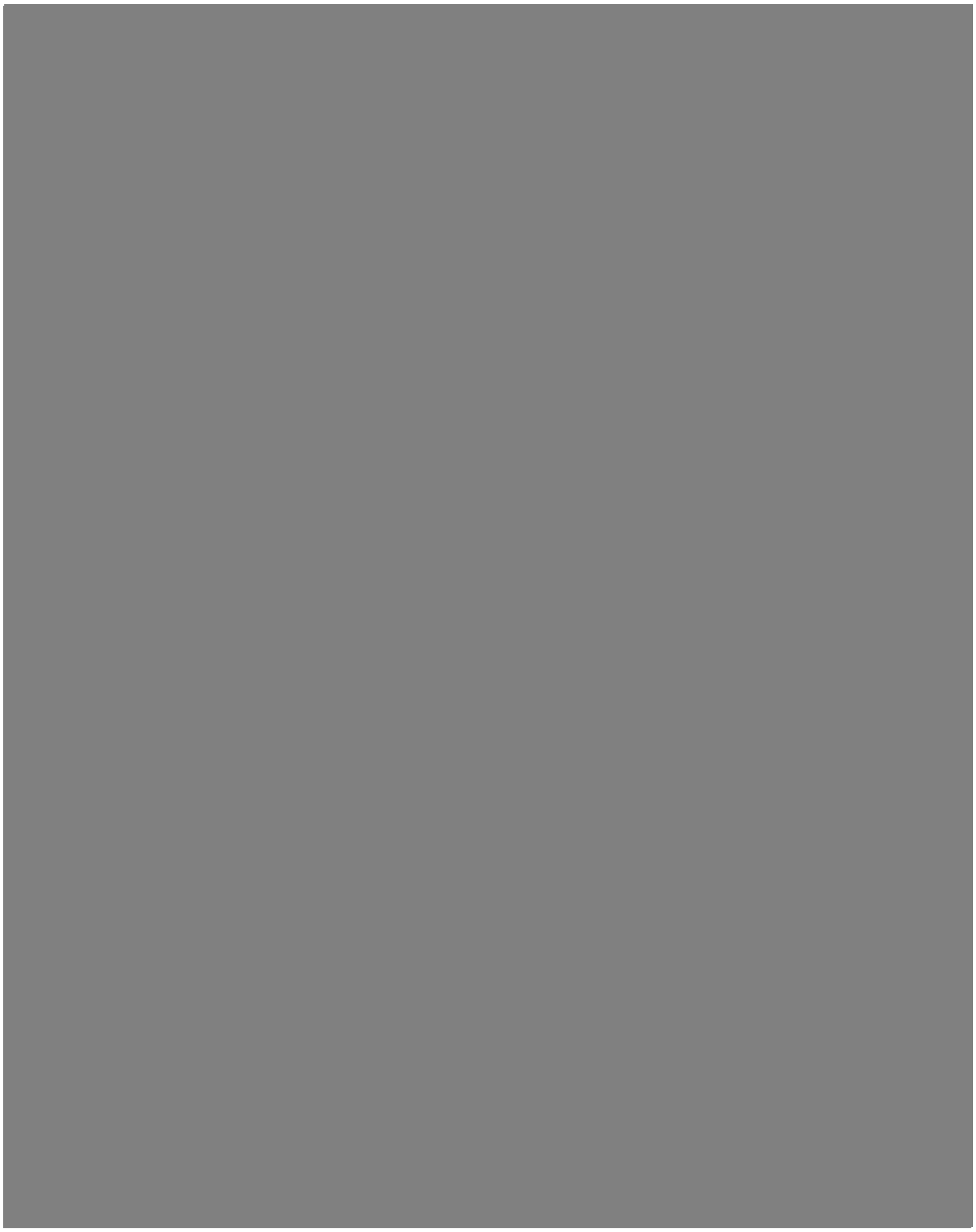

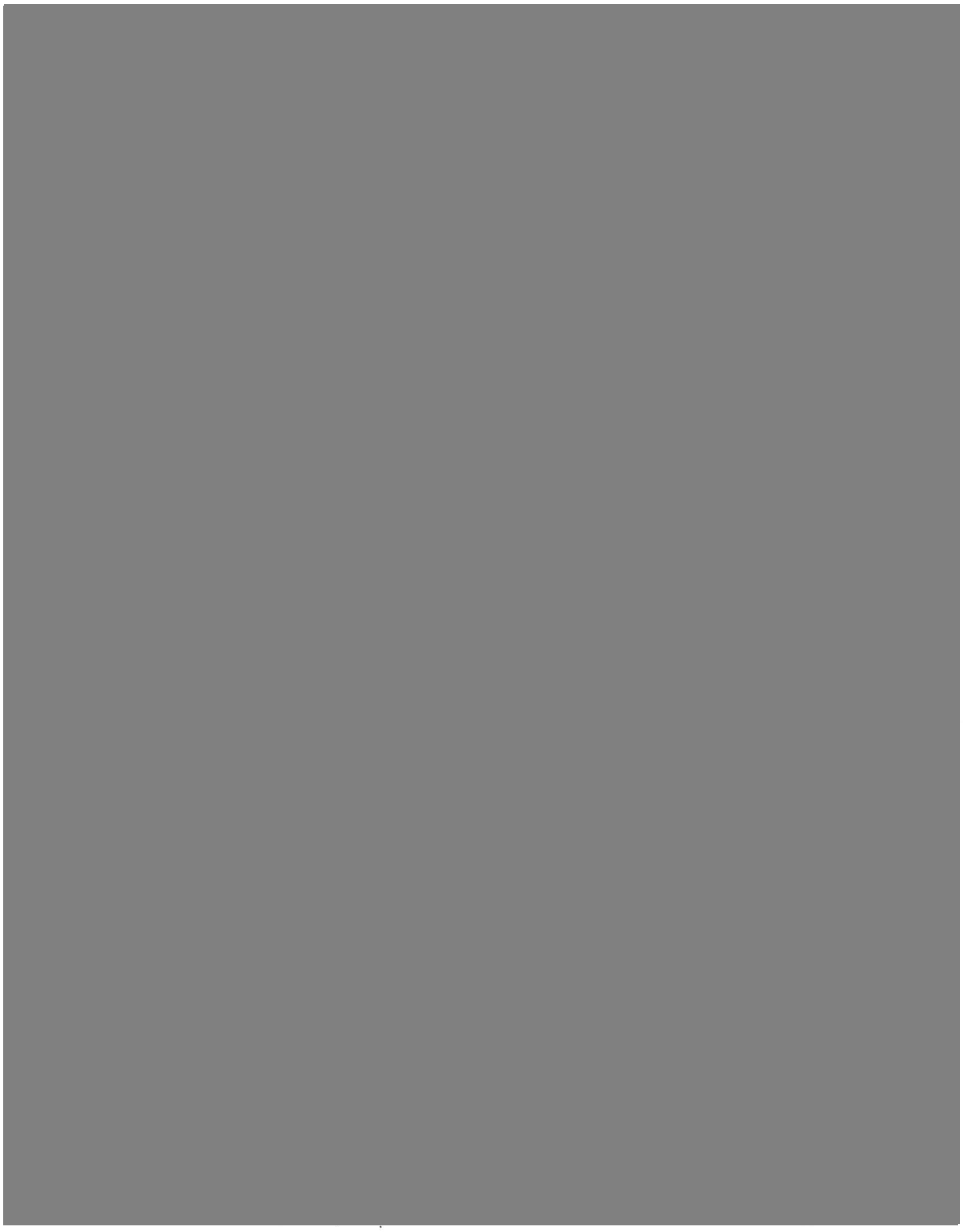

CORN, R.M.

Alteration-Mineralization Zoning, Red Mountain, Arizona

Russell M. Corn

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Economic Geology
Vol. 70, 1975, pp. 1437-1447

Alteration-Mineralization Zoning, Red Mountain, Arizona

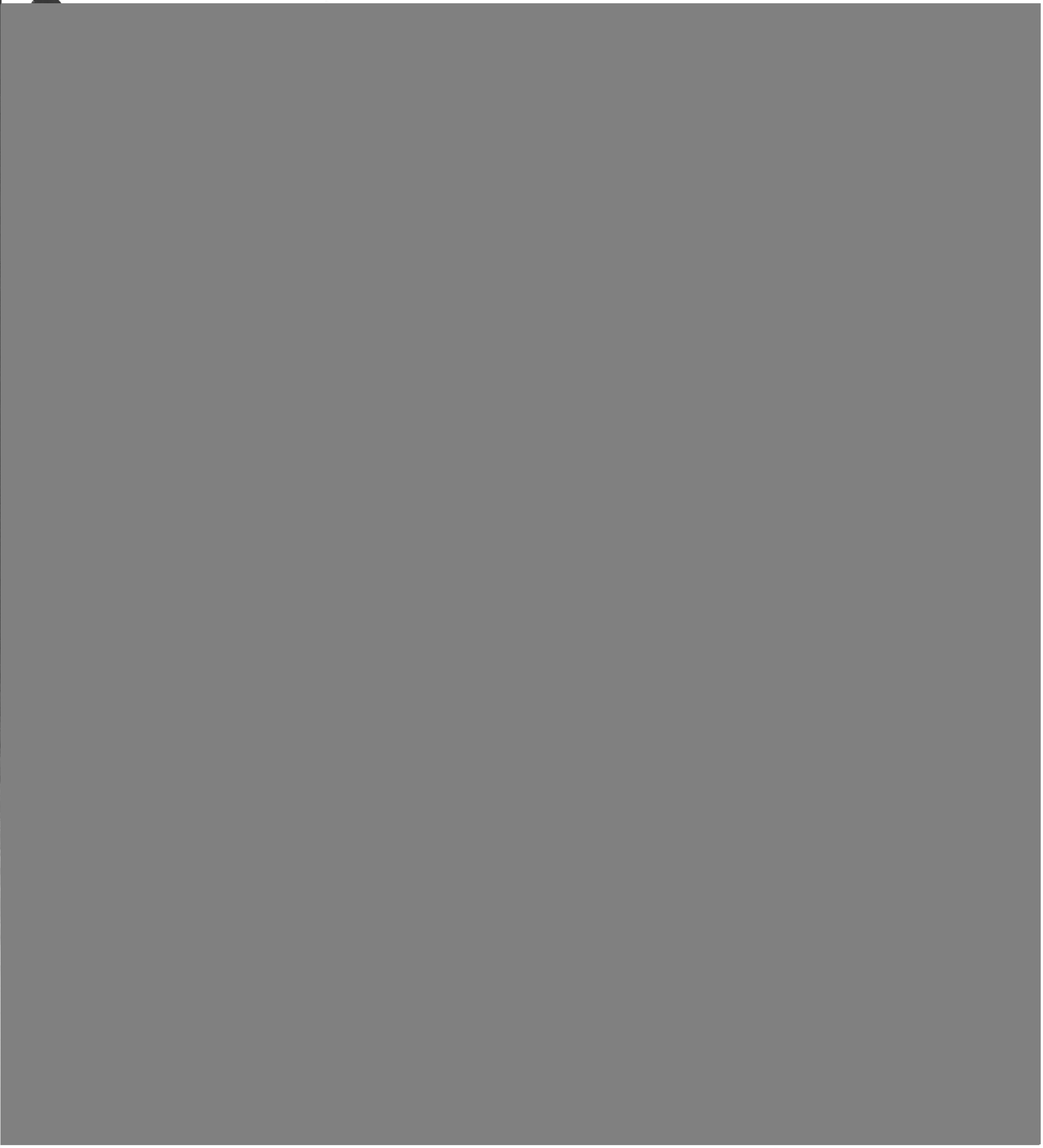
Russell M. Corn

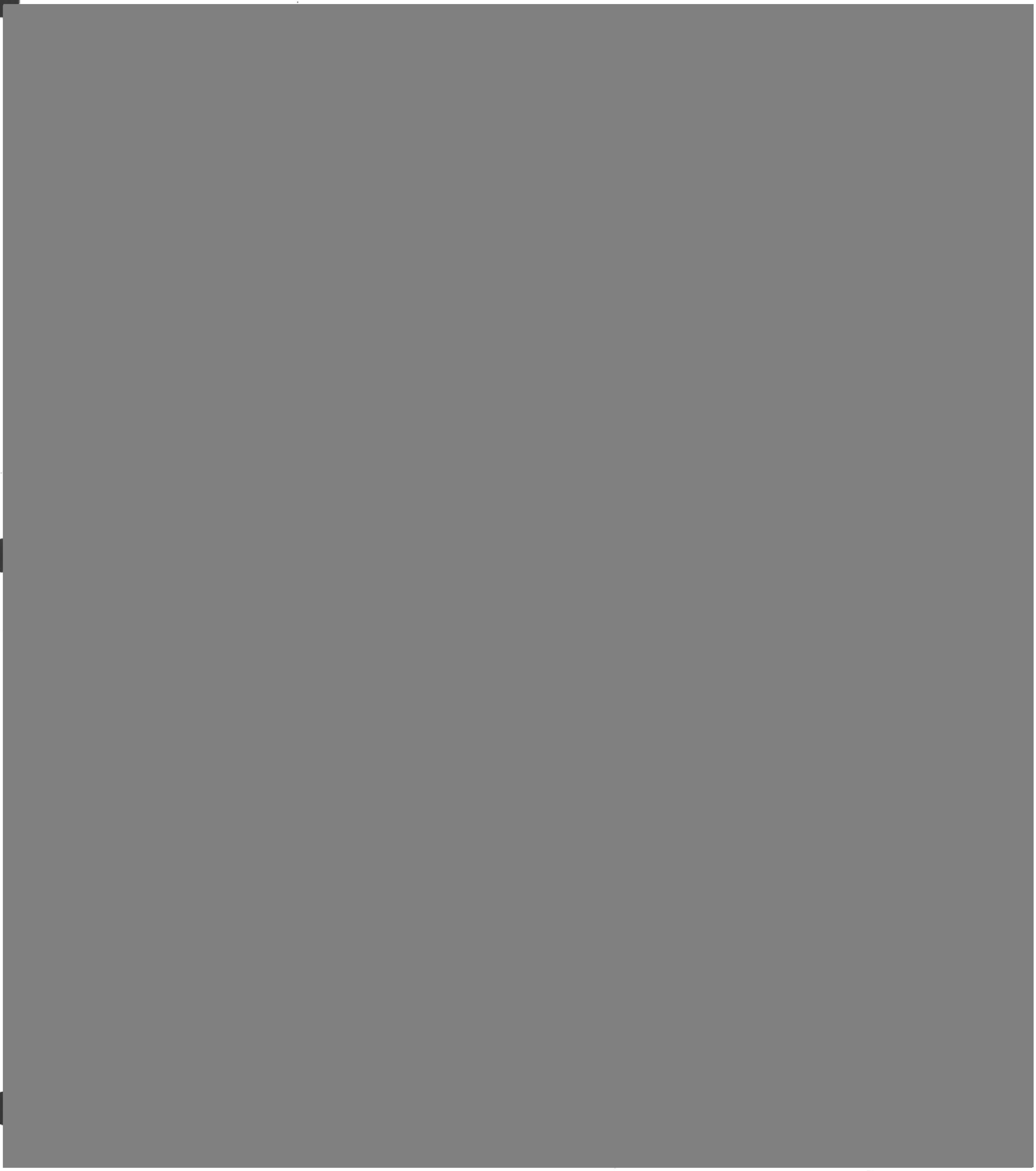
Abstract

The Red Mountain porphyry copper deposit is a hypogene deposit, occurring at depths of more than 3,500 feet beneath surface exposures of high-pyrite, phyllic alteration. The deposit was discovered as the result of deep drilling, predicated on the pattern of vertical zoning in alteration and mineralization noted during initial exploration of supergene chalcocite mineralization.

The alteration-mineralization system is believed to be centered on a caldera subsidence structure which was associated with explosive volcanism and subvolcanic intrusive activity. Surface exposures reflect a zoned pattern of alteration and mineralization, centered on an area of phyllic alteration and copper-molybdenum mineralization that is surrounded successively by zones of pyritic-argillic and propylitic alteration, with effects of hydrothermal alteration evident over an area seven to eight miles in diameter. Vertical zoning in alteration mineralogy appears to be related to a gradual decrease in sulfur content with increasing depth and shows a gradational change from near-surface, sulfur-rich phyllic alteration, through weak-potassic alteration, to low-sulfur potassic alteration at depth. The lateral and vertical zoning pattern is also reflected by the distribution of lead, zinc, molybdenum, and copper minerals, both in the zones of pervasive disseminated sulfides and within the exterior veins of the propylitic alteration zone, which are considered to be an integral part of the alteration-mineralization system.

The Red Mountain alteration-mineralization system exhibits two different types of hypogene copper mineralization. Enargite is associated with the near-surface, high-pyrite, phyllic and pyritic-argillic alteration. Chalcopyrite occurs with weak potassic and potassic alteration at depth. Although not ore-grade, the enargite mineralization did provide a protore source for the copper that was later concentrated in a "high-level" chalcocite enrichment blanket. Ore-grade chalcopyrite mineralization occurs at depths of 3,500 feet or more beneath the surface. The zoning pattern is characterized by a gradual increase in the grade of copper mineralization with increasing depth, within the zone of weak potassic alteration and the upper part of the potassic alteration zone.





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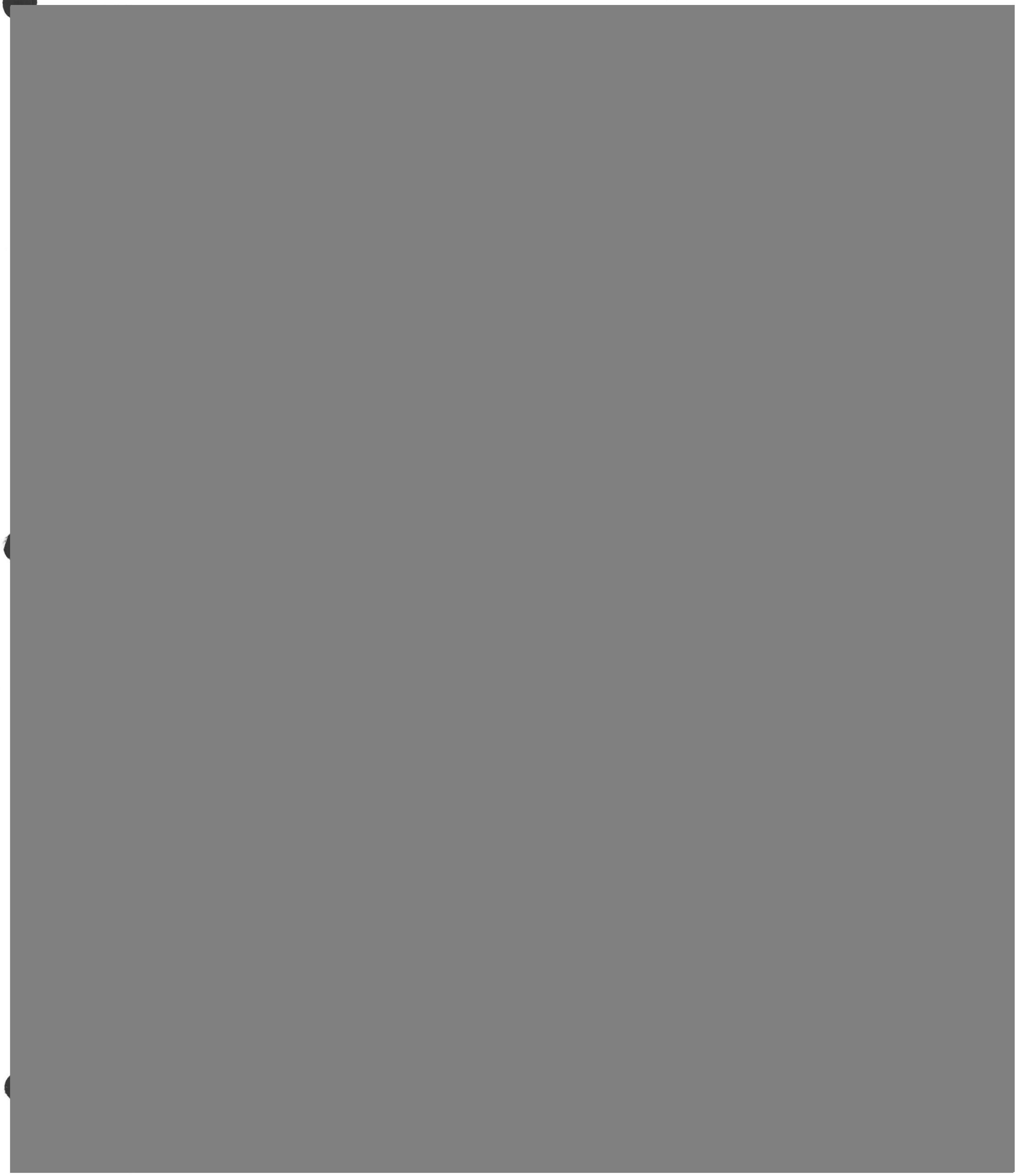
ritic-argillic alteration at higher elevations. How-



QUINLAN, J.J.

ARIZONA GEOLOGICAL SOCIETY

FIELD TRIP GUIDE

to

RED MOUNTAIN

SANTA CRUZ COUNTY, ARIZONA

March 21, 1981

Prepared by

James J. Quinlan
Kerr-McGee Corporation

Contents

Page

Illustrations

ROAD LOG FOR
RED MOUNTAIN PORTION OF
ARIZONA GEOLOGIC SOCIETY FIELD TRIP TO
PATAGONIA-RED MOUNTAIN-HARDSHELL DEPOSITS
MARCH 21, 1981

START

Mile 0.0 — Assemble parking lot at post office, Patagonia, Arizona, 9:00 a.m. Turn left out of parking lot on to road leading to Harshaw and Lochiel. Good view of Red Mountain on right.

Mile — Exposures of consolidated Tertiary gravels across wash on right, Patagonia fault at south end of outcrop.

STOP 1

Mile — Road cut exposure of Meadow Valley andesite. This is typical of many exposures outside of main Red Mountain alteration zone—would call attention to purple color and propylitic alteration; in the core of Red Mountain alteration zone, andesite is typically altered to a biotite-magnetite rich rock.

Mile

Turn off from Harshaw-Lochiel road on to road leading to Red Mountain. Outcrops in wash ahead generally propylitically altered Meadow Valley andesite. Local bleach zones are controlled by linear structures. Clay and gypsum are the most common minerals in these bleached zones.

STOP 2

Mile

Outcrop of altered Tuff unit or upper layered unit at Red Mountain (see Plates 2 and 3). Rock principally clay altered, stop at about outer limit of visible sericite in Red Mountain alteration zone.

STOP 3

Mile

Road cut and outcrop of altered Tuff unit ±1,750 feet closer to Red Mountain alteration center than Stop 2 (see Plates 2 and 3). Note increase in sericite and pyrite content over that at Stop 2.

STOP 4

Mile

Crest of Red Mountain ridge (see Plates 2, 3, 4, 10 and 11). Road cuts and outcrops of the Tuff unit are inside the area of relatively abundant sericite and iron oxides after pyrite. Adjacent drill hole data shows original pyrite content up to 18 weight percent and averages 10 to 12 percent. Will discuss and point out feature of deposit.

STOP 5

Mile

Collar of Drill Hole 148 (see Plates 2 and 3). Road, drill pad cuts and outcrops are in the altered Tuff unit, within the zone of relatively abundant sericite and iron oxide. Note quartz and alunite veinlets in drill pad cut. Will discuss deep level breccia pipe (Plate 12) and show core illustrating alteration changes with depth and breccia pipe.

GEOLOGY AND SILICATE-SULFIDE ALTERATION ZONING AT THE RED MOUNTAIN PORPHYRY COPPER DEPOSIT, SANTA CRUZ COUNTY, ARIZONA

James J. Quinlan

Abstract

This paper is the result of a study of the Red Mountain, Arizona porphyry copper deposit. The bulk of the copper recognized in the deposit lies about 5,000 feet below the summit of the mountain and 3,500 feet below a small, partly dissected, secondary enriched chalcocite blanket.

The copper deposit at Red Mountain occurs within an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Silicate alteration, sulfide distribution and assay data have been used to define the deposit and alteration system.

Alteration at Red Mountain is complex. A near classic porphyry-copper silicate-sulfide alteration pattern, including a partially defined copper shell is recognized at depth. This has been superimposed over an earlier potassic alteration assemblage which in turn is a part of a much larger zoned alteration system. Though modified by supergene agents, the early system accounts for much of the alteration recognized at the surface.

The Red Mountain deposit can be divided into three parts: (1) a near surface chalcocite blanket deposit, (2) a deep level bulk sulfide deposit and (3) a copper-molybdenum breccia pipe within the core area of the deep porphyry copper system.

The most obvious clue to the deep orebody at Red Mountain is the shallow chalcocite blanket. This apparently has formed from a low grade copper halo or plume which extends upward to the present surface or at least 5,000 feet above the deep orebody.

Introduction

The Red Mountain copper deposit is at the northern end of the Patagonia Mountains, 50 miles southeast of Tucson, Arizona (Fig. 1). The deposit was discovered and is controlled by the Kerr-McGee Corporation of Oklahoma City, Oklahoma.

The bulk of the copper recognized in the deposit lies about 5,000 feet below the summit of the mountain and 3,500 feet below a partly dissected enriched chalcocite blanket.

The geology of the Red Mountain deposit and surrounding area has been described by a number of authors. The most pertinent publications are: Schrader (1915), Drewes (1971 A & B and 1972 A & B), Simons (1971 and 1974), Corn (1975) and Bodnar and Beane (1980).

Geology

Geologic Setting

Red Mountain is underlain by an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Figures 2 and 3 are generalized maps illustrating surface geology and alteration features. Figures 4 and 6 are diagrammatic cross sections showing geologic and alteration features.

Three layered volcanic units are recognized at Red Mountain. The upper or Tuff unit, consists mainly of tuffs, flows and breccias of rhyolitic and dacitic composition. It crops out over much of the mountain and is up to 2,400 feet thick (Fig. 2 and 4). It is essentially the same as the "Volcanics of Red Mountain" described by Drewes (1971 A) and which he correlates with the Gringo Gulch volcanics of Paleocene (?) age.

Underlying the Tuff unit are approximately 3,000 feet of andesite and trachyandesite flows, breccias, sills and dikes locally referred to as the Andesite unit. Hornfels bands occur near the base of the unit. The Andesite unit crops out on the flanks of Red Mountain and is cut in drill holes (Fig. 2 and 4). It is a part of the upper Cretaceous Trachyandesite or Doreite (Ka) unit, mapped and described by Simons (1974). Simons reports a potassium argon date of $72.1\pm$ three million years for a sample from the unit.

The lowest layered rock unit is the Felsite-Latite unit. It underlies the Andesite unit and includes interlayered andesites near the top. It consists mainly of volcanic conglomerates and breccias, silicified tuffs, flows(?), interlayered and cut by latite sills and dikes. The unit crops out in Alum Gulch on the south side of Red Mountain and is recognized in deep drill holes on the south and west flanks of the mountain (Fig. 2 and 4). It correlates with the upper Cretaceous Silicic Volcanics (Kv and Kla units) mapped by F. S. Simons (1974).

The layered rocks at Red Mountain are cut by several textural varieties of porphyritic rocks which range in composition from granodiorite to quartz monzonite. The porphyries are recognized as dikes and irregular bodies in outcrop and drill holes (Fig. 2 and 4).

The layered rocks generally strike north and dip 15° E. The dominant trend of local shears and fractures is N 20° E with steep dips toward the northwest and southeast. Less numerous are shears and fractures which strike N 70° E and dip steeply northwest or southeast. No large faults are recognized on the mountain but several occur on its flanks (Fig. 2).

Silicate Alteration

Silicate alteration at Red Mountain is easy to recognize but difficult to interpret. Near the center of the deposit, changes in the alteration assemblage with depth are most obvious (Fig. 6). Lateral zoning at depth, which is a critical guide to ore, is much more subtle and to date has been best quantified by thin section studies (Fig. 5).

The strong vertical alteration zoning recognized at Red Mountain is partly controlled by differences in rock types with depth. Near the center of the system, the Tuff unit is intensely altered to an assemblage of quartz-sericite-pyrite-kaolinite-alunite. The sericite content increases with depth while the content of kaolinite and alunite decreases. At the Tuff-Andesite contact, the assemblage abruptly changes to quartz-sericite-chlorite-pyrite with minor hematite and kaolinite. With the exception of outlying Hole 158, the pyrite content rapidly decreases in depth through the upper Andesite interval (Fig. 10). The alteration assemblage further changes with depth within the andesite through a biotite-magnetite-pyrite assemblage to a biotite-orthoclase-anhydrite-magnetite-chalcopyrite assemblage. Within the Felsite-Latite unit, the assemblage is orthoclase-quartz-anhydrite-chalcopyrite-biotite. The alteration within the porphyritic rocks is generally reflective of the adjacent intruded rock and depth. It is expressed by a quartz-sericite-pyrite-kaolinite assemblage at shallow depths and an orthoclase-anhydrite-biotite-chalcopyrite assemblage at greater depth.

Lateral changes in alteration are much more subtle. At the surface hypogene alteration is strongly masked by supergene effects but is discernible. Within the Tuff unit, the lateral zoning is expressed as a central core area of more abundant sericite, quartz veining and limonitic stain (Fig. 3). Outward from the core area, a more argillic zone is characterized by abundant clays and alunite with less sericite and silica. The transition from sericitic-argillic alteration within the Tuff unit to propylitic alteration in the surrounding andesite to the northeast, east, south and southwest appears to be partly due to change in rock type. The suggestion is that the alteration mushroomed or extended farther laterally from a mineralization center in the Tuff unit than in the underlying andesite. Within the andesite on the west and northwest flanks of the mountain an intense supergene argillic alteration is superimposed directly upon hypogene biotite-magnetite alteration. Within this area of relatively low original pyrite, chalk turquoise has formed as the more common supergene copper mineral within the argillized andesite.

At depth, the central core area is marked by an orthoclase-quartz-biotite-anhydrite alteration mineral assemblage. There is a general decrease in the amount of these minerals outward from the core area with increasing amounts of sericite and chlorite. This is illustrated on Figure 5 which was developed from a study of thin sections obtained from selected holes between elevations of 2,000 and 2,500 feet.

Farther out, as seen in Holes 157 and 161, a biotite-magnetite assemblage is recognized in the andesite. In Hole 157, this assemblage changes to biotite-orthoclase in the Felsite-Latite unit. Though the assemblage is potassic, the intensity of the potassic alteration appears much less than that recognized in the core area of the deposit. Locally, late quartz-pyrite veinlets enclosed in sericitic envelopes cut the previously described alteration features.

Figure 6 illustrates in cross section the writer's concept of the major silicate alteration features at Red Mountain. That is, a large early zoned alteration system which accounts for most of the alteration recognized at the surface. The primary porphyry copper deposit lies in the potassic zone of this large early system. The alteration associated with the primary deposit has been superimposed on the early alteration system and zoning is similar to that described by J. D. Lowell and J. M. Guilbert (1970) and A. W. Rose (1970). It is suspected that the two silicate alteration systems are closely related in origin and time with the porphyry copper phase representing a late event in the development of the complex Red Mountain hydrothermal system. The sulfide distribution data also clearly points to two distinct alteration phases as does the fluid inclusion data of Bodnar and Beane (1980).

Sulfide Distribution

The principal sulfide minerals at Red Mountain are pyrite and chalcopyrite. Secondary chalcocite is present, particularly in the blanket deposit. Small amounts of molybdenite are present and bornite, enargite, tennantite, galena and sphalerite have been identified locally.

The sulfide content of the rocks at Red Mountain has been estimated during core logging and in the deep holes has been determined on the basis of sulfur and sulfide sulfur assays.

For the purposes of the sulfide distribution studies, it has been assumed that pyrite and chalcopyrite are the only significant primary sulfide minerals in the Red Mountain system. The amounts of each below the zone of secondary enrichment are calculated from copper and sulfide sulfur data by assigning the amount of sulfide sulfur needed to convert the amount of copper present in an interval to chalcopyrite and assigning the remaining sulfide sulfur to pyrite. Sulfate data has been converted to anhydrite equivalent where anhydrite is recognized in the deep drill holes.

The sulfide data has been assembled and posted in several different manners on plans and cross sections, i.e., by rock type and at various elevation intervals. Most revealing is the bulk data when assembled and posted at elevation intervals of 500 feet or more. In general, plans and sections have been prepared showing pyrite, chalcopyrite, and total sulfide (combined pyrite and chalcopyrite) distribution and pyrite to chalcopyrite ratios. The pyrite and total sulfide maps and sections are so reflective of each other that maps and sections showing pyrite distribution have not been included with this report.

Plan illustrations accompanying the report show relative bulk chalcopyrite (Fig. 7) and total sulfide distribution (Fig. 8) and relative pyrite to chalcopyrite ratios (Fig. 9) between elevations of 500 and 1,500 feet. All three maps show the same basic pattern and closely match the silicate alteration pattern shown in Figure 5. Though drilling has yet to outline the entire system, available data indicates an elongate but nearly classic sulfide copper shell. Thus all three plans, and in particular the ratio map (Fig. 9), are useful in indicating where a drill hole lies within the system.

Cross sections prepared from the sulfide data, i.e., data assembled at 500-foot elevation intervals, not only confirm the picture developed in plan but add to it. Total sulfide and chalcopyrite data have been assembled on Section A-A' which passes through the core area of the lower sulfide system as well as outlying Holes 157 and 158 (Fig. 10 and 11). The section showing total sulfide distribution (Fig. 10) clearly demonstrates a two-part system. A large primary sulfide high, mostly pyrite, is recognized near the surface in the upper parts of the central drill area and in Hole 158. This pyrite is within and generally an integral part of the intense quartz-sericite alteration assemblage. The section also suggests that Hole 157 lies in the core area of the large primary sulfide system and would account for the potassic alteration recognized in the hole. It is also apparent that the strong iron oxides recognized on the upper western slope of Red Mountain (Fig. 3) are related to the upper sulfide system.

The copper system recognized at depth in the central drill area and shown on the sulfide distribution and ratio maps (Fig. 7-9) is also apparent in the cross sections showing the total sulfide and chalcopyrite distribution (Fig. 10 and 11). Although the amount of total sulfides in the lower system (Fig. 10) is less than that in the upper system, it is clear from Figure 11 that the copper is associated with the lower system. Further it is apparent in section that the lower sulfide system closely follows the central area silicate system and like the silicate system is superimposed on the earlier and larger system.

The Ore Deposit

For discussion purposes, the Red Mountain deposit is divided into three separate and distinct parts: (1) an upper level chalcocite blanket deposit, (2) a deep level bulk sulfide deposit and (3) a breccia pipe deposit within the core area of the deep porphyry copper system.

Chalcocite Blanket

Chalcocite is recognized along fractures and as coatings on pyrite grains from the surface to a depth of 2,500 feet or more. Much of the chalcocite appears to be concentrated in a flat blanket-like deposit near an elevation of 5,000 feet (Fig. 11). As currently defined, the blanket ranges in thickness from 15 to 150 feet. It appears to be in the process of being destroyed by weathering and erosion and the deeper scattered chalcocite showings which are usually controlled by fissures or shears probably represents recent copper migration.

The chalcocite blanket almost directly overlies the deep porphyry copper orebody (Fig. 3 and 11). The distribution of copper above the deep porphyry copper system as reflected by the relative copper or chalcopyrite values shown in Figure 11, suggests the blanket was formed by enrichment of a protore halo or plume extending at least to the present surface or 5,000 feet above the main ore system. Bodnar and Beane's (1980) description of the late stage of mineralization in a quartz-pyrite veinlet containing minor chalcopyrite and galena in a surface sample, RM 11, also is evidence that the ore stage primary mineralization extends far above the main deposit.

Deep Level Bulk Sulfide Deposit

The zone of deep level porphyry copper mineralization at Red Mountain is an integral part of the copper shell as recognized in the alteration and sulfide study. Holes 146, 165 and the deeper parts of Hole 144 describe the low-sulfide, low-copper core of the system. A low-sulfide, low-copper tail extends from the core and is recognized in seven holes, 133, 135, 154, 162, 147, 143 and 152. A breccia pipe is defined in Holes 148, 148B, 148C and 155 and lies within the elongated tail area.

Nine drill holes are immediately peripheral to the core area and the elongated tail and it is in the area of these nine holes that most of the deep level copper outside the breccia pipe occurs. Seven of the nine holes contain thick and/or higher grade ore intervals. Ore is recognized on both the west and east limbs of the copper shell (Fig. 4).

Much, if not most, of the deep level copper occurs as chalcopyrite along veinlets and fractures and only a small amount occurs as disseminated grains. From work to date, it is obvious that the area of the copper shell is not uniform in grade and everywhere of interest. Local controls and structure apparently played an important part in copper mineralization within the shell area. For example, chalcopyrite enrichment is noted along both sides of andesite-porphyry contacts in several holes.

148-155 Breccia Pipe

The 148-155 breccia pipe recognized at Red Mountain has many features common to mineralized breccia pipes at other porphyry copper deposits. It is perhaps the deepest copper-molybdenum breccia pipe presently known anywhere in the world. Not only is it of potential economic interest because of the higher grade ore associated with it, but it is also of considerable scientific interest because of its depth, position within the system, and the mineralization and alteration associated with it.

The Dyna-drill has been used to control the direction of drill holes for a better evaluation of the pipe. In all, four holes have intersected the pipe, Holes 148, 148B, 148C and 155 (Fig. 12).

The 148-155 breccia pipe, as envisioned from drill hole data, is shown in plan and diagrammatic section in Figure 12. Though in part diagrammatic, the plan and section represent a reasonable interpretation based on drill hole intercepts within the pipe and the confining restrictions of adjacent holes. In plan the intercepts in Holes 148 and 155 are about 800 feet apart and define the minimum dimension of the long axis of the pipe. The pipe has been assigned a long axis of 1,100 feet. The section better illustrates the information available. As shown, the top of the pipe is at an elevation of 1,750 feet or approximately 4,000 feet below the surface and ore has been exposed over a vertical range of 1,300 feet. Hole 148 bottoms in ore within the pipe near sea level elevation.

As mentioned before, the 148-155 pipe lies within the high-potassic, low-sulfide and low-copper tail extending southward from the core of the deep porphyry copper system (Fig. 9). The alteration within the pipe is separate and generally distinct from that of the surrounding rock. This is well exemplified in Holes 148B, 148C and 155. These holes enter the pipe near its top from an area of low-sulfide, low-copper and strong potassic alteration. At or within a few feet of the pipe contact, alteration abruptly changes to phyllic with abundant sericite and up to 30 percent by weight of pyrite. Strong phyllic alteration persists near the top of the pipe but gives way to potassic alteration with depth. Only in hole 155 is a significant amount of possible mineralization leakage recognized above the pipe. Though the pipe contact in this hole is sharp and distinct, bands of pipe-type mineralization are evident for 40 feet above the pipe. Shears with chlorite, sericite and quartz-sulfide veinlets similar to pipe mineralization are recognized up to 775 feet above the pipe.

Unlike many breccia pipes described in the literature, the mixing and movement of fragments great distances up or down the pipe has not been recognized in the 148-155 breccia pipe. Though fragments are broken and rotated, the composition of fragments, with but a few exceptions, appear to be similar to those in the immediate wall of the pipe. More detail is needed to substantiate this observation.

The ore breccia generally consists of angular fragments of felsite and andesite in a matrix of orthoclase, quartz, anhydrite, chalcopyrite and pyrite. Sericite is abundant near the top and also is recognized close to the sides of the pipe in deeper intercepts. Calcite, molybdenite and a dark gray sulfosalt, tenatively identified as tennantite, are accessory minerals. Breccia fragments are commonly an inch or less in diameter. The largest fragment recognized was 18 inches in diameter. Open vugs are common.

A definite enrichment of copper, molybdenum and silver is recognized at the pipe margin, particularly in the deeper intercepts. The enrichment is related to the concentration of chalcopyrite and molybdenite rich sulfide lenses at the margins. The grade of copper at the margins of the pipe is from 1.8 to 4.8 times that in the core area of the pipe. Molybdenum enrichment at the margins is ten times and that of silver from two to four times that of the pipe core.

The silicate alteration and sulfide distribution pattern recognized in the pipe, though different in scale, is much the same as that recognized in many large porphyry copper systems, that is, a core area of strong potassic alteration with lower sulfide content. This is followed upward and to a lesser extent outward towards the pipe margins by a phyllic zone with increased sulfides. The suggestion is that the pipe itself may represent a more intense but miniature zoned porphyry copper system superimposed over the main or bulk phase of porphyry copper alteration and mineralization.

Discussion

Most of the alteration recognized at the surface of Red Mountain results from the supergene modification of a large zoned hypogene alteration system formed prior to the emplacement of the deep porphyry copper deposit.

The deep level porphyry copper is related to a more intense, less extensive event in the evolution of the complex hydrothermal system. The superposition of the breccia pipe alteration and mineralization over the main phase porphyry copper alteration and mineralization indicates an even more confining, more intense alteration, mineralization pulse late in the evolution of the system.

Though the three hydrothermal events appear separate and distinct, all three are undoubtedly closely related in time and origin to each other and to the emplacement of porphyry intrusives at Red Mountain. The indicated sequence of formation appears to start with the development of the large, barren, zoned system, with succeeding but more restrictive and intense pulses of ore mineralization within the confines of the large barren system.

The zoned nature of alteration and mineralization within the breccia pipe indicates the pipe itself may represent a miniature zoned porphyry copper system. Whereas the pipe contains open vugs, most evidence indicates that it must have formed many thousands of feet below the surface.

The most obvious clue to the deep orebody at Red Mountain is the shallow chalcocite blanket. This appears to have formed from a low-grade copper halo or plume which extends upward to the present surface or at least 5,000 feet above the deep orebody. Undoubtedly, pyrite from the early alteration system played an important part in the generation of acid for leaching of the plume mineralization.

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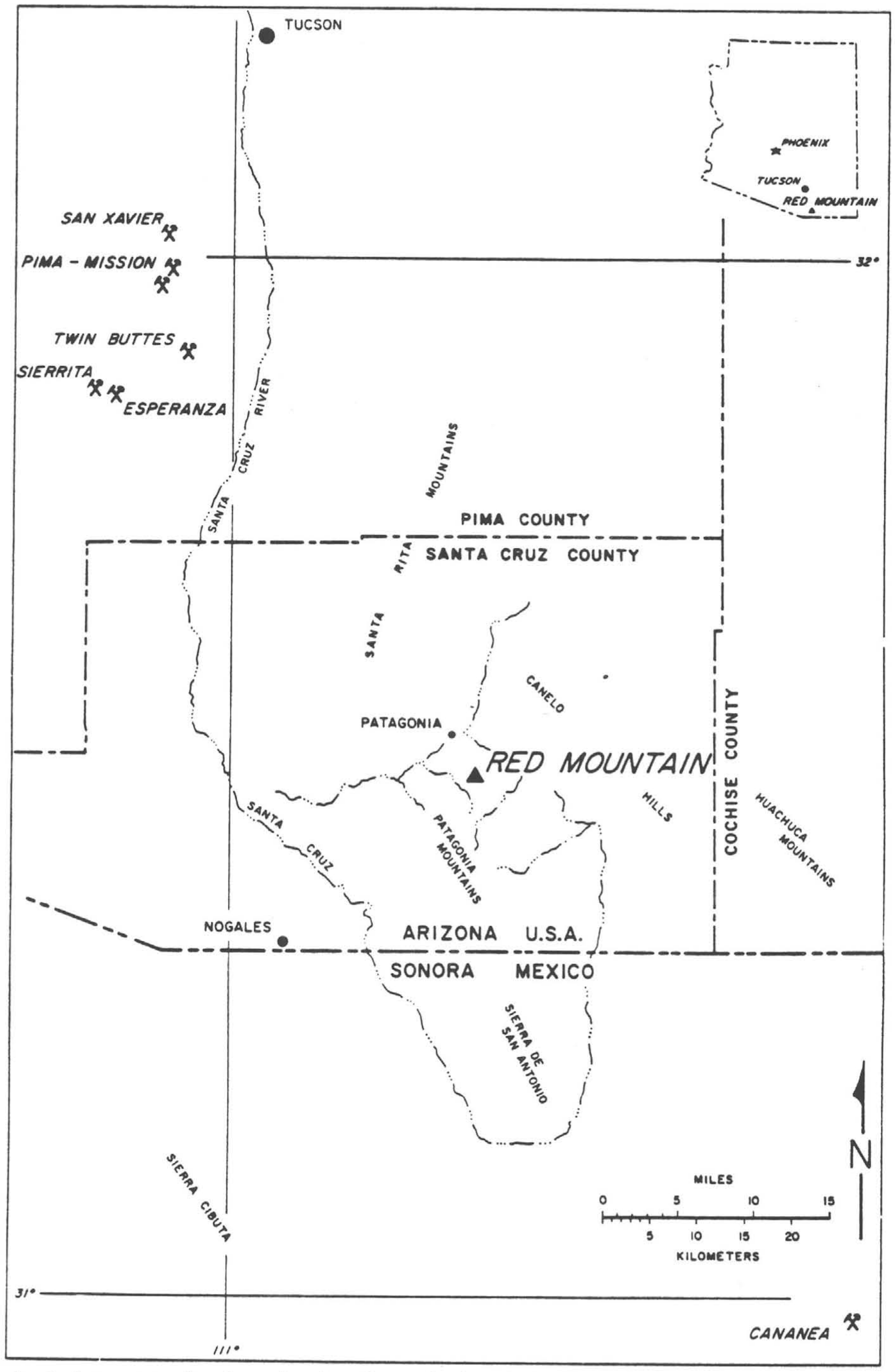
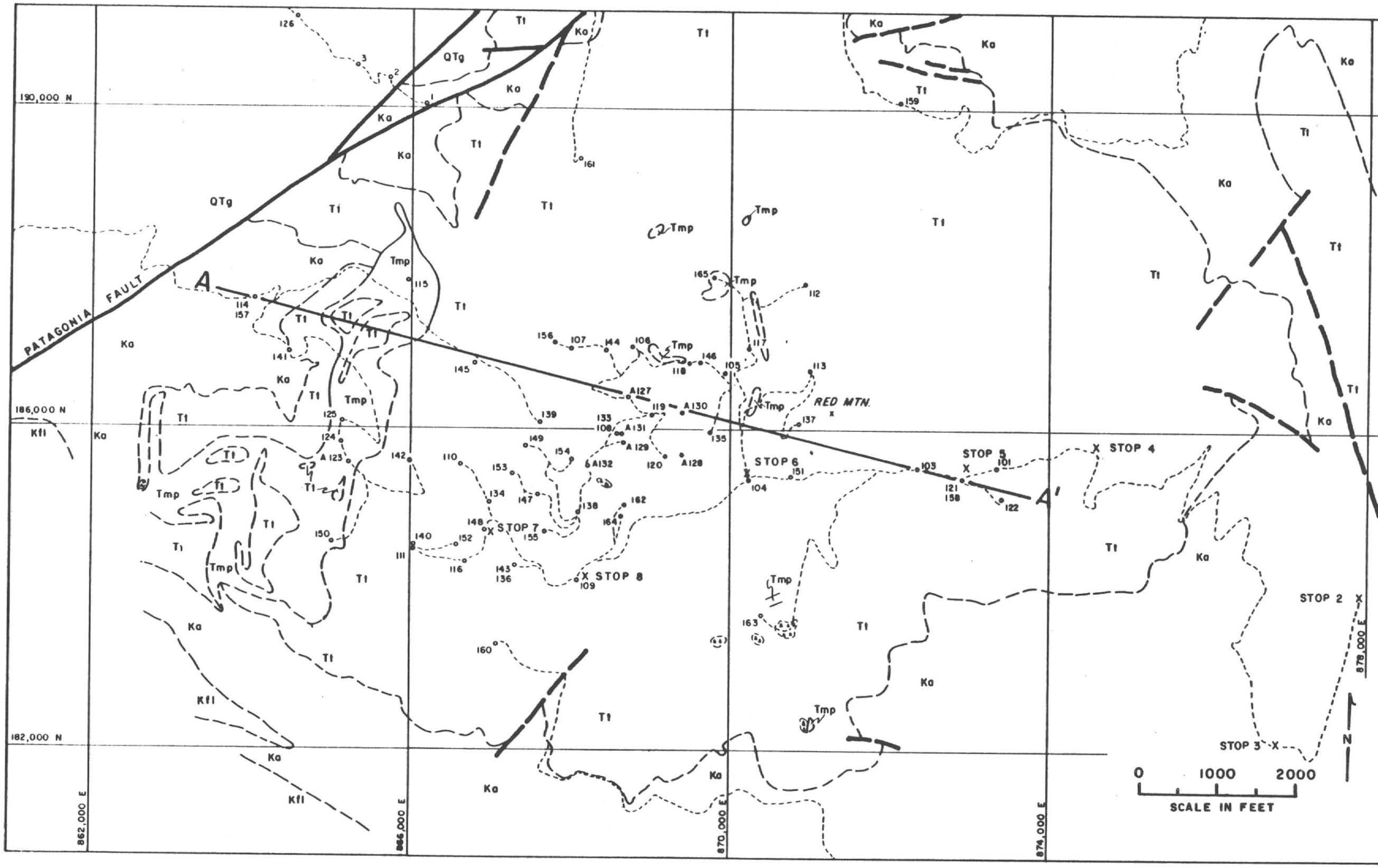


Fig. 1. Index map showing the location of the Red Mountain porphyry copper deposit. After R.M. Corn, Economic Geology, Vol. 70, No. 8, Dec. 75



EXPLANATION

QTg	GRAVELS
Tmp	PORPHYRY UNIT: porphyritic rocks – mainly quartz monzonite to granodiorite compositions
Tt	TUFF UNIT: mainly rhyolite and dacite tuffs, flows and breccia altered, may correlate with Gringo Gulch volcanics of Paleocene (?) age, Drewes (1971 A)
Ka	ANDESITE UNIT: mainly andesite and trachyandes flows, breccias, sills and dike, part of Trachyandesite or Dorelte unit of upper Cretaceous age mapped by Simons (1974)
Kfl	FELSITE-LATITE UNIT: mainly volcanic conglomerates and breccias silicified tuffs and flows, latite dikes and sills, includes interlayered andesite near top.

FAULTS
UNIT CONTACTS
ROADS
110 COLLAR LOCATION & NO. DRILL HOLE
BRECCIA

Fig. 2. Generalized surface geologic map of Red Mountain, Arizona. Modified after D.L.E. Huckins, 1975.

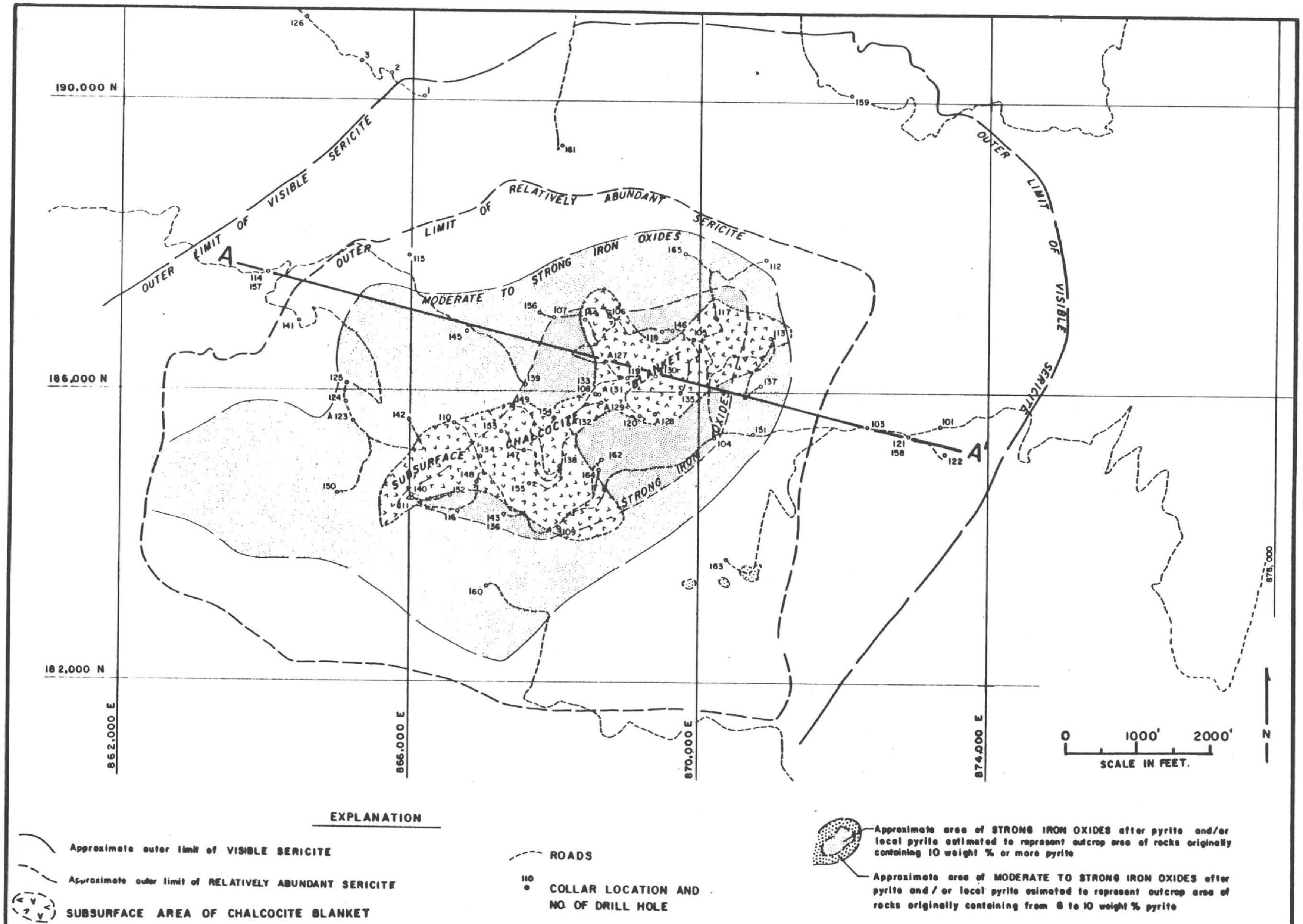


Fig. 3. Generalized surface alteration map of Red Mountain, Arizona. Modified after D.L.E. Huckins, 1975.

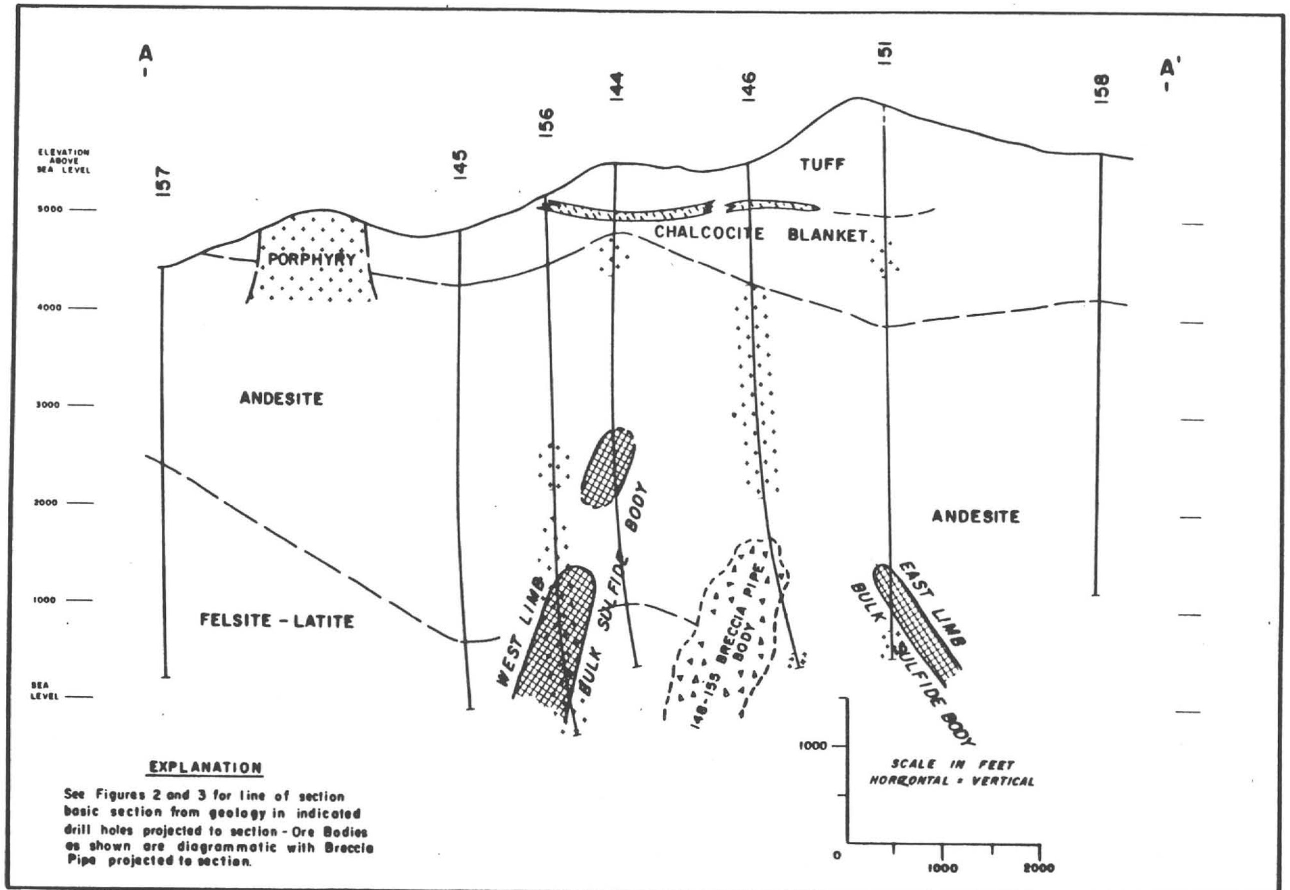


Fig. 4. cross–section A–A'. looking northeasterly, diagrammatically showing geology at Red Mountain, Arizona .

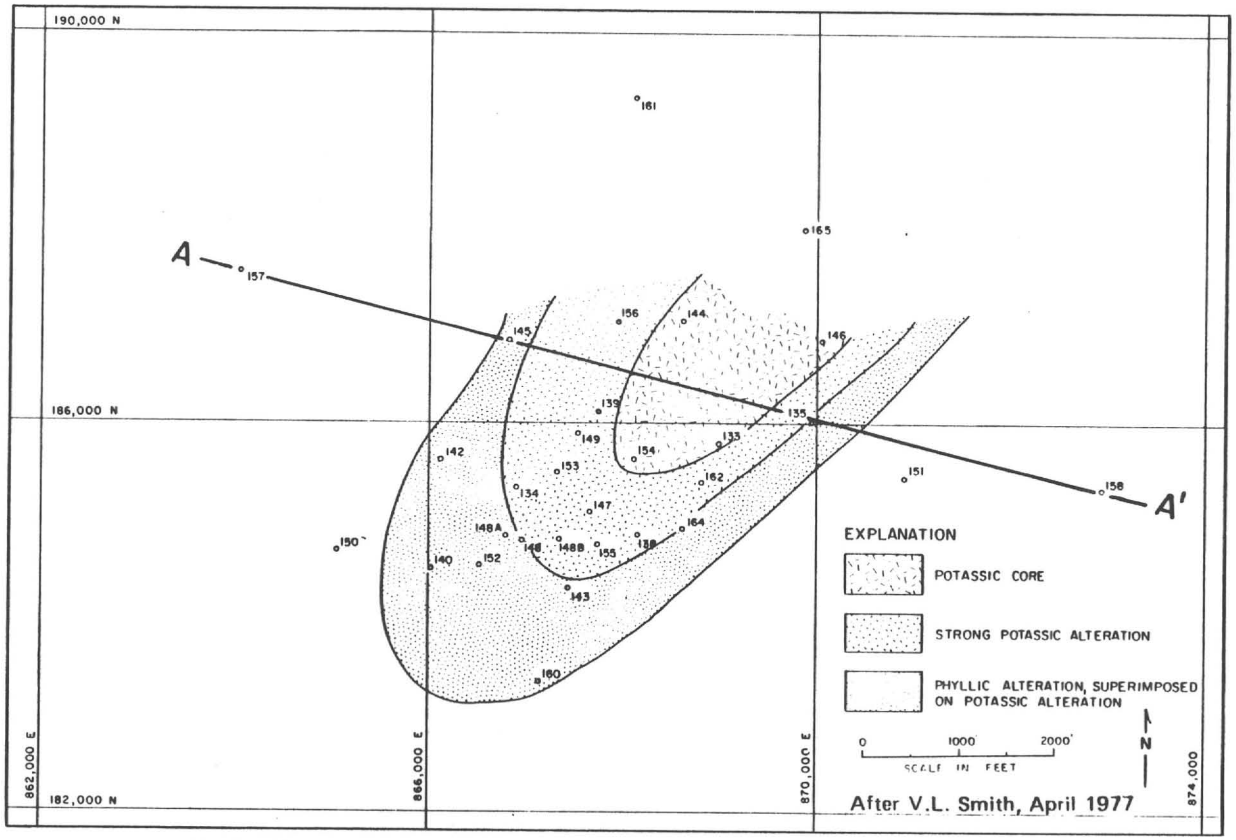


Fig. 5. Map showing silicate alteration between elevations 2,000' and 2,500' at Red Mountain, Arizona. Developed from petrographic study of thin sections from selected holes.

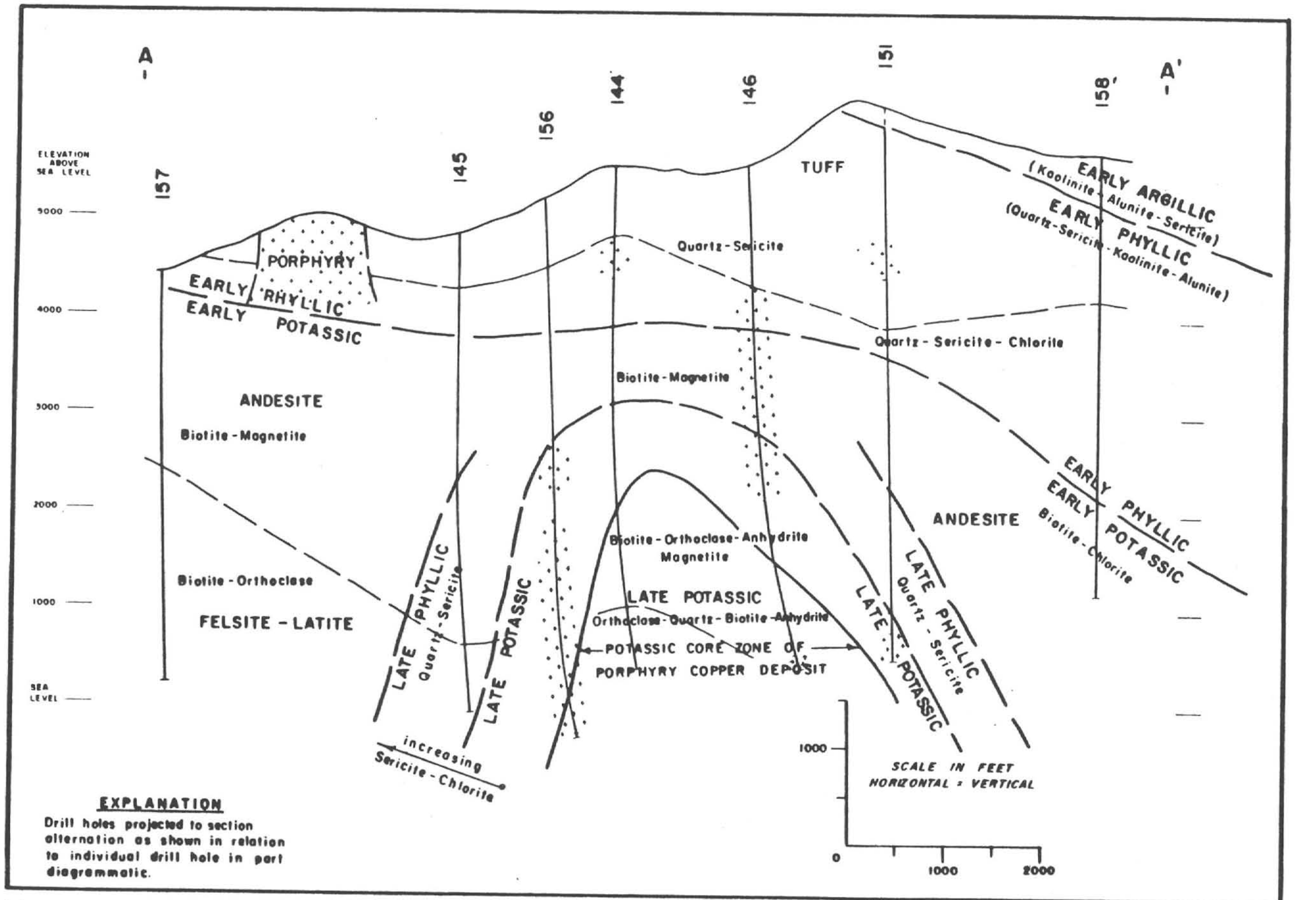


Fig. 6. Cross section A–A', looking northeasterly, diagrammatically showing silicate alteration at Red Mountain, Arizona.

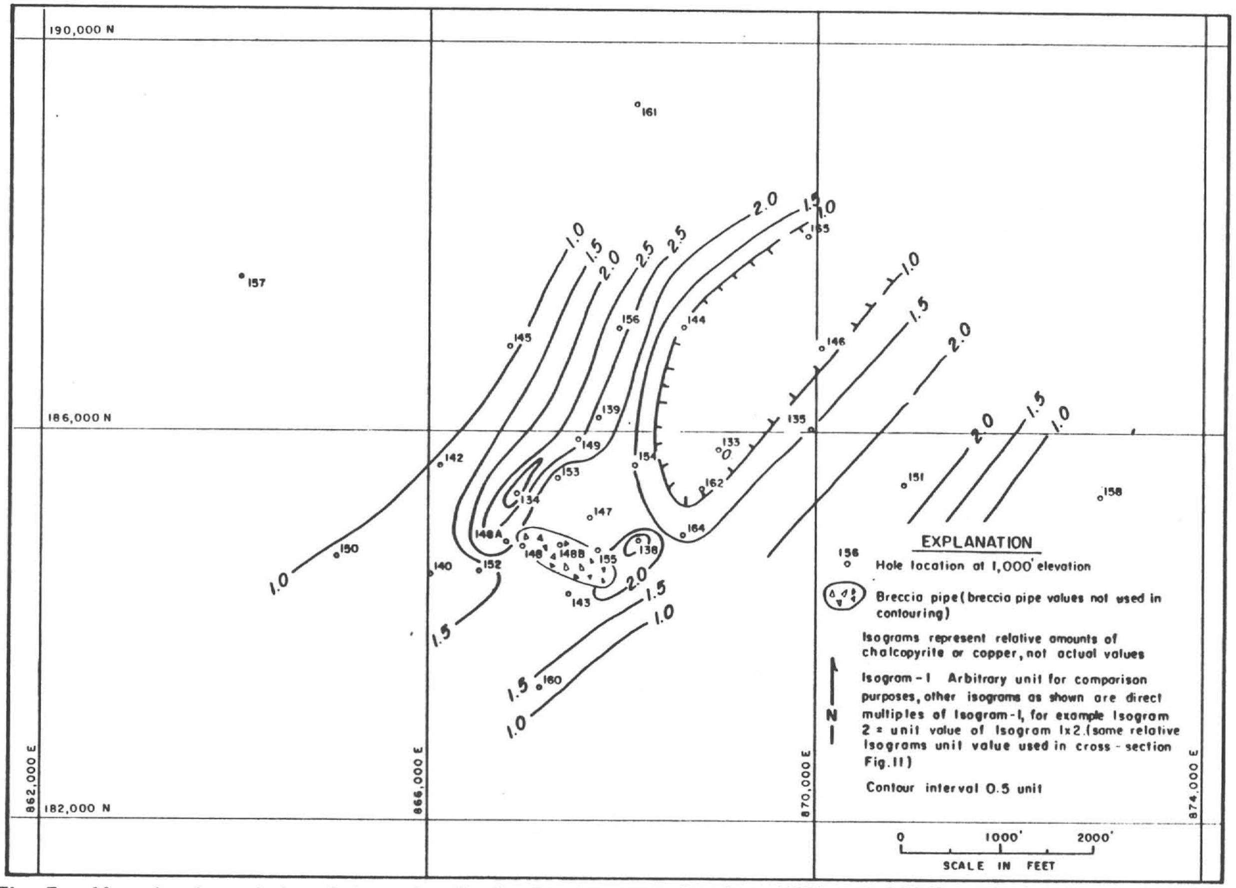


Fig. 7. Map showing relative chalcopyrite distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

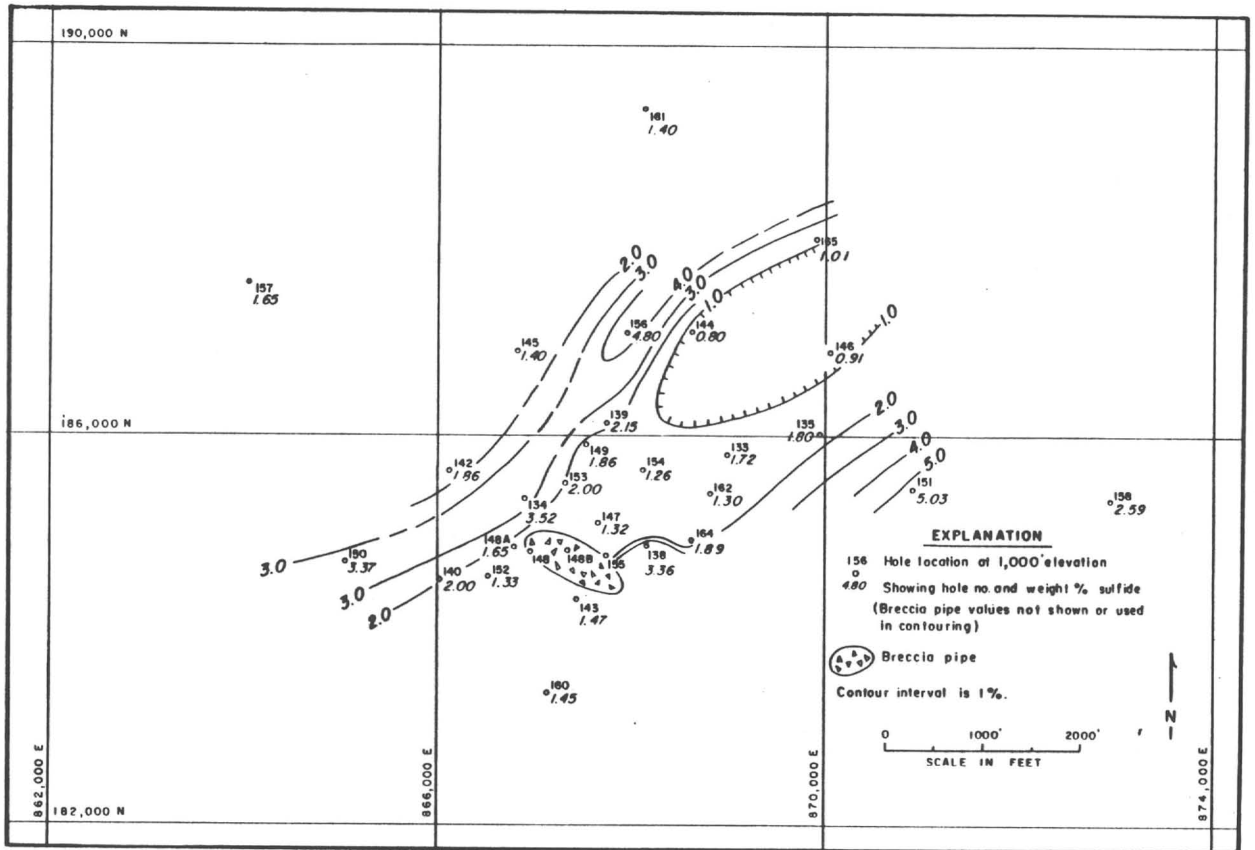


Fig. 8. Map showing total sulfide distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

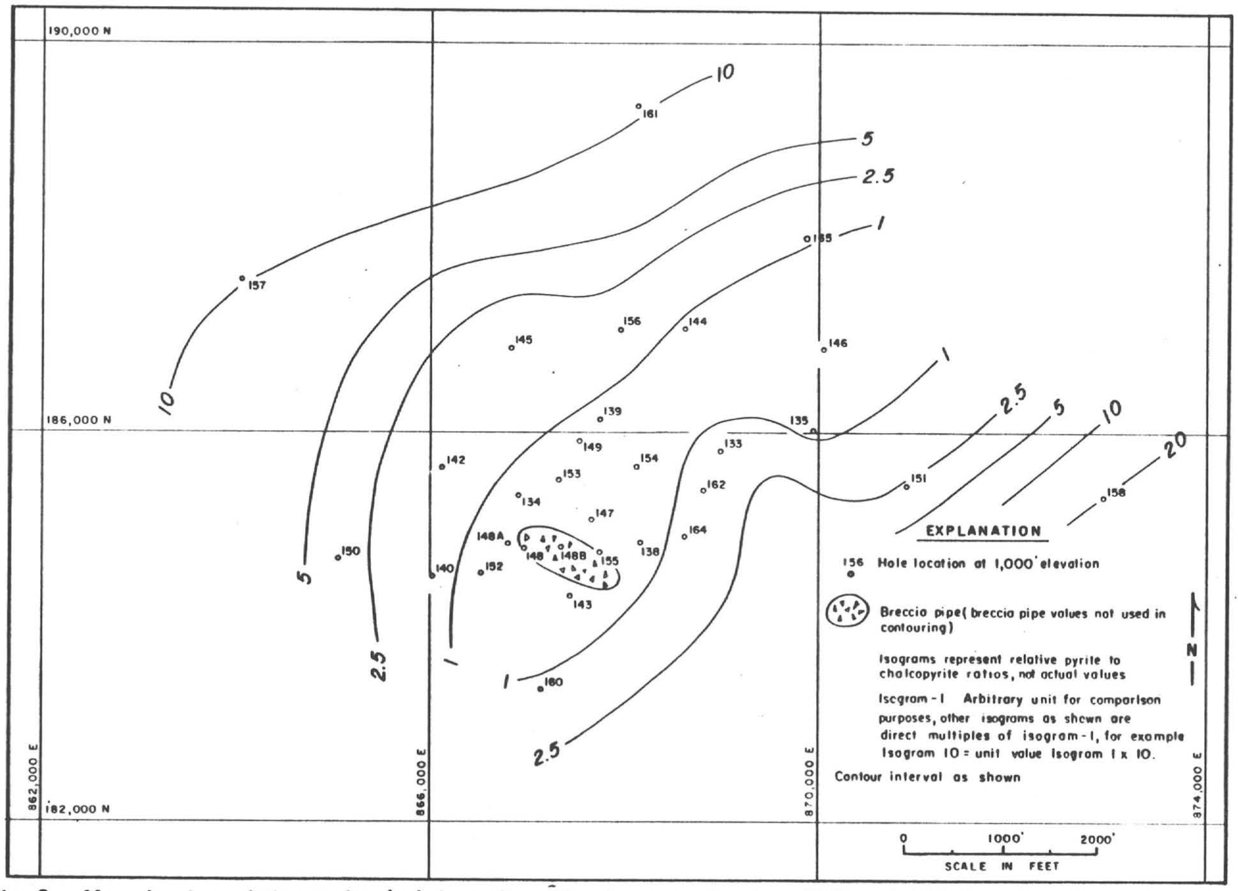


Fig. 9. Map showing relative pyrite / chalcopyrite ratios between elevations 500' and 1,500' at Red Mountain, Arizona.

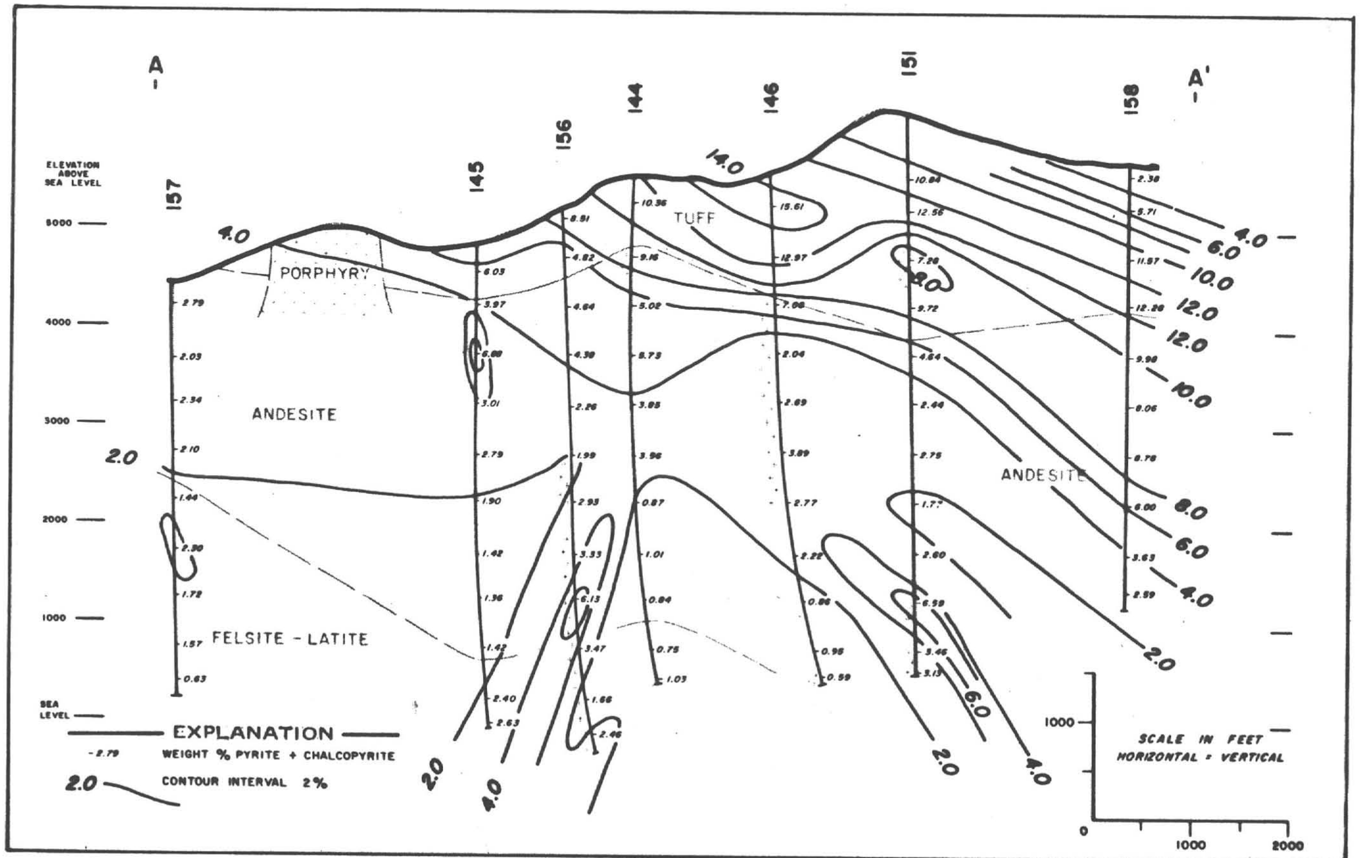


Fig. 10. Cross section A–A', looking northeasterly, showing total sulfide distribution at Red Mountain, Arizona.

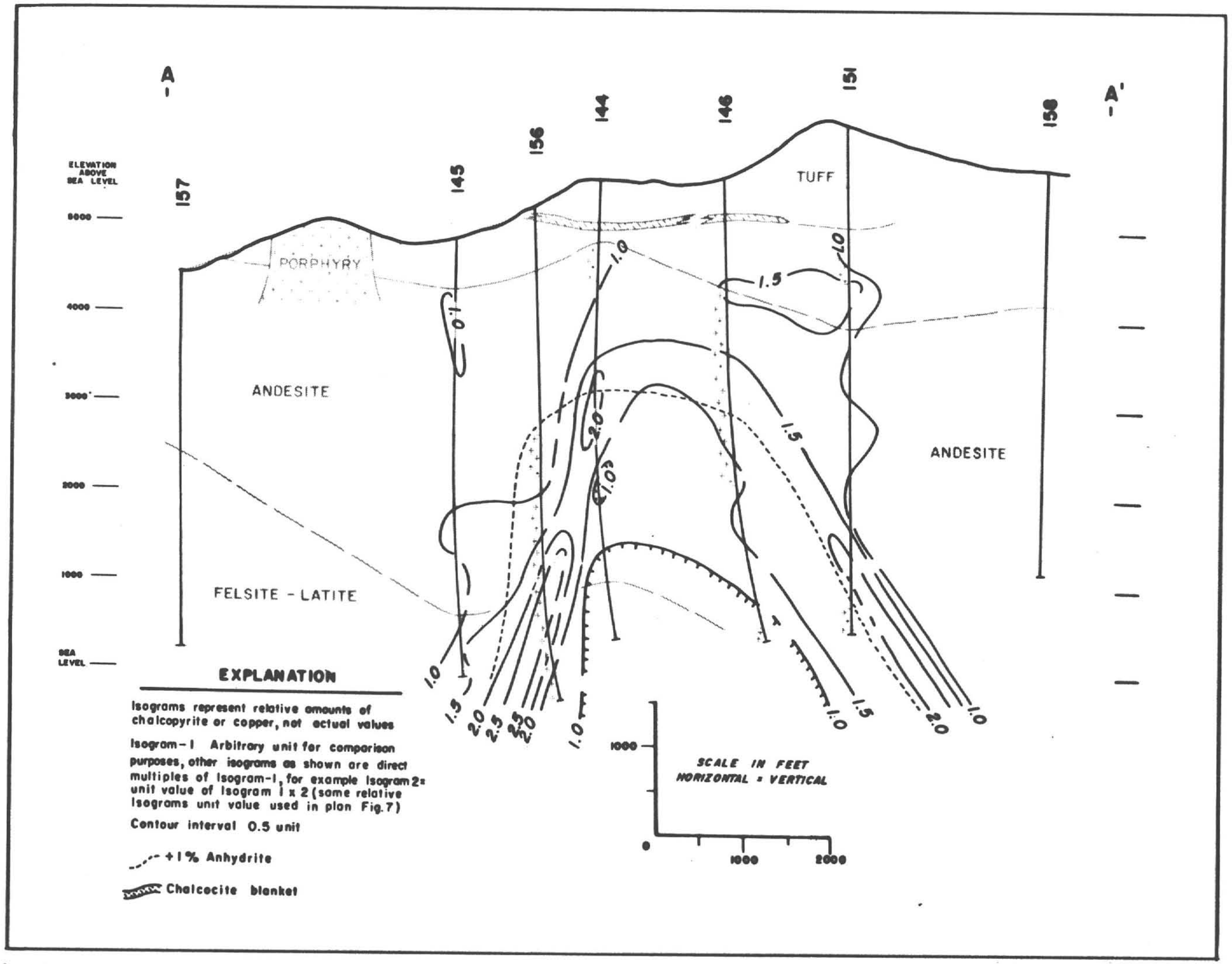


Fig. 11. Cross section A–A', looking northeasterly, showing relative chalcopyrite and anhydrite distribution at Red Mountain, Arizona.

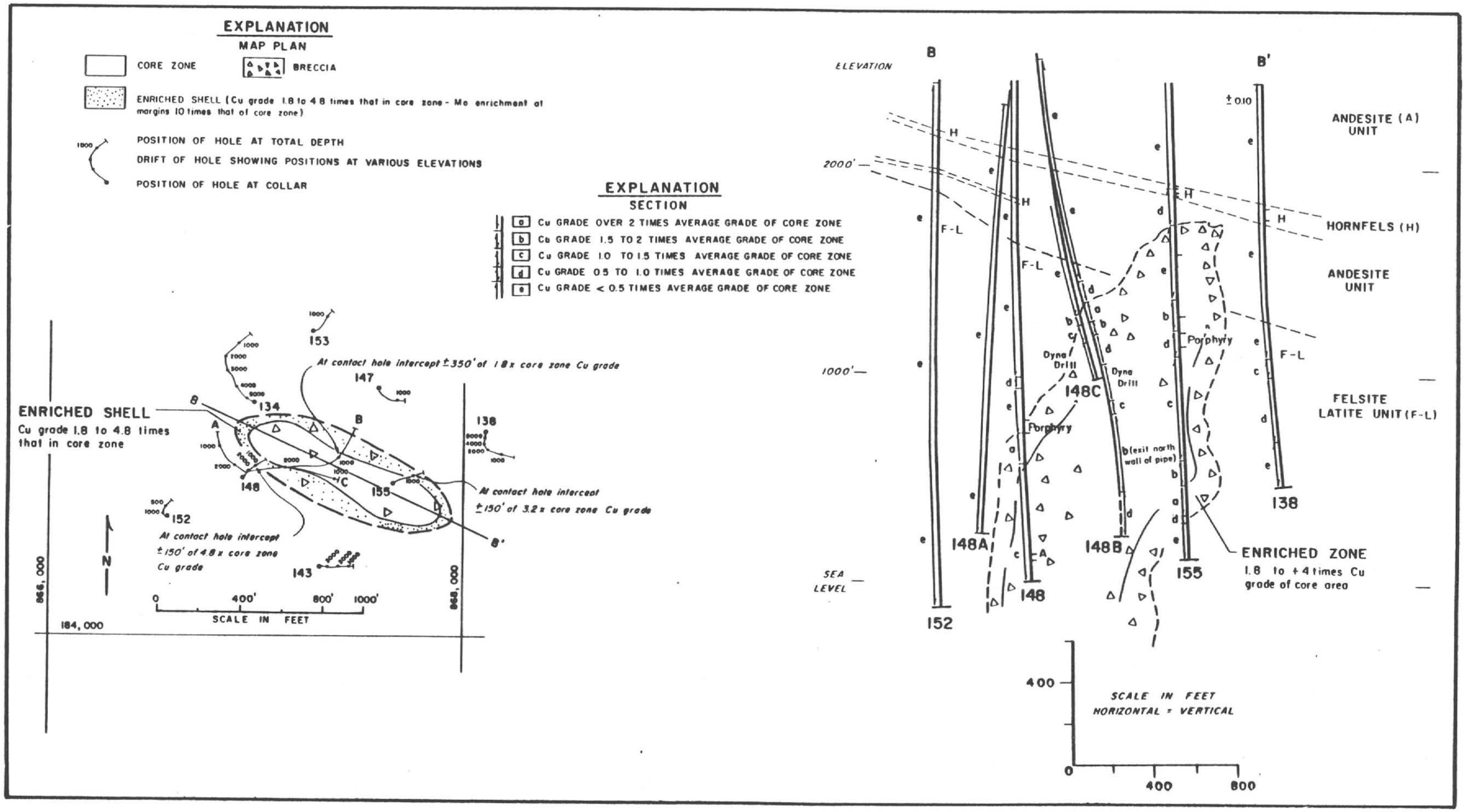


Fig. 12. Plan map and diagramatic cross section, looking northeasterly 148—155 breccia pipe at Red Mountain, Arizona.

Roland B. Mulchay
Consulting Geologist
2732 Wren Road
Salt Lake City, Utah 84117

Nov. 17, 1985

Mr. V. D. Perry
1088 Park Avenue
New York, N. Y. 10128

Dear Vin:

I have your letter of October 30th with comments on the DOSECC program, and Red Mt. and Butte in particular. It is, indeed, a sad commentary on modern geology that little attention is given to the faets in the ground, and that laboratory and generalized procedures are are recognized as the only necessary investigations.

My letter on the Red Mt. deposit was sent to Jim Quinlan after I returned to Salt Lake, and I doubt that it was circulated to any of the other participants in the conference. None of them seemed very interested in my views, and certainly Wayne Burnham actively rejected them. I do not expect to be consulted further on the Red Mt. drilling, even if it is funded by DOSECC.

I am sure that the Butte District would be a very desirable location for investigation for a deep drilling project. The wealth of information already available at Butte would demand extensive correlation before suitable sites for such drilling could be developed. Butte is a great mineral district, and it is always possible that commercial activity, based upon careful management, accurate geology and and close mining control, will disclose a series of geologic facts long before the scientists are able to do so.

Winter has arrived with a vengance, and we have had snow almost every day for the past week; I'm already tired of it, but the skiers are happy. The lifts started operating last week. Alice's collarbone has healed nicely, but a pulled muscle in my right hip has slowed me down considerably. We, also, are looking forward to some Arizona sun, and a visit with you.

Sincerely,

RBM

11/4/85

1088 Park Avenue
New York, New York 10128
October 30, 1985

Mr. R. B. Mulchay
2732 Wren Road
Salt Lake City, Utah 84117

Dear Mul:

I certainly appreciated your letter of October 22nd with its various enclosures relating to the proposed deep drilling project at Red Mt., Arizona.

The story behind those publications, cost estimates and schedules is a classic one. It tells how geologists of this generation go about a very difficult exploration problem by neglecting the old-fashioned, common sense ways of doing things and substituting so-called modern techniques like paleomagnetics, geochronology, fluid inclusion and isotope studies, geophysics and other methods that in some instances may serve useful purposes but are no substitutes for careful drill core mapping of rock types, structure, mineralogy and alteration. Laboratory investigations of significant samples are complementary to the process, but accurate field and drill core mapping provides the basic information.

I hope your letter came through loud and clear to those proposing a deep exploration test under Red Mt. Your letter outlines the only reasonable procedure for studying the problem: that is accurate core mapping and studies, and preparation of a series of plan maps and sections on which all information from the drill holes can be plotted. Such maps provide a three-dimensional view from which further drilling can be planned preparatory to a deep test.

Whether these studies will ever lead to another La Colorada type ore body is problematical. Dr. L. D. Ricketts stated the case well when he said it takes an unusual combination of features to produce a great ore deposit and such combinations are rarely duplicated in nature. However, variations may occur that can lead to other unique ore concentrations.

Again, I would like to express my long-held conviction that one of the most attractive places for future exploration is in Butte, Montana. Now that Arco has pulled out of the District, conditions may exist for a new study. Cores from Arco's deep drill holes are carefully stored and should be available for examination.

The deep drilling done by Anaconda in 1974-76 under the direction of Miller, Brimhall and others should be carefully re-examined and correlated with the wealth of information in Arco's deep holes. For example, the Colusa quartz porphyry appears to be a younger intrusive than the quartz porphyry dikes in the Belmont-Anaconda mines and has a plug-like shape. A drill hole near the porphyry contact intersected the top of a strong vein and related stringer zone with covellite mineralization nine hundred feet below the Leonard 3800 level. The drill intercept was 59.5 feet long indicating a true width of 25 to 30 feet averaging 4.69% copper. Much field evidence suggests one or more large, deep extensions to the Butte mineralization system.

Before casting your vote for a grand test of Red Mt., please give Butte consideration!

I was glad to learn that Alice's collarbone is healing and hope she will be fully recovered soon. I'll be looking forward to seeing Alice and you in Arizona in February.

My best regards to you both,

Sincerely,

Vin.

Vincent D. Perry

VDP:ec

TABLE 1: SSSDP CORING SUMMARY

CORE #	INTERVAL START (FT)	CORED END (FT)	TOTAL CORED (FT)	CORE RECOVERED (FT)	(%)	GENERAL DESCRIPTION
1	1553.0	1577.0	24.0	24.6*	100.0	Mudstone: indurated.
2	1983.0	2013.0	30.0	29.2	97.3	Conglomerate: indurated granular, minor mudstone and siltstone, with calcite veins, galena, sphalerite, and chalcopyrite.
3	2447.0	2477.0	30.0	30.0	100.0	Mudstone and siltstone: indurated, with minor sandstone, some calcite veining
4	2970.0	3030.0	60.0	59.6	99.3	Sandstone and claystone: fractured, with epidote and chlorite, and contains sulfide-bearing veins with well crystallized chalcopyrite, and traces of hematite.
5	3080.0	3087.0	7.0	7.0	100.0	Rock recovered with junk.
6	3107.0	3167.0	60.0	55.0	91.7	Sandstone: laminated, containing pyrite and calcite veins, epidote, and chlorite.
7	3470.0	3505.0	35.0	34.0	97.1	Claystone: minor calcite veins and traces of disseminated pyrite.
8	3790.0	3850.0	60.0	57.0	95.0	Mudstone: indurated, some granular conglomerate, sandstone and siltstone, scarce veining.
9	4007.0	4067.0	60.0	60.0	100.0	Mudstone: indurated, some granular conglomerate, sandstone, and siltstone, scarce veining.
10	4241.0	4301.0	60.0	60.0	100.0	Mudstone: indurated, granular conglomerate, sandstone and siltstone, anhydrite porphyroblasts, lower part contains calcite, epidote, and sulfide veinlets.
11	4301.0	4334.0	33.0	33.0	100.0	Sandstone: with calcite, epidote and sulfide-bearing veins.
12	4643.0	4676.0	33.0	33.0	100.0	Sandstone and siltstone: abundant epidote with specular hematite in veins, extensively fractured.
13	4676.0	4682.0	6.0	3.5	58.3	Sandstone and siltstone: contains much epidote, 1 cm veins of specular hematite, and large chalcopyrite crystals.
14	4718.0	4718.5	0.5	0.5	100.0	Mudstone: epidotized (rock recovered with junk).
15	5188.0	5218.0	30.0	30.0	100.0	Mudstone: black, aphanitic, indurated, with pyrite.
16	5574.0	5591.0	17.0	17.5*	100.0	Mudstone: indurated, with brecciated fractures, abundant epidote and hematite, and traces of sulfides.
17	6026.0	6044.0	18.0	18.0	100.0	Mudstone: some epidote, with quartz veins and traces of pyrite.
18	6506.0	6517.0	11.0	11.0	100.0	Claystone: grayish, with minor epidote.
19	6758.0	6771.0	13.0	8.0	61.5	Sandstone and siltstone: grayish-green.
20	6880.0	6889.0	9.0	3.5	38.9	Mudstone: indurated, laminated dark grey to light grey.
21	7100.0	7109.0	9.0	7.0	77.7	Mudstone: indurated, with minor amounts of siltstone; authigenic minerals include chlorite, hematite, and anhydrite.
22	7300.0	7313.0	13.0	11.5	88.5	Mudstone: indurated, with minor amounts of siltstone; authigenic minerals include chlorite, hematite, and anhydrite.
23	7547.0	7577.0	30.0	28.5	95.0	Mudstone: medium grey, indurated, with a single narrow bed of epidotized siltstone.
24	7704.0	7734.0	30.0	30.0	100.0	Mudstone: moderately indurated, containing anhydrite porphyroblasts.
25	8133.0	8161.0	28.0	28.0	100.0	Siltstone: dark, with minor sandstone, contains mica and epidote along fractures.
26	8395.0	8402.0	7.0	7.0	100.0	Mudstone: black, containing chalcopyrite.
27	8585.0	8604.0	19.0	12.0	63.2	Sandstone: grey, with abundant epidote along inclined bedding.
28	8800.0	8807.0	7.0	4.0	57.1	Mudstone: primarily hornfelsic, minor quartzitic sandstones with greenschist facies alteration minerals.
29	9004.0	9027.0	23.0	4.5	19.6	Mudstone: primarily hornfelsic, minor quartzitic sandstones with greenschist facies alteration minerals.
30	9095.0	9098.0	3.0	3.0	100.0	Shale: with interbedded fine grained sandstone, numerous fractures lined with epidote, chlorite, pyrite, and pyrrhotite.
31	9248.0	9253.0	5.0	3.5	70.0	Mudstone: hornfelsic, with minor quartzose sandstone exhibiting greenschist alteration.
32	9453.0	9458.0	5.0	2.3	46.0	Mafic intrusive: fairly fresh, fine-grained diabasic texture, containing minor pyrite, epidote and quartz inclusions.
33	9458.0	9473.0	15.0	5.0	33.0	Mafic intrusive: aphanitic, containing brecciated contact with hornfelsic, epidote-rich mudstone.
34	9473.0	9477.0	4.0	2.0	50.0	Mudstone: hornfelsic.
35	9694.0	9698.0	4.0	3.5	88.0	Quartzite: epidote-rich.
36	9907.0	9912.0	5.0	.8	13.0	Hornfels: fractured, black, silicified and cherty.
** TOTAL **			803.5	727.0	90.5	

* Difference reflects broken condition of core.

DOSECC
1755 Massachusetts Ave., N.W. - Suite 700
Washington, D.C. 20036
(202) 234-2100

R. B. Mulchay
2732 Wren Road
Salt Lake City, UT 84117

DOSECC

DEEP OBSERVATION AND SAMPLING OF THE EARTH'S CONTINENTAL CRUST, INC.

1755 Massachusetts Ave., N.W. - Suite 700 Washington, D.C. 20036 (202) 234-2100

DOSECC UPDATE - 3 AUGUST 1986

DOSECC 1987-1989 PROGRAM PLAN

DOSECC submitted a 3-year program plan to the National Science Foundation (NSF) in July. Guidelines from NSF indicated a probable 1987 funding level of $3,500,000, which would allow DOSECC to continue support of two ongoing projects; Cajon Pass, a proposed 16,000-ft (4900-m) drill hole to study the heat flow-stress paradox associated with the San Andreas fault in Southern California; and Project Upper Crust, a holes-of-opportunity program to collect crystalline basement samples in the central United States for analyses. DOSECC's Science Advisory Committee (SAC) recommended several other scientific drilling project proposals, including: (a) dedicated scientific drilling in the Mid-Continent U.S. under the CICSCO (Continental Interior Crustal Studies COnsortium) program; (b) scientific studies at sites proposed for ultradeep drilling (total depths greater that 20,000 ft or 6000 m); (c) continued pre-drilling studies of epithermal mineral deposit environments in the Creede Mining District, Colorado; (d) study of the active silicic magma system in the Valley of 10,000 Smokes, Katmai National Park and Preserve, Alaska; and (e) drilling, coring, and logging technology development for deep to ultradeep scientific projects. DOSECC's proposed 10-year plan includes projects identified by site and others generically referenced by geological processes to be investigated.

CAJON PASS PROJECT

The Cajon Pass Scientific Drilling Project has a primary objective of attempting to resolve the long-standing paradox concerning the level of shear stress on the San Andreas fault in southern California. Near-surface stress measurements (0 to 1 km) show an increase with depth that is consistent with stress estimates based on laboratory frictional experiments (about 90 bars/km). However, extensive conductive heat flow measurements made near the San Andreas fault show no discernible effects of frictional heating, and suggest that the upper limit for average shear stress on the fault is less than 200 bars. Thus, the near-surface stress measurements cannot be extrapolated to depths greater than 3 km without violating the heat flow constraint. The project is designed to measure both change in stress and heat flow to depths of 4 to 5 km.

The original plan for this Project was to deepen an existing 5890-ft (1795-m) at Cajon Pass to a depth of approximately 4900 m. The DOSECC Drilling and Engineering staff analysed a severe dogleg in this hole and determined that the risks in deepening the hole was too great, and drilling a new hole at the site was recommended. A solicitation for drilling bids at Cajon Pass was sent recently to about 30 drilling contractors. Drilling of the upper 1800-m of the new 4900-m hole is expected to begin by November 30.

DOSECC will award a subcontract to Stanford University (Principal Investigator Mark D. Zoback) to manage and implement scientific experiments as described in the Project Science Plan; Stanford University will, in turn, subcontract with other Project investigators. SAC welcomes proposals from other scientists for experiments to be added on to the Cajon Pass Project. The Cajon Pass Project Science Plan was described and add-on proposals were solicited at the Annual Spring Meeting of the American Geophysical Union, May 22, 1986, in Baltimore, MD (see EOS, Vol. 67, No. 16, pp. 379-380).

PROJECT UPPER CRUST/CICSCO

Project Upper Crust (Principal Investigators W.R. Van Schmus and M.E. Bickford, University of Kansas) has a fundamental scientific objective of developing a better understanding of processes involved in the formation of continental crust during middle and early Proterozoic time (1.0 to 2.5 billion years ago). The Project will continue a program initiated in 1983 of acquiring basement rock samples in the mid-continent of the United States. Three major goals of this program are (1) acquisition, curation, and distribution of samples from industry drilling activities, (2) add-on experiments to industry drill holes to collect core samples where feasible, and (3) geochronologic and geochemical analyses of samples acquired. In a recent progress report, the Principal Investigators reported obtaining drill cuttings from basement rocks in Kansas and core from South Dakota. Zircon age determinations are being conducted on samples from Kansas, Missouri, Saskatchewan (Canada), South Dakota, and Colorado.

Project Upper Crust represents an integral phase of the proposed CICSCO program. DOSECC supported a Workshop on Cratonic Processes in February 1986, organized by CICSCO to prepare a proposal for implementation of dedicated scientific drilling in the cratonic interior. Processes to be studied include growth of the craton during the early and middle Proterozoic, development of stable platform sedimentation and major cratonic basins during the Paleozoic and Mesozoic, and current transmittal of stresses by the stable continental crust, heat transfer through the crust, and/or circulation of fluids through the supracrustal rocks. CICSCO participants will identify holes of opportunity, organize research on samples from such holes, develop a program of shallow to intermediate depth (1-2 km) drill holes, and encourage proposals for dedicated deep drill holes in the continental interior.

CREEDE MINING DISTRICT

The primary objective of the Creede Mining District Project is to establish the physical connection between epithermal ores deposited along the top of a deeply-circulating hydrothermal system, and the roots of that system. The initial proposed research drilling would consist of two cored holes to depths of approximately 1 km each in the moat sediments of the Creede caldera to establish the source of salinity, metals, sulfur, and fluids in the hydrothermal system. The second stage would involve drilling a hole to a depth of 3 to 5 km to study the physical and chemical conditions in the root zone, the nature of the heat source, and heat-transfer mechanism.

The recent discovery of significant mineral concentrations in the district has provided additional data on the overall hydrothermal system. SAC recommended funding of heat flow studies in existing drill holes made available by industry, and support of aeromagnetic surveys in the district.

APPALACHIAN ULTRADEEP CORE HOLE (ADCOH) WORKSHOP

Scientific studies related to site characterization and site selection for an ultradeep (approximately 10 km) research drill hole in the southern Appalachian Mountains of South Carolina have received major support from NSF over the last two years. The ADCOH Project has a principal objective of testing the hypothesis of thin-skinned thrusting with respect to interpretation of tectonics and structure in present and ancient collisional plate boundary systems. Robert D. Hatcher, Jr., is convening a workshop on the ADCOH Project, August 17-22, 1986, at Unicoi State Park Conference Center, Helen, GA., to formulate a science plan for study of materials and processes from a proposed ultradeep drilling project. Participation will be limited to about 80 geoscientists to promote discussion among individuals who have a direct interest in long-term involvement in research for the ADCOH project. Interested persons should contact Professor Hatcher, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37916.

SALTON SEA SCIENTIFIC DRILLING PROJECT (SSSDP)

The Department of Energy's SSSDP borehole was spudded on October 23, 1985, and reached a depth of 10,564 ft (3220 m) on March 17, 1986. A program of testing was concluded and a 6-month shut-in period began on April 1, during which time the temperature profile of the well will be studied. By May 1, a temperature of 305 ± 10°C was measured at a depth of 6000 ft (1830 m) and 355 ± 10°C at 10,400 ft (3190 m). Results from the SSSDP include the following: (a) a comprehensive set of drill cuttings, normally collected at 10-ft (3-m) intervals throughout the total depth; (b) 36 core samples from depth intervals between 1550 and 9900 ft (472 and 3020 m), totaling 743 ft (226 m), and recording transitions from unconsolidated mud to epidote-rich hornfels (core descriptions summarized in Table 1); (c) short-term flow data (limited by the storage capacity of the project brine pit) and brine and gas samples from tests at 6119 ft (1865 m) and 10,475 ft (3193 m); (d) comprehensive sets of wireline geophysical logs in both open and cased portions of the hole which will become available soon for further study by qualified investigators; and (e) data from downhole experiments including measurements of differential flow rates, tests of downhole samplers, vertical seismic profiling, and downhole gravity. Based on these results, scientists involved in the SSSDP have proposed long-term flow tests and deepening the borehole to 13,000 ft (3960 m).

Scientists interested in gaining access to sample materials should submit a brief letter request by September 15, 1986, to the SSSDP Chief Scientist, Wilfred A. Elders, Institute of Geophysics and Planetary Physics, University of California, Riverside, CA 92521. The request should state the aims of the research and the methods to be used, describe the samples or data needed, and cite appropriate references or collateral studies. Except for small samples used in destructive analyses, samples will be made available for 1 year. Investigators needing samples for longer periods will be asked to submit a progress report at the end of the first year, with a request to retain the samples for a specified additional period. Requests for materials will be reviewed by the SSSDP Scientific Experiments Committee.

INTERNATIONAL SCIENTIFIC DRILLING ACTIVITIES

DOSECC met with engineers from the Kontinentales Tiefbohrprogramm der Bundesrepublik Deutschland (KTB--Federal Republic of Germany Continental Drilling Program) to discuss needed ultradeep drilling technology development. This was a continuation of a meeting with KTB personnel in Hannover, FRG, held in April 1986. The KTB program involves drilling a single scientific hole to a total depth of 14 to 15 km at a site to be selected this September. It was agreed to exchange DOSECC and KTB representatives to participate on drilling technology advisory groups.

On July 1, a 5000-m drilling project in the Siljan Ring area of central Sweden was begun, according to the Gas Research Institute, a co-sponsor of the project. A goal of the project is to test the theory of the abiogenic origin of methane. Even if methane is not found in commercial quantities within the Siljan impact crater, the project could provide important data on the origin and migration of natural gas and the interpretation of geophysical and geochemical techniques used in gas exploration.

The Coordinating Committee on Continental Drilling of the Inter-Union Commission on the Lithosphere is making plans for future symposia and discussions on scientific drilling, including: in 1987, a session at the IUGG meeting in Vancouver, Canada, and a special conference in Sweden on the Siljan Drilling Project; in 1988, a possible symposium in Russia; and in 1989, sessions and field trips during the International Geological Congress in Washington, DC.

LEGISLATION

On July 24, 1986, the Senate Subcommittee on Natural Resources Development and Production held a hearing on Senate Bill S.1026, "The Continental Scientific Drilling and Exploration Act". This bill, introduced by Senator Larry Pressler (SD), directs cooperation of the Department of Energy, U.S. Geological Survey, and National Science Foundation to develop a long-range plan for implementation of the Continental Scientific Drilling Program. Witnesses representing the three federal agencies, universities, industry, and state agencies gave testimony. At the conclusion of the hearing, Senator John W. Warner (VA), Chairman of the Subcommittee, expressed his support of S.1026 and his intent to facilitate the movement of the legislation to passage.

On April 8, 1986, Representative Claudine Schneider (RI) introduced a bill in the House of Representatives having the same wording and intent as S.1026. This bill, H.R.4523, has been referred to two House Committees; Interior and Insular Affairs, and Science and Technology.

SAMPLE HANDLING AND CURATION

In 1985, the DOSECC Board of Directors accepted an offer from the USGS to provide sample handling and curation service at drill sites and at the USGS Core Library, Denver, CO. With the assistance of geoscientists and archivists from universities, industry, and government agencies, DOSECC prepared a document entitled DOSECC Sample Handling and Curation Protocol, setting forth guidelines for a formal agreement between the USGS and DOSECC (which became effective June 12, 1986) and for assisting scientists in the preparation of research drilling proposals to DOSECC. Basic concepts for handling and curation of research drilling samples data include the following:

- Drilling samples will undergo a suite of standard analyses on site.
- A representative sample and suite of descriptive data from each drilling project will be permanently archived for future access at the USGS Core Library, Denver, CO.
- A timely and complete record of observations, measurements, and techniques employed will be included in each project's data base.
- Samples and data are owned by DOSECC and represent a national resource.

This Protocol is the second guideline prepared by and available from DOSECC. Proposal Submission Procedures gives information to investigators on DOSECC's policies concerning submission and review of scientific drilling proposals, including information on the proposed drilling plan and estimated downhole environment that is required by DOSECC to determine the feasibility of drilling and prepare an estimate of the drilling costs.

DOSECC (Deep Observation and Sampling of the Earth's Continental Crust, Inc.) is a private, not-for-profit corporation founded in 1984 by a consortium of universities to design and manage a national Continental Scientific Drilling Program for the National Science Foundation, acting in cooperation with the U.S. Geological Survey and the Department of Energy. DOSECC UPDATE is designed to communicate information about activities and plans of DOSECC and other U.S. organizations involved in scientific research drilling, upcoming drilling-related meetings, descriptions of interesting holes that may provide opportunities for add-on scientific experiments, and information on continental scientific drilling programs in other countries. Readers are invited to submit items for possible inclusion in this newsletter.

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CORPORATE OFFICE

1755 Massachusetts Ave., N.W., Washington, DC 20036
Telephone (202) 234-2100
G.Arthur Barber, President

DRILLING AND ENGINEERING FIELD OFFICE

13111 E. Briarwood Ave., Suite 140, Englewood, CO 80112
Telephone (303) 799-6100
Albert S. Johnson, Manager

SCIENCE ADVISORY COMMITTEE (SAC)

601 Elm Street, Room 438C, Norman, OK 73019
Telephone (405) 325-6111
Francis G. Stehli, Chairman

KERR-McGEE CORPORATION
KERR-McGEE CENTER • OKLAHOMA CITY, OKLAHOMA 73125

August 22, 1985

Members of The Red Mountain Arizona
Ad Hoc Task Group of PMR of CSDC
and Panel of Scientists

Gentlemen:

Here is the draft of the report covering the Preliminary Scientific Investigation for the Continental Scientific Drilling Program at Red Mountain Arizona. I have promised Frank Stehli to have 17 copies of the report to him on September 5.

To meet this deadline I need your help. I would greatly appreciate it if you could review, edit and return the sections needing corrections within two days of receipt. Simple changes probably can best be handled with a phone call to me (405/270-3975). More elaborate ones should be returned by Federal Express mail. In any event, suggested additions or revisions should be on my desk no later than 8:00 a.m. on Tuesday, September 3.

Authors, hopefully I have not changed individual sections beyond recognition, and have succeeded in integrating the parts into an organized presentation. More importantly, I trust that with your editing and suggestions the report will do the job.

Thanks for your interest and most of all your cooperation.

James J. Quinlan

JJQ:bw

Enclosure

PRELIMINARY SCIENTIFIC INVESTIGATIONS FOR LOCATIONS OF DEEP DRILL HOLES

CONTINENTAL SCIENTIFIC DRILLING PROGRAM

RED MOUNTAIN, ARIZONA

by

R. J. Bodnar, G. Brimhall, C.W. Burnham, R.F. Butler,
J.D. Corbett, M.A. Chaffee, P.E. Damon, G.H. Davis, K. Furlong
C. Meyer, H. Ohmoto, J.J. Quinlan, S. R. Titley

September, 1985

DRAFT
(Revised August 22, 1985)

TABLE OF CONTENTS

INTRODUCTION

The porphyry copper deposit at Red Mountain, Arizona was selected by the Panel on Mineral Resource (PMR) of the Continental Scientific Drilling Committee (CSDC) as the drilling target most likely to reveal scientific information about deep crustal processes attending emplacement of porphyry copper deposits. It was recognized by PMR that the unmined deposit at Red Mountain has received less scientific attention than many better known and productive porphyry copper deposits. This deficiency, however, could be remedied by a detailed science investigation prior to siting of deep drill holes to study the deep portions of the system.

PMR approached the Kerr-McGee Corporation, owner of the deposit, regarding the availability of the property to the CSDC. Kerr-McGee agreed to make the property available for study and as a possible drill site. The Company has made available split core, assay pulps and basic geologic and assay data resulting from its investigation of the deposit which includes completion of 72 drill holes totaling 55 Km (185,000 feet) of drilling. Twenty-five of the drill holes are deeper than 1.5 Km (5,000 feet), the deepest being 1.75 Km (5,790 feet).

An Ad Hoc Task Group for Red Mountain appointed by PMR reviewed and inspected the materials made available by Kerr-McGee on July 24, 1985. This review confirmed PMR initial interest and the attractiveness of the proposed deep drilling target. A program to accomplish the initial scientific investigation and drill hole siting at Red Mountain was outlined. Principal investigators to accomplish the proposed program were identified. This report discusses the proposed Red Mountain project and contains proposals and cost estimates prepared by the principal investigators to target properly and site deep drilling at the mountain.

RECOMMENDATIONS

The Panel on Red Mountain, charged by PMR of CSDC to evaluate and undertake scientific studies at Red Mountain, recommend that deep drilling to test the deep portions of the porphyry copper system at Red Mountain be given a high priority by the CSDC and DOSECC.

The group also recognizes a need to refine and enlarge the geological, geochemical and geophysical base at Red Mountain in preparation for locating the proposed deep drill holes. The following program to accomplish this objective is recommended:

1. Regional Studies including Paleomagnetic Studies.
   Principal Investigators: G.H. Davis, University of Arizona (Regional Studies); R.F. Butler, University of Arizona (Paleomagnetic Studies)

   Time: 2 years — Cost: $34,000

2. Surface Mapping and Drill Core Fracture Studies.
   Principal Investigator: S. R. Titley, University of Arizona

   Time: 2 years — Cost: $53,500

3. Geochronology Studies (25 dates)
   Principal Investigator: P.E. Damon, University of Arizona

   Time: 1 year — Cost: $12,500

4. Petrography, Petrology and Mineral Chemistry
   Principal Investigator: G. Brimhall, University of California, Berkeley

   Time: 2 years — Cost: $120,000

5. Fluid Inclusion Studies
   Principal Investigator: R. J. Bodnar, Virginia Polytechnic Institute

   Time: 2 Years — Cost: $57,000

6. Isotope Studies
   Principal Investigator: H. Ohmoto, Pennsylvania State University

   Time: 2 years Cost: $238,000

7. Thermal Modeling
   Principal Investigator: K. Furlong, Pennsylvania State University

   Time: 2 years Cost: $57,000

8. Applied Geochemistry
   Principal Investigator: M. A. Chaffee, USGS

   Time: 2 years Cost: $100,000

9. Geophysics and Remote Sensing
   Principal Investigator: J.D. Corbett, University of Utah Research Institute

   Time: 2 years Cost: $110,000

10. Management, Synthesis and Deep Hole Siting

    Principal Investigator: J.J. Quinlan, Kerr-McGee Corporation

    Time: 2 years Cost: $ 50,000

Total Cost $832,000

LOCATION AND PROPERTY STATUS

The Red Mountain property is located in the Harshaw Mining District, Santa Cruz County, Arizona, Figure 1. The property lies at the north end of the Patagonia Mountains, two miles south of Patagonia, Arizona and 18 miles northeast of the border town of Nogales, Arizona.

The Kerr-McGee property consists of 36 patented and 524 unpatented lode mining claims. These claims cover an area of 14 square miles and center on Red Mountain, Figure 2. The peak at Red Mountain is at an altitude of 1,942 meters (6,371 feet) and lies in Section 20, T.22S., R.16E.

Other claim and land owners in the area include Asarco, Inc., and Commonwealth International. Representatives from these companies; i.e., Fred Graybill and Fleetwood Koutz of Asarco; and Paul Eimon, Commonwealth International are members of, or observers of, the Ad Hoc Task Group for Red Mountain.

The Kerr-McGee property and others lie within an area managed by the U.S. Forest Service, pursuant to Forest Service Regulation 36 CFR. The regulation is reasonable and no problems have been encountered, nor are any anticipated in conducting scientific investigations or drilling operations at Red Mountain.

ENVIRONMENTAL CONSIDERATION

Scientific research or deep drilling at Red Moutnain should present no unusual or significant environmental problems.

Mining in the area predates the Spanish conquest of Mexico in the sixteenth century (Schrader, 1915). Asarco operated the Trench mine as recently as 1960. Kerr-McGee has carried on drilling operations since 1961.

GEOLOGY

The geology and base metal occurrences at Red Mountain have been intermittently studied since 1915 (Schrader, 1915; Drewes, 1971a,b, 1972a,b; Simons, 1971, 1974). More recent efforts have focused on data provided by the Kerr-McGee drilling program (Corn, 1975; Bodnar and Beane, 1980; Quinlan, 1981). Surface geochemical sampling by the U.S. Geological Survey surrounding Red Mountain was summarized by Chaffee et al. (1981). Copies of these papers are attached as Exhibit A.

The Red Mountain deposit is part of the greater mineralized Patagonia district and a part of southwestern North America porphyry copper province. Its lateral and genetic position relative to nearby vein deposits can be studied.

The geological setting of Red Mountain includes an altered complex of flat-lying volcanic and intrusive rocks of Cretaceous and early Tertiary age. Three layered volcanic units are present. These include an upper rhyolite and dacite tuff unit of 730-m (2,400 ft.) maximum thickness, a middle andesite 900 m (3,000 ft.) thick, and a basal felsite-latite unit. Porphyritic rocks ranging in composition from granodiorite to quartz monzonite cut the layered volcanic rocks.

Silicate alteration, described in detail by Quinlan (1981) and Corn (1975), varies with rock types and depth. Alteration assemblages (i.e., argillic, phyllic, and potassic) typical of porphyry copper deposits (Lowell and Guilbert, 1970; Rose, 1970) are present. The alteration zoning pattern can be explained by a deep ore-stage alteration system superimposed on an earlier, larger, and essentially copper-barren alteration system. Argillic and phyllic alteration at the surface are parts of the large, early stage system. Strong potassic and phyllic alteration at depth are parts of the deep-level porphyry copper emplacement.

Sulfide mineral zoning appears to be related to the deep-level porphyry copper stage alteration. Lead and zinc generally occur in the upper portions of the deposit, and small amounts of molybdenum are present throughout. Chalcopyrite is the predominant copper mineral. Enargite occurs in the upper levels, and minor amounts of bornite are present at depth. Chalcocite occurs as a secondary mineral in the upper parts of the deposit.

Breccia pipes crop out at the surface and a "blind" pipe is recognized in several deep drill holes. This deep level breccia pipe is within the potassic core of the deposit and may be the deepest copper-molybdenum breccia pipe known in the world. Strong quartz-sericite-pyrite alteration is recognized at the top of this pipe, and to a lesser extent at its margins. This phyllic type alteration in the pipe clearly cuts strong biotite-magnetite-orthoclase alteration in the core area of the deposit. A zone of copper, molybdenum, and silver enrichment is situated near the margins of the pipe. This pipe presents a unique environment permitting insight into vertically zoned mineral deposits in relation to other major elements of such deposits. It also provides an opportunity to compare high-level and deep-level breccia pipes in a porphyry copper environment. Understanding of the structural evolution of this district could aid in the interpretation of other mineral deposits that represent single phases of the multi-staged process at Red Mountain.

RESEARCH OBJECTIVES

The Red Mountain district represents an unusual opportunity for increasing the scientific understanding of important criteria in hydrothermal mineral genesis, geochemistry, geophysics and paleohydrology.

The district presents a number of unique features that are scientifically attractive. The deposit does not appear to have been tilted, and neither has it been extensively faulted or deeply eroded. However, more work is needed to verify these conditions. It appears to be of moderate size so its root system is likely to be within reach of present drill technology. Classic mineralogical and geochemical zoning can be studied at the well-exposed present surface and by means of the drill core resulting from 55 Km of drilling by the Kerr-McGee Corporation, including hole penetration as deep as 1.75 Km (5,790 feet). The deposit is unmined; because of this, sampling and scientific study of a nearly complete vertical system is possible.

The combination of these and other desirable features were judged by the PMR of CSDC to make the Red Mountain deposit a unique opportunity to study the movement and chemical evolution of aqueous fluids in the deep continental crust as they interacted with a large localized source of heat and chemical components related to subvolcanic processes.

PROPOSED PROGRAM

Based on present information, the Ad Hoc Task Group and panel of geo-scientists for Red Mountain is considering two proposed deep drill holes. One hole should be located specifically to test the breccia pipe and its downward extension, and a second hole to test below the known sulfide body at 2.4 to 3.0 Km. Both holes may be drilled to a depth as great as 5 Km to explore the bottom of the potassic alteration zone. These holes should penetrate the lower limit of fluid circulation and provide data on fluid transport, paleopermeability and temperatures. They should provide data regarding existing hypotheses on metal source and mobilization as well as alteration in the roots of the system. Preliminary estimates indicate that each hole would take about a year to drill and each would cost $3 million. An additional $2 million to $3.0 million would be needed to complete scientific studies and add-on experiments in the proposed holes.

The Ad Hoc Task Group and the panel of geo-scientists for Red Mountain recognize a need to refine and enlarge on the geologic, geochemical and geophysical base at Red Mountain in order to site properly the proposed deep drill holes. A program of geological, geochemical and geophysical research is proposed to accomplish this objective. This preliminary scientific investigation as designed should also provide much new data on porphyry copper deposits in general and a better understanding of the processes of formation. Whereas the overall program as outlined in the section on Recommendations represents a consensus of the Ad Hoc Task Group and panel of geo-scientists for Red Mountain, details and costs for individual parts of the program have been prepared by the principal investigator responsible for that area.

Regional Studies including Paleomagnetic Studies

Principal Investigators: G.H. Davis, University of Arizona (Regional)
R.F. Butler, University of Arizona (Paleomagnetic)

Time: 2 years Cost: $34,000

The Red Mountain mineralized system is located within a part of Arizona where Laramide, mid-Tertiary, and younger Tertiary tilting and low-angle displacement have been reported (Davis, 1979, 1981; Dickinson, 1984). Although tilting and lateral transport at Red Mountain have not been recorded, except for studies of Pliocene tectonics and stratigraphy in the Sonoita Creek Basin (Mengtes, 1981), neither is there record that such a possiblity has been reviewed or studied. Save for strike dip plots shown in the volcanic rocks of Red Mountain (Huckins, 1976) there is little to assess the possible present attitude of the Red Mountain hydrothermal system. An investigation focused on this problem is of paramount importance. The siting of a drill hole based upon surface data with a purpose of testing a deep target (e.g. 4.6 Km or 15,000 feet) will be strongly influenced by correct projections of that target; a 6° inclination of the system will result in a 460 m (1,500 feet) lateral displacement at a 4.6 Km depth - a 15° inclination will result in 1200 m (3,950 feet) of lateral displacement from the vertical.

Regional mapping and structural analysis of Mesozoic, Laramide, and younger Tertiary rocks are therefore a prerequisite to drilling. From such studies, which must be integrated with a thorough sampling of rocks for radiometric age-dating (See Geochronology section) and with a paleomagnetic study as a supplement, the faulting and tilting history of the system may be assessed. A sound basis of peripheral mapping and structural interpretation exists from which to build and extend. Further, paleomagnetic studies (Barnes and Butler, 1980; Kluth et al, 1982; Calderone and Butler, 1984) provide a working basis for additional studies in the Red Mountain system.

Surface Mapping and Drill Core Fracture Studies

Principal Investigator: S.R. Titley, University of Arizona

Time: 2 years Cost: $53,500

Distribution of flow in hydrothermal systems such as Red Mountain is chiefly controlled by an extensive interlocking network of fractures, evolved as a direct consequence of emplacement and cooling of igneous magmas. Thus the distribution of fractures is a guide to limits of fluid flow. The evolution and distribution of fractures has been detailed for a few hydrothermal porphyry-centered systems (e.g. Silver Bell: Kanbergs, 1980; Norris, 1981; Sierrita: Haynes and Titley, 1978; Titley et al., 1985, In Press) and initial surface studies have been carried out over Red Mountain (Kistner, 1984).

A principal and necessary objective of the interim science project at Red Mountain is to extend the surface study of fracture distribution and abundance to the limits of fracture occurrence, and to integrate the surface information with abundance and distribution data from drill core. Such a study is a fundamental requirement for the more basic purpose of the drilling project. Information developed provides the only basis for determining the locus of most intense flow and the patterns of peripheral flow in any genetic interpretations advanced and provides an important basis for siting the drilling to be done. Further, as the study of the sequence of fractures is diagnostic of the evolution of alteration, the results will provide the only basis for understanding the chemical-thermal evolution of the system (Titley and Beane, 1980; Preece and Beane, 1982).

Fracture density data will be collected at the surface by techniques described elsewhere (Haynes and Title, 1980; Titley et all., 1985, in press) and integrated with paragenetic studies and fluid inclusion data. Drill core fracture data will be collected by a fracture area/core volume technique in drill core and will be supplemented by petrographic studies of alteration mineralogy and fluid inclusions.

Geochronology

Principal Investigator: P.E. Damon, University of Arizona

Time: 2 years Cost: $12,500

The stratigraphic succession at Red Mountain is relatively well-established. However, the chronology of rocks and events is unknown except for scattered dates on region-wide units and a few plutonic rocks. A K-Ar or Rb-Sr chronology is required for volcanic and intrusive rocks as well as for mineralization-alteration events to verify the age, succession, and duration of thermal and geological events in this system. Such a study is especially critical to the regional tectonic analysis as it is important to verify whether or not tilting of the volcanic strata that hosts the Red Mountain ores is pre- or post-mineral event.

A minimum of twenty-five dates are projected as required to date the pre-, inter- and post-ore rocks and to date the hydrothermal event(s) as measurable in the alteration assemblages.

Petrography, Petrology, and Mineral Chemistry

Principal Investigator: G. Brimhall, University of California, Berkeley

Time: 2 years   Cost: $120,000

Objectives of the petrologic study will be to define better the deep drilling target and the petrographic and compositional criteria for clearly recognizing the parent intrusive to be penetrated during the deep drilling phase of the Red Mountain program. Identification of this source of heat, magmatic fluids, and metals is the most critical part remaining in completing the description and analysis of this magmatic-hydrothermal system. Compositions of hydrothermal and igneous biotite from core samples expressed in terms of OH, F, Cl, Mg, Fe, Ti, Al, Si, Mn, K, and Na mole fractions in specific crystallographic sites will provide a sound basis for comparison of biotite in the breccia and in potassic alteration zones of the volcanics with drilling samples of intrusives encountered at depth during the deep drilling phase. Such results can be interpreted in terms of magmatic fluid composition and temperature at the point of release of these aqueous fluids from the magma body. This mineral chemistry will be used to define the thermal and chemical evolution of magmatic fluids from purely igneous to hydrothermal processes during breccia formation, hydrofracturing, and alteration-mineralization. During the deep drilling phase, wall rocks can be analyzed using mass balance principles to assess the relative contributions of magmatic input of metals in relation to leaching them from adjacent protores.

It is proposed here to use a combination of mapping (core logging) and mineral chemistry to define the locus of early-stage mineral assemblages, and to deduce fluid composition and the temperature field during the initial stages of fluid circulation. The composition of biotite is ideally suited for this purpose as its composition and petrographic relationships clearly reflect the thermal and chemical environments of formation, including transition from magmatic to hydrothermal conditions. Biotite crystallizes both during magmatic crystallization as well as during high-temperature hydrothermal processes, making its composition an ideal monitoring device over this range in physical and chemical processes, including breccia formation and fluid-rock interaction during alteration.

Fluid Inclusion Studies

Principal Investigator: R.J. Bodnar, Virginia Polytechnic Institute

Time: 2 years Cost: $57,000

The purpose of the fluid inclusion study at Red Mountain is to provide a solid data base on the thermal and chemical characteristics of hydrothermal fluids in the system in time and space. This data will be combined with other available data to generate a predictive model for fluid evolution in a magmatic-hydrothermal environment. The final product would be a set of criteria based on fluid inclusion characteristics that could be used to predict where one is in a particular hydrothermal system and, more importantly, the direction and distance to the center of activity.

The proposed study includes detail petrographic work to determine the temporal and spatial distribution of fluid inclusion types in the hydrothermal system, and correlation of various inclusion types with specific episodes of alteration and mineralization. During this stage of the investigation, the limits of immiscibility (boiling) in time and space and relationships between boiling and mineralization would be defined. Outlining the boiling zones may provide a relatively simple means of distinguishing the epithermal from the deeper magmatic environment.

The petrographic phase of the study would be followed by microthermometric analyses of fluid inclusions to determine the temperatures and bulk salinities of the fluids and, more importantly, how these properties vary in time and space within the hydrothermal system. Raman microprobe analyses of these same inclusions would be conducted to determine the types and amounts of volatile components in the fluids. Considerable emphasis will be placed on the volatile analyses because the gas content of inclusion could prove to be the best indication of where one is in the system and probably is one of the major controls in metal transport and deposition.

Isotope Studies

Principal Investigator: H. Ohmoto, Pennsylvania State University

Time: 2 Years Cost: $238,000

Three major mutually related problems on the genesis of porphyry copper deposits are: (1) the sources of various components of the ore-forming fluids, especially H_2O, metals and sulfur; (2) the hydrology of the ore-forming systems; and (3) the mechanisms of sulfide and sulfate deposition.

Oxygen and hydrogen isotope studies of minerals and fluid inclusions in porphyry copper deposits (e.g., Taylor, 1979) have revealed that two types of waters, magmatic and meteoric waters, were involved in the formation of most porphyry copper deposits. The sulfur isotopic data at hand also suggest that a significant proportion of sulfur in most porphyry copper deposits is magmatic in origin (e.g. Ohmoto and Rye, 1979).

Some of the major unresolved questions concern: the changes with respect to time and space in the relative importance of magmatic and meteoric waters; their effect on the mineralogical and elemental characteristics of porphyry copper deposits; and the exact nature of physical and chemical interaction between magmatic fluids and meteoric water. Specific questions include the following: Did the sulfide and sulfate minerals precipitate from magmatic fluids, and only locally redistributed by circulating meteoric water? Or, was a significant proportion of metals and sulfur derived from the surrounding country rocks by circulating meteoric water or magmatic water? How did the geometries of the two fluid systems (magmatic and meteoric) change with time? Did the two fluid systems operate independently, and the dominant system in the ore zone change from pure magmatic to pure meteoric at some state in the mineralization history? Or, was the magmatic fluid system diluted continuously by meteoric water through time? If fluid mixing was an important process for changing the chemical nature of the hydrothermal system, did the mixing take place at the site of sulfide deposition, or at the peripheral or deeper parts of the plumbing system?

If a significant proportion of metals and sulfur in these deposits is found to be magmatic in origin, a question that follows concerns the mechanism through which the magmas acquired these elements. Did the magmas acquire these elements through the partial melting of source rocks in the upper mantle or the lower crust, or did they acquire them through selective assimilation of the upper crustal rocks during magma emplacement?

The mechanism of hydrothermal mineral precipitation in porphyry copper deposits remain unresolved. The possible processes include: a simple decrease in P and T; an increase in the activity of H_2S and SO_4 (caused by the hydration of SO_2 during cooling); an increase in pH due to chemical reations with wall rocks; mixing or unmixing of magmatic fluids; and mixing of magmatic fluids with meteoric water.

The main reason that the previous studies were unable to answer any of the above questions quantitatively was because essentially the previous isotopic studies on porphyry copper deposits were reconnaisance in nature. A detailed investigation of the temporal and spatial changes in the oxygen, hydrogen, carbon, and sulfur isotopic compositions of minerals and fluid inclusions in a well selected system can solve all of the above problems, if the isotopic study is coordinated with other geochemical studies (e.g., fluid inclusion, mineralogic, and major-and trace-element studies). The Red Mountain porphyry system appears to be one of the best places to solve these problems on porphyry copper deposit genesis, because the bottom and the sides as well as the top of a porphyry system can be sampled.

The research plan is to investigate systematically the oxygen, hydrogen, sulfur and carbon isotopic compositions of minerals and fluid inclusions from drill core samples, on which various other geochemical studies will be pursued by other members of the Red Mountain Research Panel. Approximately 200 to 500 samples, representing both mineralized and barren porphyry and country rocks, will be investigated. The study will be carried out by a post-doctoral fellow and graduate assistant under the direction of the principal investigator.

Thermal Modeling

Principal Investigator: F. Furlong, Pennsylvania State University

Time: 2 years Cost: $ 57,000

The thermal modeling part of the project is to develop constrained models of the detailed thermal evolution of the intrusive-hydrothermal system. At present, primarily as a consequence of a paucity of constraining data (and associated model simplications), models of the thermal evolution of such systems are relatively general in scope. The proposed work, in conjunction with the geological and geochemical data collected is intended to develop models which simulate the evolution of such systems, including the effects of conducted and advected heat, and heat produced via chemical reactions and phase changes (heat and crystallization). The modeling effort will be aimed at unraveling the thermal history of the system as a whole, and also determine the local oerturbations to the general pattern.

Currently, modeling algorithms allow for evaluation of the conductive aspect of the thermal evolution of intrusive systems. It is planned to adapt and improve these algorithms to allow for the evaluation of the effects of advected heat. Clearly in systems such as Red Mountain, an important component of this advected heat is carried by fluids moving through fracture networks. Thus, to evaluate this aspect will require inclusion of data regarding the timing of formation of fracture systems, the volumes and rates of fluid flow, and the lifetime of any one fracture system, in addition to the density and geometry of the fractures. Only with the constraints provided by the geological and geochemical data gathered as a part of this project can these models be made to realistically simulate the thermal evolution of the system. This modeling will be conducted primarily on two scales. A large system wide scale will be used to model the overall evolution, while a smaller local scale of modeling will be used to evaluate the variability in thermal history which can occur on such a small scale. The inclusion of these small scale effects is a necessary component of models of the system in general.

Expected results of this work include numerical algorithms, constrained by the available data, which will allow us to simulate the thermal evolution of an intrusive-hydrothermal system. These models will provide a means of evaluating potential deep drilling sites with particular usefulness in determining the scale of local (near borehole) variability possible in the thermal history of upper crustal intrusive systems.

Applied Geochemical Studies

Principal Investigator: M.A. Chaffee, USGS

Time: 2 years Cost: $120,000

The purpose of the geochemical studies is to determine in conjunction with other geological studies, the zoning of selected elements and minerals in the Red Mountain system. This zoning will be a primary means of establishing the history and geometry of the presently drilled part of the overall mineralized system and will thus be a valuable method for locating drill sites and targets.

Samples of drill core, as well as outcrop, soil, and mine dumps, will be collected and analyzed for as many as 40 elements. Both single and multi-element plots of the raw analyses, as well as of derived parameters such as element ratios and values created by factor analysis, will be evaluated. Selected samples will be studied to determine the mineral residences of elements shown to be zoned in the study area.

The analyses will be used to establish the abundances and distributions of ore and lithologically-related elements. The analyses, and the parameters derived from the analyses, will be used to define the 3-dimensional zoning within the presently drilled out area as well as in the area immediately surrounding the known extent of the mineralized system. The analytical data will also be used to help correlate the structurally separated gologic units mapped during the project. The mineral residences of selected elements will be determined to identify those minerals that are diagnostic of specific lithologic and (or) hydrothermal zones within the system. The zoning model will help in determining the timing, location, and intensity of mineralizing pulses in the system and will therefore help to define the geometry of the system and thus suggest possible sites for deep drilling.

The distributions and abundances of the selected elements will also assist in determining the effects and extent of supergene alteration and the possible sources of the elements associated with the mineralizing processes.

Geophysics and Remote Sensing

Principal Investigator: J.D. Corbett, University of Utah Research Institute

Time: 2 years Cost: $110,000

Supplemental geophysical studies, particularly aeromagnetic and gravity surveys, will provide a better three-dimensional physical property model of the depth, lateral extent and transitional variations of both the intrusive core and the near-surface litholigies of the Red Mountain area. Susceptibility contrasts are known within the host rocks; a density contrast between rock types can be determined from surface and drill core specimens. Geologic data, and extrapolations from known outcrops or borehole intercepts will add significant control for interpretation in the third dimension and siting of deep drill holes. Induced polarization and borehole logging will provide additional physical property data to assist research study of the geological and mineralogical features of a hydrothermal porphyry copper system and its peripheral epithermal deposits.

A detail helicopter aeromagnetic survey would cover the zone of alteration and peripheral mineralization with extensions well out over fresh unaltered rocks and background magnetic field values. A tight line spacing of about 800 feet at a draped survey terrain clearance of 300 feet is recommended. The survey should be completed early in the geologic mapping sequence for optimum utilization and could be completed in six months after a contract is approved.

Detail gravity across the rugged terrain of the Patagonia Mountains will require extensive surveying and terrain effect corrections. A study of the density of the several types of surface rocks and diamond drill core is a necessary preliminary step to the survey.

Specific studies of the electrical physical properties (chargeability and resistivity) of the nature and extent of the alteration envelope, including clay, sericite and pyritic zones should be included. With large electrode separations this study would probe the limits of the deep sulfide mineralization to the west where the near-surface secondary sulfide blanket appears thin. Short spaced electode lines would determine the electrical parameters on the near-surface alteration zones of both Red Mountain and the peripheral mineralized environments. Selection of line placement would be based upon host rock lithology, alteration type and extent, and the expectation of culture interference.

Remote sensing data needs to be updated and integrated as a part of this study. The alteration halo associated with the Red Mountain deposit was delineated using spectral reflectance data, acquired by Landstat, a field spectrometer, and NASA's Bendix 24-channel Multispectral Scanner

(MSDS)(Abrams and Siegal, 1977). This data should be recovered and integrated with the airborne geophysical data and detailed geologic mapping proposed in the preliminary investigation. Further rationing and creation of additional contour maps and/or valued color ratio composits is recommended. The budget requirements to upgrade the previous data base should be minimal if the data and programs from JPL are available.

Management, Synthesis and Hole Siting

Principal Investigator: J.J. Quinlan, Kerr-McGee Corporation

Time: 2 years Cost: $50,000

Provision is made here to manage and coordinate project work during the life of the project, and synthesize data at the end of the project so as to site proposed deep drill holes.

TIME AND COST ESTIMATE

The following time and cost estimate has been prepared from details furnished by the principal investigators of individual studies. Proposed work will be accomplished using existing equipment and facilities at the institutions of the principal investigator or will be contracted. No funds are requested or allowed for the purchase of new equipment or facilities.

1.	Regional Studies including Paleomagnetic Studies	
	Regional Studies	
	2 years, with 1/2 time R.A. = 1 R.A. year @ $16,000/yr	$ 16,000
	Transporation and Field Expenses	2,500
	Palemagnetic Studies	
	1 year with 1/2 time R.A. = 1/2 R.A.year at $16,000/yr	8,000
	1 month Faculty Expense	5,000
	Transportation and Field/Lab Expenses	2,500
	Subtotal	$ 34,000
2.	Surface Mapping and Drill Core Fractures Studies	
	2 years with 1 1/2 times R.A.=2 1/2 R.A.yrs.@ $16,000/yr	40,000
	2 months Faculty Expense	10,000
	Transporation and Field/Lab Expenses	3,500
	Subtotal	$ 53,500
3.	Geochronologic Studies	
	1 year with 1/4 time R.A. = 1/4 R.A.year @$16,000/yr	$ 4,000
	25 Age dates @ $500 ea., less $4,000	8,500
	Subtotal	$ 12,500
4.	Petrography, Petrology and Mineral Chemistry	
	2 years with 2 R.A. = 4 R.A. years @$16,000/yr	$ 64,000
	+ part time technician at 20% of R.A. time	12,800
	2 months Faculty Expense	11,200
	Transportation and Field/Lab Expenses	32,000
	Subtotal	$120,000
5.	Fluid Inclusion Studies	
	Time: 2 years with R.A. = 2 R.A. years @$16,000/yr	$ 32,000
	2 months Faculty Expense	10,000
	Transporation and Field/Lab Expense	15,000
	Subtotal	$ 57,000

6. Isotope Studies

2 years with Proj. Assoc. = 2 P.A. years at $33,500/yr	$ 67,000
1/2 time R.A. = 1 R.A. year @ $21,000	21,000
Secrectary and Technician	18,000
3 months Faculty Expense	30,000
Transportation and Field/Lab Expense	36,000
Indirect Costs	66,000
Subtotal	$238,000

7. Thermal Modeling

2 years with 1 R.A. = 2 R.A. years @$15,000/yr	$ 30,000
2 months Faculty Expense	10,000
Transportation and Lab Expense	17,000
Subtotal	$ 57,000

8. Applied Geochemistry

2 years with 1-GS-5 = 2 GS-5 years @ $15,000/yr	$ 30,000
Analysis - 2500 samples @ $20 ea.	50,500
Transportation and Field Expense	20,000
Subtotal	$100,000

9. Geophysics and Remote Sensing

2 years, Administration	$ 10,000
Aeromagnetic, includes interpretation	50,000
Gravity	25,000
Electrical Method	20,000
Remote Sensing Update	5,000
Subtotal	$110,000

10. Management, Synthesis and Hole Siting

2 years	50,000
Subtotal	$ 50,000

GRAND TOTAL	$832,000

SCHEDULE

Work can be scheduled so funds requirements are as follows:

	Year 1	Year 2	Total
1. Regional and Paleomagnetic Studies	$ 17,000	$ 17,000	$34,000
2. Surface Mapping and Drill Core Fracture Studies	26,500	27,000	53,500
3. Geochronologic Studies	12,500		12,500
4. Petrography, Petrology and Mineral Chemistry	60,000	60,000	120,000
5. Fluid Inclusion	28,000	29,000	57,000
6. Isotope Studies	114,000	124,000	238,000
7. Thermal Modeling	28,000	29,000	57,000
8. Applied Geochemistry	50,000	50,000	100,000
9. Geophysics & Remote Sensing	75,000	35,000	110,000
10. Management, Synthesis and Hole Siting	10,000	40,000	50,000
TOTAL	$421,000	$411,000	$832,000

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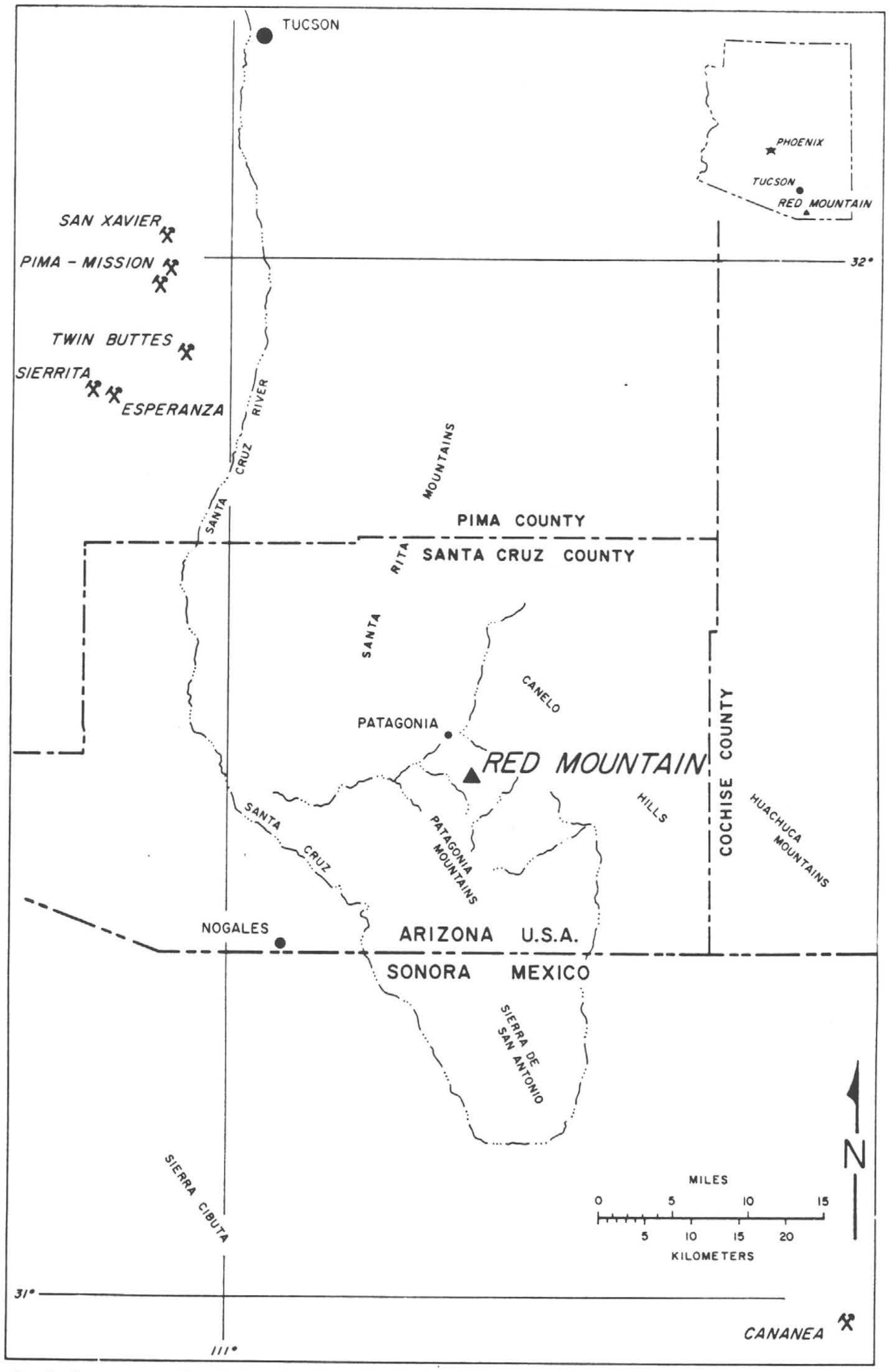
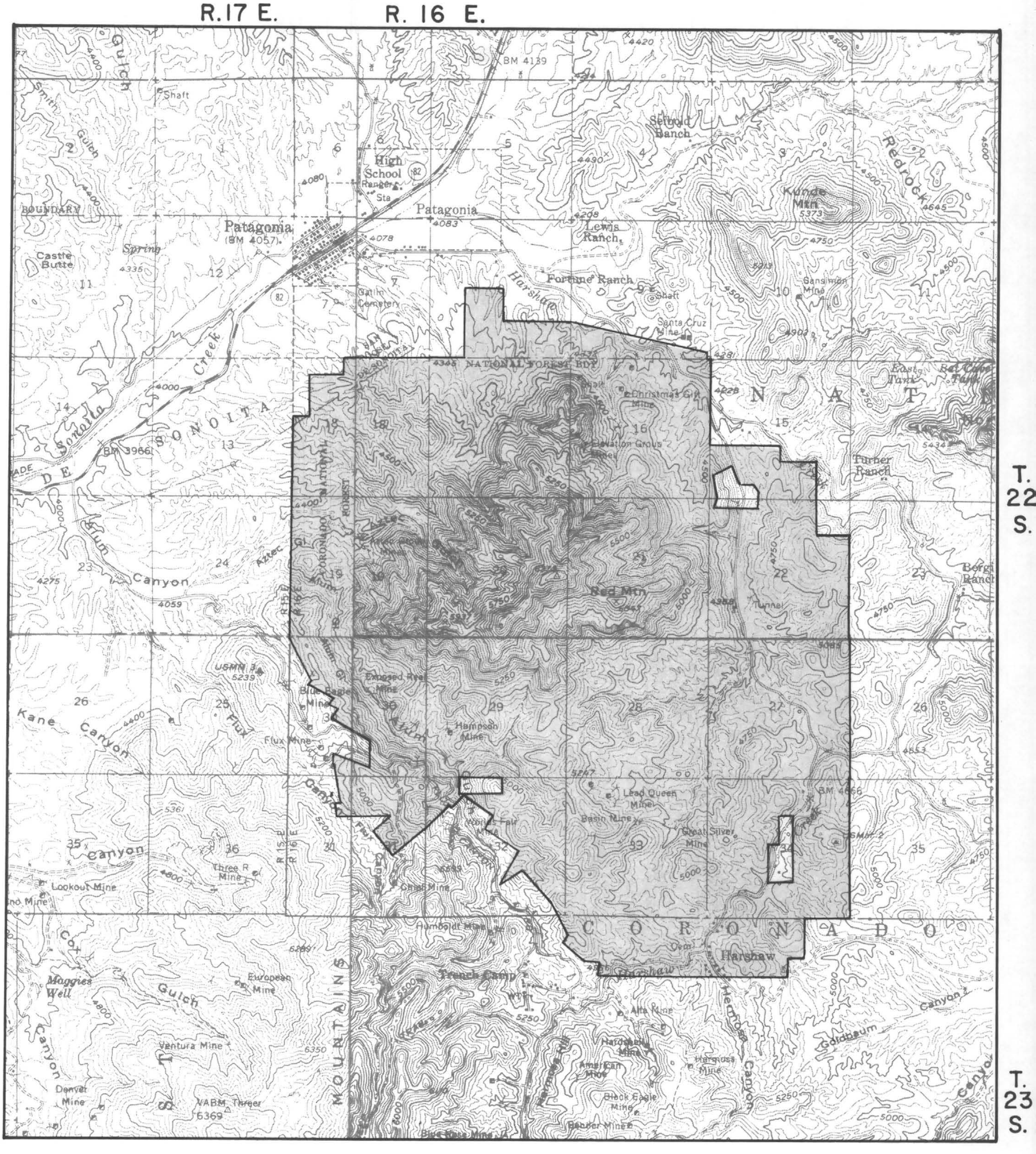


Fig. 1. Index map showing the location of the Red Mountain porphyry copper deposit. After R.M. Corn, Economic Geology, Vol. 70, No. 8, Dec. 75



EXPLANATION

KERR-McGEE PROPERTY

RED MOUNTAIN PROPERTY MAP

SANTA CRUZ COUNTY, ARIZONA

SCALE 1:62,500

TOPOGRAPHIC BASE FROM USGS 15' QUADRANGLE MAPS
ELGIN (1958), LOCHIEL (1958), NOGALES (1958), MT. WRIGHTSON (1958)

FIGURE 2

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ARIZONA GEOLOGICAL SOCIETY

FIELD TRIP GUIDE
TO
RED MOUNTAIN
SANTA CRUZ COUNTY, ARIZONA

March 21, 1981

Prepared by

James J. Quinlan
Kerr-McGee Corporation

ARIZONA GEOLOGICAL SOCIETY

FIELD TRIP GUIDE

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RED MOUNTAIN

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Contents

Page

Illustrations

ROAD LOG FOR
RED MOUNTAIN PORTION OF
ARIZONA GEOLOGIC SOCIETY FIELD TRIP TO
PATAGONIA-RED MOUNTAIN-HARDSHELL DEPOSITS
MARCH 21, 1981

START

Mile 0.0 — Patagonia, Arizona Post Office at the junction of State Highway No. 82 and county road leading to the San Rafael Valley, Harshaw and Lochiel. Good view of Red Mountain on right.

Mile 1.6 — The Patagonia fault is exposed in outcrop across wash. Fault zone consists of several strands, with consolidated Tertiary gravels on northwest and Meadow Valley Andesite (72.1 $\pm$ 3 m.y.) on southeast side of fault zone. Bold outcrops on southeast side of outcrop area are silicified breccias along fault strand in Meadow Valley andesite.

STOP 1

Mile 2.7 — Road cut exposures of Meadow Valley Andesite. These exposures are typical of many Meadow Valley exposures outside of main Red Mountain alteration zone. Would call attention to purple color and propylitic alteration. In core of Red Mountain alteration zone, andesite is typically altered to a black-colored, biotite-magnetite rich rock. Clay and limonite are common along many fractures in the exposures and quartz veinlets and manganese oxides may be seen along some of the fractures.

STOP 2

Mile 4.7 — Locations of Stops 2 through 8 shown on Figure 2. Turn off from San Rafael Valley-Harshaw-Lochiel county road on to road leading to Red Mountain. Will transfer from bus to four-wheel drive vehicles at this point. Outcrops in wash ahead are generally propylitically altered Meadow Valley Andesite. Local bleach zones are mainly controlled by linear structures. Clay, gypsum and limonite are the most common minerals in these zones.

STOP 3

Mile 5.2

View point of southeast side of Red Mountain. Would call attention to route of road leading up mountain, talus covered slopes, land slide blocks and cliffs in upper layered Tuff unit. This upper layered altered Tuff unit is much more resistant to erosion than the underlying andesite and this accounts for the present topographic high at Red Mountain.

STOP 4

Mile 7.1

At outcrop in altered Tuff unit 5,000 feet east of alteration center at Red Mountain (See Figures 2 and 3). Rock is principally clay altered, also note alunite veinlets. Stop is at about outer limit of visible sericite in Red Mountain alteration zone.

STOP 5

Mile 7.5

At collar of Hole No. 158. Road cuts and outcrops of altered Tuff unit ± 2,000 feet closer to Red Mountain alteration center than at Stop 4. Note increase in sericite and pyrite (2 to 2.5 weight %) content over that at Stop 4.

See Map Figures 2 and 3 and Cross Section Figures 4, 6, 10 and 11 illustrating geology, alteration and sulfide changes at and between Stops 5 and 6.

STOP 6

Mile 8.0

Crest of Red Mountain ridge and near collar of Hole No. 151. Road cuts and outcrops of the Tuff unit are inside the area of relative abundant sericite and iron oxides after pyrite. Adjacent drill hole data shows original pyrite content of up to 18 weight percent and an average content of from 10 to 12% (see Figure 6).

STOP 7

Mile 8.8 — At collar of Hole No. 148. Road, drill pad cuts and outcrops are in altered Tuff unit, within zone of relatively abundant sericite and iron oxide. Note quartz and alunite veinlets in drill pad cut. Will discuss and point out feature of deposit from view point at this stop. Core specimens illustrating changes in alteration and mineralization with depth will be available at the lunch stop.

STOP 8

Mile 9.0 — End of Red Mountain tour-view sight overlooking Hardshell or afternoon tour area.

GEOLOGY AND SILICATE-SULFIDE ALTERATION ZONING AT THE RED MOUNTAIN PORPHYRY COPPER DEPOSIT, SANTA CRUZ COUNTY, ARIZONA

James J. Quinlan

Abstract

This paper is the result of a study of the Red Mountain, Arizona porphyry copper deposit. The bulk of the copper recognized in the deposit lies about 5,000 feet below the summit of the mountain and 3,500 feet below a small, partly dissected, secondary enriched chalcocite blanket.

The copper deposit at Red Mountain occurs within an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Silicate alteration, sulfide distribution and assay data have been used to define the deposit and alteration system.

Alteration at Red Mountain is complex. A near classic porphyry-copper silicate-sulfide alteration pattern, including a partially defined copper shell is recognized at depth. This has been superimposed over an earlier potassic alteration assemblage which in turn is a part of a much larger zoned alteration system. Though modified by supergene agents, the early system accounts for much of the alteration recognized at the surface.

The Red Mountain deposit can be divided into three parts: (1) a near surface chalcocite blanket deposit, (2) a deep level bulk sulfide deposit and (3) a copper-molybdenum breccia pipe within the core area of the deep porphyry copper system.

The most obvious clue to the deep orebody at Red Mountain is the shallow chalcocite blanket. This apparently has formed from a low grade copper halo or plume which extends upward to the present surface or at least 5,000 feet above the deep orebody.

Introduction

The Red Mountain copper deposit is at the northern end of the Patagonia Mountains, 50 miles southeast of Tucson, Arizona (Fig. 1). The deposit was discovered and is controlled by the Kerr-McGee Corporation of Oklahoma City, Oklahoma.

The bulk of the copper recognized in the deposit lies about 5,000 feet below the summit of the mountain and 3,500 feet below a partly dissected enriched chalcocite blanket.

The geology of the Red Mountain deposit and surrounding area has been described by a number of authors. The most pertinent publications are: Schrader (1915), Drewes (1971 A & B and 1972 A & B), Simons (1971 and 1974), Corn (1975) and Bodnar and Beane (1980).

Geology

Geologic Setting

Red Mountain is underlain by an altered complex of volcanic and intrusive rocks of Cretaceous and early Tertiary age. Figures 2 and 3 are generalized maps illustrating surface geology and alteration features. Figures 4 and 6 are diagrammatic cross sections showing geologic and alteration features.

Three layered volcanic units are recognized at Red Mountain. The upper or Tuff unit, consists mainly of tuffs, flows and breccias of rhyolitic and dacitic composition. It crops out over much of the mountain and is up to 2,400 feet thick (Fig. 2 and 4). It is essentially the same as the "Volcanics of Red Mountain" described by Drewes (1971 A) and which he correlates with the Gringo Gulch volcanics of Paleocene (?) age.

Underlying the Tuff unit are approximately 3,000 feet of andesite and trachyandesite flows, breccias, sills and dikes locally referred to as the Andesite unit. Hornfels bands occur near the base of the unit. The Andesite unit crops out on the flanks of Red Mountain and is cut in drill holes (Fig. 2 and 4). It is a part of the upper Cretaceous Trachyandesite or Doreite (Ka) unit, mapped and described by Simons (1974). Simons reports a potassium argon date of 72.1$\pm$ three million years for a sample from the unit.

The lowest layered rock unit is the Felsite-Latite unit. It underlies the Andesite unit and includes interlayered andesites near the top. It consists mainly of volcanic conglomerates and breccias, silicified tuffs, flows(?), interlayered and cut by latite sills and dikes. The unit crops out in Alum Gulch on the south side of Red Mountain and is recognized in deep drill holes on the south and west flanks of the mountain (Fig. 2 and 4). It correlates with the upper Cretaceous Silicic Volcanics (Kv and Kla units) mapped by F. S. Simons (1974).

The layered rocks at Red Mountain are cut by several textural varieties of porphyritic rocks which range in composition from granodiorite to quartz monzonite. The porphyries are recognized as dikes and irregular bodies in outcrop and drill holes (Fig. 2 and 4).

The layered rocks generally strike north and dip 15° E. The dominant trend of local shears and fractures is N 20° E with steep dips toward the northwest and southeast. Less numerous are shears and fractures which strike N 70° E and dip steeply northwest or southeast. No large faults are recognized on the mountain but several occur on its flanks (Fig. 2).

Silicate Alteration

Silicate alteration at Red Mountain is easy to recognize but difficult to interpret. Near the center of the deposit, changes in the alteration assemblage with depth are most obvious (Fig. 6). Lateral zoning at depth, which is a critical guide to ore, is much more subtle and to date has been best quantified by thin section studies (Fig. 5).

The strong vertical alteration zoning recognized at Red Mountain is partly controlled by differences in rock types with depth. Near the center of the system, the Tuff unit is intensely altered to an assemblage of quartz-sericite-pyrite-kaolinite-alunite. The sericite content increases with depth while the content of kaolinite and alunite decreases. At the Tuff-Andesite contact, the assemblage abruptly changes to quartz-sericite-chlorite-pyrite with minor hematite and kaolinite. With the exception of outlying Hole 158, the pyrite content rapidly decreases in depth through the upper Andesite interval (Fig. 10). The alteration assemblage further changes with depth within the andesite through a biotite-magnetite-pyrite assemblage to a biotite-orthoclase-anhydrite-magnetite-chalcopyrite assemblage. Within the Felsite-Latite unit, the assemblage is orthoclase-quartz-anhydrite-chalcopyrite-biotite. The alteration within the porphyritic rocks is generally reflective of the adjacent intruded rock and depth. It is expressed by a quartz-sericite-pyrite-kaolinite assemblage at shallow depths and an orthoclase-anhydrite-biotite-chalcopyrite assemblage at greater depth.

Lateral changes in alteration are much more subtle. At the surface hypogene alteration is strongly masked by supergene effects but is discernible. Within the Tuff unit, the lateral zoning is expressed as a central core area of more abundant sericite, quartz veining and limonitic stain (Fig. 3). Outward from the core area, a more argillic zone is characterized by abundant clays and alunite with less sericite and silica. The transition from sericitic-argillic alteration within the Tuff unit to propylitic alteration in the surrounding andesite to the northeast, east, south and southwest appears to be partly due to change in rock type. The suggestion is that the alteration mushroomed or extended farther laterally from a mineralization center in the Tuff unit than in the underlying andesite. Within the andesite on the west and northwest flanks of the mountain an intense supergene argillic alteration is superimposed directly upon hypogene biotite-magnetite alteration. Within this area of relatively low original pyrite, chalk turquoise has formed as the more common supergene copper mineral within the argillized andesite.

At depth, the central core area is marked by an orthoclase-quartz-biotite-anhydrite alteration mineral assemblage. There is a general decrease in the amount of these minerals outward from the core area with increasing amounts of sericite and chlorite. This is illustrated on Figure 5 which was developed from a study of thin sections obtained from selected holes between elevations of 2,000 and 2,500 feet.

Farther out, as seen in Holes 157 and 161, a biotite-magnetite assemblage is recognized in the andesite. In Hole 157, this assemblage changes to biotite-orthoclase in the Felsite-Latite unit. Though the assemblage is potassic, the intensity of the potassic alteration appears much less than that recognized in the core area of the deposit. Locally, late quartz-pyrite veinlets enclosed in sericitic envelopes cut the previously described alteration features.

Figure 6 illustrates in cross section the writer's concept of the major silicate alteration features at Red Mountain. That is, a large early zoned alteration system which accounts for most of the alteration recognized at the surface. The primary porphyry copper deposit lies in the potassic zone of this large early system. The alteration associated with the primary deposit has been superimposed on the early alteration system and zoning is similar to that described by J. D. Lowell and J. M. Guilbert (1970) and A. W. Rose (1970). It is suspected that the two silicate alteration systems are closely related in origin and time with the porphyry copper phase representing a late event in the development of the complex Red Mountain hydrothermal system. The sulfide distribution data also clearly points to two distinct alteration phases as does the fluid inclusion data of Bodnar and Beane (1980).

Sulfide Distribution

The principal sulfide minerals at Red Mountain are pyrite and chalcopyrite. Secondary chalcocite is present, particularly in the blanket deposit. Small amounts of molybdenite are present and bornite, enargite, tennantite, galena and sphalerite have been identified locally.

The sulfide content of the rocks at Red Mountain has been estimated during core logging and in the deep holes has been determined on the basis of sulfur and sulfide sulfur assays.

For the purposes of the sulfide distribution studies, it has been assumed that pyrite and chalcopyrite are the only significant primary sulfide minerals in the Red Mountain system. The amounts of each below the zone of secondary enrichment are calculated from copper and sulfide sulfur data by assigning the amount of sulfide sulfur needed to convert the amount of copper present in an interval to chalcopyrite and assigning the remaining sulfide sulfur to pyrite. Sulfate data has been converted to anhydrite equivalent where anhydrite is recognized in the deep drill holes.

The sulfide data has been assembled and posted in several different manners on plans and cross sections, i.e., by rock type and at various elevation intervals. Most revealing is the bulk data when assembled and posted at elevation intervals of 500 feet or more. In general, plans and sections have been prepared showing pyrite, chalcopyrite, and total sulfide (combined pyrite and chalcopyrite) distribution and pyrite to chalcopyrite ratios. The pyrite and total sulfide maps and sections are so reflective of each other that maps and sections showing pyrite distribution have not been included with this report.

Plan illustrations accompanying the report show relative bulk chalcopyrite (Fig. 7) and total sulfide distribution (Fig. 8) and relative pyrite to chalcopyrite ratios (Fig. 9) between elevations of 500 and 1,500 feet. All three maps show the same basic pattern and closely match the silicate alteration pattern shown in Figure 5. Though drilling has yet to outline the entire system, available data indicates an elongate but nearly classic sulfide copper shell. Thus all three plans, and in particular the ratio map (Fig. 9), are useful in indicating where a drill hole lies within the system.

Cross sections prepared from the sulfide data, i.e., data assembled at 500-foot elevation intervals, not only confirm the picture developed in plan but add to it. Total sulfide and chalcopyrite data have been assembled on Section A-A' which passes through the core area of the lower sulfide system as well as outlying Holes 157 and 158 (Fig. 10 and 11). The section showing total sulfide distribution (Fig. 10) clearly demonstrates a two-part system. A large primary sulfide high, mostly pyrite, is recognized near the surface in the upper parts of the central drill area and in Hole 158. This pyrite is within and generally an integral part of the intense quartz-sericite alteration assemblage. The section also suggests that Hole 157 lies in the core area of the large primary sulfide system and would account for the potassic alteration recognized in the hole. It is also apparent that the strong iron oxides recognized on the upper western slope of Red Mountain (Fig. 3) are related to the upper sulfide system.

The copper system recognized at depth in the central drill area and shown on the sulfide distribution and ratio maps (Fig. 7-9) is also apparent in the cross sections showing the total sulfide and chalcopyrite distribution (Fig. 10 and 11). Although the amount of total sulfides in the lower system (Fig. 10) is less than that in the upper system, it is clear from Figure 11 that the copper is associated with the lower system. Further it is apparent in section that the lower sulfide system closely follows the central area silicate system and like the silicate system is superimposed on the earlier and larger system.

The Ore Deposit

For discussion purposes, the Red Mountain deposit is divided into three separate and distinct parts: (1) an upper level chalcocite blanket deposit, (2) a deep level bulk sulfide deposit and (3) a breccia pipe deposit within the core area of the deep porphyry copper system.

Chalcocite Blanket

Chalcocite is recognized along fractures and as coatings on pyrite grains from the surface to a depth of 2,500 feet or more. Much of the chalcocite appears to be concentrated in a flat blanket-like deposit near an elevation of 5,000 feet (Fig. 11). As currently defined, the blanket ranges in thickness from 15 to 150 feet. It appears to be in the process of being destroyed by weathering and erosion and the deeper scattered chalcocite showings which are usually controlled by fissures or shears probably represents recent copper migration.

The chalcocite blanket almost directly overlies the deep porphyry copper orebody (Fig. 3 and 11). The distribution of copper above the deep porphyry copper system as reflected by the relative copper or chalcopyrite values shown in Figure 11, suggests the blanket was formed by enrichment of a protore halo or plume extending at least to the present surface or 5,000 feet above the main ore system. Bodnar and Beane's (1980) description of the late stage of mineralization in a quartz-pyrite veinlet containing minor chalcopyrite and galena in a surface sample, RM 11, also is evidence that the ore stage primary mineralization extends far above the main deposit.

Deep Level Bulk Sulfide Deposit

The zone of deep level porphyry copper mineralization at Red Mountain is an integral part of the copper shell as recognized in the alteration and sulfide study. Holes 146, 165 and the deeper parts of Hole 144 describe the low-sulfide, low-copper core of the system. A low-sulfide, low-copper tail extends from the core and is recognized in seven holes, 133, 135, 154, 162, 147, 143 and 152. A breccia pipe is defined in Holes 148, 148B, 148C and 155 and lies within the elongated tail area.

Nine drill holes are immediately peripheral to the core area and the elongated tail and it is in the area of these nine holes that most of the deep level copper outside the breccia pipe occurs. Seven of the nine holes contain thick and/or higher grade ore intervals. Ore is recognized on both the west and east limbs of the copper shell (Fig. 4).

Much, if not most, of the deep level copper occurs as chalcopyrite along veinlets and fractures and only a small amount occurs as disseminated grains. From work to date, it is obvious that the area of the copper shell is not uniform in grade and everywhere of interest. Local controls and structure apparently played an important part in copper mineralization within the shell area. For example, chalcopyrite enrichment is noted along both sides of andesite-porphyry contacts in several holes.

148-155 Breccia Pipe

The 148-155 breccia pipe recognized at Red Mountain has many features common to mineralized breccia pipes at other porphyry copper deposits. It is perhaps the deepest copper-molybdenum breccia pipe presently known anywhere in the world. Not only is it of potential economic interest because of the higher grade ore associated with it, but it is also of considerable scientific interest because of its depth, position within the system, and the mineralization and alteration associated with it.

The Dyna-drill has been used to control the direction of drill holes for a better evaluation of the pipe. In all, four holes have intersected the pipe, Holes 148, 148B, 148C and 155 (Fig. 12).

The 148-155 breccia pipe, as envisioned from drill hole data, is shown in plan and diagrammatic section in Figure 12. Though in part diagrammatic, the plan and section represent a reasonable interpretation based on drill hole intercepts within the pipe and the confining restrictions of adjacent holes. In plan the intercepts in Holes 148 and 155 are about 800 feet apart and define the minimum dimension of the long axis of the pipe. The pipe has been assigned a long axis of 1,100 feet. The section better illustrates the information available. As shown, the top of the pipe is at an elevation of 1,750 feet or approximately 4,000 feet below the surface and ore has been exposed over a vertical range of 1,300 feet. Hole 148 bottoms in ore within the pipe near sea level elevation.

As mentioned before, the 148-155 pipe lies within the high-potassic, low-sulfide and low-copper tail extending southward from the core of the deep porphyry copper system (Fig. 9). The alteration within the pipe is separate and generally distinct from that of the surrounding rock. This is well exemplified in Holes 148B, 148C and 155. These holes enter the pipe near its top from an area of low-sulfide, low-copper and strong potassic alteration. At or within a few feet of the pipe contact, alteration abruptly changes to phyllic with abundant sericite and up to 30 percent by weight of pyrite. Strong phyllic alteration persists near the top of the pipe but gives way to potassic alteration with depth. Only in hole 155 is a significant amount of possible mineralization leakage recognized above the pipe. Though the pipe contact in this hole is sharp and distinct, bands of pipe-type mineralization are evident for 40 feet above the pipe. Shears with chlorite, sericite and quartz-sulfide veinlets similar to pipe mineralization are recognized up to 775 feet above the pipe.

Unlike many breccia pipes described in the literature, the mixing and movement of fragments great distances up or down the pipe has not been recognized in the 148-155 breccia pipe. Though fragments are broken and rotated, the composition of fragments, with but a few exceptions, appear to be similar to those in the immediate wall of the pipe. More detail is needed to substantiate this observation.

The ore breccia generally consists of angular fragments of felsite and andesite in a matrix of orthoclase, quartz, anhydrite, chalcopyrite and pyrite. Sericite is abundant near the top and also is recognized close to the sides of the pipe in deeper intercepts. Calcite, molybdenite and a dark gray sulfosalt, tenatively identified as tennantite, are accessory minerals. Breccia fragments are commonly an inch or less in diameter. The largest fragment recognized was 18 inches in diameter. Open vugs are common.

A definite enrichment of copper, molybdenum and silver is recognized at the pipe margin, particularly in the deeper intercepts. The enrichment is related to the concentration of chalcopyrite and molybdenite rich sulfide lenses at the margins. The grade of copper at the margins of the pipe is from 1.8 to 4.8 times that in the core area of the pipe. Molybdenum enrichment at the margins is ten times and that of silver from two to four times that of the pipe core.

The silicate alteration and sulfide distribution pattern recognized in the pipe, though different in scale, is much the same as that recognized in many large porphyry copper systems, that is, a core area of strong potassic alteration with lower sulfide content. This is followed upward and to a lesser extent outward towards the pipe margins by a phyllic zone with increased sulfides. The suggestion is that the pipe itself may represent a more intense but miniature zoned porphyry copper system superimposed over the main or bulk phase of porphyry copper alteration and mineralization.

Discussion

Most of the alteration recognized at the surface of Red Mountain results from the supergene modification of a large zoned hypogene alteration system formed prior to the emplacement of the deep porphyry copper deposit.

The deep level porphyry copper is related to a more intense, less extensive event in the evolution of the complex hydrothermal system. The superposition of the breccia pipe alteration and mineralization over the main phase porphyry copper alteration and mineralization indicates an even more confining, more intense alteration, mineralization pulse late in the evolution of the system.

Though the three hydrothermal events appear separate and distinct, all three are undoubtedly closely related in time and origin to each other and to the emplacement of porphyry intrusives at Red Mountain. The indicated sequence of formation appears to start with the development of the large, barren, zoned system, with succeeding but more restrictive and intense pulses of ore mineralization within the confines of the large barren system.

The zoned nature of alteration and mineralization within the breccia pipe indicates the pipe itself may represent a miniature zoned porphyry copper system. Whereas the pipe contains open vugs, most evidence indicates that it must have formed many thousands of feet below the surface.

The most obvious clue to the deep orebody at Red Mountain is the shallow chalcocite blanket. This appears to have formed from a low-grade copper halo or plume which extends upward to the present surface or at least 5,000 feet above the deep orebody. Undoubtedly, pyrite from the early alteration system played an important part in the generation of acid for leaching of the plume mineralization.

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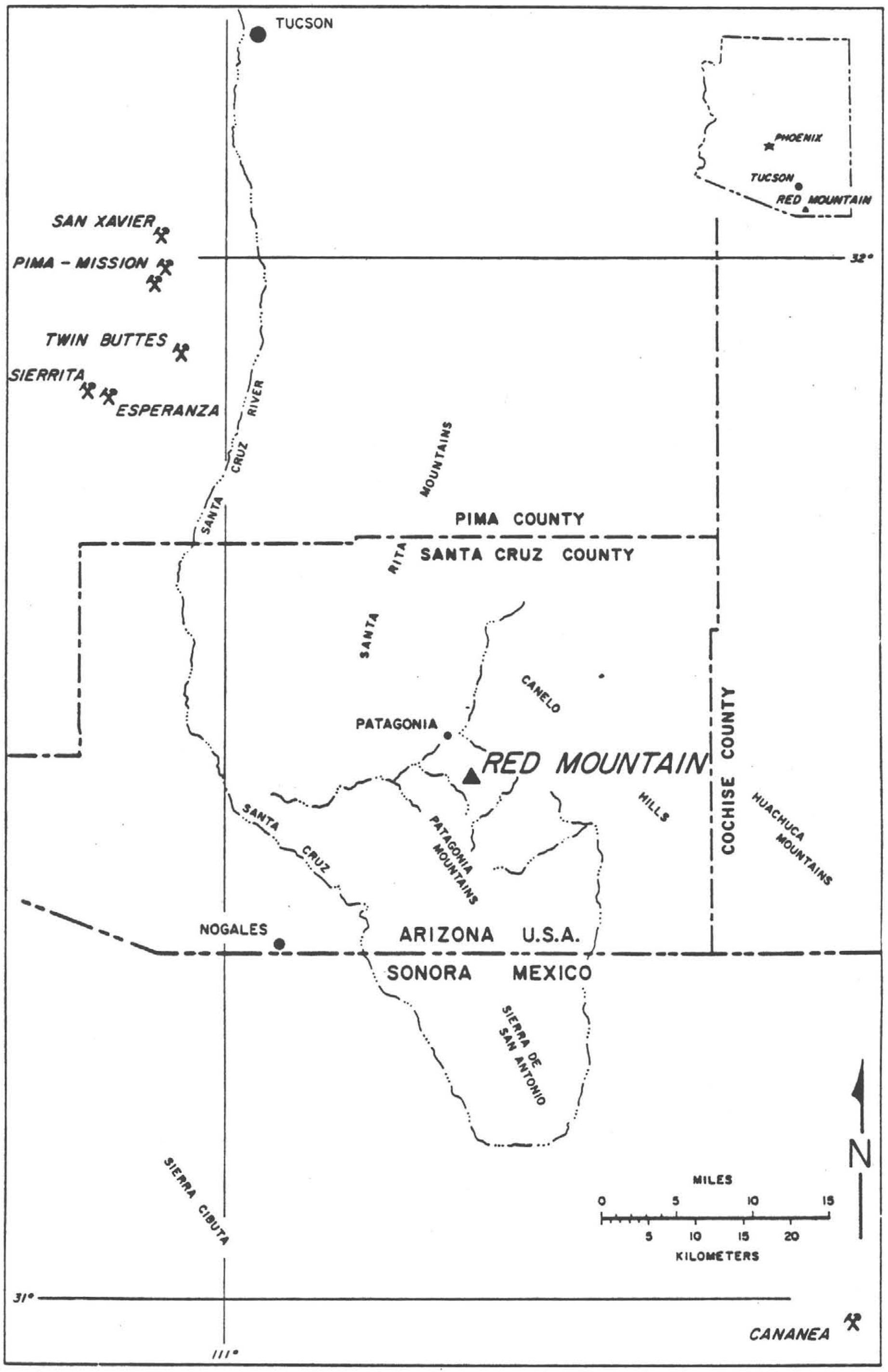
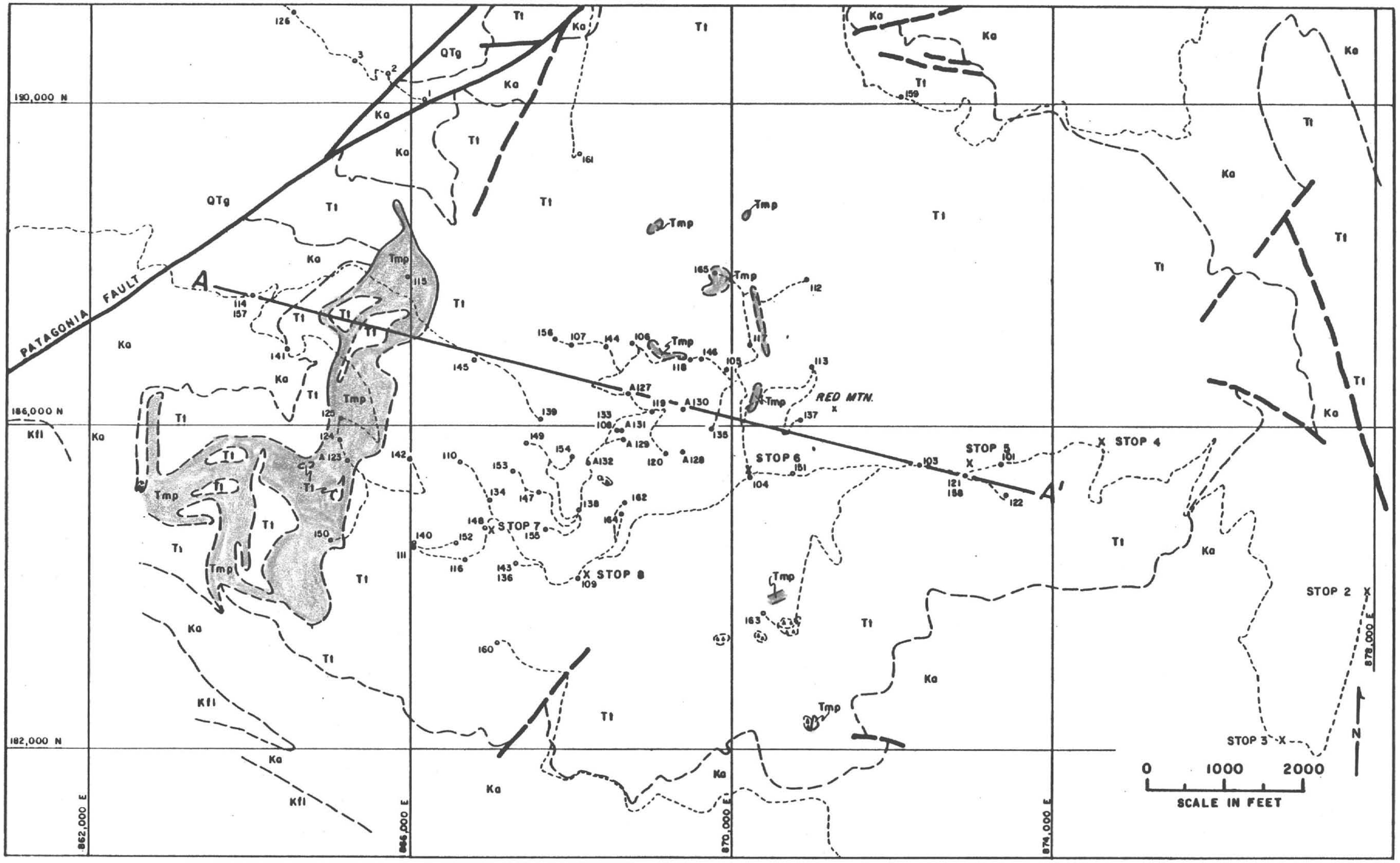


Fig. 1. Index map showing the location of the Red Mountain porphyry copper deposit. After R.M. Corn, Economic Geology, Vol. 70, No. 8, Dec. 75



EXPLANATION

QTg	GRAVELS
Tmp	PORPHYRY UNIT: porphyritic rocks – mainly quartz monzonite to granodiorite compositions
Tt	TUFF UNIT: mainly rhyolite and dacite tuffs, flows and breccia altered, may correlate with Gringo Gulch volcanics of Paleocene (?) age, Drewes (1971 A)
Ka	ANDESITE UNIT: mainly andesite and trachyandes flows, breccias, sills and dike, part of Trachyandesite or Dorelte unit of upper Cretaceous age mapped by Simons (1974)
Kfl	FELSITE-LATITE UNIT: mainly volcanic conglomerates and breccias silicified tuffs and flows, latite dikes and sills, includes interlayered andesite near top.

FAULTS

UNIT CONTACTS

ROADS

COLLAR LOCATION & NO. DRILL HOLE

BRECCIA

Fig. 2. Generalized surface geologic map of Red Mountain, Arizona.

Modified after D.L.E. Huckins, 1975.

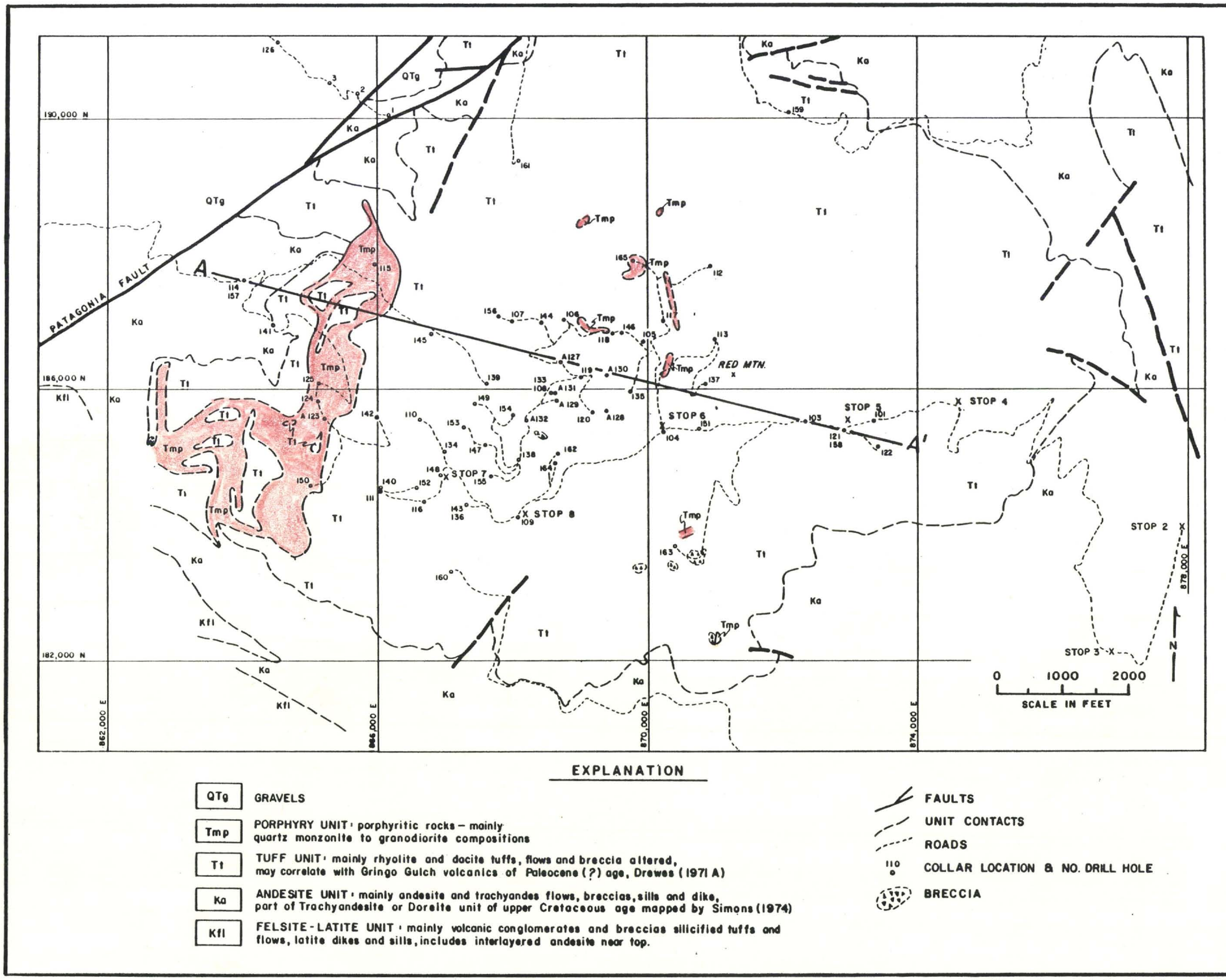


Fig. 2. Generalized surface geologic map of Red Mountain, Arizona.

Modified after D.L.E. Huckins, 1975.

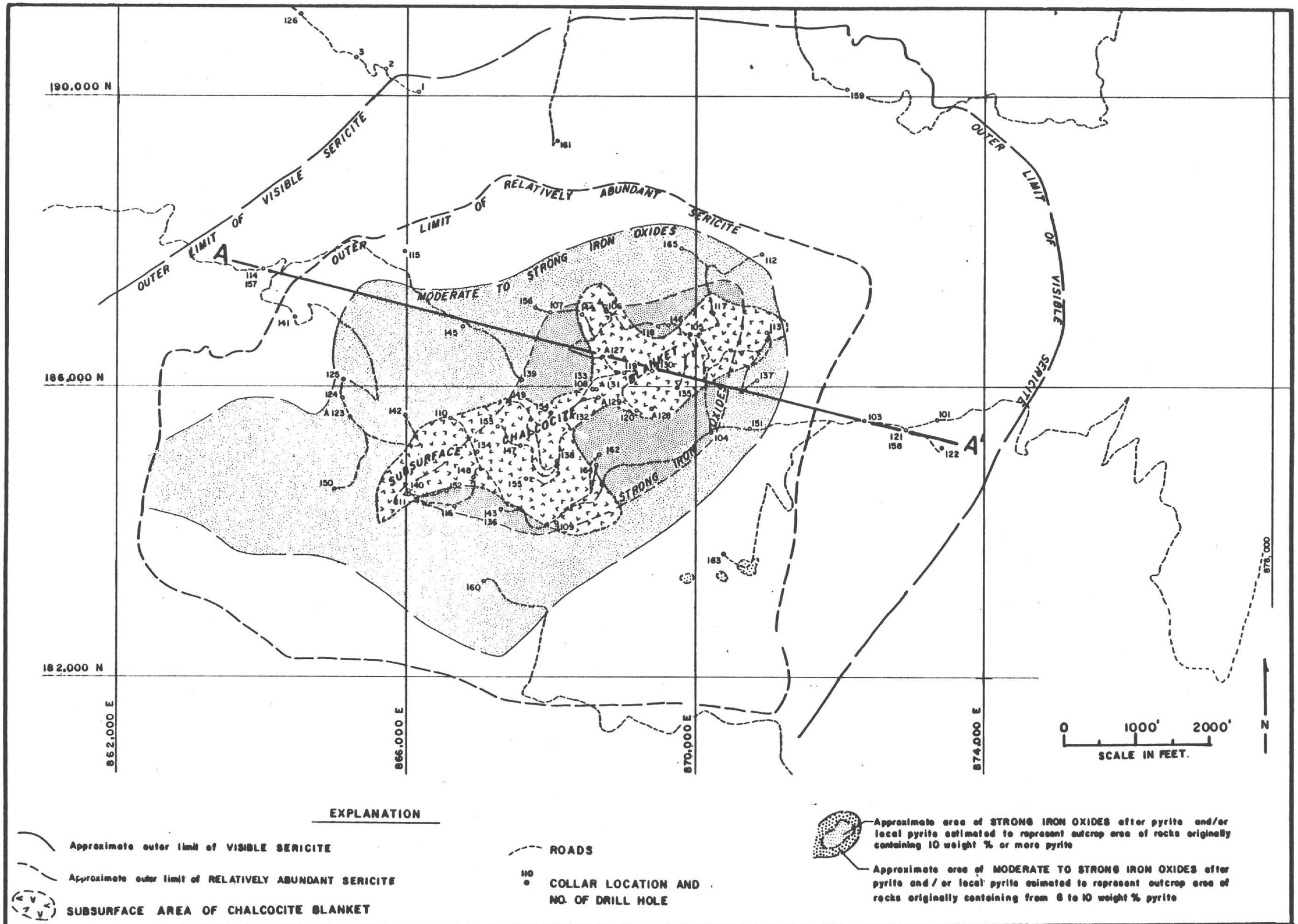


Fig. 3. Generalized surface alteration map of Red Mountain, Arizona.

Modified after D.L.E. Huckins, 1975.

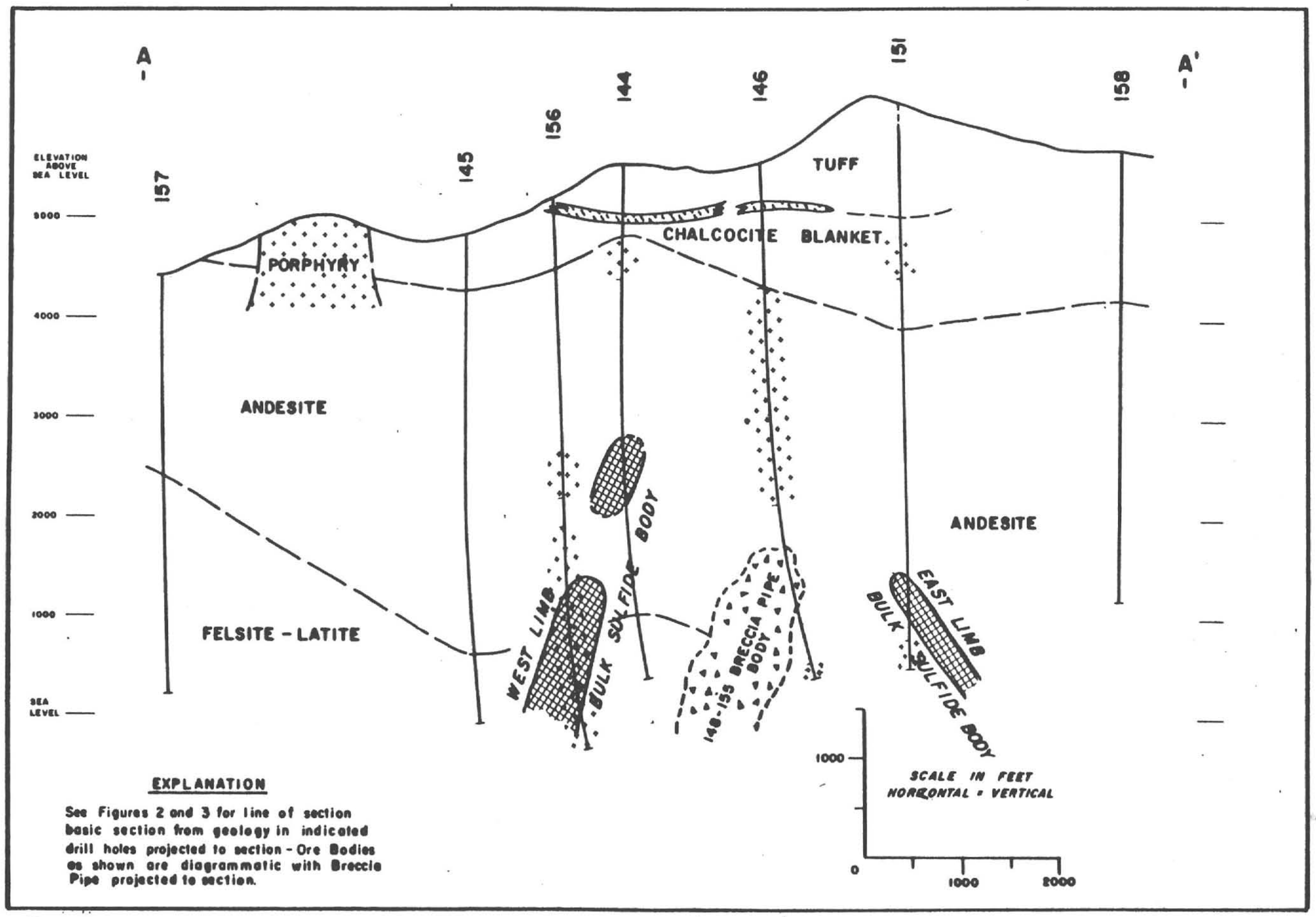


Fig. 4. cross—section A—A'. looking northeasterly, diagrammatically showing geology at Red Mountain, Arizona .

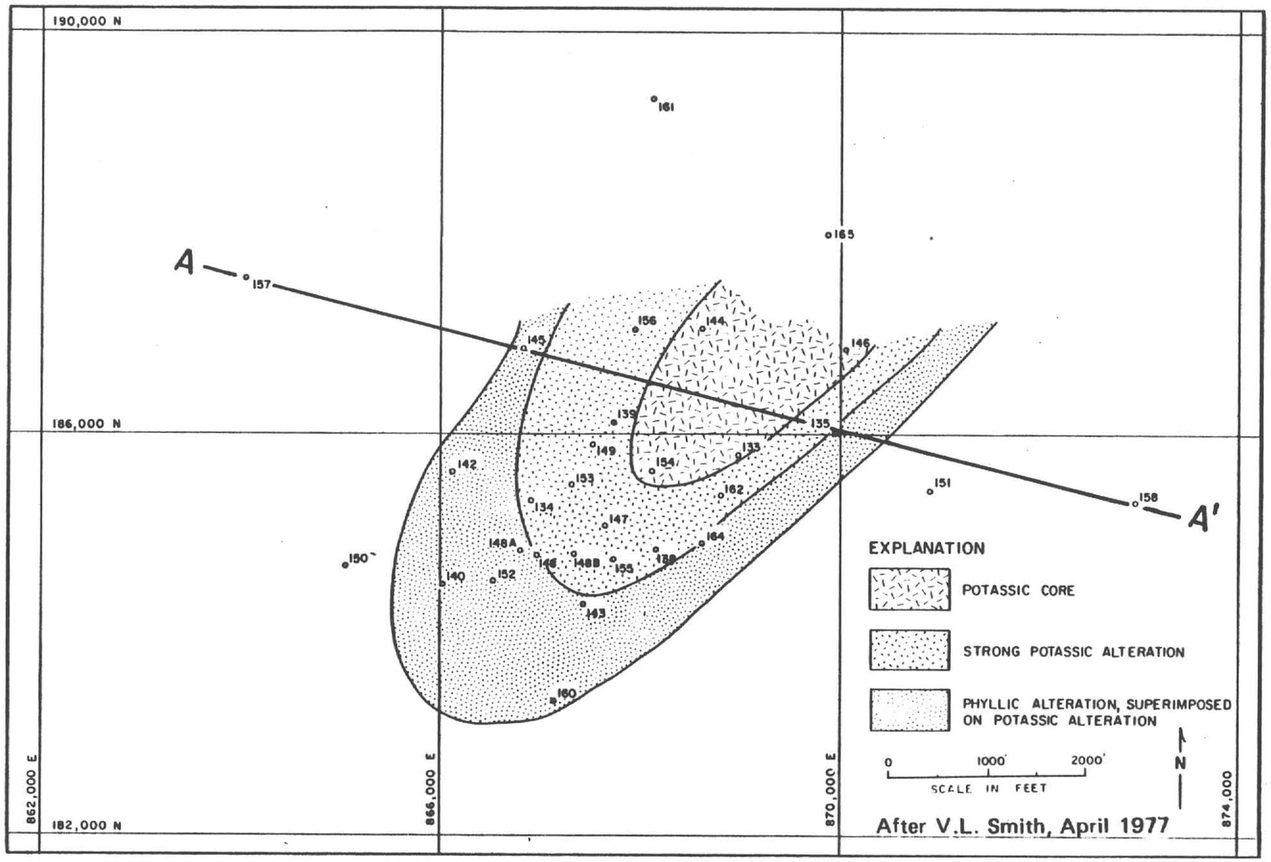


Fig. 5. Map showing silicate alteration between elevations 2,000' and 2,500' at Red Mountain, Arizona. Developed from petrographic study of thin sections from selected holes.

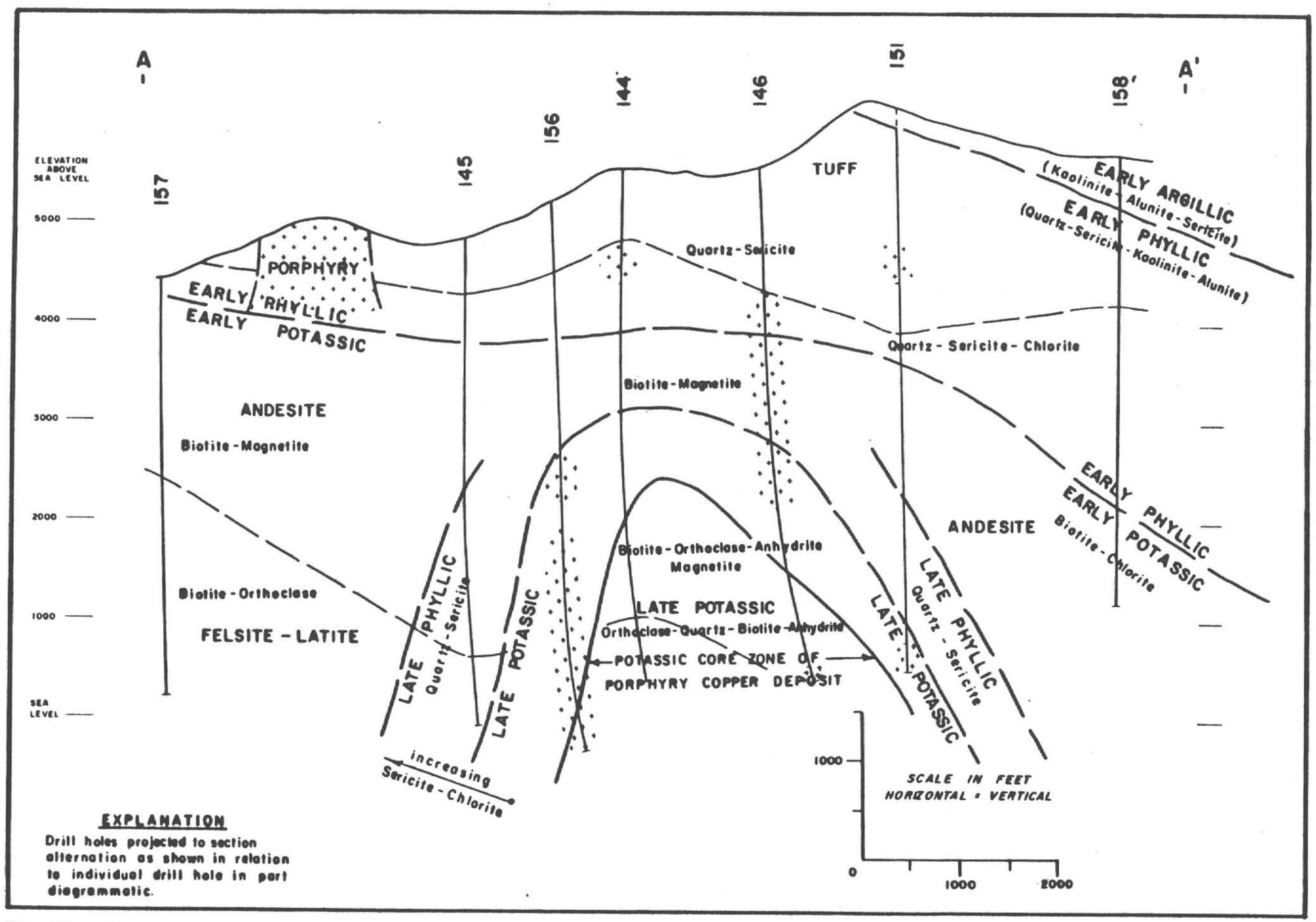


Fig. 6. Cross section A–A′, looking northeasterly, diagrammatically showing silicate alteration at Red Mountain, Arizona.

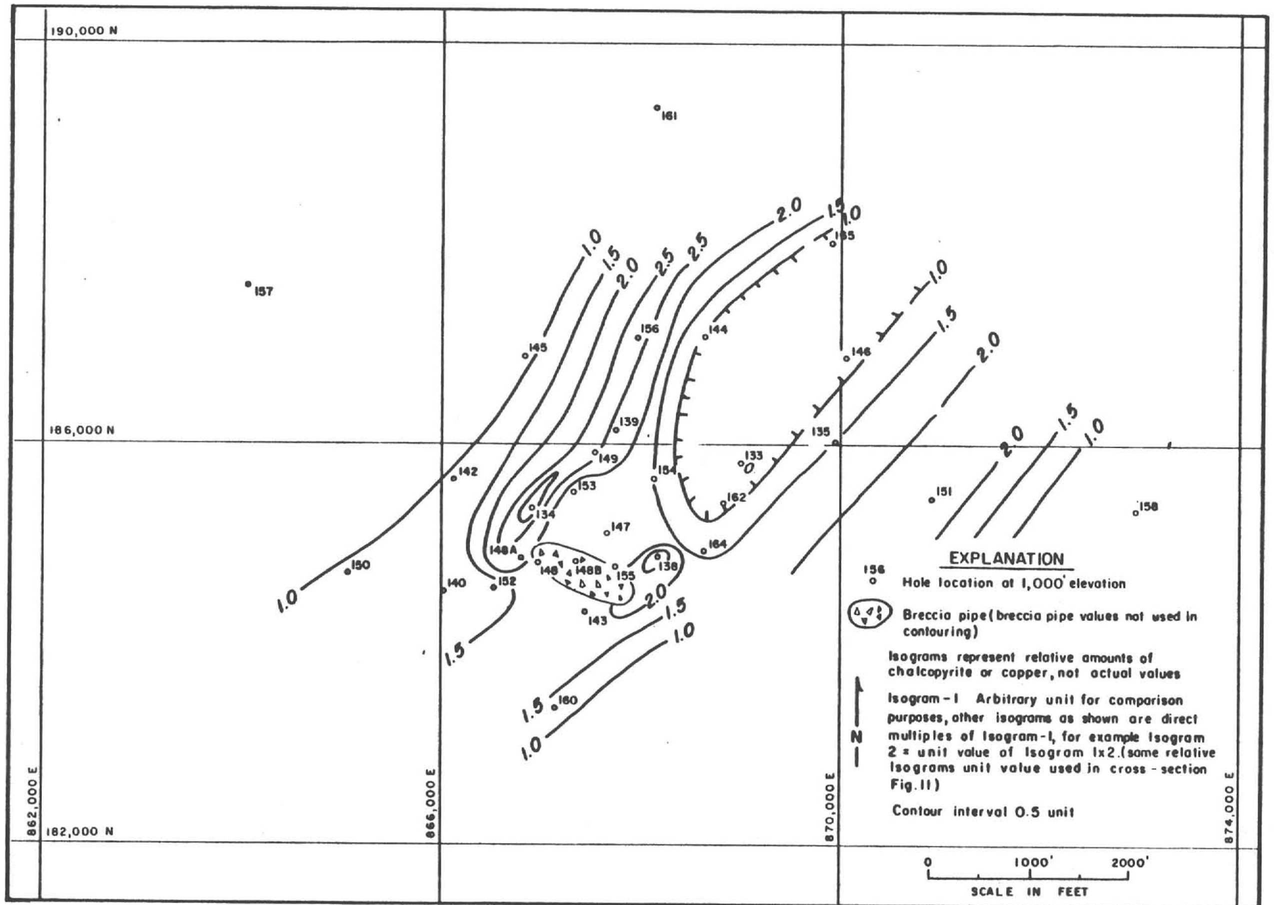


Fig. 7. Map showing relative chalcopyrite distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

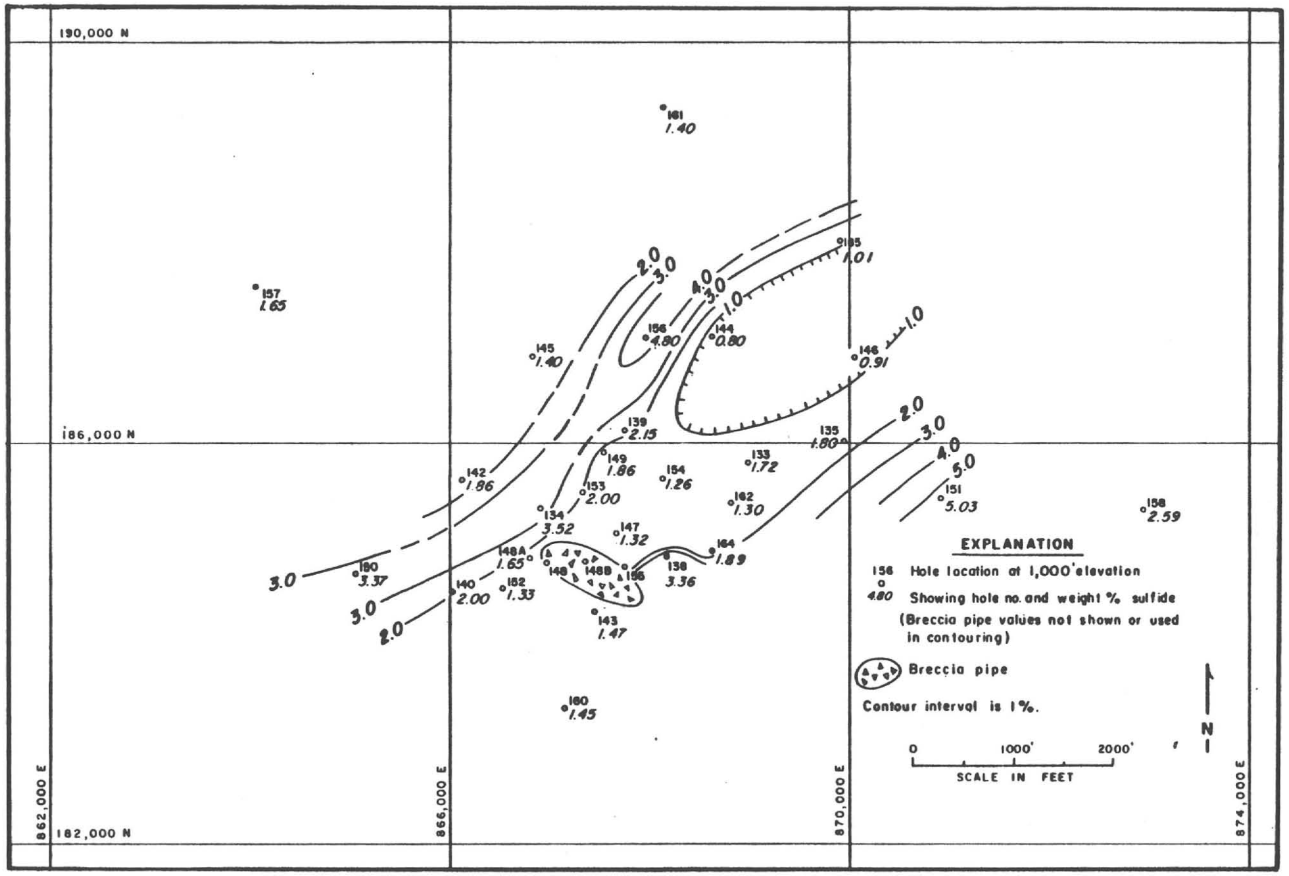


Fig. 8. Map showing total sulfide distribution between elevations 500' and 1,500' at Red Mountain, Arizona.

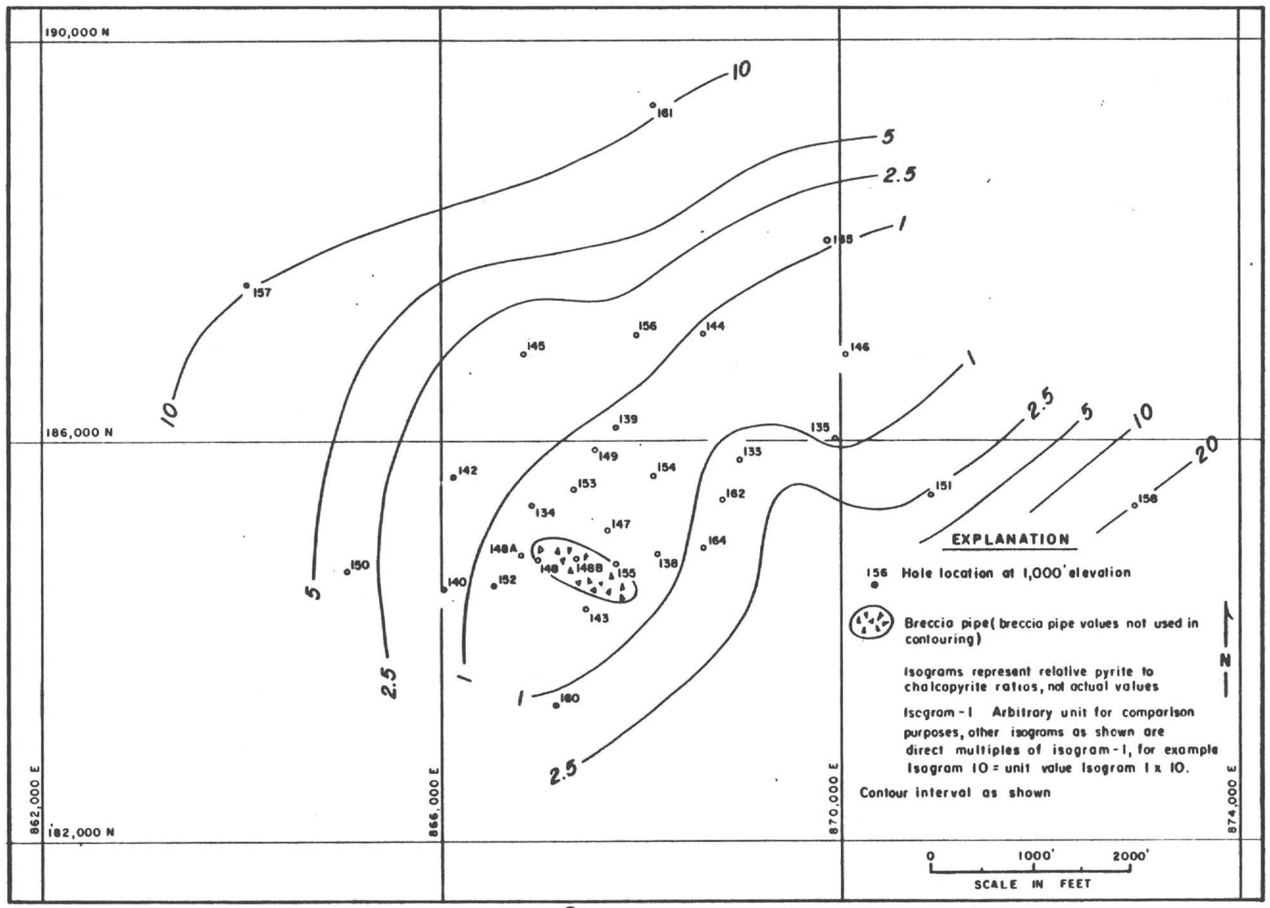


Fig. 9. Map showing relative pyrite / chalcopyrite ratios between elevations 500' and 1,500' at Red Mountain, Arizona.

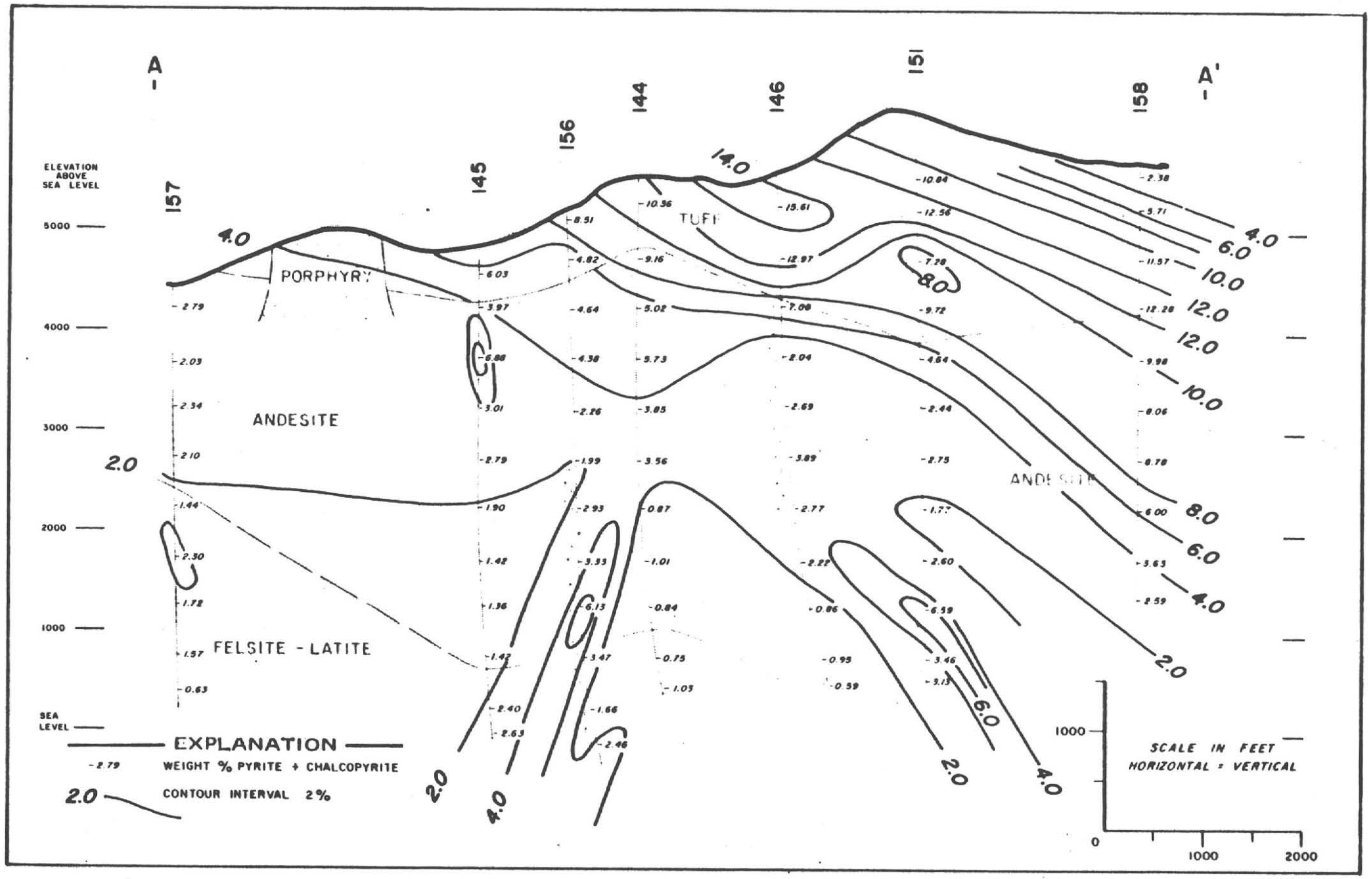


Fig. 10. Cross section A–A', looking northeasterly, showing total sulfide distribution at Red Mountain, Arizona.

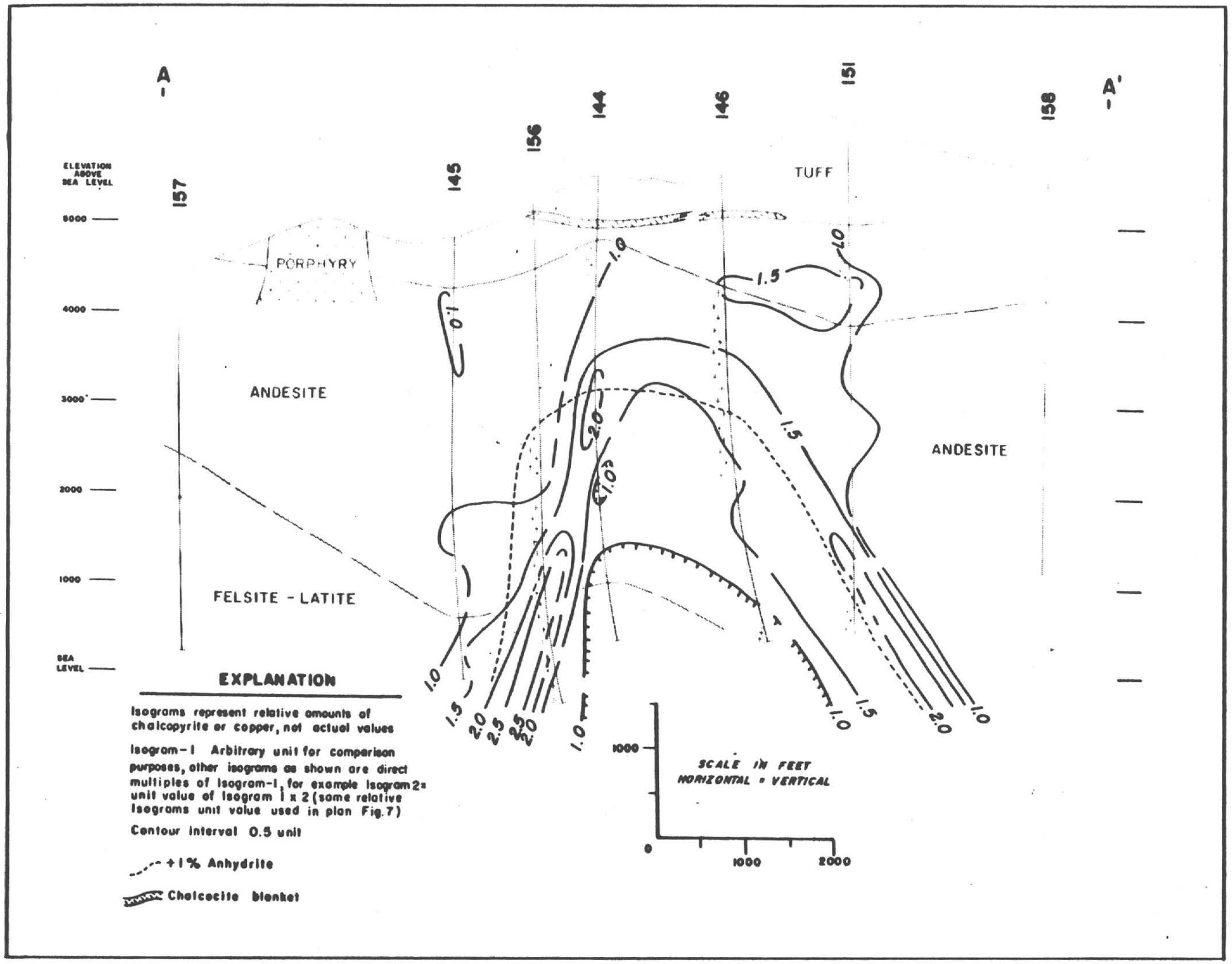


Fig. 11. Cross section A–A', looking northeasterly, showing relative chalcopyrite and anhydrite distribution at Red Mountain, Arizona.

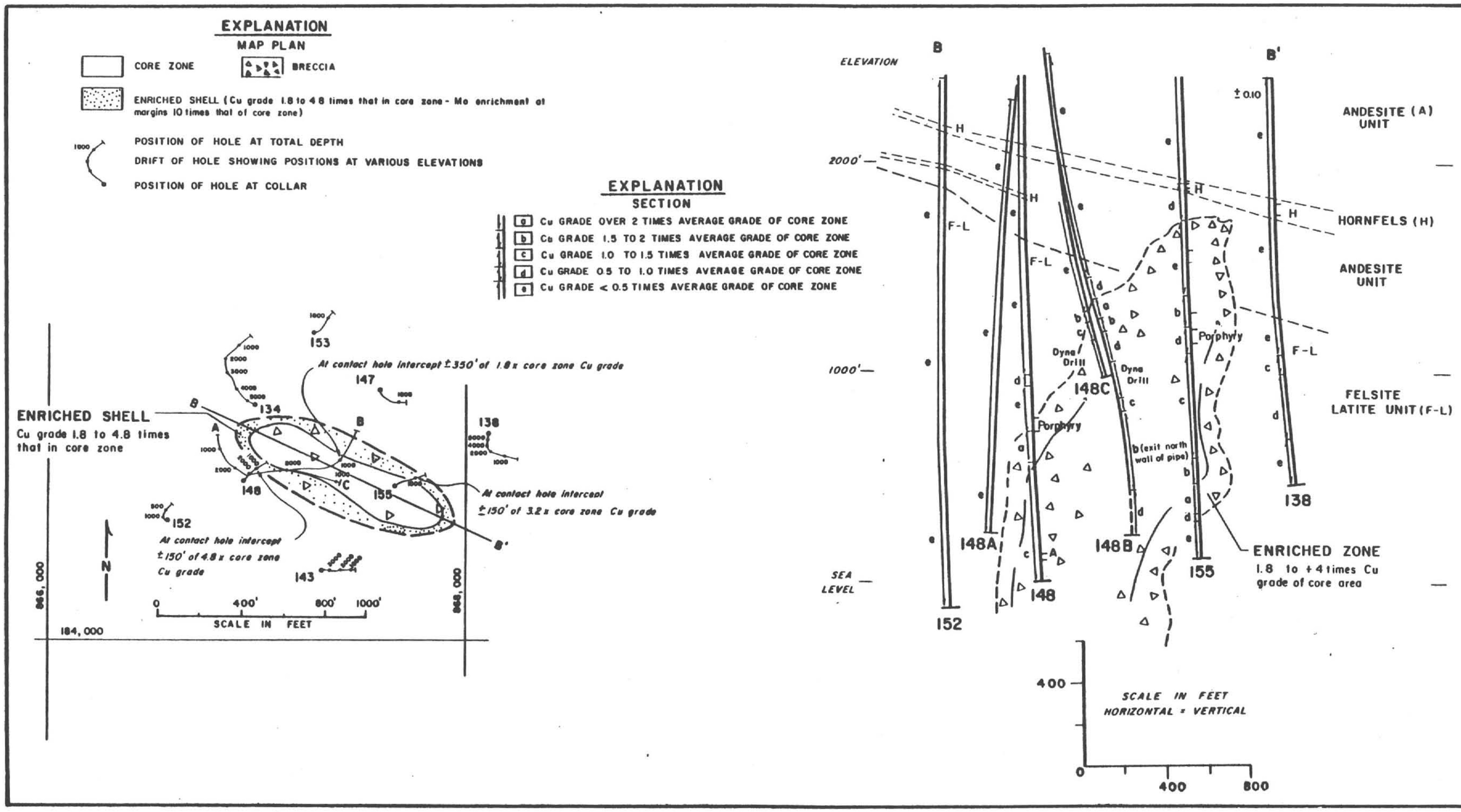


Fig. 12. Plan map and diagramatic cross section, looking northeasterly 148—155 breccia pipe at Red Mountain, Arizona.

P.O. Box 25861
Oklahoma City, OK 73125
September 5, 1985

Dr. Francis G. Stehli, Chairman
Science Advisory Committee
DOSECC, Inc.
College of Geosciences
University of Oklahoma
Norman, Oklahoma 73019

Re: Preliminary Scientific Investigations for Continental Scientific Drilling Program Red Mountain, Arizona

Dear Dr. Stehli:

Enclosed you will find a report describing the preliminary scientific investigations needed to site proposed Continental Scientific Drilling at Red Mountain, Arizona. The report has been prepared by the Panel of Geoscientists identified by the Ad Hoc Task Group for Red Mountain of the CSDC's Panel on Mineral Resources (PMR) to develop a program for Red Mountain. A directory accompanying this letter identifies members of the Panel of Geoscientists, the Ad Hoc Task Group for Red Mountain and the Panel on Mineral Resources of the CSDC.

Red Mountain, Arizona was selected by the CSDC as the drilling target most likely to reveal scientific information about deep crustal processes attending the emplacement of porphyry copper and related deposits (CSDC, 1984, Minerals Resources: Research Objectives for Continental Scientific drillings, p 23-28.) The Preliminary Scientific Investigations Report represents the culmination of nearly four years of consideration, effort and work by PMR to bring the project to the proposed investigative stage.

Kerr-McGee Corporation, owner of the property, has made the property, drill cores and basic geologic record resulting from its investigation available to the Continental Scientific Drilling Program. This includes cores resulting from 185,000 feet of drilling in 72 holes. Twenty-five holes are over 5,000 feet deep, the deepest being 5,790 feet. The scientific community is fortunate that Kerr-McGee has made this core available; and we should take advantage of this unique opportunity.

The report outlines a comprehensive scientific investigative program of geology, geochemistry and geophysics to site proposed deep drilling at Red Mountain. In accomplishing the siting objective, the studies are expected to add materially to the scientific understanding of hydrothermal processes within the continental crust.

We trust the Science Advisory Committee to DOSECC will favorably consider and support the program recommended in the report.

Yours truly,

For the Ad Hock Task Group for
Red Mountain

James J. Quinlan, Co-Chairman

Maurice A. Chaffee, Co-Chairman

For The Panel on Mineral Resources
Continental Scientific Drilling Committee

J. James Eidel, Chairman

Charles Meyer, Member

JJQ:bw

Enclosure

cc: G.A. Barber
W.W. Hay
Barry Raleigh

CONTINENTAL SCIENTIFIC DRILLING COMMITTEE
PANEL AND GROUP DIRECTORY
FOR
RED MOUNTAIN, ARIZONA

Panel on Mineral Resources of CSDC

James J. Eidel - Illinois State Geological Survey, Chairman

G. Arthur Barder - DOSECC, Inc.
Philip M. Bethke - U.S. Geological Survey, Reston
George H. Brimhall, Jr. - University of California, Berkeley
C. Wayne Burnham - Pennsylvania State University
Robert O. Fournier - U.S. Geological Survey, Menlo Park
William C. Kelley - University of Michigan
J. David Lowell - Private Consultant (until May 1984)
Charles Meyer - University of Arizona
John H. Schilling - Nevada Geological Survey (until June 1982)
Brian J. Skinner - Yale Univesity
Richard K. Traeger - Sandia National Laboratories
Donald E. White - U.S. Geological Survey (until June 1982)

Ad Hoc Task Group for Red Mountain

Maurice A. Chaffee - U.S. Geological Survey, Denver, Co-Chairman
James J.Quinlan - Kerr-McGee Corporation, Co-Chairman

George D. Christiansen - Kerr-McGee Corporation, Member
Paul I. Eimon - Pioneer Nuclear, Inc., Member
Frederick T. Graybeal - Asarco, Inc., Member
Richard H. Merkil - Arco Exploration, Member
Charles Meyer - University of Arizona, Member
Roland B. Mulchay - Private Consultant, Member

George H. Brimhall, Jr. - University of California, Berkeley, Observer
C. Wayne Burnham - Pennsylvania State University, Observer
J.D. Corbett - University of Utah Research Institute, Observer
George H. Davis - University of Arizona, Observer
Fleetwood Koutz - Asarco, Inc., Observer
Albert S. Johnson - DOSECC, Inc., Observer
Spencer R. Titley - University of Arizona, Observer

Panel of Geoscientists for Red Mountain

Robert J. Bodnar - Virginia Polytechnic Institute
George H. Brimhall, Jr. - Univeristy of California, Berkeley
C. Wayne Burnham - Pennsylvania State University
R. F. Butler - University of Arizona
Maurice A. Chaffee - U.S. Geological Survey
J.D. Corbett - University of Utah Research Institute
Paul E. Damon - University of Arizona
George H. Davis - University of Arizona
Kevin Furlong - Pennsylvania State University
Charles Meyer - University of Arizona
Hiorshi Ohmoto - Pennsylvania State University
James J. Quinlan - Kerr-McGee Corporation
Spencer R. Titley - University of Arizona