UTAH
MILLARD
CAROLINE HUNT TRUST ESTATE

15-30 CHTE
API 43-027-90003

30-24s-6w SL
WHITE SAGE FLATS
GT

El: 5711 KB.
Contr: Loffland. Spud 3-23-78. 20 @ 136, 13 3/8 @ 1218, 9 5/8 @ 5619. Ran DIL, SONL, TMPL, GR. 8021 TD. Non-productive, to be used as temp observation hole. Comp 10/1/79.

UT1-062780

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GL01532

13-15s-12w SL
DRUM MOUNTAIN
AREA S

UTAH
MILLARD
PHILLIPS PETROLEUM
NW/c 2340s 1092e.

1 Drum Mountain (Strat Test).
API 43-027-90014 (PI)

2000. El: 5285 KB.
(Init class chgd fr U).
Contr: Hiddleston. Spud 12-13-80, 7 @ 287, drld to 870, stk DP, could not rec, 1 tbg @ 840, TD 870 (FM unknown). ...Geothermal temperature observation well, comp 12-21-80.

UT1-032781

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UTAH
MILLARD
UNION OIL OF CALIF 14-29 CFSU
W/4 300n 330e.

29-25s-6w SL
COVE FORT GD

(7-20-79 BK).
Spud 6-25-79, 20 @ 225, 13 3/8 @ 1240, drld to 2620, ran ES, TMPL, TD 2620. ...D & A 7-29-79.

UT1-083179

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UTAH
MILLARD
GETTY OIL
N/4 990s 330e.

52-21 KGRA

21-17s-9w SL
ROOSEVELT HOT
SPRINGS SUS

(2-3-78 BK).
Contr: Coastal #2. Spud 2-3-78, drld to 6200 (approx), ran logs, drld to 7500 (approx), ran ES, TMPL, TD 7500 (approx).
...Sus 5-10-78.

UT4-033079

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GOETHERMAL WELL LOGS AVAILABLE FROM PETROLEUM INFORMATION

Petroleum Information's Well Log Service has available for purchase electrical well logs on more than 80 geothermal wells in nine states. Logs on wells in California may be purchased from West Coast Well Log Service, Box 9279, 4300 Easton Drive, Bakersfield, California 93389. Phone is (805) 327-5393. Logs for all other wells may be ordered from Rocky Mountain Well Log Service, 333 W. Colfax Avenue, Suite 10, Denver, Colorado 80202, phone (303) 893-2771; or from Electrical Log Services, 500 N. Baird Street, Midland, Texas 79701, phone (915) 682-0591. Reference numberes listed should be used when ordering all logs. The log list will be published periodically and expanded as new geothermal logs become available.

UTAH

MILLARD COUNTY

Union Oil of California
#14-29 Cove Fort Sulphurdale
Field: Wildcat
Sec: 29-25S-6W

K4680Z	s-di-sfl	1241-2462
K4681S	s-c-neu-for-den	1241-2468
K4681W	s-temp	230-2464
K4681X	s-cont-dip	1246-2466
K4681Y	s-dir	1246-2068
HC1371A	hc	35-2620
HC1371B	hc	35-2620

Union Oil of California
#31-33 Cove Fort Sulferdale Unit
Field: Cove Fort
Sec: 33-25S-6W

K2310Z	s-2-il-11	1675-5200
K2311S	s-c-neu-for-den	1726-5206
K2536S	s-temp	40-5207
K2536W	geo-temp-tracer	20-5205
K2971W	s-con-dip	1735-5207
K2971X	s-con-dip	1735-5207
K4711W	fluid travel	20-5205
HC1371E	hc	50-5221
HC1372A	hc	50-5221

UTAH
MILLARD
CAROLINE HUNT TRUST ESTATE
nw sw

15-30 CHTE
API 43-027-90003

30-24s-6w SL
WHITE SAGE FLATS
GT

El: 5711 KB.
Contr: Loffland. Spud 3-23-78. 20 @ 136, 13 3/8 @ 1218, 9 5/8 @ 5619. Ran DIL, SONL, TMPL, GR. 8021 TD. Non-productive, to be used as temp observation hole. Comp 10/1/79.

UT1-072580

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AREA
UT
Millard
Forminco

UNIVERSITY OF UTAH
RESEARCH INSTITUTE
EARTH SCIENCE LAB.

FORMINCO, INCORPORATED

GEOTHERMAL SULFUR RECOVERY PROJECT

The prime objective of Forminco, Inc. is to develop the proven geothermal and mineral reserves on their property at Sulphurdale, Utah into an agri-industrial complex.

This objective has been made possible because on December 31, 1979 Forminco, as per their contractual agreement with Union Oil Company, has acquired all the geothermal rights, including wells et al which were owned by that company. Accordingly, it is Forminco's intent to operate these existing wells to provide hot water for a proposed gasohol and sulfur recovery plants and thereafter to develop greenhouse agriculture, food processing and other industrial processing and space heating operations on their property.

To date, Forminco has not been an operating entity but rather had been actively engaged in the research, development and identification of the various natural resources present on their 18,000 acres of property in Beaver and Millard Counties. Although there had been a minimal effort during the past three years to market their product Sulphursoil, it has now become apparent, through industry acceptance and profitable pending contracts, that a large scale commercial marketing effort is justified. The only other operating venture of the company, which proved economically unprofitable because of artificially low prices, involved the production and sale of fluorspar.

Therefore, Forminco believes that the substantial reserves of sulfur and sulphursoil, the acquisition of the geothermal hot water, the existing grinding mill, production facilities and rolling stock and the location of their real property on the intersection of Interstates 15 and 70, combine to enable a major development of these resources to be realized.

To that end, Forminco has concluded or will soon conclude the following agreements:

1. As stated above, Forminco has acquired all the geothermal rights and holdings of the Union Oil Company. Essentially, there are three production and one injection well available for immediate use. Twenty-seven potential well sites have been identified and future development of these is under consideration.

2. The R & R Energies, Inc. of East Layton, Utah has entered into an agreement to purchase 250 MM BTUs from our well for use in their gasohol plant. An equity participation by Forminco at no cost to them is also a part of the agreement. A return of $100,000 to $250,000 per year has been projected.

3. The R & R Energies, Inc. will also contract with Forminco to perform all the construction required to establish their facility on Forminco's property.

4. Forminco has acquired a license to the Thermochem process for abstracting sulfur from sulfur ore. This is a proven technology which produces 99.6-99.85% pure sulfur.

5. Forminco is negotiating with Morris-Knudsen Engineering Company to engineer, construct and operate the sulfur reclamation plant. Needless to say, a performance bond will be required as a condition of the contract.

6. Forminco has concluded a 200,000 ton sulfur contract with L/USUF Alikam[illegible] Sabby International to deliver sulfur of a 99.6% min. grade at the rate of 4000-10,000 tons per month at a price of $90.00 per ton F.A.S., Stockton, California.

7. Forminco has entered into several sulphursoil sales contracts from which they should realize between $200,000 - $300,000 in sales during 1980.

Documents and reports supporting the above are included as exhibits.

Forminco is now preparing an application to the D.O.E. for guaranteed loans to enable the aforementioned developments to move forward expeditiously.

FORMINCO, INCORPORATED

GEOTHERMAL SULFUR RECOVERY PROJECT

1. Forminco owns approximately 25 square miles of properties in Beaver and Millard Counties, near the village of Cove Fort in the state of Utah. In addition, it leases a similar property in Thermopolis, Wyoming.

2. Based upon revaluation of results reported for a diamond drilling program carried out under Clarence King in 1952 and a rotary drilling campaign under Donald Podesta in 1967, ore reserves, classified as Drill Measured are estimated to be 1,505,000 metric tons containing 302,000 metric tons of sulphur in five deposits at an average grade of 20.1% elemental sulphur. The Thermopolis property contains a calculated additional 325,856 tons of sulfur, of an average grade of 31.4%.

3. King's reserve estimates, which can only partially be confirmed because drill logs and individual assay records are not available, were reported as 3,900,000 short tons containing 663,868 metric tons of sulphur at an average grade of 18.8% elemental sulphur after adjusting grades apparently reported as total sulphur.

4. Eight sulphur-bearing exposures which have not been evaluated but may contain additional reserves are known on the properties.

5. We consider that there is a high degree of probability of the presence of 2,500,000 metric tons containing 500,000 metric tons of sulphur on the Cove Fort lands and a reasonable

possibility of finding an additional 200,000 metric tons of sulphur.

6. A process for recovering a high purity sulfur from volcanic and fumarolic source materials is owned by Teck Corporation of Canada, to be licensed to Forminco, Inc. The Colorado School of Mines Research Foundation, Inc. at Golden Colorado developed a pilot plant which lead to plant design and engineering, and commercial feasibility analysis during 1968-69.

7. Subject to redesign for geothermal application, it is anticipated the capital requirements for a plant to treat 1000 metric tons per day to be in the range of three to four million dollars, direct operating costs to be less than $4 U. S. per metric ton treated, recovery to be 94% and product grade to be 99.9% sulfur or better.

8. The sulfur markets are currently strong, and might be described as in a period of acute shortage. Discussions with major sulfur users and key brokers indicate the current favorable market conditions are expected to continue through 1981.

   Verbal agreement has been reached with the government of India through Sabby International of Ontario, Canada. Terms are for 200,000 tons minimum, $90 U. S. per ton F.A.S. Stockton, California, backed by an irrevocable international letter of credit.

9. We believe that the Forminco sulfur recovery operation at the 1000 MT/day rate from estimated reserves will generate direct

operating profits per ton of sulfur produced in the range of $30 per ton, based upon a contract price of $90 F.A.S. Stockton, California.

10. The total reserves of 302,000 metric tons of contained sulfur at 95% recovery would produce 286,900 tons of 99.982% sulfur product and generate operating profits in the range of $8,600,000 before amortization and taxes. Based upon these reserves, the Cove Fort operation would have a life of four and one quarter years. However, if reserves quantified as highly probable are finally proven, the facility would have an operating life of 7.4 years, and a profit potential of $14,250,000.

11. If properly designed and constructed, the sulfur processing plant could be reassembled on Forminco's Thermopolis leasehold, or another sulfur property where adequate geothermal fluids are identified, thereby producing further profits.

ESTIMATED CAPITAL REQUIREMENTS

1000 metric ton per day thermochem plant, including design, engineering, and installation		$3,500,000
Pre-production		
Stripping and Mining test	60,000	(Completed)
Drilling and Sampling	50,000	(Completed)
Haulage Prod.	100,000	(Completed)
Water	40,000	(Completed)
Tailings disposal	20,000	(Completed)
Property supervision	45,000	45,000
Working Capital		500,000
Interest		200,000
Contingency		255,000
	Total	$4,500,000

DIRECT OPERATING COSTS

			Daily	Monthly	Annual (1)
(2)	Labor. 136 hrs. per day	=	$ 816	23,664	285,600
(3)	Overhead on Labor	=	408	11,832	148,920
(4)	Fuel per 24 hour day	=	100	2,900	35,000
(5)	Power per 24 hour day	=	150	4,350	52,500
(6)	Supplies per 24 hour day	=	40	1,160	14,000
(7)	Reagent, $3.00 X 188 ton	=	564	16,356	197,400
(8)	Maintenance items per 24 hour day	=	300	8,700	105,000
(9)	Planning Contingency	=	122	3,538	42,700
	Sub-total		$2,500	$72,500	$881,120
(10)	Tons Production		188	5,452	65,800
	Direct Cost Per Ton		13.30		
(11)	Mining Cost Per Ton		2.50		
(12)	Total Cost Per Ton		15.80		

Assumptions

(1) Assumes Operating on a 350 day year, 29 day month.

(2) Historic cost of labor, 1979, $6 per hour.

(3) Fringe benefits equal 28% of base labor charge ($79,900)
Two Operations Supervisors, 22% of base labor charge ($62,800)

(4) Savings due to Geothermal operation estimated at $900 per day, $315,000 per year.

(5) Consumer Price Index Adjusted.

(6) Consumer Price Index Adjusted.

(7) Industrial Raw Material Price Index Adjusted.

(8) Historic cost while operating flotation mill.

(9) Contingency Reserve.

(10) Based upon plant design of 1000 short tons of feed X 20% sulfur X 94% recover = 188 short tons of sulfur per 24 hour day.

(11) Historic cost of Forminco based upon 25,000 ton production runs, single shift per day.

(12) Reference base P.25 Thermochem Industries, Ltd.
Feasibility Report, dated March 6, 1969.

OPERATING PROFIT PROJECTIONS

	Per Ton	Day	Month	Year
Tonnage Production	1	188	5452	65,80(
Revenue ($90 U.S. Per Ton F.A.S.)	$90.00	$16,920	$490,680	$5,922,00(
Mining and Crushing (1)	$ 2.50	$ 470	13,630	164,50(
Processing (2)	13.30	2,500	72,512	875,14(
Rail Loading (3)	5.00	940	27,260	329,00(
Rail Freight (4)	25.00	4,700	136,300	1,645,00(
Management and Overhead (5)	2.00	376	10,904	131,600
Contingency (6)	12.20	2,294	66,514	802,760
Operating Costs	$60.00	$11,280	$327,120	$3,948.000
Gross Operating Profit (7)	$30.00	$ 5,640	$163,560	$1,974.000
% of Sales				33.3%
Return on Invested Capital (8)				43.9%
Payback Period (Years)				2.3 y

(1) 1000 Tons Per Day Capability

(2) Estimated Direct Operating Costs

(3) Includes hauling sulfur by truck to Black Rock rail siding, 24 miles to the West.

(4) Rail freight to Stockton, California, and delivery to dockside or client storage area.

(5) Allocated at $2 per ton.

(6) 20% contingency reserve.

(7) Before taxes and amortization.

(8) Project capital requirement of $4,500,000.

FORMINCO, INC.

TARGET CASH FLOW

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Profit after taxes	($580,000)	$ 849,000	$1,080,000	$1,300,000	$ 847,000
Depreciation	(+570,000)	+570,000	+570,000	+570,000	+570,000
Depletion	0	+270,000	+350,000	+410,000	+500,000
Capital Purchases	0	(100,000)	(200,000)	(200,000)	(200,000)
Principal Payments	0	(1,000,000)	(1,500,000)	(2,000,000)	(1,500,000)
Net Cash Flow	$ (10,000)	$+589,000	+300,000	+80,000	+217,000
Cumulative Cash Flow	$ (10,000)	$+579,000	+879,000	+959,000	+1,176,000

FORMINCO TARGET FORECAST

OPERATING PROJECTIONS YEARS 1-5

		YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
REVENUE						
Sulphursoil/ Acid-Iron	(1)	$ 225,000	$ 300,000	$ 400,000	$ 500,000	$ 600,000
Construction	(2)	200,000	100,000	100,000	100,000	100,000
Geothermal Sales	(3)	0	105,000	150,000	200,000	250,000
Geothermal Rentals	(4)	30,000	30,000	30,000	30,000	30,000
Sulfur Recovery	(5)	900,000	5,922,000	6,000,000	6,000,000	6,000,000
Total		$1,355,000	$6,457,000	6,680,000	6,830,000	6,980,000
EXPENSES						
Sulphursoil Acid-Iron	(6)	25,000	50,000	60,000	80,000	100,000
Construction	(7)	140,000	70,000	70,000	70,000	70,000
Geothermal Sales	(8)	0	0	0	0	0
Geothermal Rentals	(9)	0	0	0	0	0
Sulfur Recovery	(10)	800,000	3,948,000	4,000,000	4,000,000	4,000,000
Direct Expenses		$965,000	$4,068,000	$4,130,000	$4,150,000	$4,170,000
Gross Operating Profit		$390,000	$2,389,000	$2,550,000	$2,680,000	$2,810,000
Interest	(11)	400,000	700,000	550,000	400,000	150,000
Depletion	(12)	0	270,000	350,000	410,000	500,000
Depreciation	(13)	570,000	570,000	570,000	570,000	570,000
Net Profit		$(580,000)	+$849,000	$1,080,000	$1,300,000	$1,590,000
Taxes (48%)	(14)	0	0	0	0	743,000
Profit After Taxes		(580,000)	+$849,000	$1,080,000	$1,300,000	$847,000

ASSUMPTIONS

FORMINCO TARGET FORECAST

REVENUE

(1) Estimated 1980s sulphursoil and Acid-Iron Plus sales based upon historic sales growth and current commitments.

(2) Forminco's heavy equipment and construction capability will aid construction of $6.5 million Gasahol plant (R&R Energies)

(3) Revenues based soley upon contractual obligations between R&R Energies to buy hot water from Forminco.

(4) AMAX leases approximately 3,000 acres from Forminco at $10 per acre.

(5) Start-up period to produce 10,000 tons sulfur in 1980, thereafter according to plant design.

EXPENSES

(6) First two years sales (25,000 tons) is currently inventoried.

(7) Assumes 30% gross profit margin.

(8) Net sale with no expenses.

(9) Net lease with no expenses.

(10) Basic $600,000 direct cost, plus 200,000 start-up expense.

(11) Based upon Debt Amortization Schedule (attached).

(12) Depletion allowance of 22% of sales, maximum 50% of tax liability.

(13) Depreciation equals 7 year Straight Line, to reserve depletion.

(14) Based upon Tax Schedule (attached).

DEBT AMORTIZATION SCHEDULE

	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Beginning Debt	$2,000,000	$6,500,000	$5,500,000	$4,000,000	$2,000,000
Incremetal Debt	4,500,000	0	0	0	0
Debt Reduction	0	1,000,000	1,500,000	2,000,000	1,500,000
Net Year End Debt	6,500,000	5,500,000	4,000,000	2,000,000	500,000
Estimated Interest	400,000	700,000	550,000	400,000	150,000

TAX SCHEDULE

Beginning Tax Loss	$1,500,000	$2,080,000	$1,231,000	$ 151,000	$ 0
Incremental T.L.C.	580,000	0	0	0	0
Incremental I.T.C.	500,000	10,000	20,000	20,000	20,000
Profit Before Taxes	0	849,000	1,080,000	1,300,000	1,590,000
Ending T.L.C.	2,080,000	1,231,000	151,000	0	0
Ending I.T.C.	500,000	510,000	530,000	0	0
Taxes Paid	0	0	0	0	743,000

FORMINCO

HISTORIC OPERATING SUMMARY

Year Ending	6/30/79	6/30/78	6/30/77	6/30/76	6/30/75	6/30/74	TOTAL
(1) Revenues	$256,766	$193,635	$103,795	$100,142	$ 56,306	$ 201	$710,84
% Change	+33%	+86%	+3.6%	+78%			
(2) Operating Expenses	281,975	231,731	256,784	288,734	218,119	183,392	1,460,73
(3) Gross Operating Profit (Loss)	(25,209)	(38,096)	(152,989)	(188,592)	(161,813)	(183,191)	(749,89
(4) Asset Purchases	$3,923	$173,243	$164,859	$222,389	$280,282	$364,444	$1,209,14

1. Revenues primarily from agricultural fertilizer sales of Sulphursoil, and $18,000 Geothermal rental from Union Oil.
2. From Income Tax Returns. Asset Development, Sulphursoil Research.
3. Line 1 minus line 2.
4. Includes mining equipment and rolling stock, 200 ton per day flotation mill, Sulphursoil bagging plant, etc.

Annotated Resume

WAYNE A. PORTANOVA
58 RICHMOND HILL ROAD
GREENWICH, CONNECTICUT 06830

Education

1973-1975	HARVARD BUSINESS SCHOOL, BOSTON, MASSACHUSETTS Received Master of Business Administration with High Distinction, June 1975. Named Baker Scholar. Awarded first year honors. Elected to Century Club.
1967-1971	HARVARD COLLEGE, CAMBRIDGE, MASSACHUSETTS Received Bachelor of Arts degree in Economics, Magna Cum Laude, June 1971. Dean's List 4 years. Recipient Harvard College Scholarship and Army ROTC MS II outstanding cadet award.

Business Experience

1976-1980	ENERDYNE, LOS ANGELES, CALIFORNIA Co-founder and business manager of a privately funded research and development organization, focusing on advanced energy systems for powering electric vehicles.
1976-1980	FORMINCO, BEAVER UTAH Investor, Director, and Executive Vice President. Geothermal energy, sulfur fertilizers, and mineral asset development.
1975-1976 Summer 1974	GENERAL FOODS CORPORATION, WHITE PLAINS, NEW YORK Assistant Product Manager, Pet Foods Division, Product responsibilities included: Gainesburgers, Gravy Train, and Gaines Biscuits and Bits.
1971-1973	TRAVELERS INSURANCE COMPANY, NEW YORK, NEW YORK Field Representative in Group Department, sales and service of corporate accounts.

Associations

HARVARD-RADCLIFFE CLUB OF WESTCHESTER, Co-president.
MEAD SCHOOL FOR HUMAN DEVELOPMENT, Chairman of the Board.

I PERSONAL DATA

Name: Richard J. McComb

Address: 18 Sportsman Drive
Shelton, Connecticut 06484

Born: December 26, 1924

Place: New York City

Married: Wife - Marilyn - Children - 2 - Grandchildren - 2

II EDUCATION

Degree - B. Ch. E., New York University, 1947
Graduate Studies - Administrative Engineering
New York University, 1947-48
Public Relations - Publicity Institute of New York, 1952

III MILITARY EXPERIENCE

1943-1945 - United States Army
1st Lieutenant 15th Air Force
Military decorations: Air Medals, Purple Heart, Unit Citations, European Theatre of Operations

IV BUSINESS EXPERIENCE

1978-Present - Sales and Engineering Associate
McBar Associates, Incorporated
195 West Street
Waltham, Massachusetts

Duties: Design, development and sale of environmental test systems usually for military and special purposes. Provide computer based solutions for industrial and commercial problems. Electronic representative and specialist in instrumentation, microwave, power, and semiconductor systems.

1961-1978 - Vice President and Director - Deuterium Corporation
3 Corporate Park
White Plains, New York

Duties: Administrative: Develop sales proposals and make presentations, prepare feasibility studies, annual reports, SEC and government reports, new business development.

Engineering: Heavy water distillation process. Removal of sulfur contaminants from geothermal steam.

1963-1968 - Vice President and Director
Deuterium of Canada, Ltd.
Glace Bay, Nova Scotia

Duties: Liasion between management and engineering consultants during construction of heavy water plant. Negotiated contracts.

1963-1965 - Director, Member of Executive Committee and Organizer, Terra Chemicals International, Inc.

Duties: Participated in organizing, financing and development of a new fertilizer corporation which today is one of the leaders in the industry.

1958-1961 - President, manufacture's agency representing industrial, chemical and engineering corporations in New England.

Duties: Managed agency employing 5 salaried salesmen selling directly to customers. Trade show participation.

1949-1958 - Director of sales
Mitchell Bradford Chemical Company
Stratford, Connecticut

Duties: Recruited and trained salesmen in chemical sales, advertising and sales promotion. Trade show participation.

V MEMBERSHIPS

a. Technical Societies and Others

Atomic Industrial Forum
American Nuclear Society
Delegate for the United States to: International Atomic Energy Society, Symposium Heavy Water Reactors, Vienna, Austria, 1967.

b. Social

Huntington Historical Society
Huntington Garden Club

c. Civic

Past Chairman - Shelton Economic Development Commission
Past President - Connecticut Association of Municipal Development Commissions (CAMDC)
Member - Executive Committee, CAMDC
Member - Economic Advisory Group to Council of Governors
Corporator - Grittin Hospital, Derby, Connecticut
Director - Shelton Land Conservation Trust

d. Church

Past Vestryman - St. Paul's Episcopal Church
Huntington, Connecticut

Church (Con't.)

Episcopal Churchmen of Connecticut

e. Military

Military Order of Purple Heart
Veterans of Foreign Wars
American Legion

VI LISTINGS

Who's Who In The East - 1974-1975

VII OTHER ACTIVITIES - Current

a. Consultant to Running Brook Farm, Easton, Connecticut Development of large scale process for shredding and composting leaves into humus for commercial sale.

b. Developer - of Heritage Acres and Heritage Enterprises, Chatham, New Brunswick, Canada. Consists of 120 apartments expandable to 300 apartments. Also, projected motel and commercial development.

UNIVERSITY OF UTAH
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AREA
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K/Ar

K/AR AGES OF SILICIC VOLCANISM IN THE TWIN PEAKS/COVE CREEK DOME AREA, SOUTHWESTERN UTAH

STANLEY H. EVANS, JR.
HARRISON R. CRECRAFT
WILLIAM P. NASH
Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112

Located approximately twenty kilometers north of the Roosevelt Hot Springs Known Geothermal Resource Area is the Twin Peaks/Cove Creek Domes silicic volcanic center. Here approximately four cubic kilometers of rhyolite domes, obsidian flows and volcanoclastic deposits are exposed. The area lies in the southern portion of the Black Rock Desert graben, near the eastern margin of the Basin and Range province in west-central Utah (Fig. 1).

The silicic volcanic rocks in the Twin Peaks area were described by Haugh (1979), who proposed that the distribution of volcanics was related to ring dike fissures associated with a trap door Glencoe-type caldera collapse. Carrier (1979) undertook a gravity and heat flow study of the area and concluded that little or no subsidence had actually occurred. Present day heat flow values are near typical background for the Basin and Range (96 mW/m^2). Locally associated basalts have been studied by Condie and Barsky (1972), Best and Brimhall (1974), Hoover (1974) and Clark (1977). Local lacustrine limestones were described by Zimmerman (1961) and Clark (1977).

The work reported here was funded by the Division of Geothermal Energy, U.S. Department of Energy, contract No. DE-AC07-80ID12079, to Earth Sciences Division, University of Utah Research Institute with subcontract to the Department of Geology and Geophysics, University of Utah. The authors would also like to thank Dr. F. H. Brown, M. B. Sienkewicz, M. Jennison, N. Lundeen and B. Griffey for their assistance in running the Potassium/Argon Laboratory.

Constants Used:

$\lambda_\beta = 4.962 \times 10^{-10}\ yr^{-1}$
$\lambda_\epsilon = 0.581 \times 10^{-10}\ yr^{-1}$
$\lambda = 5.543 \times 10^{-10}\ yr^{-1}$
$^{40}K/K_{tot} = 1.167 \times 10^{-4}$ atom/atom

DISCUSSION

Volcanic activity in the Twin Peaks area produced a series of flows, domes and volcanoclastic deposits in an arcuate pattern as shown in Figure 1. No voluminous ash-flow deposits are presently exposed in the Twin Peaks field. However, small volumes of welded and non-welded ash deposits occur in the western part of the region (Haugh, 1979), and within and to the south of the area volcanic ash has been found interbedded in fluvial and lacustrine deposits which are contemporaneous with the rhyolitic volcanism. The restricted occurrence of these sedimentary sequences raise the intriguing question as to whether they are related to a cauldron lake. At present, this question remains unanswered. The occurrence of a hundred meter section composed predominantly of limestone within the area suggests an appreciable amount of subsidence with respect to the water level during its deposition. Drill hole logs (Carrier, 1979) confirm the presence of a greater than 100 meter sequence of lacustrine sediment elsewhere in the immediate area. The possibility of cauldron subsidence is indicated by the existence of a buried tuff chemically related to the Twin Peaks rhyolite system which was encountered in a drill hole ten kilometers south of any exposed silicic volcanic in the Twin Peaks area. The tuff has a minimum thickness of 80 m. A substantially larger eruptive volume than has been previously recognized (Carrier, 1979; Haugh, 1979) is probable based on this finding, and suggests that there may have been a greater degree of subsidence of the roof block than indicated by geophysical studies.

Clark (1977) considered the basalts in the area to be younger than the rhyolites. Basalt on the southwest slope of South Twin Peak is included as fragments within the rhyolite, indicating that basaltic activity commenced prior to the emplacement of South Twin Peak, the youngest rhyolite in the area. Basalts lie below, within and above the tuffaceous lacustrine sequence, indicating that basalts were erupted before, during, and after the silicic activity.

A north-south trending anticlinal arch which postdates the silicic volcanism, extends for over 10 km through the Twin Peaks area, uplifting and tilting basalts and limestones, most prominently just to the southeast of South Twin Peak. The sedimentary sequence is well exposed in the core of this anticline where it is capped by younger basalts.

Lipman and others (1977) presents two dates on silicic units from the Twin Peaks area. They date South Twin Peak at 2.33 ± 0.12 m.y. and obsidian from Cudahy Mine at 2.38 ± 0.15 m.y. Luedke and Smith (1978) report the previous dates plus two additional ones: 2.22 m.y. on material from northern Coyote Hills and 2.35 m.y. on South Twin Peak. The dates quoted by Luedke and Smith appear to have been calculated using old constants and they have apparently reversed sample locations for North and South Twin Peaks as the date reported in Lipman and others (1977) was for South Twin Peak, not North Twin Peak.

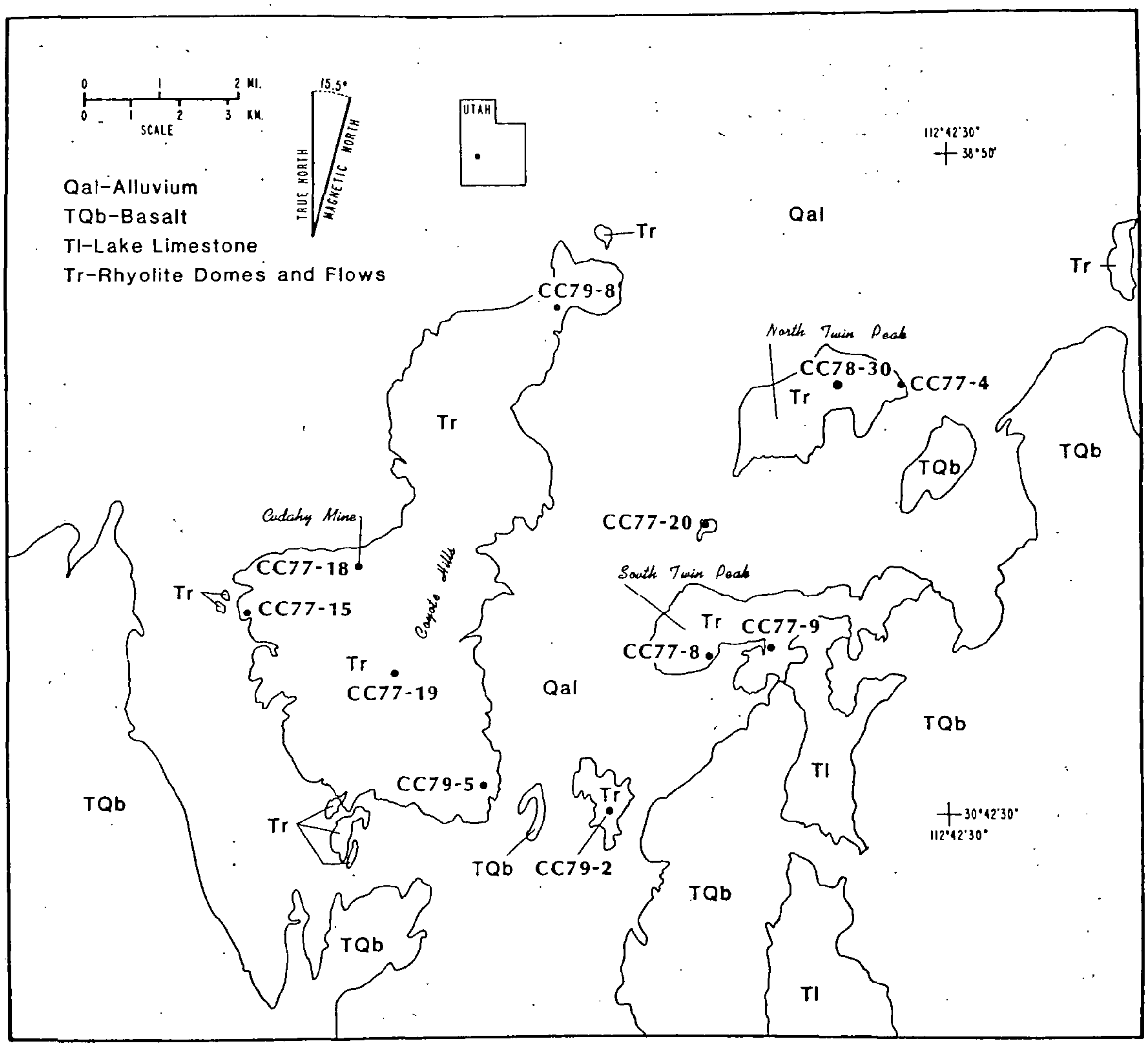

FIGURE 1. Generalized geologic map and sample locations for silicic volcanics of the Cove Creek Domes/Twin Peaks area, southwestern Utah.

Only three dates have been obtained on basalts in the area: 2.0 m.y. at Black Point (Clark, 1977), and 0.97 and 0.92 m.y. for the Black Rock flow (Condie and Barsky, 1972). The Black Point flow is at the extreme northeast of Fig. 1, the Black Rock flow occurs along the western margin of Fig. 1.

Additional dating of samples from the Cove Creek/Twin Peaks area was undertaken to provide temporal constraints on the petrological model that has been developed for the silicic rocks. The oldest dates are for rhyolite in the Coyote Hills, 2.74 m.y. and 2.67 m.y. An intermediate set of ages on obsidians from Coyote Hills and just east of South Twin Peak range from 2.63 m.y. to 2.43 m.y. The youngest ages reported here are for North and South Peaks rhyolite; 2.43 m.y. to 2.35 m.y.

Chemical modeling of the evolution of magma in the area (Crecraft and others, 1979), coupled with the dating reported here indicates that two chemically distinct eruptive sequences are present. Each sequence is characterized by progression from less silicic to more silicic rocks.

In the first sequence, represented by units in the Coyote Hills, eruption of the least silicic unit (the event dated by samples CC77-15 and CC79-2) occurred 2.7 m.y. ago. This unit is overlain by a more silicic unit (represented by samples CC77-9, 18, 19 and CC79-8) and was erupted 2.4 to 2.6 m.y. ago. The chemistry of this sequence indicates that the variation of major and trace element abundances cannot be attributed to any simple crystal fractionation model but probably are the result of liquid state differentiation similar to the model presented by Hildreth (1979). The time interval indicated (200,000 yrs) suggests the magma which was tapped first to produce the older units and then again to produce the younger units, was sustained in a liquid state for a considerable time. In order for this to occur, resupply of heat (perhaps by basaltic magma rising from the mantle) would be essential to prevent the magma from solidifying.

A second sequence of rocks is present in the North and South Twin Peaks area. Samples CC77-4, CC77-8, CC77-20 and CC78-30 have been used to date this sequence. Rocks first erupted 2.5 m.y. ago are less silicic than later erupted material dated at 2.4 to 2.3 m.y. The most silicic, and probably youngest unit, is the dome at South Twin Peak. This second sequence shows evidence for both liquid state differentiation as well as crystal settling. A detailed report on the petrology and chemistry of these units is now under preparation and will contain the detailed evidence for the evolutionary model sketched above.

SAMPLE DESCRIPTIONS

1. *CC77-4* K/Ar
Rhyolite of North Twin Peak (38°47′22″N, 112°42′39″W; UT). Contains phenocrysts of quartz, plagioclase and sanidine. Biotite is the only mafic phase. Groundmass comprises about seventy percent of this unit and is composed of quartz, feldspar and accessory oxides, apatite, sphene and zircon. *Analytical data*: K = 7.56%, radiogenic $^{40}Ar = 3.175 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 24%.
(sanidine) 2.35 ± 0.08 m.y.

2. *CC77-8* K/Ar
Rhyolite of South Twin Peak (38°43′47″N, 112°45′55″W; UT). Phenocryst content of this rhyolite varies from 3 to 20%. Quartz, plagioclase, sanidine and biotite comprise the phenocryst content. The groundmass is composed of fine grained quartz, sanidine, plagioclase, oxides, and zircon. *Analytical data*: K = 9.38%, radiogenic $^{40}Ar = 3.830 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 24%.
(sanidine) 2.35 ± 0.08 m.y.

3. *CC77-9* K/Ar
Obsidian (just E of South Twin Peak; 38°43′51″W, 112°45′03″W; UT). Sample consists of apache tears sampled from a partially devitrified obsidian flow; contains rare sanidine, plagioclase and oxides. Total crystal content is less than one percent. *Analytical data*: K = 4.36%, radiogenic $^{40}Ar = 1.986 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 46%.
(whole rock) 2.63 ± 0.10 m.y.

4. *CC77-15* K/Ar
Rhyolite of Coyote Hills (38°44′22″N, 112°52′05″W; UT). Plagioclase is the dominant phenocryst with smaller phenocrysts of sanidine, augite and hypersthene. Groundmass comprises 84% of the rock and consists mainly of plagioclase with quartz, sanidine, oxides, and zircon. *Analytical data*: K = 4.91%, radiogenic $^{40}Ar = 2.335 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 38%.
(sanidine) 2.74 ± 0.10 m.y.

5. *CC77-18* K/Ar
Obsidian from Coyote Hills (38°45′24″N, 112°51′03″W; UT). This glass is essentially devoid of any minerals with extremely rare biotite, sanidine, and plagioclase crystallites. *Analytical data*: K = 3.99%, radiogenic $^{40}Ar = 1.758 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 42%.
(whole rock) 2.54 ± 0.09 m.y.

6. *CC77-19* K/Ar
Obsidian from Coyote Hills (38°43′17″N, 112°50′30″W; UT). Rock is similar to CC77-18. *Analytical data*: K = 4.11%, radiogenic $^{40}Ar = 1.733 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 60%.
(whole rock) 2.43 ± 0.12 m.y.

7. *CC77-20* K/Ar
Rhyolite (from an outcrop midway between North and South Twin Peaks (38°45′47″N, 112°45′58″W; UT). Petrographically unit is similar to North Twin Peak.

Analytical data: K = 8.52%, radiogenic $^{40}Ar = 3.720 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 21%.

(sanidine) **2.51 ± 0.08 m.y.**

8. *CC78-30* K/Ar

Rhyolite (North Twin Peak; 38°47'22"N, 112°44' 03"W; UT). Sample is similar to CC77-4. *Analytical data*: K = 8.27%, radiogenic $^{40}Ar = 3.491 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 22%.

(sanidine) **2.43 ± 0.08 m.y.**

9. *CC79-2* K/Ar

Rhyolite of Coyote Hills (38°42'04"N, 112°47'23"W; UT). Sample is similar to CC77-15, both chemically and petrographically. *Analytical data*: K = 1.54%, radiogenic $^{40}Ar = 0.715 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 54%.

(plagioclase) **2.67 ± 0.10 m.y.**

10. *CC79-8* K/Ar

Obsidian (northern Coyote Hills; 38°48'13"N, 112° 48'06"W; UT). Sample is similar to CC77-9. *Analytical data*: K = 4.60%, radiogenic $^{40}Ar = 2.096 \times 10^{-11}$ m/gm, atmospheric ^{40}Ar = 23%.

(whole rock) **2.63 ± 0.09 m.y.**

REFERENCES

Best, M. G., and Brimhall, W. H. (1974) Late Cenozoic alkalic basaltic magmas in the western Colorado Plateau and the Basin and Range transition zone, U.S.A., and their bearing on mantle dynamics: Geol. Soc. Amer. Bull., v. 85, p. 1677–1690.

Carrier, D. L. (1979) Gravity and heat flow studies at Twin Peaks—an area of Late Tertiary silicic volcanism in Millard County, Utah: M.S. thesis, Univ. Utah.

Clark, E. E. (1977) Late Cenozoic volcanic and tectonic activity along the eastern margin of the Great Basin in the proximity of Cove Fort, Utah: Brigham Young Univ. Geol. Studies, v. 24, pt. 1, p. 87–114.

Condie, K., and Barsky, C. K. (1972) Origin of Quaternary basalts from the Black Rock Desert region, Utah: Geol. Soc. Amer. Bull., v. 83, p. 333–352.

Crecraft, H. R., Nash, W. P., and Evans, S. H. (1979) Chemical evolution and development of compositional gradients in a silicic magma: G. S. A. Ann. Meeting Abs., v. 11, no. 7, p. 406.

Haugh, G. R. (1978) Late Cenozoic, cauldron-related silicic volcanism in the Twin Peaks area, Millard County, Utah: Brigham Young Univ. Geol. Studies, v. 25, pt. 3, p. 67–82.

Hildreth, W. (1979) The Bishop Tuff—evidence for the origin of compositional zonation in silicic magma chambers: Geol. Soc. Amer. Spec. Paper 180, p. 47–75.

Hoover, J. D. (1974) Periodic Quaternary volcanism in the Black Rock Desert, Utah: Brigham Young Univ. Geol. Studies, v. 21, pt. 1, p. 3–72.

Lipman, P. W., Rowley, P. D., Mehnert, H. H., Evans, S. H., Jr., Nash, W. P., and Brown, F. H. (1978) Pleistocene rhyolite of the Mineral Mountains, Utah Geothermal and archeological signifiance: U. S. Geol. Survey Journal of Research, v. 6, no. 1, p. 133–147.

Luedke, R. G., and R. L. Smith (1978) Map showing distribution composition and age of Late Cenozoic volcanic centers in Colorado, Utah, and southwestern Wyoming: U.S. Geol. Survey Map I-1091-B.

Zimmerman, J. T. (1961) Geology of the Cove Creek area, Millard County and Beaver County, Utah: M.S. thesis, Univ., of Utah.

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UNITED STATES
DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY
Conservation Division, MS-92
345 Middlefield Road
Menlo Park, CA 94025

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UNIVERSITY OF UTAH
RESEARCH INSTITUTE
EARTH SCIENCE LAB.

JUL 0 2 1981

Memorandum

To: Interested Parties

From: Acting Deputy Conservation Manager, Geothermal

Subject: Plan of Exploration, Phillips Petroleum Co., Federal Leases U-47588, U-47589, U-47592, U-48104, U-48107, U-48109, and U-48113, Drum-Mountain Unit, Juab and Millard Counties, Utah
Ref: 2403-01 U-47588 (CER for CER 179-81)

Phillips Petroleum Co. has submitted a Plan of Exploration in accordance with 30 CFR 270.34 to construct access roads and drill up to three geothermal exploration wells from any of ten proposed drilling sites. A copy of the Plan is available upon request.

The office of the Deputy Conservation Manager, Geothermal will prepare a Categorical Exclusion Review (CER 179-81) for the proposed action.

You are invited to participate in a field inspection to be led by Mr. Douglas Koza, of the Salt Lake District Office, USGS, on July 21, 1981. Participants are asked to meet at the City Park, across the street from the Rancher Cafe in Delta, Utah at 10 a.m.

We urge you to send written commentary and will appreciate hearing from you even if you believe that existing regulations, lease terms, and operational orders provide adequate environmental protection.

All comments concerning the proposed actions should be received no later than August 5, 1981 by :

DCM, Geothermal
U.S. Geological Survey
Conservation Division
345 Middlefield Road, MS-92
Menlo Park, CA 94025
ATTN: Rich Hoops
(415) 323-8111, ext. 2848
FTS: 467-2848

We will consider all comments in the preparation of the CER and any subsequent condition of approval.

INTERESTED PARTIES for EA #179-81

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MID-TERTIARY VOLCANIC STRATIGRAPHY, SEVIER-COVE FORT AREA, CENTRAL UTAH

by Charles F. Caskey[1] *and Ralph T. Shuey*[2]

ABSTRACT

The mid-Tertiary stratigraphic section north and east of Cove Fort, Utah, is a series of latitic to rhyolitic flows and ash-flow tuffs with minor fluvial deposits intercalated. The Bullion Canyon Formation comprises the lower part of the volcanic section. By paleomagnetic and radiometric data one member of the Bullion Canyon Volcanics is identified as the Wah Wah Springs Tuff of the Needles Range Formation, herein dated at 30.6 ± 0.3 m.y. Detailed stratigraphy shows no profound stratigraphic break between the Bullion Canyon Volcanics and the overlying Dry Hollow Formation, and radiometric data show a separation in time of no more than 3 m.y. A thick tuff sequence, herein named the Clear Creek Tuff of the Dry Hollow Formation, is thought by Mackin (1960) to be correlative with the Needles Range Formation, but we conclude that it is younger and relatively local. Paleomagnetism reveals this tuff to consist of at least eight cooling units, the lowermost of which has been mapped by Callaghan and Parker (1962b) partly as Dry Hollow Tuff and partly as Dry Hollow Latite. Previously unmapped major faulting is the site of partial release of stress caused by eastward tilting of the Pavant Range to the north of the study area and westward tilting of the Tushar Mountains to the south.

INTRODUCTION

This work is one phase of a larger project aimed at determining the regional stratigraphy of the Needles Range Formation, a mid-Tertiary sequence of ash-flow tuffs. A previous paper (Best and others, 1973) reported on the type localities of several Needles Range Formation regional members.

The area studied in the present paper lies on Utah Highway 4 between the towns of Sevier and Cove Fort (figure 1). It is on the northern flank of the Marysvale volcanic pile, which comprises the bulk of the Tushar Mountains. To the north is the Pavant Range. The study area lies within Millard and Sevier counties and is contained on the USGS Cove Fort and Sevier 15-minute quadrangles.

The earliest detailed work on the Marysvale pile was by Callaghan (1939), and it provided the foundation for subsequent study of the volcanics in the area. The first column of figure 2 shows the portion of his stratigraphy which is represented in our area of study.

Callaghan's work was refined and expanded to complete four 15-minute geologic quadrangles and part of a fifth (Callaghan and Parker, 1961a, 1961b, 1962a, 1962b, Willard and Callaghan, 1962). Several changes from the earlier work have been made and are reflected in the second column of figure 2. Significantly, it was apparent that the Dry Hollow Latite and the Joe Lott Tuff could not interfinger because of the presence of the intervening Mt. Belknap Rhyolite (not present in our study area). The Dry Hollow Formation was expanded to include tuff which lay within the Dry Hollow Latite.

Mackin (1963) presented a reconnaissance stratigraphy of the Needles Range Formation in southwestern Utah. He examined numerous exposures and reported the stratigraphic relations of selected areas. His columns, numbers 11 and 12, represent two places within our study area: one, along Clear Creek and the other, a few miles north of Cove Fort (figure 1). At both locations the very thick tuff, which he considered to be a single cooling unit of the Needles Range Formation, was underlain by earlier volcanic rocks. Post-Needles Range volcanics were exposed only along Clear Creek. Because Mackin interpreted Callaghan's (1939) previous work as including the Needles Range Formation in the Bullion Canyon Volcanics, he felt Callaghan and Parker (1962b) had over-expanded the Dry Hollow Formation by including the thick tuff at Clear Creek. Mackin (1963) also felt that several places mapped by Callaghan and Parker (1962b) as Dry Hollow Latite actually were the redder and more strongly indurated lower portion of the tuff.

In the geologic map of southwestern Utah (Hintze, 1963), previously unmapped rocks on the western flanks of the Tushar Mountains were shown as Bullion Canyon, apparently by extrapo-

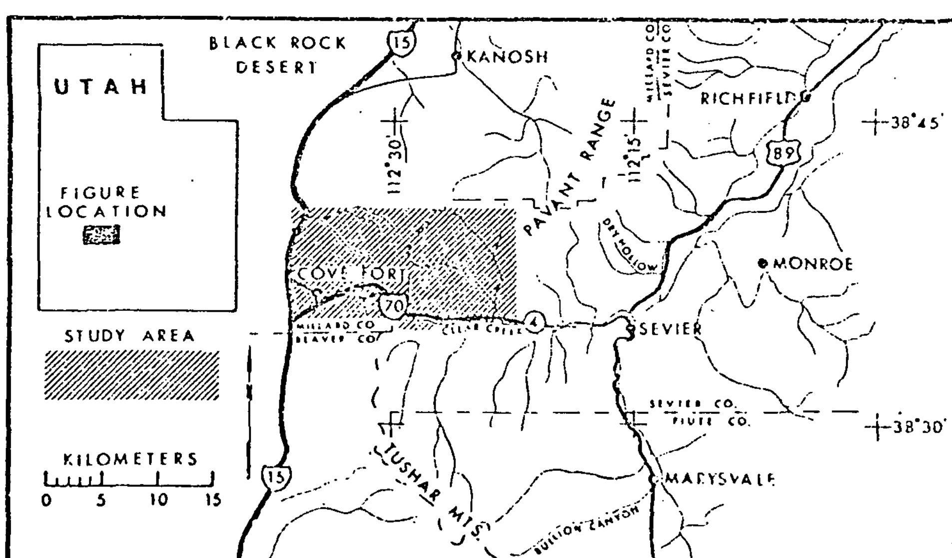

Figure 1. Index map of Cove Fort-Sevier area, central Utah.

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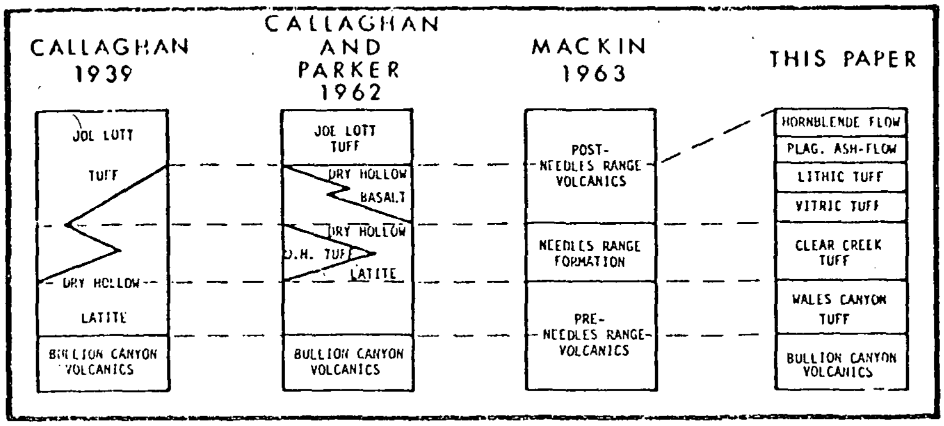


Figure 2. Tertiary volcanic stratigraphic column in the Cove Fort-Sevier area as interpreted by various authors.

lation from the map of Callaghan and Parker (1962b) into the Cove Fort quadrangle. The volcanic rocks of the area north of Cove Fort were mapped as undifferentiated Tertiary volcanics.

More recently Callaghan (1973) published a comprehensive review of mineral resources of Piute County and adjoining area which involved synthesis of all published work in the area and some additional fieldwork, particularly on the western flanks of the Tushar Mountains. A geologic map, showing an area of 3,700 square km around Marysvale, is included in Callaghan's work.

Our work on the Needles Range Formation in the Sevier-Cove Fort area began with the observation that several questions raised by Mackin needed to be answered: Was the Needles Range Formation equivalent to the Bullion Canyon Volcanics, to the Dry Hollow Formation, or perhaps to neither? Did the Dry Hollow Latite lie below and intertongue with the tuff, or was the lower latite just lithified tuff? To resolve these questions as well as the general stratigraphy, we began mapping individual flows at Mackin's two previously mentioned sections and continued until the stratigraphic order at these sections seemed unambiguously determined. This paper presents the resultant stratigraphic column and geological sketch map (figure 3) together with an informal description of the mapped volcanics.

As an aid in stratigraphic analysis within the study area we sampled a number of outcrops for determination of paleomagnetic direction. The sampled sites are shown on figure 3 and the corresponding magnetic data are given in table 1.

STRATIGRAPHIC SECTION

Pre-Volcanic Rocks

North of the study area on the western flank of the Pavant Range, extensively folded and faulted Paleozoic and Mesozoic rocks are exposed (Crosby, 1959; Callaghan and Parker, 1962b). The youngest of these is the Jurassic Navajo Sandstone. These rocks are not exposed in the northwestern Tushar Mountains. Locally overlying these is a sequence of sandy conglomerates and boulder conglomerates of Cretaceous (?) and Tertiary age. These are mapped by Callaghan and Parker (1962b) in the northwestern corner of the Sevier geologic quadrangle. We have found one small exposure of equivalent rocks in the area north of Cove Fort, where they serve to locate the bottom of the volcanic section.

Bullion Canyon Volcanics

The rocks of the Bullion Canyon Volcanics represent the earliest Tertiary volcanism in the Marysvale area. Quartz monzonite intrusion is restricted to the Bullion Canyon Formation and older rocks. Field recognition is aided by a commonly high degree of alteration. (Callaghan and Parker, 1962b).

The earliest volcanic rock in our mapped area is an andesitic flow. Euhedral phenocrysts of plagioclase and hornblende up to a centimeter in length and lesser amounts of biotite are seen in hand specimens. The groundmass is commonly gray but is locally yellow, red, or purple. In thin section the groundmass is seen to be mainly tiny crystals of plagioclase and hornblende. Flow structures are commonly seen in hand specimens.

We propose that this rock be named the Sulphur Peak Member of the Bullion Canyon Volcanics for its prominent exposure at Sulphur Peak (figure 3) where it is several hundred meters thick. Although it is commonly very thick where exposed, it does not extend as far west as the area north of Cove Fort, and it appears to thin rapidly less than 2 km east of Sulphur Peak. The base of the member is not exposed in the mapped area. These observations suggest that the Sulphur Peak Member was relatively viscous at the time of extrusion and might possibly be associated with a dome or a spine.

The Sulphur Peak Member was sampled for magnetic investigation (site 96) and was found to have a distinctive horizontal and westerly magnetic direction (table 1).

Subsequent to deposition of the Sulphur Peak Member a sequence of flows and ash-flows was deposited. These commonly include up to 40 percent Sulphur Peak detritus, which give the flows a red and white blotchy appearance. The flows commonly have 30 percent feldspar, amphibole, and biotite phenocrysts and can vary in color from red to white.

These units are commonly very soft and do not outcrop well. The best exposure is in a roadcut on the western edge of the map (figure 3), south from site 200.

Magnetic sampling records at least two flow cooling units. A lower unit (sites 200, 221) has a reversed direction, whereas near the top the magnetic direction is intermediate (site 222). There are possibly several intervening units.

In the northwestern portion of the Sevier quadrangle, Callaghan and Parker (1962b) have mapped a southwest-trending arc of Bullion Canyon Volcanics. In brief reconnaissance we find the area to be highly altered and generally covered by foliage. If the arc is continued southwestward into the Cove Fort quadrangle, the volcanics extrapolate into the area of Sulphur Peak.

Dry Hollow Formation

The Dry Hollow Formation is defined as following a "profound break" in the volcanic sequence subsequent to deposition of the Bullion Canyon Volcanics (Callaghan and Parker, 1962b). In contrast with the older volcanics it is seldom highly altered and is never intruded.

Wales Canyon Tuff Member
(new name)

On the east side of Wales Canyon (figure 3, sites 219, 220) parallel twin cliffs of nearly identical ash-flow tuff run the length of the canyon wall. We designate these as Wales Canyon Tuff Member. Callaghan and Parker (1962b) have drawn the contact between the Dry Hollow Formation and the Bullion Canyon Volcanics in Wales Canyon at the base of this tuff. This seems a somewhat arbitrary choice because we find no evidence for a large erosional unconformity in the volcanic section anywhere in our area of study, though minor fluvial deposits suggest that a smaller period of erosion has occurred below this tuff as well as elsewhere in the mid-Tertiary volcanic section. Anderson and Rowley (1975) have found no evidence for a significant unconformity at this stratigraphic level in their comprehensive study of the area some 50 km to the south. The Wales Canyon Tuff is a good field marker with a locally distinctive appearance and good cliff-forming abilities.

Hand specimens of the Wales Canyon Tuff contain 30 to 40 percent phenocrysts, mostly euhedral platelike feldspar, 3 or 4 mm in length with hornblende and biotite as conspicuous mafic phenocrysts. At the lower cliff, phenocrysts are consistently smaller than in the upper. The groundmass is fine grained and glassy and occasionally finely vesicular. Foliation of elongate and platelike phenocrysts and compaction foliation of rare pumice fragments indicate that this unit is an ash-flow tuff.

Platy weathering characterizes this tuff in outcrop. Locally it is marked by lines and swirls of red stain: this is possibly oxidation coincident with planes and surfaces of differential laminar flowage which may occur during the late stages of deposition of ash-flows (Schimke and Swanson, 1967). Locally there is enhancement of red staining and platy weathering which may be associated with post-depositional processes.

There is a black basal vitrophyre wherever the bottom is exposed in the mapped area. At the type area both cliffs are underlain by a vitrophyre suggesting a multiple cooling unit. Paleomagnetic

Table 1. Paleomagnetic data: D, I = declination and inclination of magnetization; N = number of samples; K = Fisher precision parameter; alpha 95 = semiangle of cone of 95 percent confidence of mean; H = peak demagnetization field, gauss. Data from middle units, Clear Creek Tuff arranged in stratigraphic order.

Site no.	D	I	N	K	alpha 95	H
			Plagioclase Ash-flow Tuff			
166	180	-30	9	27	10.0	300
			Upper Unit, Clear Creek Tuff			
224[1]	172	-16	4	493	4.1	300
225[1]	201	-3	5	163	6.0	0
226[1]	193	-18	6	295	3.9	0
227[1]	174	-26	5	100	7.6	300
Mean	185	-16	4	24	19.3	
			Middle Units, Clear Creek Tuff			
197	181	31	6	28	12.8	300
196	95	0	14	9	13.7	300
195	232	-10	11	59	6.0	150
194	13	42	25	50	3.1	0
202	23	10	9	16	13.0	0
149	346	2	8	11	17.1	1,000
150	346	47	9	113	4.8	150
191	9	29	9	109	12.3	600
153	351	39	7	310	3.4	200
152	347	53	9	790	1.8	100
151	10	47	8	751	2.0	100
36	10	51	6	990	2.1	0
34	0	49	5	270	4.6	0
154	345	41	12	634	1.7	100
			Lower Unit, Clear Creek Tuff			
35	32	50	8	540	2.4	0
38	51	51	7	220	4.1	0
155	34	45	6	76	7.7	800
156	35	74	9	57	6.8	800
165	25	32	16	195	2.6	300
190	36	40	20	16	8.2	150
198	67	39	9	53	7.1	0
223	30	27	9	72	6.0	0
Mean	38	45	8	21	12.1	
			Upper Unit, Wales Canyon Tuff			
199	169	-55	16	40	5.9	0
201	177	-66	16	129	3.2	0
220	207	-50	9	168	3.9	0
Mean	186	-58	3	34	21.5	
			Lower Unit, Wales Canyon Tuff			
219	174	-28	7	102	6.2	300
			Upper Part, Bullion Canyon Volcanics			
222	93	43	9	89	5.4	0
			Lower Tuff, Bullion Canyon Volcanics (Wah Wah Springs Tuff)			
200	230	-40	14	169	3.0	0
221	213	-45	12	211	2.9	0
Mean	222	-43	2	72	29.7	
			Sulphur Peak			
96	261	-6	10	239	3.1	300

[1] N cores drilled in laboratory from one oriented hand specimen.

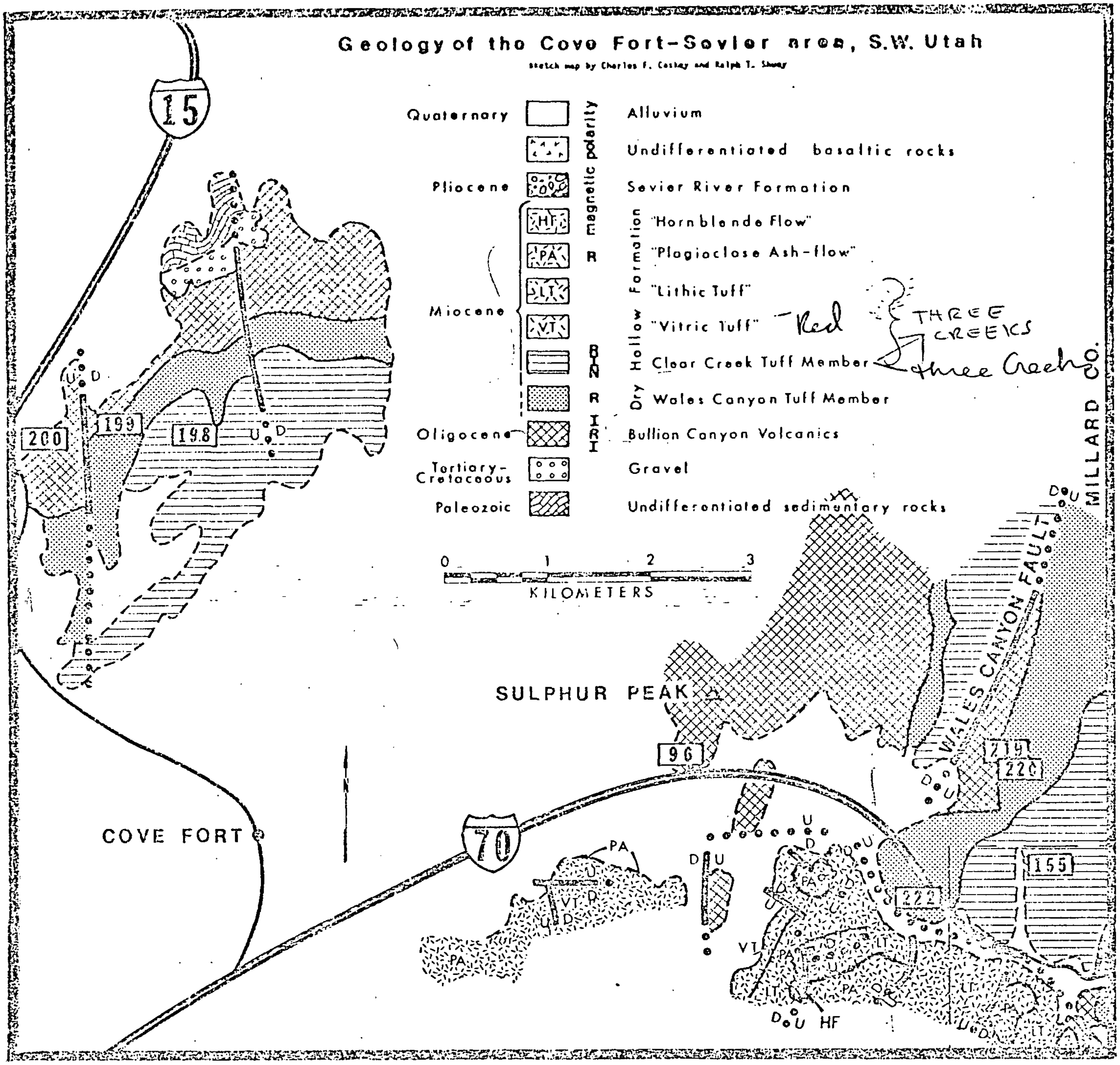


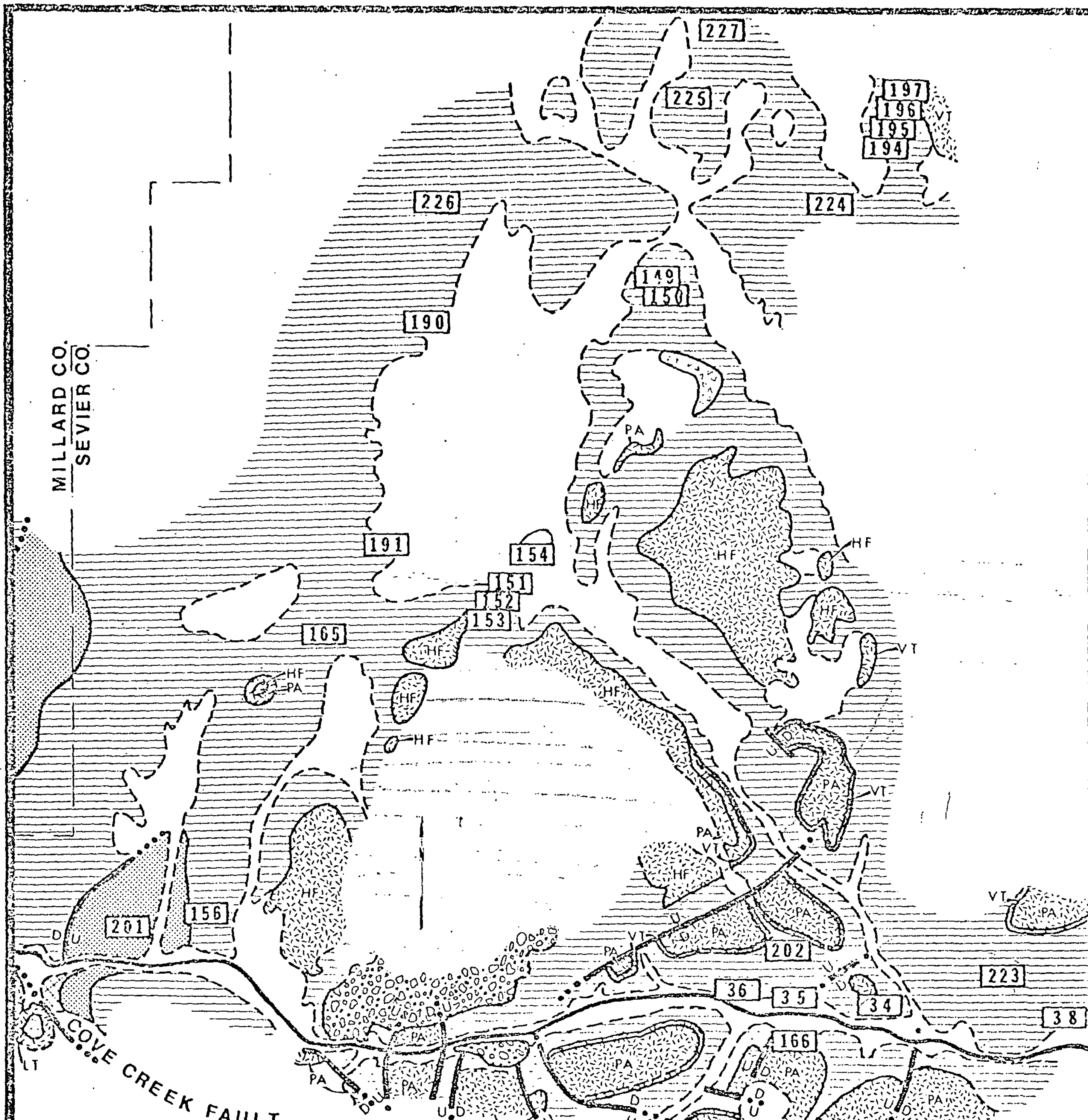
Figure 3. Geologic sketch map of the Cove Fort-Sevier area. Paleomagnetic sampling sites of table 1 are shown by numbered rectangles. Faults dashed where inferred. Unmapped areas are left blank. *(figure 3 continued on page 5)*

sampling confirms this observation (table 1, sites 219, 220).

The Wales Canyon Tuff is exposed only in the west portion of the mapped area, almost entirely north of Interstate Highway 70 and Utah Highway 4. The thickest exposure of over 200 m is at the type area. At sites 199 and 201 the tuff is on the order of 100 m thick. In the field it appears that only the upper cooling unit is present at these sites, and paleomagnetic sampling confirms this.

Clear Creek Tuff Member
(new name)

Exposed along Clear Creek in the mapped area is a thick section comprised of a number of ash-flow cooling units. These are nearly indistinguishable in hand specimens and are what Mackin (1963) has considered to be the Needles Range Formation (figure 2). We propose this to be named the Clear Creek Tuff Member of the Dry Hollow Formation. Although we have not mapped them separately, we recognize three divisions within the tuff sequence.



The lowest division is apparently a single cooling unit. It is a highly crystalline rock with as little as 50 percent hard, red groundmass made of ash-size glass shards. The red color is due *in part* to post-depositional hematite staining. Feldspars, several mm in size, are the most abundant phenocrysts. Large biotite, hornblende, and some quartz phenocrysts are also visible in hand specimens. This cooling unit is a cliff former. Occasional lithic inclusions can be seen in outcrop.

The lowest unit is the most widespread of the Clear Creek Tuff and is apparently present wherever the tuff is exposed. It has a relatively uniform thickness of 70 to 100 m. It overlies the Wales Canyon Tuff in the western part of the mapped area, but the base is not exposed in the eastern part.

The lowest unit has been sampled magnetically in a number of places. These directions and their mean are shown in table 1. All directions have been adjusted to account for apparent secondary tectonic tilt at the site. The direction at site 156 is different enough from the mean to warrant special attention. Without the 20-degree dip correction, which is determined from the plane of foliation of flattened pumice, the magnetic direction is within one degree of the 95 percent confidence limit of the mean. The direction moves significantly away when a structural correction is applied, suggesting that the dip of the flattened pumice is actually a primary dip of the depositional surface. The authors have experienced this problem elsewhere, notably at Wah Wah Springs in the Wah Wah Mountains of southwestern Utah.

We believe Mackin (1963) was correct when he suggested that Callaghan and Parker (1962b) had mapped as latite the lower red portion of a single ash-flow cooling unit exposed along Clear Creek. We have examined three such places where the mapped contact of latite and tuff is vertical but no fault is shown. In all three cases we find no change in mineralogy across the contact and the mapped latite corresponds with an apparent reddening and lithification which occurrs gradually within a single ash-flow tuff. At each contact we have taken paleomagnetic samples along a traverse extending up to 300 m on either side (sample sites 165, 190, and 223 in figure 3 and table 1). The relatively high Fisher precision constant reflects the lack of systematic change of paleomagnetic direction across the contact. We interpret the hard, red areas within the lower ash-flow tuff unit as being the result of locally heavy secondary hematite coating of phenocrysts and matrix material which have acted to cement and color the rock without appreciably affecting its remanent magnetism. In his 1973 map, Callaghan no longer distinguished between the tuff and the latite.

In hand specimens, the middle division of the Clear Creek Tuff is nearly identical to the lower in phenocryst types and relative percentages but contains 10 to 20 percent fewer total phenocrysts. The groundmass is normally white, ashy, and loosely indurated, but there are local areas of lithification and reddening accompanied by and possibly the result of hematite staining.

The middle unit can be identified in the field by its high percentage of xenolith inclusions, some up to 30 cm in size, which have possibly been swept up and incorporated from the underlying tuffs. Weathering results in slopes with a "Swiss cheese" effect of large holes in steeper surfaces which is characteristic of loosely indurated tuffs (Ross and Smith, 1961, p. 30).

The middle division of the Clear Creek Tuff is persistent from the eastern border of the mapped area west to the Wales Canyon area. Often, where it is exposed, nearly horizontal parallel outcrops along the side of a hill give topographic suggestion that this part of the Clear Creek Tuff has been created by a sequence of ash-flows. At one site we sampled three such vertically adjacent outcropping cliffs for magnetic investigation (sites 151, 152, and 153). The magnetic directions shown in table 1 are statistically distinct. Because the three sets have been taken clearly within a single unfaulted scarp, the differences in the magnetic directions are not affected by relative structural rotation. Thus we conclude that the middle unit of the Clear Creek Tuff is composed of at least three ash-flow tuff cooling units at this site. In the north part of the map area (figure 3) a similar set of cliffs gives the impression of four ash-flow cooling units (sites 194, 195, 196, and 197). Magnetic sampling gives a normal direction for the lowest, whereas the upper three are intermediate (table 1). This suggests that part of a geomagnetic field reversal may be recorded in the upper three tuffs. Stratigraphic relations place these tuffs at or near the top of the middle division of the Clear Creek Tuff. Because the magnetic direction on only the lowest of the four (site 194) could be brought into coincidence with those previously mentioned by the relatively minor structural corrections warranted in the mapped area, there must be a minimum of six distinct magnetic directions and corresponding ash-flow tuffs within the middle unit of the Clear Creek Tuff. Structural uncertainties make it difficult to correlate other entries for the middle unit in table 1 with the six directions already noted.

Although the middle unit has a relatively constant thickness of 100 m, individual constituent ash-flow tuffs are not laterally continuous over the mapped area as determined by the magnetics.

The upper ash-flow cooling unit of the Clear Creek Tuff is very highly crystalline, mineralogy being dominated by euhedral feldspar phenocrysts several mm in size. Similar to the lower units, it contains conspicuous hornblende and biotite in hand specimens but, by contrast, has up to 10 percent quartz phenocrysts. Foliation of phenocrysts nearly parallel to the horizontal is interpreted as compaction foliation. The groundmass is uniformly pink and glassy and is well indurated.

This unit is found only in the northern extent of our mapped area but is never less than 50 m thick where present. Callaghan and Parker (1962b) consistently mapped it as Dry Hollow Latite. We have found no younger rocks in place above this rock. A reversed magnetic direction (sites 224, 225, 226, and 227) suggests that the magnetic activity recorded in the upper part of the middle division had become reversed by the time the last ash-flow of the Clear Creek Tuff was deposited.

Dry Hollow Formation, Upper Members

The section above the Clear Creek Tuff has served basically to define the upper limit of possible Needles Range Formation in our original project and is therefore not studied in as much detail as are the underlying volcanics. We have identified four upper members of the Dry Hollow Formation and have given them informal descriptive names to aid in field recognition. These four upper members are well exposed in section about 2.4 km south-southeast of Sulphur Peak along a power line construction road.

We have called the lowest member the "vitric tuff." It rarely exceeds 15 percent phenocrysts in glassy, finely vesicular, red to orange groundmass, and it exhibits rare zones of highly flattened pumice. Quartz and amphibole are the most common phenocrysts. This rock occasionally shows flow structures in hand samples. It is usually less than 6 m thick, but exceeds 30 m in the area south-southeast of Sulphur Peak. It is easily obscured by talus from the overlying units and may thus be present in places where it is not mapped.

The next higher informal member we have mapped has two facies which are probably genetically independent but have been mapped together because they are present only in a small part of the mapped area and they always appear together there.

The lower facies contains up to 80 percent rounded, somewhat weathered volcanic phenocrysts in a fine grained, ashy matrix. Bedding suggests this facies may be the result of reworking by water of the loosely indurated middle unit of the Clear Creek Tuff.

The upper facies contains up to 20 percent euhedral quartz phenocrysts and relatively minor amounts of biotite in a pink, ashy groundmass. The groundmass is often highly vesicular with up to 30 percent of included pumice. This facies often contains several percent stoney xenoliths, hence our informal designation of "lithic tuff." Both facies are slope forming and do not outcrop well. The lithic tuff is exposed only south of Interstate 70 near the center of the map (figure 3), but is 30 to 60 m thick there. It is clearly not present in the north and east extremes of the mapped area where the unit above lies directly on the vitric tuff.

The "plagioclase ash-flow" member is named for the abundance of large plagioclase phenocrysts which contrast against a dark brown to gray, fine-grained groundmass. Quartz and biotite phenocrysts are also visible in hand specimens.

The "plagioclase ash-flow" forms steep slopes and cliffs. It weathers into blocks which form thick talus slopes at its base. Areas of extremely flattened pumice and ubiquitous black basal vitrophyre indicate its ash-flow origin. It is exposed in the extremes of the study area, except north of Cove Fort, and is always 30 to 100 m thick, making it an excellent stratigraphic marker. It is probably the same as sample number 8 from Callaghan's (1939) original work. Magnetic sampling gives a reversed direction (site 199).

A "hornblende flow" is the top of the Dry Hollow Formation in our map area (figure 3). It contains up to 20 percent of equant feldspar and elongate amphibole phenocrysts in a fine-grained brownish gray matrix. It is commonly vesicular with clear flow structures on upper surfaces. It is relatively thin, never exceeding 10 m in outcrop, and forms thick talus slopes.

To the east of our study area Callaghan and Parker (1961a, 1962b) have included as Dry Hollow Formation a thick sequence of basaltic andesite flows which intertongues with the Dry Hollow Latite. They state, and we concur, that the tuffs and latite flows of the Dry Hollow Formation come from an eruptive center in the Tushar Mountains, but the basaltic andesites have their source northeast of Monroe in the Sevier Plateau. Callaghan and Parker (1962b) also recognize an episode of limited volcanism of Pliocene or Pleistocene age. We have encountered two areas of basaltic rocks in our mapping but have not attempted to correlate them stratigraphically.

Sevier River Formation

The Sevier River Formation, a sedimentary unit formed from fluvial deposits of local volcanics, was deposited during late Pliocene or early Pleistocene time. We have mapped this unit in one locality in our study area. Significant faulting here is confined to rocks below the Sevier River Formation in agreement with Callaghan and Parker's (1962b) belief that it has been deposited subsequent to major tectonic activity.

AGE DETERMINATIONS AND STRATIGRAPHIC CORRELATION

As an aid in relating the stratigraphic section in the study area to the regional stratigraphy we had radiometric age determinations made on samples taken from site 200 and site 156. Core samples were crushed and the biotite was separated from sieve fractions by shaking-table techniques. The biotite was further purified by water flow which removed the platelike flakes from the more equant constituents. Argon was extracted under ultra-high vacuum by fusing with an induction furnace. The gas was cleaned in a two stage process using copper, copper oxide, and titanium furnaces. Isotopic analysis of the argon was done by mass spectrometry. Potassium was analyzed by flame photometry using lithium buffers and potassium external standards. Blanks were taken throughout the entire potassium analysis. The constants used in the calculation are $\lambda_\epsilon = 0.585 \times 10^{-10}$, $\lambda_\beta = 4.72 \times 10^{-10}$, $K^{40}/K_{total} = 1.19 \times 10^{-4}$ mole percent.

The date determined from site 200 is 30.6 ± 0.3 m.y. This is within the range of ages determined by Kistler (1968), Armstrong (1970), and Fleck and others (1975) for the Needles Range Formation. This unit is lithologically and stratigraphically identical to the Needles Range Formation. Consideration of the magnetic direction (table 1) indicates that this unit is the Wah Wah Springs Member of the Needles Range Formation (Best and others, 1973). This is consistent with the observations by Mackin (1963, p. 77) and Anderson and Rowley (1975) that the Needles Range Formation is included within the Bullion Canyon Volcanics. We have also found the Wah Wah Springs Tuff 60 km to the east and 70 km to the southeast (Caskey, 1975). The possibility that the Lund Member of the Needles Range Formation lies above the Wah Wah Springs in the Bullion Canyon Volcanics is not precluded by our magnetic data. Poor exposures of the Bullion Canyon Volcanics make it difficult to obtain a complete section.

Site 156 is within the lower unit of the Clear Creek Tuff within the Dry Hollow Formation. The age has been determined to be 27.5 ± 0.4 m.y., only three m.y. younger than sample 200 from the bottom of the Bullion Canyon Volcanics. This is consistent with the absence of a large erosional unconformity between the Dry Hollow Formation and Bullion Canyon Volcanics in our study area.

In the central Sevier Plateau, the Wah Wah Springs Tuff is overlain by a relatively local tuff of almost identical lithology, with the intervention of about 40 m of fluvial sediments derived from volcanics. This upper tuff is considered part of the Needles Range Formation (Rowley, 1968; Anderson and Rowley, 1975; Caskey, 1975). The question then arises: Should the Clear Creek Tuff also be considered a member of the Needles Range Formation as proposed by Mackin (1963)? We recommend that it should not for several reasons: The 3 m.y. difference in K/Ar dates and the intervening tuffs and flows not of Needles Range lithology both mean that the stratigraphic association with the regional Needles Range Member is much weaker for the Clear Creek Tuff than for the upper tuff in the central Sevier Plateau. Furthermore, the designation of the Needles-like rock in the Clear Creek area as part of the Dry Hollow Formation has historical priority (Callaghan and Parker, 1962b). In our detailed mapping it has been possible to use the Callaghan stratigraphic nomenclature consistently with its previous usage.

It should be mentioned that as used by us and by Callaghan (1973) on the north flanks of the Marysvale volcanic pile, the name Dry Hollow Formation includes a great thickness of rocks from several source areas and spanning about 6 m.y. in time. The oldest member is probably the Wales Canyon Tuff, which by interpolation of our data has an age of 28 m.y. The younger Dry Hollow members in the mapped area are overlain by the basaltic andesite members which become dominant further east. At their source area in the mountains northeast of Monroe, the basaltic andesites are capped by the Osiris Tuff (Rowley, 1968; Williams and Hackman, 1971) which is dated by Fleck and others (1975) at 22.4 m.y.

The Osiris Tuff is an excellent stratigraphic marker and is easily identified at the top of the Dry Hollow basaltic andesites in the volcanics of the northern Sevier Plateau. For this reason it may seem appropriate to restrict the Dry Hollow Formation to pre-Osiris Volcanics.

However, Callaghan has consistently mapped the Osiris Tuff as Dry Hollow Latite. Furthermore, on the south flanks of the Tushars, Callaghan (1973) includes in the Dry Hollow Formation some post-Osiris flows dated by Fleck and others (1975) at 21.8 m.y. Anderson and Rowley (1975) restrict the Dry Hollow name to these flows and propose the name Mt. Dutton Formation for all rocks of the southern plateaus between the Needles Range Formation and the Osiris Tuff. The rocks of the Mt. Dutton Formation, time-equivalent to the Dry Hollow Formation in the Sevier-Cove Fort area, are dominantly breccia and have been mapped in part by Callaghan (1973) as Roger Park Breccia.

Figure 4 summarizes the Tertiary stratigraphy on the periphery of the Marysvale volcanic pile. It shows a certain difficulty with the Dry Hollow name: At the type locality the Dry Hollow Formation consists of latites from the west and basaltic andesites from the east, both being pre-Osiris. In the southern Tushars rocks of similar appearance are post-Osiris.

STRUCTURE

Major basin and range type faulting which was responsible for the present topography of the mapped area (figure 3) occurred during the late Pliocene or early Pleistocene time. We see no evidence of significant tectonic activity during deposition of the Dry Hollow Formation. The paleotopography within the Dry Hollow Formation can be attributed to non-uniform volcanic deposition and erosion.

Mackin (1960) said that ignimbrite stratigraphy is the key to understanding structure. We find this to be especially true in the area of this study. As shown on figure 3, we were able to locate numerous small faults in the area around Clear Creek after we had determined the stratigraphy. Many of these are not shown on the Sevier geologic quadrangle (Callaghan and Parker, 1962b). Structural detail is not as well mapped by us to the north of Clear Creek but is likely to be less complicated.

In the eastern end of the mapped area the structure is basically horizontal layering of depositional units, complicated by numerous relatively small, high angle faults and horst-graben relationships. Further west on the north side of the road faulting becomes antithetic, tending to repeat the section and causing ridge-valley topography. The general east to southeast dip causes the section to

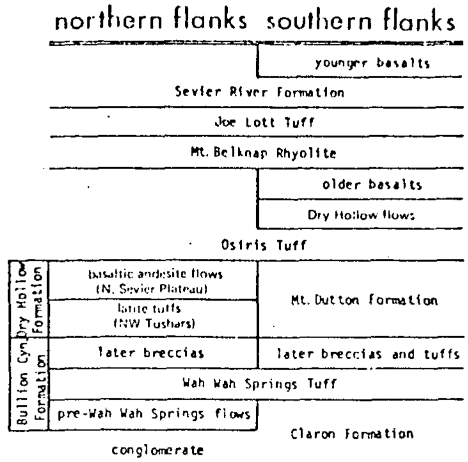


Figure 4. Tertiary stratigraphic column on the north and south flanks of the Marysvale volcanic pile.

become older to the west. Wales Canyon lies along a dramatic fault which brings the Clear Creek Tuff on the west wall of the canyon down against the Bullion Canyon Volcanics at the base of the east wall, a displacement of at least 150 meters. We propose to call this fault the Wales Canyon fault.

On the south side of Interstate Highway 70, opposite the Wales Canyon area, the exposed rocks are much higher in section but at the same altitude. This is due to a large fault which locally is nearly coincident with Cove Creek. We propose the name Cove Creek fault. Because outcrops are well developed on either side of the fault, the major displacement of the fault zone is easily located to within several tens of meters. Minor faulting of several meters displacement which is not mapped accompanies the Cove Creek fault as can be seen in road cuts north of site 222. In general, rocks on the south side of Utah Highway 4 are lower than the same members on the north side. We believe that this may be the effect of a branch of the Cove Creek fault extending along the road to the east, although we have not included it on figure 3.

Neither the Wales Canyon fault nor the Cove Creek fault were mapped in previous works. Because the displacement of the Cove Creek fault was not recognized at the time the state map of Utah (Hintze, 1963) was completed, it was logical to extrapolate the arc of Bullion Canyon Volcanics from the Wales Canyon area in the Sevier quadrangle (Callaghan and Parker, 1962b) across the route of Interstate 70 into the western flanks of the Tushar Mountains. It is now clear that this was in error.

In the Pavant Range the exposed rocks progress in age from the Dry Hollow Basaltic Andesite on the eastern flanks to the Paleozoic formations on the west, indicating an eastward tilted fault block. In the Tushar Mountains the pattern is reversed due to an opposite, westward tilt. This has been mentioned by Callaghan (1973, p. 14). The Cove Creek fault and its probable eastward extension are part of the implied "scissors" displacement.

ACKNOWLEDGMENTS

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REFERENCES

Anderson, J. J. and P. D. Rowley, 1975, Geology of the southwestern High Plateaus of Utah: part II Cenozoic Stratigraphy: Geol. Soc. Am. Spec. Paper 160 (in press).

Armstrong, R. L, 1970, Geochronology of Tertiary igneous rocks, eastern Basin and Range province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, p. 203-232.

Best, M. G., R. T. Shuey, C. F. Caskey, and S. K. Grant, 1973, Stratigraphic relations of members of the Needles Range Formation at type localities in southwestern Utah: Geol. Soc. Am. Bull., v. 84, p. 3269-3278.

Callaghan, Eugene, 1939, Volcanic sequence in the Marysvale region in southwest-central Utah: Am. Geophys. Union Trans., 20th Ann. Mtg., Washington, D. C., 1939, pt. 3, p. 438-452.

______1973, Mineral resource potential of Piute County, Utah, and adjoining area: Utah Geol. and Mineral Survey Bull. 102, 135 p.

Callaghan, Eugene and R. L. Parker, 1961a, Geology of the Monroe quadrangle, Utah: U. S. Geol. Survey Geol. Quad. Map GQ-155.

______1961b, Geological map of part of the Beaver quadrangle, Utah: U. S. Geol. Survey Min. Inv. Field Studies Map MF-202.

______1962a, Geology of the Delano Peak quadrangle, Utah: U. S. Geol. Survey Geol. Quad. Map GQ-153.