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

March 24, 1980

I called back Mr. Tom Goodnight to find out what he wanted. He said that Don Burch, a friend of KLB, had left some CSM reports and geological survey reports regarding the Halvetia District near Tucson. Mr. Goodnight would like to retrieve those reports that are in our files, since they belonged to Mr. Burch and Mr. Goodnight said they now belong to him.

Mr. Goodnight can be reached by phone at 1-584-3317. Call him when KLB returns to office regarding the reports then mail them to him at 12919 Sky View Drive, Sun City West, Arizona 85375.

Mail reports when copied.

NUCLEAR DYNAMICS

P. O. BOX 20766 | PHOENIX, ARIZONA 85036 | 2871 SKY HARBOR BLVD. | 602/267-0581

KELSEY L. BOLTZ — CHAIRMAN

April 22, 1980

Mr. Tom Goodnight
12919 Sky View Drive
Sun City West, Arizona 85375

Dear Mr. Goodnight:

At Mr. Boltz's request, enclosed are the reports and other information on the property in the Helvetia Mining District which you recently talked to Mr. Boltz about.

Sincerely,

Sue Matteson

(Mrs.) Sue Matteson
Secretary to Mr. Boltz

Enclosures

Report on

ROTARY KILN CALCINATION OF LIMESTONE SAMPLE

Tucson Lime and Chemical Company

Project No. 191107 **November 28, 1962**

COLORADO SCHOOL OF MINES RESEARCH FOUNDATION

Report on

ROTARY KILN CALCINATION OF LIMESTONE SAMPLE

Prepared for

Tucson Lime and Chemical Company
4730 West 2nd Avenue
Vancouver 8, B. C.

By

Chemical Division

Colorado School of Mines Research Foundation, Inc.
Golden, Colorado

Approved:

Project No. 191107
November 28, 1962

E. H. Crabtree
Director

J. L. Drobnick
Assistant Manager

C. J. Lewis
Director of Research

Phil Jameson
Project Engineer

AUTHORIZATION

This work has been authorized by contractual arrangement of October 8, 1962, between the Tucson Lime and Chemical Company, Inc. and the Colorado School of Mines Research Foundation, Inc.

TABLE OF CONTENTS

OBJECTIVES

The purpose of this undertaking has been (1) to determine the yield of quicklime product resulting from processing a large sample of Tucson Lime and Chemical Company high calcium limestone through a pilot size rotary kiln under commercial production conditions and (2) to thus obtain a substantial quantity of the quicklime product for further evaluation. These objectives are more fully outlined in a letter of October 8, 1962, from C. J. Lewis of the Research Foundation to Mr. J. D. Mason of Tucson Lime and Chemical Company (appendix).

FOREWORD

Commercial high calcium quicklime is usually manufactured from limestone containing at least 95% calcium carbonate. In this respect the high calcium product differs from dolomitic quicklime which is manufactured from dolomitic limestone containing calcium carbonate and magnesium carbonate in about equal molar ratio.

Practically all commercial quicklime is produced by calcining the limestone in direct-fired brick-lined rotary kilns. However, under some circumstances, vertical (stationary shaft) kilns are used and in special cases hearth roasters and fluid bed kilns are in operation. It can be stated however, that unless special circumstances warrant otherwise, the rotary kiln is preferred.

When limestone is converted to quicklime, the volatile matter including carbon dioxide, moisture and organic matter is driven off and, of these, the carbon dioxide usually represents from 41-43% of the weight loss. Thus for 100 tons of limestone fed to the calcining operation, only about 60 tons of quicklime could be potentially realized and this figure would be further decreased as the result of loss of fine limestone and quicklime in the kiln exhaust gases. On the other hand, the loss of this volatile matter during calcination increases the amount of non-volatile impurities in the resulting quicklime. For example, a limestone feed containing 1% silica (SiO_2) would result in a quicklime containing about 1.81% silica, assuming 42% weight loss during calcination. For this reason non-volatile impurities in the raw limestone become quite significant in the quicklime product.

In the case of the limestone of interest to the Tucson Lime and Chemical Company, a previous evaluation of samples of this material by the Research Foundation had indicated the sample material to be a good grade of high calcium limestone which upon calcination, would result in a quicklime product meeting the chemical specifications for a high calcium quicklime. The only adverse characteristic of the quicklime produced from the samples was that of color - - the products being somewhat darker (less white) than the usual high calcium quicklimes. However this was and is, not believed highly significant to the potential uses in the market areas involved. These considerations are more fully described in a report of February 10, 1960, entitled "Evaluation of Limestone Samples for Production of Lime".

However, the studies resulting in the aforementioned report brought out the highly significant fact that limestone as represented by the samples tended to decrepitate during the calcining operation. In other words, the limestone broke up into substantially -1/8" particles when changed from limestone to quicklime. Such decrepitation subsequently results in the formation of a substantial amount of dust and fine material which is entrained in the gases leaving the kiln, thus causing an important materials loss. In such cases, hearth roasters or fluid bed kilns may be required for technical reasons and to minimize the loss of fine material. However, in the studies as reflected in the report to which reference has been made, it was determined that the limestone sample decrepitated during calcination without producing the expected large amount of fines and dust. This fact was interpreted as indicative of the amenability of limestone, as represented by the samples, to convetional rotary kiln calcination.

Also, it was apparent that if the limestone decrepitated to approximately -1/8" during calcination, there would be no need to remove fine limestone (quarry screenings) from the limestone feed prior to calcination. As is well known, limestone feed to the rotary kiln must be sized for most efficient kiln operation and quicklime quality control in the case of limestones which burn normally and do not decrepitate. This results from 10-20% of the limestone mined or quarried being rejected as "screenings". However, as indicated, the nature of the Tucson Lime and Chemical material offered the possibility of eliminating the problem of "screenings".

As the result of the foregoing considerations, Tucson Lime and Chemical Company authorized the work represented herein, primarily to determine the behavior of a large sample of limestone when converted to quicklime under actual commercial rotary kiln operations, and secondarily to thus produce a large quantity of quicklime for possible further laboratory testing and market evaluation.

This calcination, involving nearly 5 tons of limestone, was undertaken in a direct gas-fired rotary kiln approximately 18' in length and 16" internal diameter.

SAMPLES

1. Limestone - Approximately 10 tons of limestone crushed to pass a 6" square opening were delivered to the Research Foundation by Tucson Lime and Chemical Company. Nine tons of this material was crushed to pass a 3/4" square opening. No effort was made to screen out the fine material resulting from the crushing operation since it was known that the limestone would decrepitate to approximately 1/8" during the calcination. This -3/4" crushed limestone is referred to as "feed" throughout this report.

2. Quicklime - During the calcining operations 5065 lbs. of quicklime product were recovered. During calcining, samples of quicklime product were taken every hour. These samples were later composited into 2 master samples referred to herein as "product first half" and "product second half".

3. Dust - A dust sample was taken on an hourly basis near the dust chamber at the feed end of the rotary kiln. This sampling point was considered significant in that it represented the first major decrease in velocity of the gases leaving the rotary kiln and is in the normal dust collecting area of a rotary kiln operation. The samples were composited and analyzed.

4. Stack discharge sample - At the end of the calcining operation a quantity of extremely fine dust on the roof of the building housing the kiln was obtained, mixed and sampled. This is considered to reflect the stack discharge of the very fine material which would normally not report in the conventional dust collecting chamber.

Rotary Kiln Specifications and Operating Conditions

Length	18'
Diameter	16"
Slope	0.0448 ft./ft. or 0.537 in./ft.
r.p.m.	3/4
Retention time	90 min.
Load %	10.1
Bed depth	2.6"
Retaining ring	2" (inside diameter 16")
Feed chute	2 1/2"
Feed rate	150 lbs./hr.

SUMMARY

The limestone feed to the kiln calcined normally as compared with the high calcium quicklimes of commerce. The optimum calcining temperature range was between 2000° F. and 2200° F. At temperatures below 1800° F. core (unburned limestone) appeared in the product and the feed rate would have had to be substantially reduced to produce a quality product in the 1800°F. range. On the other hand, the quicklime product began to glaze at around 2300° F. thus suggesting over-burning and possible damage to the kiln lining. The optimum temperature range therefore lies between 2000°F. and 2200° F. and the preferred temperature, within this range, would have to be established in terms of the commercial kiln involved.

The expected decrepitation of the limestone occurred and appeared to be maximum in the hottest zone of the kiln where quicklime was being formed at the maximum rate. The dust loss resulting from decrepitation was surprisingly low. From the approximately 9600 lbs. of limestone feed to the kiln, 5065 lbs. of quicklime product were obtained. From the inventory of feed and product the actual dust loss calculates to only 3.9%. It may be concluded therefore, that from all limestone as represented by the sample, an overall quicklime yield of at least 95% could be obtained via rotary kiln calcining.

Based on all data and observations arising from this undertaking, material as represented by the limestone sample should be able to be converted to quicklime in a conventional rotary lined kiln under conditions which should render the quicklime product economically competitive in its market area.

DETAIL OF WORK PERFORMED

1. Preliminary batch calcination operations in rotary smelting furnace. The purpose of these experiments was to gain reassurance that the limestone sample would decrepitate without severe dust loss and to establish a suitable size to which all the large samples should be crushed.

Four grab samples of the 6 inch limestone were taken and were crushed and screened as follows:

1.	-1 1/2	+1/4
2.	-1 1/4	+ 1/4
3.	-1	+ 1/4
4.	-3/4	+ 1/4

Ten lbs. of No. 1 were calcined at 2040° F. for 20 min. 4.96 lbs. of quicklime was recovered. Running time was 3 hours 45 minutes.

Fifty lbs. of No. 2 was put into a preheated (1500° F.) furnace. Running time 2 hrs. 20 min. The final temperature was 2010° F. for 30 min. 29.5 lbs. of product recovered.

A screen analysis was made on the two batch calcined products:

Tyler screen	Wt. % retained No. 1	Wt. % retained No. 2
+ 3 mesh	13.2	5.6
- 3 + 6	13.5	11.7
- 6 + 10	22.4	25.4
- 10 + 20	29.4	31.3
- 20 + 28	11.1	13.3
-28	10.7	12.8
Total	100.3	100.1

As a result of these studies, particularly based on observations of the decrepitation, it was concluded that the sample could all be crushed to pass a 3/4" square screen for the rotary kiln feed. Nine tons of the limestone was therefore crushed and screened to -3/4" with no removal of dust or fines. The remainder of the original limestone sample was reserved for possible further use.

2. Kiln operations.

A. Start up.

The kiln was fired up and heated for 6 hours. The exhaust fan was turned off because temperature could not be attained. The feed was started in at a rate of 100 lbs./hr. The first discharge was 50 minutes from start to feed. 50-75 lbs. was returned to the kiln because it was not completely calcined. The feed rate was increased to 150 lbs./hr. 3 ½ hours after initial feed. The initial shakedown lasted for 8 hours before the kiln was judged to be in a steady-state. Additional information is presented in the Operations Log.

B. Operation

9590 lbs. of -3/4" limestone was fed to the kiln and 5065 lbs. of quicklime was recovered. A dust loss of 374 lbs. (3.9%) was calculated from a material balance. Additional information is presented in Operations Log. The product was sealed in barrels to prevent adsorption of moisture and carbon dioxide.

C. Operating conditions

The temperature ranged from 1830° F. to 2200° F. but averaged between 2000° F. and 2100° F. The feed rate initially was 100 lbs./hr. but was increased to 150 lbs./hr. The retention time was approximately 90 minutes.

D. Sampling

1. The feed was sampled as it was crushed and placed in the barrels. The samples were composited and a screen and chemical analysis made.

2. The product was sampled every hour and the sample was placed in a labeled bottle. The samples were then composited into two samples, 1st half of run and 2nd half of run, for analysis.

3. A dust sample was taken on an hourly basis at the feed chute. A screen analysis and a chemical analysis was run on this sample.

A stack discharge sample was taken at the end of operation. This was taken from the roof of the building near the flue stack discharge. An analysis was run on this sample.

E. Design data

The following design information pertains to the pilot kiln used in this study:

Length	18'
Diameter	16"
Slope	0.0448 ft./ft. or 0.537 in./ft.
r.p.m.	3/4
Retention time	90 min.
Load %	10.1
Bed depth	2.6'
Retaining ring	2"(inside diameter 16")
Feed chute	2 1/2"
Feed rate	150 lbs./hr. limestone sample

F. Operational difficulties

The only trouble that was encountered during the operation was mechanical. The fan on the stack was too large, thus pulling too much air and cooling the limestone charge. The speed of the fan was reduced.

The feed conveyor motor was over the feed chute and the heat caused motor failure. During the 2 hour period required for repair of the motor, hand feed was employed. The difficulties encountered were easily solved.

ANALYSIS

I. Chemical

Constituents	% Feed	Product 1st half	Product 2nd half	Dust	Stack discharge
CaO	55.20	97.9	95.9	55.4	70.9
R_2O_3	0.24	0.37	0.42	0.55	0.64
SiO_2	1.13	1.47	3.46	2.30	2.27
MgO	0.05	- - -	- - -	- - -	- - -
CO_2	43.20	0.31	0.45	41.0	25.2
LOI	43.30	0.34	0.47	41.1	26.3
Moisture	0.48	nil	nil	0.03	nil
Total (minus LOI)	100.2	99.05	100.23	99.28	99.01

Screen:

Tyler Standard Screen:	Feed - wt. % retained
+ 3	54.7
- 3 + 6	10.9
- 6 + 10	8.5
- 10 + 20	9.3
-20 + 28	4.2
- 20 + 65	6.6
-65	5.9
Total	100.1

Tyler Standard Screen	Dust Sample wt. % Retained	Stack Discharge wt. % Retained
+ 48	0.1	2.1
- 48 + 65	1.3	7.9
- 65 + 100	13.7	24.9
-100 + 150	23.2	26.1
- 150 + 200	24.8	20.1
- 200	36.9	19.0
Total	100.0	100.1

Dust Loss Calculations

Feed	9590 lb.	
CO_2 loss	4161 lb.	(43.2% x 9590 lb.)
Product	5065 lb.	
Dust loss	374 lb. or 3.9%	

OBSERVATIONS

The operation proceeded so smoothly that about the only generalized observation which can be made is that material as represented by the sample is amenable to quicklime production via the rotary kiln route. It should be pointed out that the size of the feed for commercial production will probably lie between a top size of 1 1/2" and a bottom size of 1/2". However, there appears to be no reason to crush any finer than the limiting top size since decrepitation to about 1/8" will occur in any case. The limiting top size is that which will become completely decrepitated during calcination so that no large pieces of partially burned limestone report with the quicklime product. While these could be readily screened out, their occurrence would reflect a materials loss. Based on prior experience, we believe the limiting top size would be around 1 1/2".

The quicklime product is definitely off-color as compared to the normal white high-calcium quicklimes of commerce. However, this should not impair its usefulness for application where color is not at a premium. The quicklime product is violently reactive in water and slakes normally to a putty which is whiter than the quicklime itself. The slaked product diluted to a hydrated lime slurry containing about 10 weight per cent solids appears almost as white as the best grades of high-calcium hydrated quicklime. It appears that much of the discoloring matter reports as a residue which can be settled out of the milk of lime slurry. This further suggests that dry air classification might considerably upgrade the appearance of the quicklime product. However, as may be noted from the chemical analysis, the product is nearly 98% calcium oxide and it is unlikely therefore, that either air or water classification could chemically upgrade the product to any important degree.

RECOMMENDATIONS

1. Because the lime putty resulting from slaking the quicklime product appears to be unusually plastic to the touch, plasticity characteristics should be investigated on a laboratory basis in order to ascertain whether the quicklime product might be superior in building construction applications.

2. Since it is probable that the quicklime product will require a further crushing or possibly an air classification in the interest of uniformity, crushing, grinding, and air classification of the product should be investigated in order to determine which route, if any, might improve the color of the product.

3. Since a market for high calcium hydrated lime in bags might be developed, the dry hydration of the quicklime product followed by the usual air classification of a hydrate should be examined.

The Colorado School of Mines Research Foundation is presently in position to undertake studies in any or all of the foregoing areas, including a market survey.

OPERATION LOG

SUMMARY

Feed	9590 lbs.	Total feed	9691 lbs.
Product	5064 lbs.	- Spillage	101 lbs.
CO_2 loss	4153 lbs.	Net feed	9590 lbs.
Dust loss	374 lbs.*		
% Dust loss	3.9		

Products

Normal product	4764 3/4 lbs.
Special products	
A. End of Run	90 1/4 lbs.
B. Ideal Roast	55 1/4 lbs.
C. 2300 Product	95 1/4 lbs.
D. 2100-2200 Prod.	59 1/2 lbs.
Total	5064 lbs.

*Calculation

OPERATION LOG

Date	Time	lbs. Feed Cumulative	lbs. Product	Temp. Range ° F.	Notes
Oct. 12, 1962	1810	100			
	1800-1900	250			Fan turned on. Adjusted feed to 100 lbs. /hr.
	1900-2000	350			
	2000-2100	450			
	2100-2200	575			
	2200-2300	725			Adjusted feed to 150 lbs/hr.
	2300-2400	875			
Oct. 13, 1962	2400-0100				
	0100-0200	1091	309 3/4	1980-2030	End of shake down.
Oct. 13, 1962	0200-0300	150		1950-2200	
	0300-0400	300		1800-2100	
	0400-0500	450		1900-1940	
	0500-0600	600		1900-2180	
	0600-0700	750	372 3/4	1890-2010	Product barrel No. 2
Oct. 13, 1962	0700-0800	150		1930-2000	
	0800-0900	300		1850-1880	
	0900-1000	450		1800-1830	
	1000-1100	600		1860-2020	
	1100-1200	750		1980-2070	
	1200-1300	900		2080-2110	
	1300-1400	1050		2040-2100	

OPERATION LOG

Date	Time	lbs. Feed Cumulative	lbs. Product	Temp. Range °F.	Notes
Oct. 13, 1962	1400-1500	1200	359 1/4	2060	Product barrel No. 3
	1500-1600	1350	350 1/2	2060-2090	Product barrel No. 4
Oct. 13, 1962	1600-1700	150		2040-2090	
	1700-1800	300		1990-2030	
	1800-1900	450		1980-2080	
	1900-2000	600		1990-2100	
	2000-2100	750	325 1/4	2010-2090	Product barrel No. 5
	2100-2200	900		2030-2090	
	2200-2300	1050		1980-2110	2325 Feed to kiln plugged 2340 Feed to kiln open
	2300-2400	1200	295 3/4	1990-2100	Product barrel No. 6
Oct. 14, 1962	2400-0100	150		1910-1990	Gas meter reading@0020 h 920,410 cu. ft.
	0100-0200	300		1990-2110	
	0200-0300	450		2010-2110	
	0300-0400	600		1990-2020	
	0400-0500	750		1990-2080	125 lbs. of reburn added. 0400 hrs.
	0500-0600	900	337 3/4	2010-1860	Product barrel No. 7
	0600-0700	1050		1910-2040	
	0700-0800	1200	280 1/4	1980-2040	Product barrel No. 8
Oct. 14, 1962	0800-0900	50		2040-2000	0800 hrs. Conveyor motor stopped - hand feed.
	0900-1000	200		2000	1040 hrs. Conveyor back on.
	1000-1100	350		2000-1900	
	1100-1200	500		1860-1900	
	1200-1300	650		1830-1880	
Oct. 14, 1962	1300-1400	800		1900-2020	Exhaust fan on.
	1400-1500	950		2000-2030	Exhaust fan off, cooled charge.
	1500-1600	1100		2020-1850	
	1600-1700	1250	465	1990-2080	Barrel No. 9
	1700-1800	1400		1970-2030	
	1800-1900	1550		2030-2150	
	1900-2000	1700	424	1990-2020	Barrel No. 10
Oct. 14, 1962	2000-2100	150		2000-2050	
	2100-2200	300		2100-2230	
	2200-2300	450		2050-2080	Gas meter reading@2345 hrs 946,100 cu. ft.
	2300-2400	600	275 1/2	2050-2080	Barrel No. 11
Oct. 15, 1962	2400-0100	150		1900-2000	
	0100-0200	300		2000-2080	
	0200-0300	450		2010-2050	
	0300-0400	600		1910-2010	
	0400-0500	750	342 3/4	1960-2030	Barrel No. 12
	0500-0600	900		2010-2090	
	0600-0700	1050		2060-2140	Gas meter reading@ 0620 953,850 cu. ft.
	0700-0800	1200	326	2000-2080	Barrel No. 13
Oct. 15, 1962	0800-0900	150		2050-2110	
	0900-1000	300		2080-2120	
	1000-1100	450		1990-2050	Gas meter reading@ 1040 959,270 cu. ft.
	1100-1200	600	299 1/4		Barrel No. 14. Fuel off. End of operation

PROPERTY SABADO LIMESTONE, Mount Fagan Area DRILL HOLE NO. 1 A SHEET 1

Location: Tunnel face

BEARING

LAT.

DATE COMMENCED

DIP AT COLLAR Horizontal. Strike: West.

DEP.

DATE COMPLETED

DEPTH OF HOLE 220 feet

ELEV.

REMARKS

PURPOSE OF HOLE To determine width and grade of white ls. formation

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	Ca O ASSAY	Mg O ASSAY	SiO_2 ASSAY	Fe_2O_3 ASSAY
0' - 3.3'	White marblized recrystalized ls. Very coarse	4958	0'-50'	53.6			
3.3' - 3.5'	Basic fine grained green dyke material. Sharp contacts. No alteration in ls. Dyke rock contacts at rt. angles to core.						
3.5' - 27.5'	White marblized ls. Few bands up to 3" of light grey ls. Slips iron stained.						
27.5' - 28.5'	Light grey impure band of ls. Some garnetization. Two 1/4" seams of fine grained pyrite?						
28.5' - 54.3'	Typical white marblized ls. Very minor iron staining on slips. Becomes gradually finer grained.	4957	50'-84'	52.6			
54.3' - 59'	White ls. but more impurities than previous section.						
59' - 84'	Typical white marblized ls. Almost no iron staining on slips. Last 2 1/2 ft. very siliceous.	4959	88'-134	54.3			
84' - 88'	Mixed basic green dyke material and lime. Only 30% core recovery this section but gives impression that dyke may be only a few inches wide and cutting hole at a flat angle.	4960	134'-192.8	53.8			
88' -192.8'	Typical white marblized ls. with exception of 6" band of slightly greyish material at 102'. From 182' to 189' ls. still white and pure but more sugary in texture and sheared at rt. angles to hole. Rock cored in buttons.						

PROPERTY SABADO LIMESTONE

DRILL HOLE NO. 1A SHEET 2

Location: Tunnel face

BEARING

LAT.

DATE COMMENCED

DIP AT COLLAR Horizontal. **Strike:** West.

DEP.

DATE COMPLETED

DEPTH OF HOLE 220 feet

ELEV.

REMARKS

PURPOSE OF HOLE To determine width and grade of white Ls. formation

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY	ASSAY CaO	ASSAY
192.8' - 220'	Massive banded blue-grey Ls. Banding at 75 - 80° to course of hole. Two 2" chlorite seams at 206' and 210'.	4961	192.8'-220'		45.6	
	End of hole					
	Comment: Would appear that Ls. to 192.8' is of uniform enough grade to be mined as a unit.					
	Hole # 1A averages 53.6% CaO for a length of 188.8'					

PROPERTY SABADO Limestone Mount Fagan Area DRILL HOLE NO 1 SHEET 1

BEARING

DIP AT COLLAR 40°

DEPTH OF HOLE 400'

LAT.

DEP.

ELEV.

DATE COMMENCED

DATE COMPLETED

REMARKS

PURPOSE OF HOLE To obtain a vertical section of Limestone body with adit and Hole #1A

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY CaO	ASSAY MgO	ASSAY SiO_2	ASSAY Fe_2O_3
0' - 51'	Granite porphyry - altered, hard. Contains less than 0.5% sulphides, mostly pyrite.						
51' - 55'	Fine grained basic dyke cuts core at 50°. No noticeable contact alteration.						
55' - 79.7'	Fresher porphyry. Less 0.5% Fine sulphide.						
79.7' - 86'	Sheared, soft, altered porphyry, brecciated. Contains 1" chert seam at 80'. Cutting core at 55°.						
86' - 98'	Typical fresh porphyry.						
98' - 129'	Highly altered porphyry. Numerous water courses and brecciated; last 6' of section altered to gauge	Composite 801, 802, 803, 805.			0.08	2.0%	0.08
129' - 132'	Impure, altered Ls. Contact area	801	132-150	52.3%			
132' - 199'	White lime. Crystal size varies from 1/8". Sugary texture to 1/4" size. Numerous water courses. Slightly iron stained.	802	150-175	54.8%			
199' - 200'	White Ls. Fractured water course, iron stained	803	175-200	52.9%			
200' - 209'	White-grey Ls. Not as pure looking	804	200'-209	52.0%	0.11%	3.5%	0.17%
209' - 282'	White Ls. Still open, rusty water courses. Last 15' of section greyer color and few hair line cracks with black mineral.	805 806	209-235 235-280	54.3% 54.3%	0.04	1.6	0.14

OPERTY SABADO Limestone, Mount Fagan Area DRILL HOLE NO. 2 SHEET 1

ARING ____ LAT. ____ DATE COMMENCED ____

DIP AT COLLAR ____ DEP. ____ DATE COMPLETED ____

PTH OF HOLE 400' ELEV. ____ REMARKS ____

URPOSE OF HOLE ____

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	$CaO\%$ ASSAY	$MgO\%$ ASSAY	$SiO_2\%$ ASSAY	$Fe_2O_3\%$ ASSAY
0 - 8'	Casing						
8' - 24'	Fine grained green basic dyke. Fractured poor core recovery.						
24' - 32'	Limestone Breccia, included dyke rock. Seconday green micaceous mineral, very slight copper stain.						
32' - 70'	Coarse crystalized white Limestone, numerous water courses and iron stained fractured "N" core ends at 70'	1204	32'-70'	54.1			
70' - 159'	Similiar white limestone to above. Grain size decreases between 80' - 110'. Badly fractured and stained 110' - 140'	1207	70' - 159'	51.8			
159' - 168.2'	Fine grained green basic dyke upper contact at flat angle to core. Few pyrite masses up to 1/4". Bottom contact at 80' to course of hole. Contacts sharp limestone not altered but slightly silicified.	Composite Sample #1204 - #1213 inclusive			0.05	2.9	0.18
168.2' - 175'	Typical White Ls.						
175' - 178'	Basic green dyke contacts at 80° to hole.						
178' - 188.7'	White Ls. Fine grained.						
188.7 - 194.7	Basic green Fine grained dyke.						
194.7' - 256'	Typical white limestone between 202.2' and 203.7' Some alteration minerals between 232-242'. Impure bands up to 1/2" more grey in color. 3" basic dyke and alteration at 254'.	1208	194.7'-250'	53.5			

[illegible]PERTY Mt. [illegible]gan Line DRILL HOLE NO. #3 SHEET 1

[illegible] LAT. DATE COMMENCED

[illegible] DEP. DATE COMPLETED

[illegible] HOLE ELEV. REMARKS

[illegible] OF HOLE

[illegible]	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	$CaO\%$ ASSAY	$MgO\ \%$ ASSAY	$SiO_2\%$ ASSAY	$Fe_2O_3\ \%$ ASSAY
	Casing						
[illegible] - 11'	Altered Granite Porphyry						
[illegible] - [illegible]8'	Limey brecciated granite porphyry, heavily alteration. Brecciation increases towards end of section.						
[illegible] - 41'	Fine grained white limestone slightly silicified first 5' of section.	1214	23.8'-60'	44.8			
[illegible] - 48'	Fine grained green basic dyke. Sharp contacts at 45° to course of hole. No visible alteration of limestone.	(Composite Sample #1214- #1216 inclusive)			0.05	2.0	0.14
[illegible] - [illegible]76'	Typical white marblized limestone "N" core ends at 60', balance of hole "B" core. Grain size increases around 80°. The rock becomes soft and sugary. Sheared in many sections at rt. angles to hole and core tends to break in buttons in Sections up to several feet long. The soft sugary Ls. looks as pure as the more massive sections.	1215 1216 4901	60 - 100' 100'-150' 150'-176'	54.4 55.2 54.1			
[illegible]6' - 190.5'	Fine grained green basic dyke. 1" gauge on upper contact several short silicious sections up to 1" mineralized with small amount fine iron sulphides less than 1/2% . 1' included limestone at 188'.						
[illegible].5'-227'	Typical white marbilized limestone. 1/2" basic dyke material at 192.2' and 2" basic dyke at 200'. Grain size becomes coarser after 205'. 3" sheared buttons at 213.7'. Very few rusty fractures.	4902	190.5'-240'	52.2			

...RTY ______ **DRILL HOLE NO.** #3 ______ **SHEET** 2

... ______ LAT. ______ DATE COMMENCED ______

...LLAR 40° ______ DEP. ______ DATE COMPLETED ______

... HOLE ______ ELEV. ______ REMARKS ______

... OF HOLE ______

[illegible]	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY Ca O %	ASSAY	ASSAY	ASSAY
[illegible]8'	White cherty quartz. Sharp contacts at 85° to course of hole.						
- 303'	Typical white Ls. two 1" chert bands at 243.8' and 244.1' cut core at 85°. Between 248' - 260' Ls. becomes less pure looking not so white. Several rusty stained fractures. Becomes very coarse grained up to 1/4" and is extremely white and pure looking from 294' to 298.8' is sheared and tends to break in buttons at right angles to core.	4903 4904	240-264 264-303'	48.4% 53.0%			
- 308.3'	Same coarse Ls. but contains several 2" bands of cherty material cutting core at 80°.	4905	303'-308.3	50.5			
- 324'	Coarse white Ls. continues.	4906	308.3-324	48.6%			
- 344.5'	White Ls. grain size changes abruptly at 324'. Becomes very fine grained and siliceous. A 1" band of chert cuts core at rt. angles at 327.3'.	4907	324'-344.5'	33.0			
- 348'	White Ls. with about 60% cherty quartz in bands up to 4" wide.	4908	344.5-348'	19.8			
- 360'	Fine grained impure LS. Slightly pink in sections, very silicious. Small amount of fine pyrite on fractures	4909	348-360	27.9			
367'	Grey Blue impure limestone, fractured and recemented much chlorite.	4910	360-367'	26.6			

PROPERTY Mt. Fagan Line DRILL HOLE NO. #3 SHEET #3

BEARING

DIP AT COLLAR 40°

DEPTH OF HOLE

PURPOSE OF HOLE

LAT.

DEP.

ELEV.

DATE COMMENCED

DATE COMPLETED

REMARKS

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY Ca O %	ASSAY	ASSAY
367' - 377.5'	Impure fine grained grey-pink Ls. appears to be contaminated, probably due to proximity to dykes, badly fractured and recemented. Soft with large amount of secondary alteration minerals.	4911	367-377.5'	24.2		
377.5'-387.4'	Mixed dyke and limey material, brecciated, gaugy about 70% dyke. Fine grained grey-green.					
387.4'-394.5'	Soft gougey impure ls. abundant alteration minerals	4912	387.4'-394.5	24.9		
	End of hole					
REMARKS:	Should present no problem in mining dyke section between 176' - 190.5' separately, but pit layout would have to be planned to take this into consideration. Hole #3 omitting dyke Section Averages 53.1 % CaO For a core length of 238.5'.					

PROPERTY SABADO LIMESTONE PROPERTY Mt. Fagan Area DRILL HOLE NO. #4 SHEET 1

BEARING ______ LAT. ______ DATE COMMENCED ______

DIP AT COLLAR 40° DEP. ______ DATE COMPLETED ______

DEPTH OF HOLE 402' ELEV. ______ REMARKS ______

PURPOSE OF HOLE ______

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	CaO ASSAY	MgO ASSAY	SiO_2 ASSAY	Fe_2O_3 ASSAY
- 26'	Altered Acid Porphyry.						
26' - 31.9'	Very impure brecciated Ls. Many Vugs.						
31.9' - 40'	White Ls. badly fractured and brecciated end of "N" core.	49.13	31.9-40'	50.5			
40' - 57	Impure white Ls. iron stained, much chert and some short bluish bands.	4914 4915	40'-50' 50'-57'	43.6 34.4			
57' - 95.5'	Chiefly dark grey and impure mettled Ls. 2' Lost core at 92' in gauge zone. Abundant chloride.	4916	57'-95.5'	28.8			
95.5' - 101.7'	About 50% White Ls. balance Secondary Line altera-tion minerals very rusty at 99.8'						
101.7'-104.5'	Largely altered basic dyke material. Extremely fractured. Some limey alteration minerals.						
104.5' - 106.6'	Garnetiferous skarn limey zone.						
106.6'-122'	White Ls. much fractured and iron stained silicious and contains secondary alteration minerals.	4917	106.6-122'	38.8			
122' - 149.7'	Course grained white Ls. High grade a 1' band at 143' is chloritized and contains less than 0.5% fine iron sulphides.	4918	122'-149.7'	51.1%			
149.7 - 172	Blue-Grey Ls. Medium grained. Mottled in part	4919	149.7-172	48.8%			
172 - 194'	Impure white Ls. Rust on fractures core badly grease stained. About 1" of iron rich impurities at 180.0'	4920	172-194	49.0%			

PROPERTY SABADO LIMESTONE PROPERTY, Mt. Fagan Area DRILL HOLE NO. #4 SHEET 2

LAT. DATE COMMENCED

AT COLLAR 40° DEP. DATE COMPLETED

OF HOLE 402' ELEV. REMARKS

OF HOLE

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY CaO	ASSAY	ASSAY	ASSAY
194-195	Impure dyke basic contacts sharp no alteration to Ls						
195' - 229	Good White Ls. Medium grained	4921	195'-229	52.6			
		(Composite #4918 to 4921 inclusive)					
229 - 246'	Grey mettled limestone, impure abundant chloride	4922	229-232.3	37.1			
		4923	232.3'-246	48.6%			
246'-248.4'	Mostly altered basic dyke						
248.4 - 258	Impure white Limestone silicified	4924	248.4-274	45.3			
258'-274	Limestone continues becoming more pure looking - not real white, much iron staining on fractures, silicified						
274' - 295.8'	Light grey Ls. Still silicified.	4925	274'-295.8	44.6			
295.8'-332	Light grey pure looking Ls. Coarse grained.	4926	295.8-332	49.8			
332'-332.4'	Chlorized green basic dyke. No visible alteration	4927	332-343.5'	50.9			
332.4-343.5'	Coarse pure looking Light-Grey Ls.						
343.5'-402'	Coarse White Ls. Pure looking few grey bands. Less than 0.5% Sulphides Fn G" at 302.5'	4928	343.5-402	51.9			
	End of hole						

Hole # 4 From 122' to 402' a Core Length of 280' averages 49.5% CaO. From 122'-229' a length of 107' averages 50.7% CaO

PROPERTY SABADO PROPERTY Mt ‸gan Area DRILL HOLE NO. 5 SHEET 1

BEARING

LAT.

DIP AT COLLAR 40°

DEP.

DATE COMMENCED

DEPTH OF HOLE 400'

ELEV.

DATE COMPLETED

PURPOSE OF HOLE

REMARKS

FOOTAGE	DESCRIPTION	SAMPLE No	WIDTH IN FEET	ASSAY (Ca O %)	ASSAY	ASSAY	ASSAY
0' - 5'	Casing (Note, surface exposure shows hole to start on granite contact)						
5' - 21'	Good white limestone, broken about 2' last core in section						
21' - 43'	Mixed white and grey banded Ls. banding at 80° to core, medium grained.	4935	5' - 21'	51.7			
43' - 50.6'	White Ls. with about 30% chert bands 1' core last in section	4936	21'- 43'	47.5			
50.6' - 58'	White and light grey limestone medium grained	4937	43'-50.6'	40.1			
58' - 65.5'	White Ls. with about 30% Chert bands. 1' at 58, 6" at 59.8' and 18" at 62.4'. End of "N" core.	4938	50.6'-58'	49.0			
65.5' - 95'	Excellent white limestone pure medium grained 2" chert at 68.4'	4939	58' -65.5'	40.6			
		4940	65.5'- 98.8	53.6			
95' - 98.8'	Same as above but grain size increase to about 1/4"						
98.8' - 106'	Green fine grained basic dyke. Sharp contacts. Upper one at flat angle to hole. No visible alteration to Ls.						
106' - 205'	Excellent white Limestone. Grain size coarse to 198' becomes finer 198' - 205'. 1' of sheared buttons at 116'	4941	106'-155'	55.0			
		4943	155'-205'	53.9			

PROPERTY SABADO PROPERTY, Mt. Fagan Area DRILL HOLE NO. SHEET 2

BEARING

LAT.

DATE COMMENCED

DIP AT COLLAR 40°

DEP.

DATE COMPLETED

DEPTH OF HOLE 400'

ELEV.

REMARKS

PURPOSE OF HOLE

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY Ca O %	ASSAY	ASSAY	ASSAY
205' - 207'	Band of mottled grey limestone	4945	205'-207'	48.6			
207' - 215.2'	Excellent coarse white Ls.	4946	207'-215.2'	54.3			
215.2'-226.5'	Typical Fine grained green basic dyke material contacts sharp with no visual alteration to limestone						
226.5'-237.5	White limestone continues but grain size becomes much finer, is harder and more silicious	4947	226.5-237.5	45.4			
237.5'-239'	Largely vein quartz ~~to~~ + chloritized Ls. Fine disseminatated pyrite.	4948	237.5-239	22.4			
239'-255'	Dense very fine grained white limestone very silicious ~~to~~ & hard.	4949	239'-255'	31.3			
255'-268'	Grey-white silicified Ls. Fine grained 4" chert 257'. 3" at 358.5' and 3" at 366.7'	4950	255-268'	24.1			
268'-272'	Same as above but no chert bands.	4951	268'-272'	32.0			
272'-293'	Dark to light grey. Fine grained siliceous limestone impure.	4952	272'-293'	21.8			
293'-307'	Fine grained, Fine bedded light grey shaley- slate tends tp cleave at 45° to course of hole.						

PROPERTY SABADO PROPERTY, Mt. Fagan Are. DRILL HOLE NO. 5 SHEET 3

[illegible] ______ LAT. ______ DATE COMMENCED ______

[illegible] COLLAR 40° DEP. ______ DATE COMPLETED ______

[illegible] OF HOLE 400' ELEV. ______ REMARKS ______

[illegible] OF HOLE ______

[illegible]	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY (Ca O %)	ASSAY	ASSAY	ASSAY
[illegible] - 312.9'	Sediments continue lightly altered bleached whiter						
[illegible] 2.9' - 317'	Same rocks continue but have browner color and consist of alternating bands of light brown and more light color silicious bands. From 1/8" to 1" wide. Sediments are limey.						
- 329'	Chloritized impure Limestone.						
- 335.5'	Fine bedded buff limestone, narrow beds up to 1/2" laternating with whiter beds. Dense fine grained.	4953	329'-335.5	21.4			
[illegible]5.5'-337.6'	Altered section more chloritized soft more limey	4954	335.5'- 337.6'	30.0			
[illegible]7.[illegible]-364'	Soft fine grained mouse colored pinkish limestone Some chloritized sections	4955	337.6'- 364	29.9			
[illegible] - 400'	Fine grained white silicious limestone	4956	364'-400'	28.4			
	End of hole.						

Hole # 5 From 0'- 237' a Length of 237' averages 51.7 % CaO.

PROPERTY ~~SABADO LIMESTONE PROPERTY, Mt. Fagen Area~~ DRILL HOLE NO. 6 SHEET 1

BEARING

LAT.

DATE COMMENCED

DIP AT COLLAR 40°

DEP.

DATE COMPLETED

DEPTH OF HOLE 400'

ELEV.

REMARKS

PURPOSE OF HOLE

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY CaO %	ASSAY	ASSAY	ASSAY
0' - 18.6'	Casing						
18.6' - 21.6'	Grainte Porphyry.						
21.6' - 42.7'	Typical white limestone fine grained silicified much fractured and iron stained.	4930	21.6-42.7	37.8			
42.7'-43.3'	Basic green fine grained dyke material						
43.3' - 80'	Relatively pure white limestone 6" chert at 71' Stained and fractured. End of "N" core.	4931	43.3' - 80'	45.7			
80' - 91.5'	Same as last section finer grained contains 1% alteration products as 82'	4933	80' - 91.5'	44.0			
91.5' - 94.8'	Fine grained green basic dyke material sharp contacts.						
94.8' - 118.2'	Medium grained white limestone, few impurities	4934	94.8' -	43.9			
118.2' - 120.8'	Mixed white Ls. & chert about 40% Chert.						
120.8' - 122.5'	Mixed white Ls. & dyke rock cherty.						
122.5' - 135'	Fine grey green basic dyke rock.						
135' - 149.7'	Mottled impure grey limestone much contaminated with dyke rock. First 6' very iron stained and fractured 2' % dyke at 144'.						

PROPERTY SABADO LIMESTONE PROPERTY, Mt. Fagan Area DRILL HOLE NO. 6 SHEET 2

BEARING

LAT.

DATE COMMENCED

DIP AT COLLAR 40 °

DEP.

DATE COMPLETED

DEPTH OF HOLE 400'

ELEV.

REMARKS

PURPOSE OF HOLE

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY Ca O %	ASSAY	ASSAY	ASSAY
149.7 - 152'	Mostly chert bands and green dyke rock.						
152' - 161.7'	About 50-50 dyke to limestone. Core chert and gauge brecciated and broken.						
161.7' - 166.7'	Medium grained white-grey limestone few chert bands.						
166.7' - 175'	Medium grained white-grey limestone						
175' - 176'	Mixed Limestone and dyke.						
176' - 177.4'	Basic dyke. (probably two types and ages ~~% dykes~~ this on. Seems to alter the ls in contact areas) One type of dyke no phenocrysts.						
177.4'-180.2'	Altered white limestone contaiminated with dyke material.						
180.2' - 186.5'	Largely dyke rock with included limestone.						
186.5'-192.5'	Pink mouse colored Ls. (Similar to Hole 5?) Fine grained dense. Large amount of included Chlorite could be altered Aplite dyke.						
192.5' - 194.5'	White fine grained silicious limestone.						
194.5' - 211'	Grey limestone, soft much chloritized. First part of section much fractured and recemented.						

PROPERTY: SABADO LIMESTONE PROPERTY, Mt. Fagan, Area DRILL HOLE NO. 6 SHEET 3

BEARING: LAT.: DATE COMMENCED:

DIP AT COLLAR: 40° DEP.: DATE COMPLETED:

DEPTH OF HOLE: 400' ELEV.: REMARKS:

PURPOSE OF HOLE:

FOOTAGE	DESCRIPTION	SAMPLE No.	WIDTH IN FEET	ASSAY CaO	ASSAY Au	ASSAY Ag	ASSAY
211' - 220'	White impure Limestone contains few narrow chert bands. Few soft gauge sections.						
220' - 223	Largely cherty material.						
223' - 229.4'	White Limestone with about 10% chert banded up to 4" wide.						
229.4' - 234.4'	White Limestone grade improves less chert.	1962	1.2		tr.	0.1	
234.4'-252'	White coarse to medium Ls. few 1" bands of chlorite material rust on fractures 10" quartz with 1% pyrite at 242'.	1963	1.5		tr	0.1	
		1964	229.4-252	50.0			
252' - 254.6'	Fine grained basic dyke green in color. No alteration. Sharp contact. Rock contains small 1/4" white phenocrysts.						
254.6'-350'	Excellent white LS medium to coarse grained 3" chert at 339' and 4" chert at 343.3'.	1965	254.6-300	47.3	Being rechecked		
350' - 351'	White cherty limestone.						
351' - 363.2'	Coarse white Limestone 2" chert at 351.4'	1966	300'-350	53.5			
363.2' - 363.9'	White chert.						
363.9'-400'	Excellent coarse white limestone. Few buttons at 381.7' - 18" sheared.	1967	350'-400	53.2			

End of hole

Hole #6 has 168' averaging 51.3% CaO from 229.4' to 400'. Hole ended in Excellent looking material.

Hole #6 indicates a width of 125' - 150' of typical white limestone at the south end of the drilled area. Similar to [illegible]

Report on

Survey of Market
for
High Calcium Lime Products
from
Mt. Fagin Limestone Deposit

Prepared for

Cordillera Petroleum of Canada, Limited

By

Colorado School of Mines Research Foundation, Inc.
Golden, Colorado

Project No. 191107

April 26, 1965

Report on

Survey of Market for High Calcium Lime Products From Mt. Fagin Limestone Deposit

Prepared for
C 'llera Petroleum of Canada, Limited

By

Colorado School of Mines Research Foundation, Inc.
Golden, Colorado

April 26, 1965
Project No. 191107

Approved:

E. H. Crabtree
Director

C. J. Lewis
Director of Research

OBJECTIVE AND SCOPE

The purpose of this study has been to ascertain whether there is a sufficiently attractive market for lime and limestone products which might be produced from the Mt. Fagin limestone deposit near Sahuarita, Arizona, to warrant further developments leading to a commercial lime and limestone operation based on the deposit. To accomplish this objective, the following work was initially believed necessary: -

1. Examination of the present market for high calcium limestone, high calcium quicklime and high calcium hydrated lime within an approximately 500 mile radius of the Mt. Fagin ore body.

2. Locating the present suppliers of the indicated products within this area, including price structure and freight rates to the extent possible.

3. Evaluation of future trends with respect to new sources of supply or new markets for the indicated products which might be anticipated as the result of economic growth or technology.

4. Preparation of a formal report summarizing the results of the foregoing effort as indicated, together with any opinions and conclusions which the Research Foundation believes justified on the basis of the information resulting from this study.

This objective and scope is more fully outlined in a letter of December 30, 1964 from C. J. Lewis of the Research Foundation to Mr. Jesse H. Knight of Cordillera Petroleum of Canada, Limited. (Appendix)

In accordance with the Research Foundation's verbal understanding with Mr. Knight, the work as outlined was allowed much flexibility in the interest of practicability and efficiency as information became available.

FOREWORD

This study may be considered as the market survey phase of a project which was started by letters of November 7, 1959 and December 30, 1959 from Mr. G. A. Freeman, of Transarizona Resources, Inc. to C. J. Lewis of the Research Foundation. This initial work involved examination of limestone samples and resulted in a report to Transarizona Resources, Inc., dated February 10, 1960, entitled "Evaluation of Limestone Samples for Production of Lime". In essence, the report stated that limestone, represented by the samples studied, decrepitates and disintegrates to a relatively small particle during burning to quicklime and the resulting quicklime may be considered to be a good chemical grade of high calcium quicklime. The February 10 report enumerated 9 opinions based on the work done.

Subsequently, a contractual arrangement of October 8, 1962 between the Tucson Lime and Chemical Company, Inc. and the Colorado School of Mines Research Foundation, Inc. involved the processing of a large sample of high calcium limestone presumably represented by the samples involved in the February 10 report. This processing consisted of passing -3/4" limestone through a direct gas-fired pilot rotary kiln to obtain information on calcining characteristics of the limestone as well as to obtain a substantial quantity of the quicklime product for further evaluation. This work resulted in a report dated November 28, 1962 to Tucson Lime and Chemical Company entitled "Rotary Kiln Calcination of Limestone Sample". In essence, this report states that limestone represented by the sample is amenable to quicklime production via the direct-fired rotary kiln and that the dust loss due to decrepitation of the calcine to about -1/8" does not appear economically prohibitive. Reference is made in the November 28 report to the quicklime product being off-color as compared to the normal white high calcium quicklimes of commerce, as well as to the gratifyingly reactive nature of the quicklime during slaking.

Still later, the Research Foundation received a telegram dated September 27, 1963 signed "Tucson Lime and Chemical Company, Limited Per New Astral Mining and Resources, Limited" which authorized the Research Foundation to proceed with certain plasticity determination studies. This was followed by an authorization letter of October 9, 1963 from Plaxton and Company, 80 King Street West, Toronto 1, Canada. This plasticity study involved the preparation of hydrated lime at the Research Foundation using a sample of the quicklime product to which reference is made in the November 28 report and then submitting this hydrated lime to testing laboratories for its evaluation in terms of Type "S" building lime requirements. This work resulted in a letter report of November 29, 1963 from the Research Foundation to Mr. Herbert Plaxton. In essence, the letter stated that the high calcium hydrated lime which could be produced by conventional methods from the quicklime product of the November 28 report would very likely meet Type "S" building lime requirements but could scarcely hope to compete on a performance basis with the Type "S" hydrate produced by pressure hydrating dolomitic quicklime. The report also recommended a market survey to ascertain the local situation with reference to high calcium lime products from the deposit of interest. Since Messrs. J. D. Mason and G. A. Freeman received copies of the November 29, 1963 letter report, and are involved with this present market survey study, the foregoing reference to the November 29 report appears to be in order.

Finally, under date of December 30, 1964, Mr. Jesse H. Knight of Cordillera Petroleum of Canada, Limited authorized the Research Foundation to conduct the market survey which is reported in the pages following.

WORK DONE

1. The National Lime Association was contacted to obtain up-to-date information on the location of existing lime plants or lime plants under construction, particularly in the Southwestern United States. A map locating such installations appears in the Appendix.

2. Questionnaires were mailed to a total of 482 concerns within a 500 mile radius of Sahuarita, Arizona in the United States, exclusive of copper mills. Names of the concerns were obtained from up-to-date trade directories and selected on the basis of the Research Foundation's experience pertaining to the type of operations which do or could use lime. The questionnaire as well as the complete list of those receiving it appears in the appendix.

3. The 500 mile radius area around Sahuarita, Arizona was divided into 75 mile, 75 mile to 150 mile, and 150 mile to 500 mile radius regions and said regions subsequently considered in terms of market potential and competition. A map indicating these radius regions appears in the appendix. The map also includes the same radii working outward from the Paul Lime Company plant at Paul Spur, Arizona and the U. S. Lime Products plant at Nelson, Arizona.

4. Mr. C. J. Lewis of the Research Foundation visited the Mt. Fagin ore body in conjunction with calls on potential lime users in the Tucson and Phoenix areas.

5. Potential competition, railroads, purchasing agents, lime salesmen, etc. were contacted with reference to various factors which might affect the

feasibility of establishing a high calcium lime plant at or near the Mt. Fagin limestone body.

6. C. J. Lewis personally contacted the copper mills in New Mexico and Arizona in the course of which field trip he also visited the Paul Lime plant near Douglas, Arizona and the Hoopes Lime plant near Globe, Arizona. Some photographs taken in the course of this field trip appear in the appendix.

CONCLUSIONS

1. The market for high calcium quicklime which may be considered as the local market for a lime burning operation at or near the Mt. Fagin limestone deposit is at present at least 35,800 net tons per year. Practically all of this potential market is represented by flotation quicklime for the copper mills in the local market area.

2. The use of flotation quicklime by the existing copper mills in the local area will probably increase due to some expansion, and also because of the completely new Anaconda Copper milling operation which is expected to be on stream within a few miles of Sahuarita in the last quarter of 1969.

3. If flotation quicklime for the copper milling industry is excluded, the remaining local market for limestone and/or lime products from the Mt. Fagin ore body is relatively meager and very vulnerable to competition from established producers of lime products.

4. The Paul Lime Company with complete rotary kiln, and supplementary high calcium lime processing operations at Paul Spur, Arizona is at present well-established in the market area which may be considered as the local market area for a lime-producing operation based on the Mt. Fagin limestone deposit.

5. The Hoopes Lime Company with a rotary kiln operation, a few miles from Miami, Arizona, is well-established in the Globe-Miami copper milling area.

6. The U. S. Lime Products Division of The Flintkote Company with

plants at Henderson, Nevada and Nelson, Arizona, is well-established in the Kingman-Bagdad, Arizona copper milling area.

7. Possibility of negotiating a long-term arrangement with Anaconda Copper Company with reference to supplying flotation quicklime for their announced new operations near Sahuarita warrants careful consideration.

RESULTS

1. Typical Rail Freight Rates on Lime. (Information received from railroads).

From Nelson, Arizona (U. S. Lime Products) to Phoenix, Arizona:

Minimum 15 ton car .... $6.70 per net ton

Minimum 20 ton car .... $5.70 per net ton

From Lucerne Valley, California (Charles Pfizer Lime Plant) to Phoenix, Arizona:

Minimum 30,000 lbs. .... $18.40 per net ton

From Lucerne Valley, California to Tucson, Arizona:

Minimum 30,000 lbs. .... $20.60 per net ton

From Cushenburg Railhead, California (presumably freight interchange for Henderson, Nevada lime plants) to Casa Grande, Arizona:

Minimum 30,000 lbs. .... $16.20 per net ton

From Paul Spur, Arizona to Bisbee, Arizona:-

Presumably minimum 25 ton cars .... $0.89 per net ton

From Paul Spur, Arizona to Ajo, Arizona:

Presumably minimum 25 ton cars .... $4.30 per net ton

*From Paul Spur, Arizona to Phoenix, Arizona:

Presumably minimum 15 ton carloads ...... $6.60 per net ton (approximately)

* (Information received from Paul Lime plant)

Flotation quicklime from Paul Spur, Arizona to Sahuarita, Arizona:

Minimum 44 ton car .... $2.50 per net ton

Flotation quicklime from Paul Spur, Arizona to Tucson, Arizona:

Minimum 44 ton car .... $2.50 per net ton

Typical Truck Freight Rates

From Paul Spur, Arizona to Morenci, Arizona $24.60 per net ton

From Paul Spur, Arizona to Silver Bell, Arizona $4.00 per net ton

2. Typical Prices.

Bulk pebble quicklime from Paul Spur, Arizona f.o.b. Bisbee, Arizona $14.00 per net ton

Type "S" hydrated lime f.o.b. Paul Lime Plant, Paul Spur, Arizona $1.20 per bag or $23.00 per net ton

Chemical hydrated lime in bags f.o.b. Paul Lime plant $21.85 per net ton

Bulk quicklime f.o.b. Paul Lime plant $14.00 to $16.00 per net ton

Bulk pebble quicklime f.o.b. A.S. & R. Mission Unit, near Sahuarita, Arizona - $15.00 to $16.00 per net ton carload delivery

Bulk quicklime f.o.b. other copper mills near Sahuarita (Duval, Pima) Arizona - $17.50 to $18.00 per net ton f.o.b. bin site truck delivery

Chemical hydrated lime in bags from Paul Spur, Arizona to San Manuel, Arizona - $0.73 per bag f.o.b. warehouse truck delivery.

Copper mills, Miami, Arizona - pebble quicklime in bulk - $15.50 per net ton f.o.b. lime bins truck delivery.

Inspiration Copper Company, Christmas, Arizona - pebble quicklime in bulk - $15.50 to $16.00 per net ton f.o.b. lime bins truck delivery.

Miracle hydrated lime in bags (Type "S"), Henderson, Nevada to Phoenix, Arizona - $0.96 per 50 lb. bag f.o.b. dealer's warehouse.

Miracle hydrated lime in 50 lb. bags f.o.b. dealer's warehouse - Phoenix, Arizona - $1.30 to $1.40 retail.

3. Information on Building Lime Market.

(a) National Lime Association claims 95% of the market for masonry (building) lime is either Type "S" hydrated lime or quicklime putty. Quicklime putty involves a high local demand since it is not practical to truck the putty any distance.

(b) The Superlite Builders Supply Company, Phoenix, Arizona, the largest building supply dealer in the area, states that all lime for mortar and stucco in the area is high plasticity and that Miracle lime (Type "S" dolomitic) from U. S. Lime Division of The Flintkote Company, Henderson, Nevada, furnishes at least half of all Type "S" lime sold in the Phoenix area.* About 125 to 150 small dealers in the Phoenix area sell Miracle lime for between $1.30 and $1.40 per bag. A large retail order is considered to be from 10 to 20 bags. Superlite would be interested in a new source of Type "S" lime providing its plasticity were at least as high as that of Miracle lime.

(c) The Paul Lime Company of Paul Spur, Arizona, produces a high calcium Type "S" lime by special hydrating process believed to include a chemical additive to produce plasticity. Paul's Type "S" high calcium hydrate is having difficulty competing with Miracle lime from Henderson, Nevada.

* $0.96 per 50 lb. paper bag delivered.

4. Limestone.

(a) No major uses for limestone from the Mt. Fagin limestone body have been located.

(b) It is highly unlikely that the new Spreckles Sugar Company mill which is expected to be on stream in the area early in 1967, could use Mt. Fagin limestone. It is conventional practice in a sugar beet refinery to burn limestone to quicklime and treat the raw sugar solution with quicklime to form a soluble compound of calcium sucrate. This solution is then clarified and blown with carbon dioxide gas from the lime kiln producing the quicklime in the first place. The carbon dioxide gas treatment precipitates the calcium of the calcium sucrate as a calcium carbonate sludge while simultaneously regenerating the sugar in a pure water soluble form. The sugar solution is clarified and crystallized to produce the commercial sugar product.

Conventional practice is to burn the limestone in a vertical lime kiln since this type of kiln is the most efficient in terms of both quicklime and carbon dioxide recovery as well as in terms of the cyclic operation of a beet sugar refinery. Obviously, a limestone which decrepitates during burning to lime would block the upward draft of a vertical lime kiln. Spreckles Sugar Company specifications for their limestone at present are minimum calcium carbonate 93%, maximum magnesium carbonate 4%, maximum silica 2%, fine grained limestone which will not shatter or decrepitate. While the Mt. Fagin deposit meets the chemical specifications, it does not meet the physical specifications. Spreckles Sugar expects to consume about 20,000 net tons of limestone per year and do not plan to recover the by-product calcium carbonate sludge.

5. Soil Stabilization Market.

(a) This is a large market for high calcium hydrated lime in Texas, Ohio, Indiana, and other relatively high rainfall states, especially where freezing and thawing along highways occurs. However, the State of Arizona has not yet begun to use hydrated lime for soil stabilization in conjunction with highway maintenance and/or construction programs. Arizona is very much interested, particularly with reference to stabilization of chinley clay along Highways 66 and 40 and Highway 89 north of Flagstaff. The University of Arizona has a research program under way on Arizona soil stabilization and Arizona State University is attempting to get some work started in this field.

6. Agricultural Markets for Lime.

(a) This area has not been positively examined during the course of this market survey. Arizona agricultural soils are, for the most part, alkaline and the consumption of agricultural lime in Arizona is known to be relatively small. No indication of any important use of agricultural lime was apparent during the approximately 2500 mile field trip surveying the copper mills. Dr. W. H. Fuller, Head of the Department of Agricultural Chemistry and Soils at the University of Arizona, stated that Arizona soils are calcareous or soon become calcareous as the result of irrigation water and that, for this reason, lime is not used on Arizona soils for agricultural purposes.

7. Response to Questionnaires.

Of the 482 questionnaires mailed, returns were as follows:

(a) Total replies	189,	representing a return of	39%.
(b) No reply at all	247,	representing	51%.
(c) Returned to sender, unopened,	46,	representing	10%.
(d) Returns indicating no interest,	154,	representing	32%.
(e) Returns affirmative	35,	representing	7%.
		Total % accounted for	100%.

8. Chemical and Miscellaneous Markets for Lime.

(a) Based on the response to the affirmative questionnaires, conversations with City of Phoenix Purchasing Office, lime producers and lime salesmen, this market is relatively insignificant although growing with population and industrial expansion.

(b) The located market (see affirmative replies in the appendix) is as follows:

0 to 75 mile radius of Sahuarita	less than 50 tons of hydrated lime per year.
75 to 150 mile radius of Sahuarita.........	about 250 tons of high calcium quicklime, and less than 160 tons of high calcium hydrated lime. There is apparently some market for a Type "S" hydrated lime as well as dolomitic quicklime in this area.

150 to 500 mile radius of Sahuarita	fairly attractive for one lime plant but obviously (see appendix) not to be considered as a support for a new lime plant near Sahuarita in view of the already well-established competition (see map, appendix).

It is again emphasized that the questionnaires have not necessarily covered all of the potential market, particularly the market beyond the 150 mile radius of Sahuarita, but a serious effort has been made to have the questionnaires cover at least the major potential in the 150 mile radius. It is obvious from the returns that the market within the 150 mile radius is not such that would afford a quicklime plant only at Sahuarita, either adequate sales potential or adequate "local situation" protection unless the plant at Sahuarita were firmly anchored to the flotation quicklime market. This latter being the case, a high calcium lime plant at Sahuarita might then find it possible to broaden its base for the purpose of obtaining additional lime markets, particularly the market for chemical hydrated lime in bags.

9. <u>Market for Flotation Lime for Copper Mills.</u>

(a) The market for flotation quicklime in the area highly local to Sahuarita is as follows:

Company	Location	Present annual consumption flotation quicklime (net tons)
A. S. & R.	Sahuarita	6000
Duval Copper	Sahuarita	8400
Pima Mining Co.	Sahuarita	7200

(b) In addition to the foregoing, the following may, for all practical purposes, be considered a part of the local market:

Phelps Dodge	Ajo	8700 net tons
A. S. & R.	Silver Bell	5500 net tons

(c) The foregoing present consumption in the local and near local copper milling market thus totals to 35,800 tons per year.

(d) To the foregoing may be added an additional 7200 tons for Pima Mining Company which expects to double its capacity in the reasonably near future; and also, an estimated 25,000 tons per year of flotation quicklime for Anaconda Copper Company's mill which is scheduled to be in production the last quarter of 1959 near Sahuarita.

(e) Flotation quicklime is presently delivering into the Sahuarita area in a price range of from about $15.00 to about $17.50 per net ton, depending on contract and on whether delivery is by rail or truck. Truck freight from Paul Spur to Silver Bell was $4.00 per net ton in March, 1965; rail freight from Paul Spur to Ajo was $4.30 per net ton in March, 1965.

(f) The following copper mills should not be considered as offering potential market for lime produced at or near the Mt. Fagin limestone ore body:

(1) Kennecott Copper, Hurley, New Mexico	captive
(2) Phelps Dodge Corporation, Morenci, Arizona ..	captive
(3) Phelps Dodge Corporation, Bisbee, Arizona ...	too near Paul Lime plant.
(4) Magma Copper, San Manuel, Arizona..........	captive
(5) Kennecott Copper, Hayden, Arizona...........	captive
(6) Inspiration Copper Company, Christmas, Arizona	too near Hoopes Lime plant.
(7) Inspiration Copper, Miami, Arizona	too near Hoopes Lime plant.
(8) Miami Copper Company, Miami, Arizona......	too near Hoopes Lime plant.
(9) Duval Copper Company, Kingman, Arizona....	too near U. S. Lime Products plant.
(10) Bagdad Copper Company, Bagdad, Arizona ...	too near U. S. Lime Products plant.

(g) One local copper mill, Pima Mining Company, will probably change from truck delivery to rail delivery of lime by July, 1965.

Further information pertinent to the above items (a) through (g) appears in the appendix.

COMMENTS

Because reports of this nature may remain active for a considerable time and their ultimate distribution can not be completely anticipated, the Research Foundation has intentionally withheld some information sources and some supporting data from this report. However, such backup information is in the Research Foundation's files and can be examined by those properly authorized to do so.

The following comments in addition to the conclusions already stated, are based on the information gathered during this market survey, other pertinent information which the Research Foundation can ethically use, and the nearly 15 years of experience of Mr. C. J. Lewis in the lime industry: -

1. The freight rate of $2.50 per net ton for bulk flotation quicklime from the Paul Lime plant to the Sahuarita-Tucson area is surprisingly low. Indeed, this rate may not be much more than the amortization cost on a net ton of lime produced in a new lime plant as compared with that of a lime plant which has been or is nearly amortized. This may be one reason why the Pima Mining Company near Sahuarita will soon be taking flotation lime from the Paul Lime plant via rail delivery all the way. Further activity with reference to a commercial lime plant at or near the Mt. Fagin deposit should include an examination of this freight rate to establish whether it is a special rate similar to the special rates on fluxing quicklime from eastern lime plants to major steel producing areas. Another line of activity could include informing the local

copper mills that truck deliveries may be available from a Mt. Fagin operation, thus making it unnecessary to anticipate railroad delivery to the lime bins of these copper mills. This $2.50 per net ton freight rate may prove to be the limiting factor with reference to the economics of a lime plant based on the Mt. Fagin deposit.

2. The value of the Mt. Fagin limestone deposit, assuming proved reserves and conventional mining costs, should, as a source for quicklime production by a new lime company, be assessed in terms of the local market for copper mill flotation quicklime. Other possible markets for both limestone and high calcium lime products which a new company might develop from Mt. Fagin limestone ore are too small and too well served from other sources to afford justification for a <u>new</u> company operation on the Mt. Fagin ore body.

3. The foregoing comment is somewhat less pertinent in the case of an existing and well-established high calcium lime operation interested in expanding its operation by locating a lime plant to use Mt. Fagin limestone ore. An existing operation such as the Paul Lime Company at Paul Spur, Arizona or the U. S. Lime Products Division of The Flintkote Company at Nelson, Arizona might gain some advantage if, in addition to the flotation lime for the copper mills in the local area, the potential of a lime plant near Sahuarita could be used to supplement the present market coverage or to strengthen an existing position in the lime industry.

4. As has already been pointed out in this report, potential markets covering high calcium building lime, agricultural lime, limestone and limestone products, and lime for soil stabilization should be considered as practically non-existent as far as the market potential for Mt. Fagin ore body products is concerned. This leaves only the flotation quick-lime requirement of the local area and the small but gradually growing market for general purpose chemical quicklime and hydrated lime within the Phoenix-Tucson area.

5. It may be expected that the Paul Lime Company will continue to ship chemical lime products into the Tucson-Phoenix area as well as make every effort to maintain a market for their Type "S" building lime. It may also be expected that the U. S. Lime Products Division at Nelson, Arizona, having an already well-established market for Type "S" lime from Henderson, Nevada, will continue to be also a source of high calcium chemical lime in the Phoenix-Tucson area. It seems unwise, therefore, that a "new company" lime plant with operations based on the Mt. Fagin deposit, should depend on any markets other than the flotation lime market in the local area. At the same time, it is reasonable to anticipate that a "new company" operation so based would, under the market shelter of the local copper mills, gradually obtain its share of the high calcium chemical lime business in the competitive area.

6. Since the Mt. Fagin limestone ore body as represented by the limestone sample covered in the November 28, 1962 report decrepitates during burning, it should be possible to feed all limestone mined directly to a

rotary kiln and ship <u>all</u> quicklime produced directly for flotation, thus simplifying operations and avoiding the necessity for stockpiling quarry screenings or disposing of quicklime dust and fines via a hydration plant. While this is probably a minor consideration, profitwise, it is a factor opposing the relatively high amortization cost on a new lime plant which must compete with an established operation at Paul Spur, Arizona.

7. It should be borne in mind that the Paul Lime plant was shipping about 70 tons per day of flotation quicklime to the Phelps Dodge mill at Morenci, Arizona until November, 1964. The Morenci mill then became a captive lime operation. Loss of tonnage business of this nature would no doubt encourage the Paul Lime Company's efforts to maintain their present markets in the Sahuarita area. On the other hand, no indication has been found that the copper mills in the Sahuarita area have any traditional obligation to a lime operation as apparently exists around Miami and Douglas, Arizona; and it is believed that the copper mills in the Sahuarita area would welcome a second source of flotation quicklime, particularly a local source.

8. There is strong likelihood that the copper milling industry in the Sahuarita area will substantially increase its ore processing tonnages within the reasonably near future. It is reported on reliable authority that interest in copper mining and milling operations around Safford, Arizona are likely to remain dormant for the next 10 years while existing mills near Sahuarita undergo planned expansion and Anaconda Copper brings in its announced new mill near Sahuarita late in 1969.

These factors further reflect the potential interest of the copper mills around Sahuarita in a new and/or second source of flotation quicklime.

9. Rounding off the present 36,000 net ton per year quicklime useage distributed between the mills at Ajo, Silver Bell and the Sahuarita area, this calculates to approximately 107 net tons per day quicklime from a plant operating 335 days per year. These figures are believed to be realistic. The 335 day operating year allows for 30 days down time for maintenance of the rotary kiln. This, in turn, indicates about 200 net tons per day limestone feed to the kiln. On the basis of known expansion under way in the Sahuarita area, this further calculates to an eventual 200 tons per day of flotation quicklime use involving about 400 tons per day of limestone ore feed.

The potential profit which might be realized from an operation based on 200 net tons per day limestone feed to kiln involves many, many factors, the consideration of which is not part of this market survey study. However, the following are offered as "order of magnitude" figures which could be used to give an economic flavor to the market survey information just reported: -

Total cost of raw limestone as fed to rotary kiln	$1.00 (per net ton)
Cost of fuel for converting 1 ton of limestone to quicklime	1.25 (per net ton)
Operating cost per ton of limestone burned..........	1.25 (per net ton)
5-year amortization - $750,000 (guesstimated) investment for processing 200 tons limestone per day...........	2.25 (per net ton)
Total costs per net ton	$ 5.75

Approximate yield of product as quicklime (due to loss of approximately 44% by weight carbon dioxide gas) ... 56%

Cost per ton of quicklime $\frac{(\$5.75)}{(\ .56)}$ .... $10.27 (per net ton)

Estimated quicklime price net ton f.o.b. plant $14.00

Potential estimated profit 100 tons per day quicklime shipment...... $373.00

The foregoing figures are very, very rough and are included herein simply to give some economic flavor to this report and to provide some basis for considering the next phase which should logically be an economic feasibility study based around what we now know about the limestone ore body, its calcining characteristics and the potential market for the product.

10. Based on all information and knowledge at our disposal concerning the potential of the Mt. Fagin limestone deposit, we believe the item merits further study, particularly involving economic feasibility studies and direct contact between the principals involved and the copper mills in the market area described.

APPENDIX

#2

FOLLOW-UP REPORT

ON THE

MT. FAGAN MARBLE DEPOSITS
(SABADO LIMESTONE DEPOSITS)

PIMA COUNTY, ARIZONA

-- Submitted to Tucson Lime and Chemical Company

January 12, 1963

By E. N. Pennebaker

E. N. Pennebaker

FOLLOW-UP REPORT

ON THE

MT. FAGAN MARBLE DEPOSITS

PIMA COUNTY, ARIZONA

INTRODUCTION

The writer has done the following things with respect to the further investigation of these deposits, also known as the Sabado limestone deposits, and described in his report dated January 17, 1961.

1. In company with Mr. J. D. Mason the core obtained from seven exploratory diamond drill holes was examined.
2. A trip was made to the property with Mr. T. A. Goodnight in order to verify the drill holes, their locations and attitudes.
3. In the office rough estimates were made of the tonnage and grade of material that might be extracted from two different quarry designs.
4. Data from the experimental calcining operations conducted by the Colorado School of Mines Research Foundation were studied.

These various items are discussed in the following report.

DIAMOND DRILL HOLES

Seven diamond drill holes have been put into the so-called "Northern Deposit". These are along five profiles spaced at about 200 feet. Three holes are along profile A-A; one each are along the others. Thus a strike length of about 1,000 feet was tested. The holes are of BX diameter and excellent recovery was obtained.

The holes, with one exception, are pointed southerly at a minus angle of about 40 degrees. The exception is a flat hole drilled southerly into the face of the old tunnel. These holes are shown on a plan map prepared by Mr. Mason, and four of them appear on the two cross-sections also prepared by him. The writer has constructed three other working sections for the reserve estimate.

The geologic logs of the holes were made by Mr. Mason and were judged to be properly done. The sampling was generally adequate, although in places the sample intervals are rather long.

The chemical analyses were made by Jacobs Assay Office of Tucson, Arizona, a laboratory with an excellent reputation. All samples were tested for CaO content referable to calcite (also to dolomite, gypsum and scheelite if such were present, which is very doubtful). Tests for impurities were made on composites for intervals selected by Mr. Mason. These do not cover all of the better limestone in all of the holes, and further tests for intervals falling within the tentative quarry profiles would be helpful.

The analyses made available to the writer were mostly on compilations prepared by Mr. Mason. The original reports by Jacobs were not transmitted.

INSPECTION OF THE GROUND

The writer was not present during the drilling of the holes, but the drill hole locations were inspected on November 18, 1962, and the drill hole collars were verified.

The slopes of the profiles above the drill holes were also checked by Brunton at this time, along with the bearings of the holes and their inclinations.

RESERVE ESTIMATES

Tonnage

It is obvious that more limestone of good quality has been outlined by drilling than can be conveniently and economically quarried, because of the configuration of the ground with respect to the shape of the limestone body. Consequently, in order to estimate a reserve tonnage, the writer has set up two tentative quarry outlines and has estimated the quantity of rock within them.

Quarry A. This tentative excavation has a steep south bank about with the inclination of the bedding, ranging from 70 to 80 degrees to the north. The north bank slopes southerly at 60 degrees. This quarry is about 1,000 feet long with a width at the top varying from about 100 to 250 feet. Its floor is at an elevation of 4,400 feet above sea level. The vertical heights of the steep south bank varies from 200 to 250 feet.

The tonnage for Quarry A, using a factor of 11.5 cu. ft. of rock in place equals 1 short tons, is as follows:

Total tonnage...............	1,643,500
Less 10%....................	164,350
	1,479,150

The 10% subtracted is an arbitrary figure for waste material (dikes and chert) to be cast out, for near-surface dirty material to be discarded, and to compensate for the drill holes not being parallel with the block margins.

Quarry B. Inasmuch as the south margin of Quarry A, above, is very steep and it may be found impossible to mine to it, another quarry outline was tentatively set up with a south bank slope at 60 degrees. This lifted the floor to an elevation of 4,450 feet above sea level and gave the following results:

Total tonnage..................	970,000
Less 10%	97,000
	873,000

The above tonnage estimates were made from five vertical cross-sections showing the shapes of the limestone body and the outlines of the quarries. Two of the profiles were obtained from Mr. Mason's cross-sections. The other three were determined by the writer using a Brunton clinometer. Consequently the profiles are approximate and they yield only a rough estimate.

Limestone areas within the quarries, as shown on the vertical cross-sections, were determined by planimeter. These were multiplied by block lengths within which each hole (or the three holes on Section A-A) was considered to have an influence on tonnage and grade. The volume so determined was divided by a factor of 11.5 to convert to short tons in place.

Cross-sections and maps do not accompany this report. However Mr. Mason has prepared a plan map and two cross-sections, and the writer's working sections are available upon request.

Grade

The grade, or chemical content of lime (CaO), was averaged over various interval groupings for the individual holes. This is a "weighted average", and those intervals falling within the quarry outlines were used to derive the grade of each block. Where analyses from surface sampling were available, or where several holes fell on a section (such as Section A-A), a general average was determined. Using the tonnage in each block, a weighted general average was then obtained, with the following results:

Quarry A .... 52.06% CaO

Quarry B .... 52.08% CaO

Impurities

The general average amounts of the impurities present in the limestone are more difficult to estimate because the intervals analyzed do not fall neatly within the quarry limits. Probably the best estimate is that obtained by a weighted average of all the core analyzed, regardless of whether it is within or outside of the tentative quarry outlines. This is as follows:

Silica - SiO_2	2.92%
Ferric oxide - Fe_2O_3	0.19%
Magnesia - MgO	0.05%
Alumina - Al_2O_3	0.25 to 0.60% (?)

The writer believes that the above-noted amount of silica (2.92%) may be somewhat too high and that a figure of 2.50 to 2.75% is probably more correct. However, some additional sampling for this impurity would yield helpful information.

The foregoing estimates should be considered as "probable" tonnages and grades rather than as "proved". This is because of the various reasons already noted and also because most of the diamond drill holes cut well below the quarry floors and their information must be projected up a considerable distance. This is partly offset by two profiles sampled by Mr. Mason at the surface, but from such sampling it is difficult to obtain representative samples of the impurities present.

On the other hand, the evenness of grade obtained from all sources is definitely reassuring.

CALCINATION TESTS

Test work was conducted by the Colorado School of Mines Research Foundation, Inc. Results of the work are contained in a report dated November 28, 1962, a copy of which was made available to the writer on January 11, 1963.

A brief summary of some of its conclusions are as follows:

Good Points

1. "The limestone feed to the kiln calcined normally as compared with the high calcium quicklime of commerce".
2. "Material as represented by the limestone sample should be able to be converted to quicklime in a conventional rotary lined kiln under conditions which should render the quicklime product economically competitive in its market area".
3. Previous tests, reported in 1960, "indicated the sample material to be a good grade of high calcium limestone which upon calcination would result in a quicklime product meeting the chemical specifications for a high calcium quicklime".
4. The limestone decrepitated in a manner that makes it unnecessary to remove quarry screenings prior to calcination.
5. "The dust loss resulting from decrepitation was surprisingly low".

Problems

1. "The quicklime product is definitely off-color as compared to the normal white high calcium quicklimes of commerce. However, this should not impair its usefulness for applications where color is not at a premium". It is suggested in the report that "dry air classification might considerably upgrade the appearance of the quicklime.

2. The material tested by the Colorado School of Mines Research Foundation was somewhat higher in quality than the writer's determination of the general average tenor of the deposit.

CONCLUSIONS

The foregoing point should be particularly noted. The following is a comparison of analyses:

	Material Tested in Colorado	Average Grade Estimate by E.H.P.
CaO	55.16%	52.07%
CO_2	43.20	(40.93, calculated)
SiO_2	1.13	2.75
R_2O_3	0.24	0.19 (Fe_2O_3)
MgO	0.05	0.05
H_2O	0.10	0.25 - 0.60 Al_2O_3)

Nevertheless, the quality of the average feed can probably be improved by careful quarry practice plus hand sorting.

Air classification tests should be undertaken on material of <u>average grade</u> to determine if improvements in both color and chemical quality can be made. (This is contrary to the Foundation's conclusion on page 15 of the report dated November 28, 1962, because the tests were made on material that turned out to be purer than the average.)

An added safeguard would be the drilling of several additional exploratory holes that would pierce the limestone within the suggested quarry outlines.

In general the writer's view is favorable to the project. The tonnage of raw material is adequate, a quality of feed better than some of the other operating Arizona plants can be provided if proper care be exercised, and the test work yielded promising results.

E. N. Pennebaker

E. N. Pennebaker

Scottsdale, Arizona
January 12, 1963

#1

MOUNT FAGAN

MARBLE DEPOSITS

PIMA COUNTY, ARIZONA

Submitted to Mr. Kemper Marley

-- January 17, 1961

By E. N. Pennebaker
E. N. PENNEBAKER

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SUMMARY

The Mount Fagan marble deposits possess the following favorable features:

1. Substantial size.
2. One sampled section of encouraging quality.
3. Nearby facilities to service a plant.
4. A local market for some of its products.

On the other hand, there are a number of difficulties that must be recognized. These are:

1. Silica as an impurity may exceed the acceptable limit, and its amount and range throughout the deposits have not yet been determined.
2. The abundance of other impurities needs to be more fully investigated.
3. An excessive amount of fines may be produced during crushing.
4. The lump form of the marble is reported to be lost during calcining.
5. Excessive dusting may accompany burning.

Even assuming the adequate purity of the raw material, the field of use of the product is somewhat limited by the destruction of the lump form during calcining. However, it now appears that one of the deposits contains material

suitable for making reagents employed in the flotation of copper ores, flux for copper smelting, material for cement manufacture, and probably rock for roofing granules. Other uses are possible but are dependent on further analyses for purity and various testing procedures.

Consequently the deposits need to be further explored and systematically sampled, preferably by diamond drilling. Additional testing in the laboratory and in a treatment plant is also required. The feasibility of the project will not be apparent until such steps have been taken, but the writer believes that the outlook is promising.

Attention is directed to the sections entitled "Conclusions" and "Recommendations" at the end of the following report.

MOUNT FAGAN
MARBLE DEPOSITS

INTRODUCTION

Limestone deposits of possible economic value occur a few miles southwest of Mount Fagan in southeastern Pima County, Arizona. The area of interest is about 25 miles in a beeline southeast of Tucson, and is presently reached by traveling 20 miles of paved highway followed by 12 miles of fair gravel road and 2 miles of very rough and steep road. (See Map No. 1). Actually this "limestone" is a coarse-grained marble, and it will be referred to as "marble in the following report.

That marble of interest occurs here is shown by analyses reported by Mr. J. D. Mason and by a sample analyzed by The Colorado School of Mines Research Foundation, Inc. The latter gave by analysis the following, according to the Foundation's report.

CaO	54.85%
CO_2	43.30%
SiO_2	1.08%
R_2O_3	0.23%
Fe_2O_3	0.04%
MgO	0.21%
K	0.01%
Na	0.01%

The amount of possibly useful material is not known, and purpose of the writer's investigation was to determine the extent and distribution of deposits that might contain marble of commercial grade in order to outline an exploration program if the results were promising.

Two preliminary trips were made to the property, and then 14 days were spent in mapping and studying the occurrence over an area about one-half mile square. Much of this ground is precipitous, and the geologic relations are complicated. Many of the survey control points are far apart, and this, coupled with the foregoing, makes the geologic study of reconnaissance nature rather than precise. Nevertheless, essential relations were determined and are portrayed on the accompanying sketch map (Map No. 2) on a scale of 1 inch equals 200 feet.

The Mount Fagan marble deposits are favorably situated as regards facilities. Railroad transportation and U. S. Highway 80 lie 11 miles to the north at Vail, and 12 miles to the northwest at Sahuarita are Highway 93 and a railroad line. A natural gas pipeline and a power line are also available on the north near Highway 80, and another power line is located about 6 miles west of the property.

The expanding ore treatment plants near Tucson and the building boom at Tucson and Phoenix offer potential nearby markets for certain lime products. This matter was not investigated by the writer, but the general outlook appears to be promising.

Two reports are available concerning the property and treatment tests made on the marble. These are:

1. "Summary Report, Mount Fagan Lime Deposit", by J. D. Mason, December 10, 1959.
2. "Report on Evaluation of Limestone Samples for Production of Lime", by The Colorado School of Mines Research Foundation, Inc., February 10, 1960.

TOPOGRAPHY

The marble deposits occur in rugged mountainous country about two miles northeast of the mining camp of Helvetia. There are two deposits of interest, one along each side of a commanding ridge that strikes northwest and north. (See Maps Nos. 1 and 4).

The deposit on the north extends along the middle slope of the ridge and is reached at one point by the rough, steep road already mentioned. The mountainside along which this deposit crops out slopes down northeasterly at about 27 degrees inclination from the horizontal.

The southerly deposit is reached by a trail going around the end of the ridge for about 1200 feet. This zone passes through a saddle, but much of it crops out on a mountainside as steep as 25 degrees of inclination. Well above it are precipitous cliffs leading to the ridge top.

The southerly deposit just mentioned and the westerly tip of the northerly deposit are at the edge of rugged country facing the broad valley of the Santa Cruz River on the west. Access to the railroad and highway at Sahuarita or Continental could be developed in this direction, thereby reducing haulage to the ore treatment plants south of Tucson.

A third marble deposit occupies part of the high country and ridge, between the two zones just described. A fourth and larger zone is found in still more rugged topography a few hundred feet to the south, and this slopes down to and across the main gulch on the south. A fifth body occurs still farther to the southwest, near the southwest corner of Butch No. 9 claim, and is probably connected to the fourth. Because of the difficult access to these third, fourth and fifth deposits, only parts of them were briefly inspected. Furthermore, they may be covered by mining claims of other ownership. Therefore this report will be concerned with the two more favorably situated deposits first mentioned.

THE PROPERTY

The property apparently consists of 15 partly overlapping unpatented lode mining claims, and possibly another lode claim has recently been staked to cover an open fraction on the east. It is the writer's understanding that the ground has also been blanketed by unpatented placer claims in order to cope with the possibility that placer claims are required to hold limestone and marble deposits. The matter of claim titles and ownership was not checked.

The mining claims discussed above contain an aggregate of about 230 acres, most of which is within the National Forest.

DEFINITIONS OF GEOLOGIC TERMS

Before discussing the geology of the area, the following definitions are presented for the reader's guidance:

Limestone is a fine-grained or dense sedimentary rock consisting of calcium carbonate accompanied by various impurities in variable amounts. Limestones are deposited as horizontal beds or layers in water-filled basins. They are later uplifted to form land and may become tilted or severely folded. As a consequence they may occur as beds that stand steeply, but, regardless of how they are arranged, their thickness is always measured at right angles to the plane of the beds.

Granitic Rocks are derived from molten material that has cooled within the earth's crust to form an aggregate of minerals, such as quartz, feldspar, and mica.

Marble is a granular rock developed by the recrystallization of a limestone due to the near approach of an invading granitic body. By such action an aggregate of visible calcite crystals is formed, yielding a rock that may vary from fine to coarse-crystalline. This transformation is caused by heat and pressure, perhaps aided by emanations from the granite's source, and is called metamorphism.

A sandy limestone is one with sand grains (of quartz) forming an impurity. Upon its conversion to marble various lime silicates may be developed.

A sandstone is a sedimentary rock made up predominately of grains of quartz (SiO_2). This may be converted to quartzite as a consequence of nearby granitic intrusion, which recrystallizes and hardens the sandstone.

Chert is a common impurity of limestone and marble. Chert is composed of silica (SiO_2) and occurs in the form of nodules and irregular sausage-like bodies of various sizes, from less than an inch to several feet in length.

A fault is a plane of breaking in the rocks of the earth's crust, along which one side has moved with respect to the other. The amount of movement may vary from a few feet to several miles, and the plane of the break may be flat or steeply inclined.

GEOLOGY

INTRODUCTION

The geology in the vicinity of the Mount Fagan marble deposits is complex. Not only are there numerous rock formations to be considered, but their arrangement, or structural pattern, is unusually complicated. The region around Helvetia and to the northwest is well known for its abundance of flat and gently inclined faults along which great rock slices have been moved for considerable distances. The area that includes the marble deposits is in this environment, and some of these marble deposits are involved in such slices. Consequently in the following report certain deposits are described as occurring in a lower, or Subjacent Block, and other bodies of marble are discussed as being found in overlying fault slices that rest upon this Subjacent Block. Furthermore, other flat faults may occur at depth and limit the downward extent of favorable zones.

The age relations of the various formations were generally not revealed by mapping in the limited area studied by the writer. These relations can only be determined by detailed mapping over a broad area, which would require many months of study. Therefore the following descriptions of the various formations are arranged geographically, partly with respect to the prominent body of granitic rock that trends northwesterly through Sabado Nos. 1, 2 and 4 claims in the northeasterly part of the area mapped. The area occupied by this granitic rock is colored yellow on Map No. 2, accompanying this report.

In many cases it has not been established whether two adjacent formations are in contact along a normal depositional or intrusive contact or whether the contact is due to faulting. This is because of the limited area studied and because some faulting of unknown importance seems to follow a number of the surfaces of contact.

ROCK FORMATIONS

1. Dark-Blue Limestone. Along the northeast edge of the area mapped there occurs a moderate thickness of dark-blue thin-bedded limestone. This strikes northwest and borders the granitic rock on its northeast side. On Map No. 2 the area occupied by this formation is colored gray.

On the weathered surface this limestone is a dark-bluish gray, little different from that of the fresh surface. Certain beds carry abundant chert nodules and others show the remains of small fossils. The Dark-Blue Limestone possesses a dark color and carries abundant silica as an impurity in the form of chert.

Consequently it is not of economic importance where such features are deleterious.

2. Granitic Rock. A body of granitic rock occurs on Sabado Nos. 1, 2 and 4 claims, as mentioned above. This strikes northwest and was mapped for a strike length of about 2,000 feet with a width of about 500 feet. The contact along its northeast side is probably a steep fault; that along the southwest is possibly an intrusive contact, believed to be steep, along which some faulting has taken place.

This granitic rock consists of a granular intergrowth of quartz, feldspar and biotite mica. It has been variously called a diorite and a granite. In this report it is referred to by the non-committal term "granitic rock".

3. Marble in the Subjacent Block. Bordering the granitic rock along its southwest side is a substantial body of limestone recrystallized to form granular marble. The area of its occurrence is colored light-blue on Map No. 2. This marble occurs in two areas striking northwest along the two sides of a steep ridge, and these areas are joined where the marble wraps around the nose of the ridge on Butch No. 1 claim. Thus the marble on the far side of the ridge is some 1200 feet distant from the exposed granitic rock.

On the northeast side of the ridge the marble beds strike northwest with very steep dips, generally to the northeast. A group of beds about 150 feet thick along the northeast edge is generally free from chert impurities and may be of economic importance. This is described in more detail farther along in the report. The remaining steep beds on the southwest, some 150 to 300 feet in thickness, carry abundant but erratically distributed chert and are believed to be of no value as a source of chemical grade marble because of this impurity in silica.

On the southwest side of the ridge, in Butch Nos. 3 and 5 claims, is the other occurrence of marble in the Subjacent Block. Here the beds also strike northwest but with variable steep dips in both directions. Along the southwest margin (in Butch No. 3 claim, possibly extending into Butch No. 5) is a 200-foot stratigraphic thickness of marble that is essentially free from chert, and some of this may be of possible economic importance. It is described in more detail in a following section of this report. Farther northeast, up toward the ridge, chert becomes abundant, and due to this impurity of silica the marble here is probably of little potential value.

4. Mouse-Colored Limestone. The rock formation here called the Mouse-Colored Limestone is intimately associated with the marble in the Subjacent Block. This particular kind of limestone was mapped in two areas. One of these is in and near Butch No. 1 claim, near where the trail goes around the nose of the ridge. The other is far to the south in Butch No. 9 claims. The areas in which the Mouse-Colored Limestone occurs are colored olive-green on Map No. 2.

This limestone weathers to a distinctive gray color, although the surface of the fresh rock varies from light-gray to dark bluish-gray. Much of it appears to carry fine sand (silica) grains as an impurity. Other sections are pronouncedly cherty, and in places thin cherty veinlets have migrated along fractures. A few small fossils are to be noted here and there. Some of this formation is marbleized and resembles the marble in the Subjacent Block.

The impure nature of the Mouse-Colored Limestone is shown by the following partial analysis. This sample was a collection of fragments chipped off outcrops scattered over the northerly occurrence and gave the following results:

CaO	29.12%
CO_2	20.10%
MgO	11.88%
SiO_2	20.80%
	81.90%

5. Thin-Bedded Cherty Limestone. Two bodies of the Thin-Bedded Cherty Limestone are found on the west, and additional mapping might show that they join. The areas in which this formation occurs is colored emerald-green on accompanying Map No. 2.

The Thin-Bedded Cherty Limestone is made up of alternating layers of chert and limestone. Most of the chert layers range from 1/4 to 3/4 inch in thickness, although some reach 2 inches, and such chert usually makes up from 25% to 75% of the rock body. Croppings of this formation are brown-weathering, and several cuts shown minor staining by iron oxide.

On the north these thin-bedded rocks underlie the Mouse-Colored Limestone (in and near Butch No. 2 claim), but on the south they underlie the marble in the Subjacent Block (in and near Butch Nos. 6 and 8 claims). Consequently in one of these areas the contact must be a fault, but it has not been established in which area this is the case.

6. Marble in Overlying Slices. In this structural situation marble occurs in three areas, which are colored dark-blue on Map No. 2. One of these is at the top of the ridge in and

near Butch No. 3 claim, well above the trail where it goes around the nose of the ridge. A second begins near the high point of the ridge in Butch No. 5 claim and extends down southerly to the section corner in Butch No. 9 claim. A third body appears near the southwest corner of Butch No. 9 and extends on south. Additional mapping would probably show that the second and third bodies join together.

These three bodies of marble were not studied closely because of their inaccessibility; however the following comments are offered:

The body on the north is cherty in part, and one area is mineralized and displays dark-colored dikes. The southern areas contain an undetermined amount of marble that may be of economic value, but much of this ground is apparently covered by claims of outside ownership.

7. Sandy and Cherty Limestone. This formation, which also includes some interbedded white quartzite of fine grain, is found in the high country on the southeast. On the geologic maps the area in which it occurs is colored pink.

The Sandy and Cherty Limestone may be the equivalent of the Mouse-Colored Limestone, but this was not established by the writer's brief examination. This formation contains a variety of material of inferior purity and was not studied closely.

8. Quartzite. Considerable brown-weathering quartzite occurs west of the area of interest. A small body also occurs in Sabado No. 2 claim, on the north. Whether these are the same formation was not determined.

9. Dikes. A number of igneous dikes of dark color were observed during the examination. Only a few of these are shown on the map because of their small size and the scarcity of survey control points required for their mapping.

There appear to be several varieties of dikes. Generally they range from a few feet to a few tens of feet in thickness. They would need to be wasted during quarrying operations, but they do not appear to be too abundant in areas of possible operations. Systematic drilling of the favorable zones would be needed to give details of their occurrence.

STRUCTURE

There is a structural alignment from southeast to northwest in the area of interest. This trend is followed by the strike of steep beds of sedimentary rocks, by the dike-like body of granitic rock, and by fissuring in the old mine area. In and near Butch No. 1 claim the beds wrap around the ridge as a structural nose, suggesting a plunging fold. Farther west, mostly beyond the area studied, U. S. Geological Survey maps show a great flat fault with granite on its underside.

Resting upon the block with northwest structure and steep dips, here called the Subjacent Block, is an "Upper Slice" with moderate dips on the north and steep dips on the south. This upper slice occupies the high ridge above the Main Tunnel, and its cliff-forming westerly face exhibits pronounced flat fractures that mark the plane of rupture of a flat fault or are sympathetic to such a fault that may be masked by slide-rock near the base of the cliff. On the northeasterly side of the ridge the junction of these two blocks can be followed southeasterly to near the end-line of Sabado No. 1 claim, where it may represent the axis of a fold rather than a fault.

There appears to be another, still higher, slice of marble farther south on Butch Nos. 5 and 7 claims, although its structural details could not be determined with certainty.

The attitude of the beds in the Subjacent Block is steep with rather uniform strike to the northwest, accompanied here and there by local twisting and minor folds. In contrast, the beds forming the overlying slice on the north, in and near Butch Nos. 1 and 3 claims, generally show flat to moderate dips in a southerly direction. The cliffs exposing this slice on the southwest display various small folds and contortions, showing that the structure of this overlying slice is not simple.

METAMORPHISM

A common effect of metamorphism is the conversion of limestone to crystalline marble. The marble in the five areas described is medium to coarse in grain, with individual calcite crystals commonly ranging from one-eighth to one-half inch in diameter. On fresh surfaces most of it is milk-white in color, although gray areas of considerable size do occur here and there. During the transformation of cherty limestone to marble the chert has remained intact; its characteristic form is preserved and it persists as an impurity.

Under the influence of metamorphism the sandy limestone appears to have reacted in several different ways. For example, the silica grains may be preserved in the marble as an impurity.

Or, this silica may combine with calcite to form silicate minerals. On the other hand, an unusual behavior is the apparent elimination of silica during marbleization to produce a rock with lower silica content than the original limestone. This was tested by sampling on each side of a contact where coarse marble was sutured onto fine-granular limestone, the junction being neither along bedding nor faulting. The somewhat sandy limestone was found to carry 3.55% of SiO_2, whereas the marble, apparently derived from it, contained only 0.75%.

In addition to the five main occurrences of marble noted above, there are zones and streaks of marble formed in some of the other limestone formations, particularly in the Mouse-Colored Limestone.

The development of silicate minerals by metamorphism is not a striking feature in the area of interest, but such minerals do occur in scattered patches and along beds here and there, and their abundance in the promising zones must be determined by systematic drilling.

Several small bodies of so-called "skarn" were noted. These consist of quartz, epidote, and probably other silicate minerals. They generally occur in the marble within 50 feet of the southwestern edge of the body of granitic rock, although there are some more distant occurrences.

The marble along this southwestern margin appears to be related to the granitic rock as a consequence of its intrusion near a limestone. It is believed to be along a steep contact, and therefore this granitic rock would not be expected to limit the persistence of the marble at depth.

On the other hand, marble extends far to the south away from the exposed granitic rock and may be bottomed here by such a rock. Or this marble may have been faulted away from the granite responsible for its metamorphism.

MINERALIZATION

The area is one of scattered mineralization by quartz, pyrite and various base metal sulfides. In general such mineralization occurs in patches a few tens of feet across or in widths of a few feet along fissures. On the other hand, a mining area of some importance occurs on the east, near the 1/4 Corner on Sabado No. 4 claim, well away from the marble deposits of interest. It is evident that dark-colored igneous dikes commonly occur in or near the mineralized zones.

Dikes and mineralization are also found in and near the Main Tunnel in Sabado No. 1 claim, and where they constitute zones of impurities in the marble. To the southwest, on the ridge above this tunnel, dike rocks and mineralization occur in the overlying slice, but it has not been determined whether this is connected to the mineralization near the tunnel.

MARBLE DEPOSITS

INTRODUCTION

As described above, there are two groups of marble beds, which, because of their relative purity are of possible economic value. One of these occurs on the northeast side of the ridge above the Main Tunnel and is here called the "Northern Deposit". The other is situated on the southwest side of the ridge and termed the "Southern Deposit". Both of them are in the so-called "Subjacent

Block" where steeply dipping beds strike northwest. The areas occupied by these beds are colored red on Map No. 3 accompanying this report.

It is suspected that these two deposits may be composed of the same group of beds, whose separated positions have been determined by complicated folding and faulting.

It must be emphasized here that these two zones do not now contain a proved tonnage of commercial rock; however, they are the most promising sections in which to conduct a search for such material.

NORTHERN DEPOSIT

The Northern Deposit has a mapped length of about 1,350 feet. At its northwest end it abuts the Mouse-Colored Limestone; on the southeast comes up to quartzite of the Sandy and Cherty Limestone formation.

The (stratigraphic) thickness from northeast to southwest across the beds ranges from 100 to 175 feet, with an average of probably 150 feet. The northeast side of this promising zone is close to the granitic rock, and in places there is a 50-foot thickness next to the granitic rock with erratic occurrences of skarn as an impurity. Beyond the southwest edge of the Northern Deposit the marble continues up the ridge but contains variable amounts of chert in the form of nodules and lenses in sufficient amounts to probably render it of little commercial value.

The Northern Deposit crops out on a slope with an inclination of about 27 degrees. It is partly covered by vegetation and slide-rock, and its dimensions and quality are only party revealed by surface examination.

The central part of the Northern Deposit is pierced by the Main Tunnel, at an elevation of about 4,450 feet above sea level. This tunnel runs S65W and cuts the granitic rock for about 75 feet, beyond which it exposes white marble. The contact between these two rocks is smooth with minor faulting along it, and there is no skarn showing near it. The tunnel continues in white, glistening marble for 160 feet to near the face, where it cuts a dark-colored igneous dike about 10 feet thick. The face of the tunnel extends a few feet beyond the dike and again is in white marble. The face is about 100 feet below surface, where the dike accompanied by mineralization may be seen in an open cut.

The marble beds exposed in the tunnel strike about N50-75W with steep dips in a southerly direction. The tunnel crosses them at an angle but cross-cuts a true thickness of about 125 feet. The thickness of relatively pure beds beyond the face remains to be determined but probably does not exceed a few tens of feet.

Channel samples taken in the tunnel are reported by Mr. J. D. Mason. The following is quoted from his report dated 12/10/59:

"Samples commencing near face and proceeding towards portal.

MASON				FREEMAN	
Width	CaO %	Fe %	SiO_2 %	Width	CaO %
27.5'	54.3	0.3	2.5	49'	53.8
42'	52.4	0.35	3.7	22'	53.5
46'	54.0	0.35	2.4	53'	53.2

Note:- The above are channel samples. On a 1500-lb. bulk sample the Colorado School of Mines obtained iron assays of 0.02%. Additional iron determination is necessary."

End of quotation.

Two sample analyses of crude marble are listed in the report by The Colorado School of Mines Research Foundation, Inc., under date of 2/10/60. The following is a quotation from this report:

"Limestone Sample No. 1: An approximately 50-pound sample of crushed raw limestone (minus 1 3/4, plus 3/8 inch) received from Dye and Bathrick Mining Company of Kingman, Arizona, on November 10, 1959.

Limestone Sample No. 2: A 42-pound sample of raw limestone stated to be "representative of a section of the deposit, 53 feet across what appears to be the highest grade and whitest in color." This sample was received via air express on December 30, 1959.

TABLE I
CHEMICAL ANALYSIS DATA

	Limestone Sample No. 1	Limestone Sample No. 2
CaO	54.85	54.80
CO_2	43.30	42.15
SiO_2	1.08	1.25
R_2O_3	0.23	0.23
Fe_2O_3	0.038	0.17
MgO	0.21	0.20
MnO_2		
LOI	43.2	42.8
P	0.004	
S	Nil	

TABLE II

LIMESTONE NO. 1, HEAD SAMPLE

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS

(Figures are percentage estimates)

Aluminum	0.05	Potassium	0.01
Barium	0.01	Silicon	1
Calcium	Major	Strontium	0.01
Copper	0.001	Sodium	0.01
Iron	0.05	Titanium	0.01
Magnesium	1	Vanadium	0.001
Manganese	0.01		

End of quotation.

The foregoing analyses are quoted for indicative purposes only. The writer did not observe the taking of these samples and therefore cannot vouch for them. Presumably all came from the tunnel and represent only one cross-section of sampling for a strike length of some 1,350 feet. Obviously these results cannot be applied to the entire zone, which must be systematically sampled along a number of other sections to provide a reliable picture of its quality. The range in silica content should be particularly noted, because some are above the commonly accepted maximum for chemical grade.

The marble in the Northern Deposit is medium to coarse-granular in texture. It is milk-white and sparkling on fresh surface. Weathered outcrops are gray, with generally white marble beneath a thin surface coating. There are patches and zones of gray marble in the fresh rock, but these appear to be of subordinate extent.

SOUTHERN DEPOSIT

The Southern Deposit has a mapped length of about 500 feet, but it may extend considerably farther to the southeast under the slide-rock which mantles the steep mountainside. There may also be a moderate extension to the northwest.

The Southern Deposit is best exposed in the saddle near the southwest corner of Butch No. 3 claim. Here the beds strike northwest with steep dips, and a (stratigraphic) thickness of about 200 feet is exposed that is generally free from chert. Along its southwest side it is in contact with the Thin-Bedded Cherty Limestone; on the northeast it becomes cherty and extends up to the cliffs under a 25-degree slope.

The marble here appears similar to that on the north side. It is medium to coarse granular and the fresh surface is generally of white color, although large patches and zones of gray appear here and there.

The Southern Deposit has only been explored by a few cuts, two of which are in the 200-foot section that appears to be mostly free from chert.

The writer took five consecutive outcrop samples across the Southern Deposit. Each of these represented about 35 feet of stratigraphic thickness, for a total of about 175 feet. These were designated A, B, C, D and E, from southwest to northeast. (See Map No. 3.) They returned by analysis the following:

	CaO	MgO	CO_2	SiO_2
A	48.44	1.30	39.40	5.20
B	51.52	0.50	40.90	4.40
C	48.72	2.46	39.10	4.30
D	44.80	5.97	36.70	1.85
E	49.84	2.93	40.20	1.30

The foregoing were chipped samples from exposed surface croppings, and they were not precise channel samples. They were also fouled by a little dirt and were not as clean as though taken from a cut or tunnel. Even discounting this they are disappointing, because of the contained amounts of magnesia, silica, and undetermined impurities. Although some useful marble may occur in this deposit, such must be proved by careful sampling, preferably by diamond drilling. Furthermore, the possibility that these beds may be an offset continuation of those composing the Northern Deposit makes it mandatory to more fully sample the latter.

MARBLE IN THE UPPER SLICES

Marble in substantial amounts also occurs in three places in the Upper Slices, but, as previously mentioned, it was not given as much attention as the marble in the Subjacent Block because of difficult accessibility and lack of time. The quality of the material in the Upper Slices appears to be comparable to that of the Subjacent Block, but to date this material has not been sampled and analyzed.

MARBLE IN THE MOUSE-COLORED LIMESTONE

There are a number of marbleized zones in the Mouse-Colored Limestone. One of these has been exposed by the location cut for Butch No. 1 claim, near the end-line just above the trail along the west-facing hillside. This is a fine-textured marble that has been pointed out as desirable material because of its compact texture and light-gray color, and we are advised that its burning characteristics are good and its silica content is low. On the other hand, two specimen samples from this cut were analyzed for the writer and these returned 11.90 and 4.90% of SiO_2 respectively. The reason for this discrepancy is not apparent, but, considering the generally impure character of the Mouse-Colored Limestone, it is very doubtful if there is any substantial tonnage in this formation that is of economic interest.

ECONOMIC FEATURES

PURITY

The principle impurity to contend with is silica (SiO_2). This occurs as sand grains, in silicate minerals, and as chert nodules. The sand grains are generally so small that they are not readily seen, and the silicate minerals are most apparent only where they are rather abundant. On the other hand, chert occurs in the form of nodules, sausage-like bodies, and as irregular veinlets and is readily seen. The reported silica analyses of crude rock from the tunnel range from 1.08% to 3.7%. This higher figure is above the 1.5 to 2% maximum allowed for a number of commercial uses, and it is obvious that careful sampling will be needed to determine the range and general average silica content throughout the Northern Deposit. Silica and other impurities in troublesome amounts are indicated by the limited sampling of the Southern Deposit, and much more accurate sampling will be needed to determine its worth. Tests should be conducted to determine whether any of the silica can be rejected by air classification.

Iron as an impurity appears to be low in amount except in localized areas of mineralization. Analyses presently available suggest a range from 0.02% to 0.32%, but further iron determinations are needed to determine if the marble is suitable for the glass-making industry (which accepts a maximum of only 0.015% Fe). Where iron is abundant in mineralized patches, the rock would have to be wasted.

The dark-colored igneous dikes are rich in silica, iron and magnesia. They constitute localized impurities that would also have to be wasted.

Mineralization, commonly associated with dikes, constitutes only a subordinate part of the marble bodies.

TREATMENT FACTORS

The writer believes that the granular character of the marble may predispose its crushing to be accompanied by a considerable amount of fine material. These fines would be unsuitable for the rotary kiln but apparently would be acceptable for burning in a FluoSolids kiln. On the other hand, Mr. Mason advises that "Tests conducted at Kingman, Arizona, show the rock crushes readily and does not produce an excessive proportion of fines". If fines are excessive, they constitute a loss, unless a market (such as the glass-making industry) can be found for them.

The Colorado School of Mines Research Foundation report states that on burning "a major portion of the material decrepitates and disintegrates to a relatively small particle quicklime". Hence the lump form required for certain industrial uses (such as for calcium carbide making, for steel flux, and for beet-sugar manufacture) is lost. Although this restricts the field of use for products derived from the Mount Fagan marbles, nevertheless there may be a number of other uses for which it is suitable. However, the average content and range of such impurities as silica, magnesia, iron, etc., must be accurately determined before such uses can be known.

For other results of test work, the report of the Colorado School of Mines Research Foundation should be consulted. One conclusion, of the report must be noted:

"While dust loss as a result of decrepitation during calcination in the rotary batch furnace does not appear to be excessive (on the basis of the two burns made), the item of dusting during calcination should be especially explored with rotary kiln manufacturers if a commercial rotary kiln operation is anticipated".

POSSIBLE TONNAGE

At the present stage of the property's development no tonnage estimate is warranted. However, it appears that the marble zones are extensive enough to hold sufficient tonnage above relatively shallow depths to support a substantial operation over a period of years, provided that future drilling and sampling determine the silica content and other impurities to be within acceptable limits. Because of the prevalence of flat faults, no tonnage estimate should be presented until exploration by drilling has been carried to adequate depth.

FACILITIES

Convenient facilities such as highways, railroad transportation, natural gas line, and power lines have already been mentioned.

There is an unknown amount of water available in an old mine shaft on the property. It is probably sufficient for diamond drilling and is situated about 600 to 1,400 feet distant from the Northern Deposit at an elevation about 250 feet lower than probable drilling sites. To reach the more distant Southern Deposit, some 2,400 to 3,000 feet of pipeline and road would be needed.

CONCLUSIONS

1. The property is promising for the development of large amounts of coarse granular marble of white color.

2. On the basis of present sample data, the Northern Deposit is the more attractive.

3. However, the Northern Deposit has been sampled only along one cross-section (the Main Tunnel) and samples listed in available reports show silica analyses both below and above the commonly accepted maximum.

4. Therefore drilling and sampling are required to determine the amount of raw material available with the quality demanded for particular uses.

5. There is no substantial body of dense, compact limestone (or fine-grained marble) of chemical grade in the area.

Hence the project must be based on the processing of a medium- and coarse-granular marble that may produce an excessive amount of fines during crushing.

6. A use for the fines derived from crushing must be found, or a type of kiln must be used that can handle such fines.

7. The problem of dusting during burning must be explored.

8. As above noted, it is evident that the raw material contains varying amounts of silica (SiO_2) as an impurity. Its abundance must be determined, and test work should be conducted to find out whether a worthwhile portion can be eliminated by low-cost treatment.

9. Without knowing the range and general average of the silica and iron content, and whether silica can be reduced in amount by air classification, it is impossible to state all of the commercial products that can be made from this marble.

10. There is a limited field of use for any calcined product from this source because of the loss of lump form during burning.

11. From the information now available, it appears that one of the deposits may contain material suitable for making reagents employed in the flotation of copper ores, flux for copper smelting, material for cement manufacture, and probably rock for

roofing granules., Other uses are possible but are dependent on further analyses for purity and various testing procedures. Such possible uses are lime products for the building industry, whiting and fillers, and limestone for the glass-making industry.

12. The writer did not investigate markets and demand for products, but the general situation appears promising.

13. This is a good prospect, but it must be systematically explored and sampled and the material further tested and markets developed before the financing of a commercial project can be based on the use of raw material from this source.

RECOMMENDATIONS

Although these marble deposits may presently be considered to be of marginal value because of the several difficulties and uncertainties listed above, the writer believes that they have sufficient promise to merit some further investigations.

At this stage a modest program of diamond drilling is suggested to obtain a better idea of the size and quality of the more easily accessible Northern Deposit. This will require development of a local water supply, some road building, and the drilling of three or four diamond drill holes. Should the outcome be encouraging, both as regards adequate core recovery and satisfactory analytical results, then additional drilling at closer spacing maybe required to block out the deposit. Although the Southern Deposit has certain advantages as regards location for a quarry, preliminary outcrop samples are not encouraging and the Northern

Deposit can be more cheaply tested because of nearby road and water.

The cost of preliminary exploration is difficult to estimate at this time, prior to any discussions with contractors. The following estimate is therefore tentative and subject to substantial correction:

1,000 ft. of drilling @ $6.00	$ 6,000
750 ft. of road building	1,000
Pump and 1,500 ft. of pipeline	2,000
Core logging, splitting & sampling	500
Chemical analyses	1,250
Supervision	500
Surveying	350
	$ 11,600

The writer recommends that size BX core be taken during drilling and that the drilling contract be on a basis of cost-per-shift rather than on cost-per-foot of hole drilled. This is because these procedures are more likely to yield a satisfactory core recovery.

Further testing in the laboratory and in a treatment plant is also required to answer a number of questions brought up in the foregoing report. Whether this should precede or follow additional exploration and sampling is a matter of viewpoint; both are necessary.

A project to make commercial use of the Mount Fagan marble deposits is full of problems that will cost money to investigate, and the feasibility of the project will not be apparent until such steps have been taken. On the basis of presently available information it is not possible to forecast the outcome, but the writer concludes that the venture is promising.

E. N. Pennebaker

E. N. PENNEBAKER

Scottsdale, Arizona
January 17, 1961

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VALLEY LABORATORIES
Incorporated
Telephone ALpine 2-2782 • Post Office Box 4153 • 242 South First Avenue • Phoenix, Arizona

AMERICAN COUNCIL OF INDEPENDENT LABORATORIES, INC.

REPORT

Nature of Specimen Limestone

Date 1-14-61

Laboratory No. A61009-1 -- A61009-5

Date Received 1-11-61

Submitted By For: E. N. Pennebaker
Thomas A. Goodnight
% P.O.Box 1792, Phoenix, Ariz.

Report Telephoned

Tests Made As Listed

RESULTS

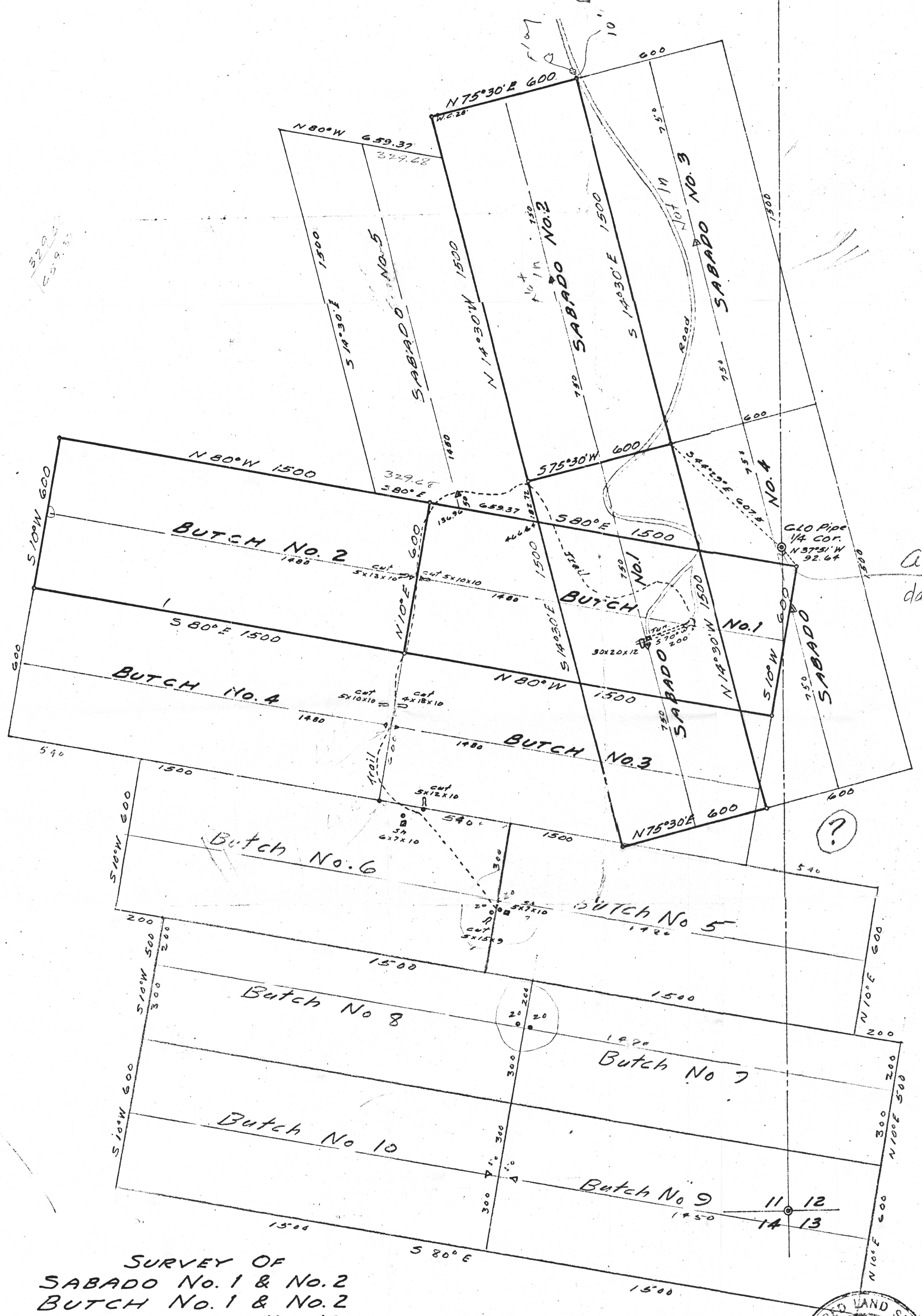
Sample Marking	Calcium Oxide (CaO)	Magnesium Oxide (MgO)	Carbon Dioxide (CO_2)	Silicon Dioxide (SiO_2)
A	48.44%	1.30%	39.40%	5.20%
B	51.52%	0.50%	40.90%	4.40%
C	48.72%	2.46%	39.10%	4.30%
D	44.80%	5.97%	36.70%	1.85%
E	49.84%	2.93%	40.20%	1.30%

Respectfully submitted,

VALLEY LABORATORIES

Michael J. Sullivan

Michael J. Sullivan



At toe of dark dump.

SURVEY OF
SABADO No. 1 & No. 2
BUTCH No. 1 & No. 2
IN SECTIONS 11 & 12
T. 18 S., R. 15 E.
HELVETIA MINING DIST.
PIMA CO. ARIZ.

SCALE 1"=300' SEPT. 1960

T. A. Goodnight - Claimant

E. H. Jenkins
Registered Land Surveyor 2306
Mineral Surveyor B.L.M.

REGISTERED LAND SURVEYOR
CERTIFICATE EXPIRES
E. H. JENKINS
DEC. 31, 1960
ARIZONA, U.S.A.

Location Notices to this plan

2 additional holes to dig

Total 15 claims

The last recorded location notices are not as bad as I expected, however the amended notices describe ~~the~~ claim boundary more accurately

I will complete the plat when I hear from you.

M 202