

**A RECONNAISSANCE OF THE GEOLOGY AND  
MINERAL DEPOSITS**

OF THE

**LAKE MOUNTAINS, UTAH COUNTY, UTAH**

BY

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ALFRED M. BURANEK



**Circular No. 35**

OF THE

**UTAH GEOLOGICAL AND MINERALOGICAL SURVEY**

Prior to 1949, a Part of the

RAW MATERIALS DIVISION

DEPARTMENT OF PUBLICITY & INDUSTRIAL DEVELOPMENT

STATE OF UTAH



December, 1948

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## UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

The Utah Geological and Mineralogical Survey was authorized by act of the Utah State Legislature in 1931; however, no funds were made available for its establishment until 1941 when the State Government was reorganized and the Utah Geological and Mineralogical Survey was placed within the new State Department of Publicity and Industrial Development where the Survey functioned until July 1, 1949. Effective as of that date, the Survey was transferred by law to the College of Mines and Mineral Industries, University of Utah.

The *Utah Code Annotated 1943, Vol. 2, Title 34*, as amended by *chapter 46 Laws of Utah 1949*, provides that the Utah Geological and Mineralogical Survey "shall have for its objects":

1. "The collection and distribution of reliable information regarding the mineral resources of the State."

2. "The survey of the geological formations of the State with special reference to their economic contents, values and uses, such as: the ores of the various metals, coal, oil-shale, hydro-carbons, oil, gas, industrial clays, cement materials, mineral waters and other surface and underground water supplies, mineral fertilizers, asphalt, bitumen, structural materials, road-making materials, their kind and availability; and the promotion of the marketing of the mineral products of the State.

3. "The investigation of the kind, amount, and availability of the various mineral substances contained in State lands, with a view of the most effective and profitable administration of such lands for the State.

4. "The consideration of such other scientific and economic problems as, in the judgment of the Board of Regents, should come within the field of the Survey.

5. "Cooperation with Utah state bureaus dealing with related subjects, with the United States Geological Survey and with the United States Bureau of Mines, in their respective functions including field investigations, and the preparation, publication, and distribution of reports and bulletins embodying the results of the work of the Survey.

6. "The preparation, publication, distribution and sale of maps, reports and bulletins embodying the results of the work of the Survey. The collection and establishment of exhibits of the mineral resources of Utah.

7. Any income from the sale of maps and reports or from gifts or from other sources for the Survey shall be turned over to the State Treasurer and credited by him to a fund to be known as the Survey Fund to be used under the direction of the Director of the Survey for publication of maps, bulletins or other reports of investigation of the Geological and Mineralogical Survey."

The Utah Geological and Mineralogical Survey has published maps, circulars, and bulletins as well as articles in popular and scientific magazines. For a partial list of such publications see the inside back cover of this bulletin. For other information concerning the geological and mineralogical resources of Utah address:

Director, UTAH GEOLOGICAL AND MINERALOGICAL SURVEY

College of Mines and Mineral Industries

University of Utah

Salt Lake City, Utah

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## PREFACE

### To Second Impression

As noted in the Introduction, this circular was first released (in 1948) as a progress report to serve the interim until the appearance of the more exhaustive study by Professor Kenneth C. Bullock. His treatise, entitled "The Geology of Lake Mountain, Utah," is now available as Bulletin No. 41 of the Utah Geological and Mineralogical Survey, price \$1.00.

However, since Dr. Bullock gave most of his attention to general geology, stratigraphy and geomorphology, there is still need for the present circular until a more detailed investigation can be made of the mineralogy and economic geology. This Reconnaissance treatment of the subject is therefore reprinted and offered free to those who are interested.

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OF THE LAKE MOUNTAINS, UTAH COUNTY, UTAH

by

Arthur L. Crawford 1/  
Alfred M. Buranek 2/

INTRODUCTION

The Lake Mountains of north-central Utah have received but little geologic interpretation thus far, even though the range has contributed notable amounts of limestone, clays, manganese ore, commercial "calcite" and "onyx" over a period of many years. One of the few geologic reconnaissances of the area is Loughlin's description incorporated in the U. S. Geological Survey Professional Paper 111, "The Ore Deposits of Utah", 1920. Mineralogically, the range has attained considerable fame for its magnificent groups of limonite pseudomorphs after pyrite which occur in relative abundance east of Pelican Point. Most museums of the United States and many foreign museums have representative specimens from this celebrated locality.

Since 1941 the writers have had occasion to study some of the economic aspects of the Lake Mountains, and in 1944 an information circular was published, <sup>3/</sup> in which certain clay and manganese deposits were described. During the past two years the writers revisited the area on three different occasions to examine other mineral deposits of economic significance.

At present the Raw Materials Division of the Utah Publicity and Industrial Development Department is sponsoring a detailed study of the Lake

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1/ Commissioner, Raw Materials Division, Utah Publicity & Industrial Development Department.

2/ Geologist, Raw Materials Division, Utah Publicity & Industrial Development Department.

3/ Crawford, Arthur L., Buranek, Alfred M., The Geology and Mineral Deposits of the Lake Mountains, Utah County, Utah: Utah Publicity & Industrial Development Department, Circular No. 13, 1944. (Out of print)

Mountains by Kenneth C. Bullock,<sup>1/</sup> who has chosen this problem for his dissertation for a Ph.D. degree at Wisconsin University. Until Mr. Bullock's study is completed and published as a bulletin of this department, the following presentation of the geology and mineral deposits of the Lake Mountains is necessarily a statement of progress in the accumulation of data assembled by the writers since 1941, released primarily to serve the urgent need for information on the clay deposits of the range. During the past few months, clay production from the Lake Mountains has been on a marked rise, and several representatives of large refractory industries have expressed considerable interest in the area. Source information for most of this paper is from hasty reconnaissance rather than from detailed surveys. Therefore, the geologic concepts set forth lack the higher standards of accuracy obtained from detailed study.

Mr. Byron J. Sharp, candidate for the M.A. degree in 1949 at the University of Utah, has chosen for his thesis "The Mineralogy of the Fox Clay Deposits of the Lake Mountains, Utah". It is hoped that this dissertation will be completed in time to be incorporated in the forthcoming bulletin.

Acknowledgment is made to Roger Cedarstrom, Dr. Bertil H. Lee, Dell Steel, and John Hutchings, for their helpful assistance as guides to many of the mineral deposits examined.

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<sup>1/</sup> Assistant Professor of Geology, Brigham Young University, Provo, Utah.

## GENERAL GEOLOGY

The Lake Mountains of Utah County, Utah, constitute the relatively low-lying range that flanks the western shores of Utah Lake, Utah County, Utah. The range is typical of the north-south ranges of the Basin and Range Province. To the north are the Oquirrh Mountains, to the west the closed basin of Cedar Valley, to the south the Tintic Mountains, and to the east Utah Lake. Geographically and geologically the range is an important link between the Oquirrh Mountains on the north and the Tintic Mountains on the south, which together have contributed more wealth than all of the remaining districts of Utah in gold, silver, copper, lead, and zinc.

### Sedimentary Rocks.

The Lake Mountains are composed chiefly of Paleozoic limestones that have been folded into a synclinal structure, the axial trend of which is approximately north-south. Where the Saratoga road crosses the north end of the range, near the axis of the structure, the strata are nearly vertical. This fact, together with other observations of Loughlin and the writers, indicates that the center of the range is compressed into an isoclinal fold, with the dips on the flanks flattening progressively outward. Minor flexures, such as the slight arching of the beds immediately west of Pelican Point, flank and merge into the main range structure. The reconnaissance made by the writers substantiates in general Loughlin's <sup>1/</sup> description of the Lake Mountains, which is as follows:

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<sup>1/</sup> Butler, B. S., et al, The Ore Deposits of Utah, U. S. Geol. Survey Prof. Paper 111, pp. 334-5.

"The Lake Mountains have a north-south length of about 17 miles and a maximum width of 6 miles. They lie between Utah Lake on the east and Cedar Valley on the west. There is no known record of ore produced from these mountains, though some prospecting has been carried on. Only the north and south ends of the ranges were visited.

"At the north end, which includes the Lehi mining district, the rocks of the eastern slope consist of bluish-black dense and mostly thin-bedded fossiliferous limestones of upper Mississippian age, which dip about 20° SW. Fossils collected by the writer were determined as follows by G. H. Girty of the United States Geological Survey, who states that the strata containing them can safely be placed in the upper Mississippian:

*Stenopora* sp.  
*Spirifer increbescens*.  
*Productus oileiformis*.  
*Batostomella* sp.  
*Fenestella* sp.  
*Cliothyridina sublamellosa*.  
*Diaphragmus elegans*.  
*Zaphrentis* sp.  
*Spirifer keokuk* var.  
*Derbya kaskaskiensis*?

"These strata belong to the series which lies beneath the Pennsylvanian quartzite and which, in the Wasatch and Oquirrh Mountains and in the Tintic district, is characterized by alternating beds of limestone, shale, and limy quartzite. The shale and quartzitic beds are very scarce or absent in the northern Lake Mountains, as well as in the northern part of the East Tintic Mountains, 15 miles to the southwest. Although no quartzite was found in place the great number of quartzite cobbles and boulders in the canyons and eastern alluvial slopes indicates that the Pennsylvanian quartzite is probably present along the backbone and western slope of the northern part of the range.

#### Lehi District

"The Lehi district, organized January 11, 1894, is in Utah County, southwest of Lehi, a station on the Denver & Rio Grande

Railroad and the Los Angeles & Salt Lake Railroad. The district borders the west shores of Utah Lake. Marble, 'onyx marble', and clay are the predominating useful mineral products found.

"The only evidences of mineralization seen by the writer are a few veinlets of columnar (scalenohedral) calcite. These veins, although accompanying or lying near ore bodies in some places, are by no means sure indications of ore, and the type of ore which they accompany is very unlikely to form deposits of industrial importance in so dense and impervious a rock as the local limestone. Some fabulously high assays of samples from this district at one time caused considerable excitement but proved to be fraudulent. Nothing of value was ever found.

#### North Tintic District

"The southern end of the Lake Mountains is included in the eastern part of the North Tintic district. The rocks here have an irregular anticlinal structure, lying nearly horizontal with slight undulations for nearly the entire width of the range (about 2 miles) but curving sharply to a nearly vertical dip in the easternmost exposures. The strata seen correspond in character to the Pine Canyon limestone of the Tintic district, which is mostly of lower Mississippian (Madison) age, but whose upper beds are tentatively correlated as upper Mississippian. At the Wanless, the only active prospect visited, a shaft had been sunk 75 feet in coarse-grained limestone similar to that containing the 'Colorado Channel' ore body in the Tintic district. Some veins of white columnar calcite, or travertine, accompanied by some soft red iron oxide, were exposed in the bottom of the shaft."

#### Igneous Rocks.

Extrusive igneous rocks occur in the Lake Mountains in several areas. Perhaps the most dominant area is the southwestern portion of the range where Tertiary silicic pyroclastics and younger basalt flows mantle the older sedimentary rocks. In the long strike valley north and east of the Fox Clay deposits, remnants of pyroclastic material occur in several isolated patches, thus indicating that the areas covered by extrusive rocks were formerly more continuous and have been separated by erosion and possibly faulting. No intrusive rocks were

observed by the writers.

West of Mosida near Soldiers Pass in T. 7 or 8 S., R. 1 W., igneous rocks outcrop on the western flank of the range. They have a gentle westward dip toward Cedar Valley. Where the Soldiers Pass road reaches the foothills, pumicitic flow breccia is exposed as massive rounded clean-swept surfaces. Fragments of light porous pumice of fibrous texture are included in the flow breccia. Some of the fragments attain a maximum dimension of 12 inches, although most are approximately 1 inch in size. The angular fragments are usually white or pinkish in color, passing into smoky-gray. The matrix has a pale to dark salmon-pink tone. The breccia rock is relatively light and comparatively free from cracks and joint planes. Because of its tenacity, it has been used with considerable success by William H. Prince and Sons Block Company, Inc., Salt Lake City, for light-weight aggregates and light-weight building blocks.

The pumicitic flow breccia is believed to represent one of the lower members of the tuffaceous series that grade upward into volcanic ash and beds of tuff, well exposed in the region of Faust farther to the west. Associated with the tuffs are marly beds that progressively grade into interstratified limestone members. The limestones are white in color and are readily differentiated from Paleozoic limestones which they overlap.

#### The Relation of Pyroclastics to the Evolution of Topography and Drainage.

The topography of the area north and east of the Fox Clay Deposits indicates that the Tertiary volcanics previously extended eastward up the flank of the Lake Mountains to an elevation of approximately 500 feet above the valley floor. They may have been deeper, but the long gentle

slopes below this horizon suggest an old mature topography that has been exhumed. The topographic evidence is substantiated by remnants of volcanic ash, weathered lavas, and marl found in the bottom of protected strike valleys at these upper elevations. From the hog-back ridge north of Soldiers Pass, a splendid view is obtained of Cedar Valley and the central portion of the Lake Mountain range. The rocks composing this hog-back dip uniformly to the east from 30 to 40°. The strike of the strata which is N. 15° W. in the vicinity of the manganese deposits several miles to the north here curves so that the strike becomes approximately N. 50° W.

It appears that these volcanics completely covered the Lake Mountain crest south of this point for some distance. This area may have been an erosion valley cutting diagonally across pre-Tertiary structure of the Lake Mountain range, draining the area now occupied by Cedar Valley prior to the rejuvenation of the range in Tertiary time. In accordance with this interpretation, the drainage of Cedar Valley which now has no outlet, once flowed southeastward south of Soldiers Pass into Utah Valley. With the blanketing of the area with Miocene (?) pyroclastics, this drainage pattern was possibly destroyed, and subsequently a rejuvenation of the same forces that folded the Paleozoic rocks of the range brought forth a further uplift. The interior drainage of Cedar Valley is not sufficient to overflow and establish a new outlet. The porous nature of the pyroclastics may have permitted an appreciable seepage of water along the old drainage channel reappearing as springs in the Mosida area.

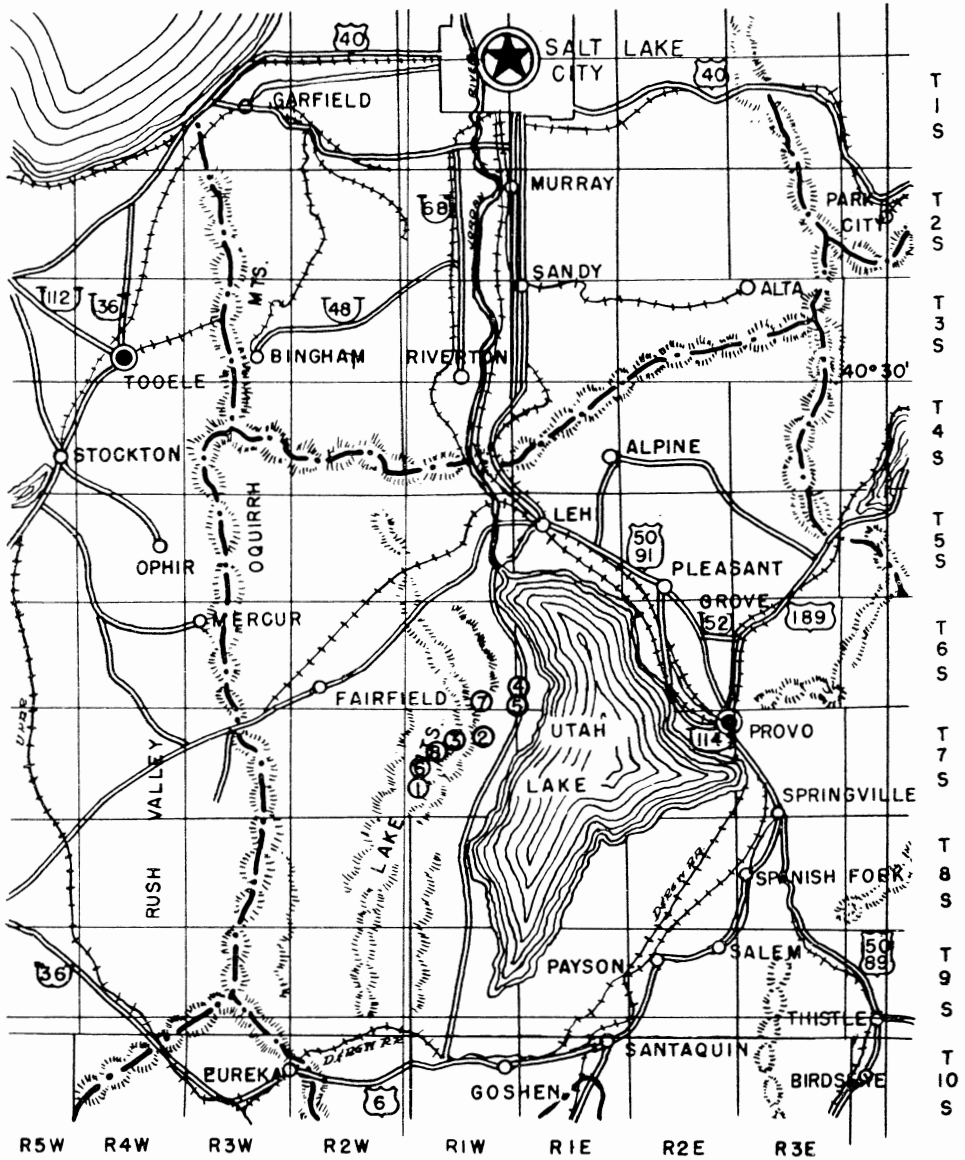


Fig. 2 Map of the Lake Mountains and Adjacent Areas, Utah, showing Mineral Deposits Described.

- (1) Fox Clay Deposits;
- (2) Western Fire Clay Co. Deposits;
- (3) Wild Cat and Black Hawk Manganese Deposits;
- (3) Roger Cedarstrom Calcite Deposit;
- (5) Lakeside Lime and Stone Deposit;
- (6) Wm. H. Prince and Sons Block Co. Inc. Pumice Deposits;
- (7) Pelican Point Limonite Deposit; and
- (8) Onyx-marble Deposits.

MINERAL DEPOSITS

Fox Clay Deposits.

Introduction:- The Fox Clay deposits are near the southwest extremities of the Lake Mountains, approximately 9 miles southwest of Fairfield and nearly 50 miles south of Salt Lake City. They are recorded as being in the Lehi Unorganized Mining District, and are covered by 6 placer claims embracing 545.76 acres in secs. 20 and 29, T. 7 S., R. 1 W., SLBM. The clay deposits are known as the "Fox Clay Beds" and are controlled by C. D. Fox, other members of the Fox family, and associates. The Fox family of Salt Lake City have had possession of the property since 1889, the year during which the clay was discovered.

Production:- Total clay production from the property has been approximately 30,000 tons.<sup>1/</sup> The material has been shipped to Washington, California, and locally throughout Utah, for use in brick, pipe, and paper industries. During recent years the property has been relatively dormant except for small shipments made to the Pacific States Cast Iron Pipe Company of Ironton, Utah, where the clay has been used as a binder for molding sands in the manufacture of pipe.

Geology:- Clay beds are exposed in two large open cuts and several small pits. The greatest exposed thickness of clay is approximately 10 feet, although it has been reported that at one time the face of clay was opened to a depth of 20 feet. Normally the clay beds are overlain by a variable thickness of Tertiary limestone, which in turn is capped by basaltic lava. A section exposed in the large open cut reveals approximately 10 feet of white clay, grading upward irregularly into a zone of red to brown iron and manganese-stained clay. The latter zone is from 5 to 10 feet thick and is

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<sup>1/</sup> Verbal communication with C. D. Fox.

in turn capped by a thin layer of travertine in part covered by alluvial wash. The extent of the reserves of the clay deposit was not studied by the writers, but should future geologic examinations substantiate the theory of origin held by the writers, it should be possible to map the extent and probable tonnage with the aid of a few carefully chosen drill holes. Estimates have been made that indicate 50,000 tons of clay are near the open cuts, and assuming an average depth of 10 feet of clay and a continuity of 25 percent over the approximate 550 acres, 3,000,000 tons are inferred.<sup>1/</sup>

Under present mining conditions much of the white clay is being wasted by admixture with the iron-rich material that overlies this better quality clay. Apparently the mining methods employed in the past were undercutting and extraction of as much of the valuable clay as possible before caving the overlying material and then permitting sloughing to equalize the front so that danger of cave-ins would be lessened. This caved material has in part been mucked out and in part allowed to accumulate at the foot of the quarry. Obviously this is wasteful as well as dangerous and has resulted in an unusually high percentage of loss, except when mixture of the white and iron-rich clays was not especially detrimental to the consumer. This has been the case with respect to shipments to the Pacific States Cast Iron Pipe Company of Ironton, Utah, where all the clay was suitable providing the iron content was not excessive, although preference was given to the white or yellow clays.

The clay appears to be essentially halloysite intermixed with finely divided quartz grains. The following analysis indicates the quality of the various colored clays:

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<sup>1/</sup> Extracted from an unpublished report on the Fox Clay Deposits by Paul T. Allsman, Mining Engineer, U. S. Bureau of Mines, Salt Lake City, Utah.

ANALYSIS OF FOX CLAY (HALLOYSITE)

	' Al <sub>2</sub> O <sub>3</sub>	' SO <sub>3</sub>	' Fe <sub>2</sub> O <sub>3</sub>	' TiO <sub>2</sub>	' K <sub>2</sub> O	' Na <sub>2</sub> O	' CaO	' MgO	' SiO <sub>2</sub>	' P <sub>2</sub> O <sub>5</sub>	% Loss l ' Ignitic
White Clay <sup>1/</sup>	32.7	1.70	1.40	1.80	0.74	0.84			44.4	0.068	
White Clay <sup>2/</sup>	30.1	0.4	2.43	0.40	1.13	0.60	0.40	0.70	48.4		
Cream colored, Clay <sup>3/</sup>	30.44		1.96				0.4	0.70	55.4		11.0
Red Clay <sup>2/</sup>	30.43		3.57				0.4	0.72	53.2		9.8

Origin:- The dominant drainage of the southwestern flank of the Lake Mountains extends headward as a canyon northeasterly from Soldiers Pass. Near its head it is joined by a main tributary which drains a long strike valley to the north. A similar though shorter strike valley to the south also contributes to its drainage. Several smaller strike valley tributaries enter the canyon on the lower flanks of the range. The direction of drainage from the main canyon was formerly southwestward into Cedar Valley proper. This drainage was subsequently captured by headward erosion of a short tributary which diverted drainage into Utah Lake by way of Soldiers Pass. Both during the long period while the drainage was directly into Cedar Valley and after diversion had been accomplished, subsurface drainage continued to flow from Soldiers Pass through the porous volcanic ash directly southwestward into the south end of Cedar Valley.

The extremely dry climate plus the fact that most of the surface rocks are limestone assures a high percentage of calcium bicarbonate in the moving ground water. Carbonic acid and calcium bicarbonate are sufficiently alkaline in

- 
- <sup>1/</sup> Analysis 250 lb. composite sample, U. S. Bureau of Mines, Salt Lake City, Utah.  
<sup>2/</sup> St. Clair, H. W., Ravitz, S. F., Sweet, A. T., and Plummer, C. E., The Ammonium Sulphate Process for Reduction of Alumina from Western Clays: A.I.M.E. Transactions, Vol. 159, p. 260, 1944.  
<sup>3/</sup> Crismon and Nichols, Salt Lake City, Analysts.

reaction to effectively leach varying quantities of silica from unstable silicates in the glassy constituents of volcanic ash. Alkalies are also extracted and carried off in solution by this process, thus leaving an end material relatively rich in kaolin, halloysite, similar clay-like silicates, and some free quartz. It is this material which now forms the Fox Clay deposit, and it is believed that the Fox Clay beds now occupy the abandoned ancient Cedar Valley drainage outlet, established prior to the pyroclastic deposits and later exhumed, as described on page 9.

Western Fire Clay Company Deposits.

Introduction:- The Western Fire Clay Company, Inc., P.O.Box 2197, Salt Lake City, Utah, controls 12 lode claims in Ts. 6 and 7 S., R. 1 W., all of which show exposures of clay. The area in which the clay occurs is several miles south and west of Pelican Point on the east side of the Lake Mountains. The claims owned by the Western Fire Clay Company are as follows:

Buck Clay Lode Claim - sec. 1, T. 7 S., R. 1 W.  
Fawn Lode Mining Claim - sec. 1, T. 7 S., R. 1 W.  
Burnt Cedar Lode Mining Claim - Center of Big Cove 1-1/2 miles west of Utah Lake and 3 miles southwest of Pelican Point.  
Smuin Mine Lode Mining Claim - in small hills 1 mile east of Potters Canyon and 3-1/2 miles southwest of Pelican Point.  
Brown Jug Lode Mining Claim - in small hills, 1-1/2 miles from Utah Lake and 3-1/2 miles southwest of Pelican Point.  
Jade Lode Mining Claim - sec. 25, T. 6 S., R. 1 W.  
Jack Rabbit Lode Mining Claim - sec. 12, T. 7 S., R. 1 W.  
Clay Baby Lode Mining Claim - sec. 12, T. 7 S., R. 1 W.  
Iron Hill Lode Mining Claim - sec. 12, T. 7 S., R. 1 W.  
Palm Olive Lode Mining Claim - sec. 29, T. 7 S., R. 1 W.  
Lake View Lode Mining Claim - sec. 29, T. 7 S., R. 1 W.  
Overcross Lode Mining Claim - sec. 1, T. 7 S., R. 1 W.

Production:- At present production of clay is from the Jack Rabbit claim. It is reported that approximately 750 tons per month are shipped

to Geneva, and contracts are pending for large shipments of clay to California.<sup>1/</sup>

Geology:- The Jack Rabbit, Buck, and Overcross claims near the mid-eastern front of the Lake Mountains were examined by the writers. The rocks of this area consist of limestone, quartzite, and interbedded shales. Age assignment of the sedimentary series is uncertain due to the lack of diagnostic fossils. Lithologic characteristics suggest a possible correlation with the Manning Canyon shale formation of the Oquirrh Mountains, as described by Gilluly.<sup>2/</sup> In the vicinity of the Jack Rabbit claim, the sedimentary strata strike N. 10 to 15° E. and dip 55 to 75° to the SE. Faulting is indicated by change of strike and dip approximately 1/2 mile to the north, where the strata strike N. 5° W. and dip 25° SW. This fault may possibly terminate the northern extremities of the clay beds of the Jack Rabbit claim.

Jack Rabbit claim: The Jack Rabbit claim in the SE 1/4 of the SE 1/4, sec. 12, T. 7 S., R. 1 W., several miles south of Pelican Point, is at the base of the east slopes of the Lake Mountains. This claim is readily accessible over a graded road that parallels the western shores of Utah Lake. The clay on this claim is approximately 25 feet in thickness and has a known length of 2400 feet. The exposed rocks from west to east consist of (1) a gray-brown highly fractured quartzite, (2) a thick-bedded, dark blue limestone which is transected by numerous calcite veinlets and contains an interbedded aluminous shale (the Jack Rabbit claim clay), and (3) a quartzite similar to that described as (1). A generalized cross-section of the sedimentary beds, as exposed at the portal of the Jack Rabbit claim mine is as follows:

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<sup>1/</sup> Verbal communication with Dr. Bertil H. Lee.

<sup>2/</sup> Gilluly, James, Geology and Ore Deposits of the Stockton and Fairfield Quadrangles, Utah: U. S. Geol. Survey Prof. Paper 173, 1932.

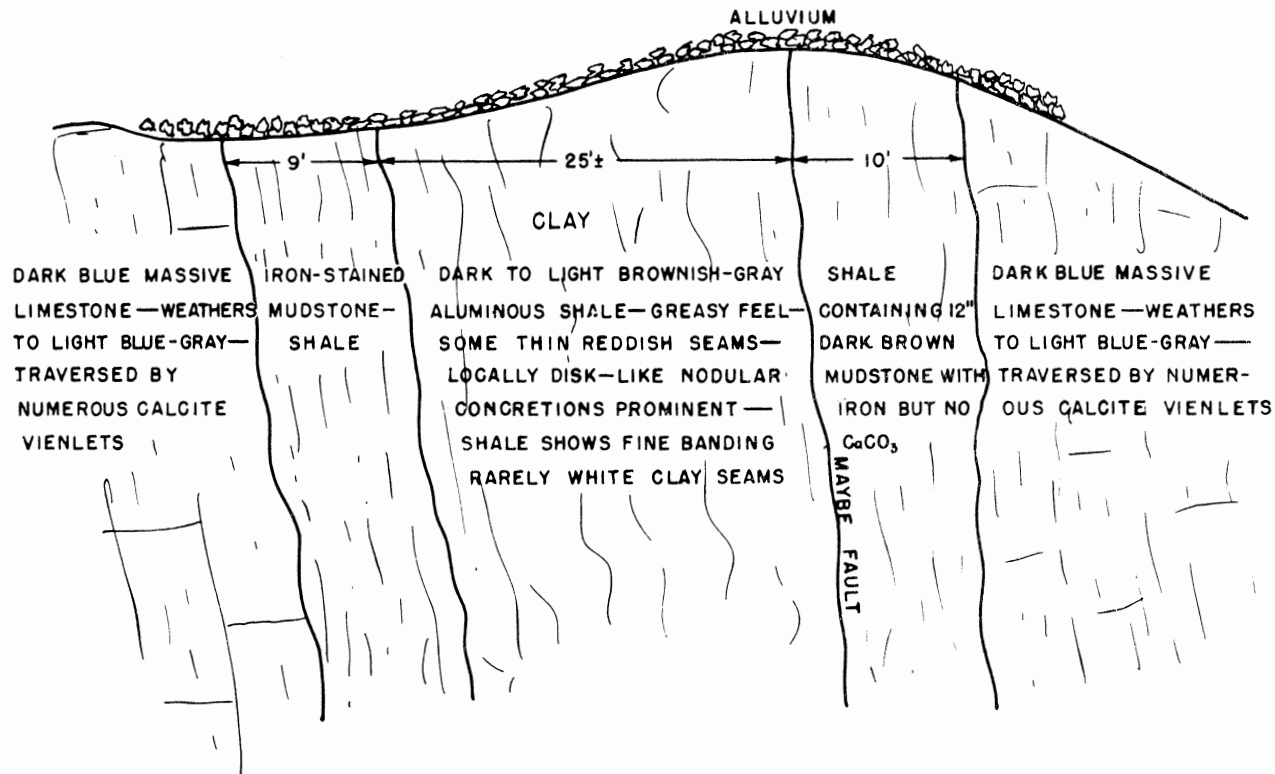


Fig. 3 Cross-section of the Sedimentary Rocks of Jack Rabbit claim, Lako Mountains, Utah.

An unusual feature of the clay shale zone is the occurrence of disc-like nodules in which the shrinkage cracks are filled with secondary opal and quartz. These nodules are peculiar to this shale bed and are a ready correlation criteria elsewhere in the area. On the Buck claim a 21-foot section of similar clay contains identical concretions, indicating that it is the same shale as exposed on the Jack Rabbit claim.

Mining operations of the Western Fire Clay Company are at present confined to the Jack Rabbit claim, on which a main tunnel has explored some 300 feet of the clay along the strike at depth. The total tonnage mined thus far is not known, although all the clay produced has been shipped. The entire output of the mine is from underground workings. Relatively low cost production is sustained because of the soft nature and high dip of the clay shale between the rigid walls of massive limestone, permitting ease of overhead stoping.

Buck and Overcross claims:- The Buck and Overcross claims are east from and at a higher elevation than the Jack Rabbit claim. A bulldozer trench exposed 21 feet of clay shale on the Buck claim for a length of several hundred feet, and outcrops of this member have been reported to extend along the strike for a distance of several thousand feet. The quality of this clay is shown in the subsequent analysis which constitutes a composite sample of the entire 21-foot width.

The Overcross claim is north and west from the Buck claim and embraces chiefly a low ridge within the heart of the range proper. Development work consists of several long irregular surface cuts which expose a large potential clay area. The clay shale is similar to that exposed on the Buck and Jack Rabbit claims, as indicated by the analysis of a composite sample cut from a distance of approximately 200 feet. However, none of the peculiar nodular concretions common to the other claims were noted.

CLAY ANALYSES

WESTERN FIRE CLAY COMPANY

CRISMON & NICHOLS -- ANALYSTS

	No.	SiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	CaO	MgO	MnO <sub>2</sub>	K <sub>2</sub> O	Na <sub>2</sub> O	P <sub>2</sub> O <sub>5</sub>	V <sub>2</sub> O <sub>5</sub>	TiO <sub>2</sub>	SO <sub>3</sub>	CO <sub>2</sub>	% Calci- nium loss	Qualitative test for Bar- ium & Stron- tium shows
Jack Rabbit	(1)	61.74	2.12	27.50	0.40	0.22						0.17				
Jack Rabbit	(2)	36.86	7.88	17.08	15.43	1.59						0.38				
Jack Rabbit	(3)	44.40	14.64	24.01	2.62	0.32						0.66				
Jack Rabbit	(4)	50.38	4.84	27.91	0.61	0.24						0.79				
Jack Rabbit	(5)	49.40	7.12	21.93	1.40	0.10	0.46	0.61	1.27	0.77	0.22	0.81	3.17	2.00	10.68	None
Jack Rabbit	(6)	53.80	4.94	18.29	2.20	0.30	0.38	0.71	2.41	2.19	0.34	0.67	0.37	1.66	11.70	None
Buck	(7)	54.28	4.31	25.35	0.48	0.03	0.23	0.56	2.20	0.54	0.16	0.70	0.14	2.80	7.64	None
Overcross	(8)	55.84	6.71	21.83	1.48	0.26	0.46	0.41	2.91	0.38	0.11	0.75	0.14	1.32	7.36	None

- (1) White clay veinlets in shipping clay - Jack Rabbit claim.
- (2) 5' clay on footwall - Jack Rabbit claim. (See Fig. 3.)
- (3) 5' to 9' off footwall (4' iron-stained impure clay) - Jack Rabbit claim. (See Fig. 3.)
- (4) - - - Jack Rabbit claim.
- (5) Shipping clay from face 200 ft. underground - 300 ft. in from portal - Jack Rabbit claim.
- (6) Vanadium test on black shales and qualitative test for phosphate - Jack Rabbit claim.
- (7) Composite sample of clay shale 21' in width - Buck claim.
- (8) Approximately 200' composite sample from surface (bulldozer) trench - Overcross claim.

The Wild Cat and Black Hawk Manganese Claims.

Introduction:- The manganese deposits of the Lake Mountains were examined by the writers during the month of April 1942. Mr. Dell Steel of Nephi, Utah, acted as guide. The west side of the range was observed from the extreme north end to as far south as the Fox Clay deposit. The manganese occurrences examined consisted of several small manganiferous outcrops in a strike valley north of the Fox Clay beds and what was reported to be the better grade deposits of the Wild Cat and adjoining claims farther to the north. No manganese ore body which seemed to have economic significance was noted other than that exposed on the Wild Cat claim.

Mr. Dell Steel and associates control the unpatented Wild Cat claim and four other adjacent claims designated as the Black Hawk group. The only producer has been the Wild Cat claim.

Location:- The manganese deposits are in the southwestern slopes of the Lake Mountains, about 8 miles southeast of Fairfield, Utah, and are approximately 1-1/2 miles S. 75° E. of the northeast marked corner of sec. 7, T. 7 S., R. 1 W., SLBM. The section corner is approximately 100 yards south of the mine road near the point where it intersects the main foothill road along the west side of the range.

General Geology:- East from the foothills to the crest of the Lake Mountains, the rocks are chiefly limestones. They dip approximately 45° E. The rocks at the foot of the west flank of the range near the manganese deposits are believed to be Mississippian in age. Crinoid stems and brachiopods are abundant in certain strata. Some of the latter are believed to be partially preserved spirifers and other Upper Mississippian fossils. Productids, bryozoa, and what appeared to be fusulina were noted in strata

above the Mississippian beds, indicating that the basal portion of the Pennsylvanian limestone series is represented.

The rocks show abundant evidence of being manganiferous. The quartzose members, such as siliceous limestones, show blackened cherty weathered surfaces, covered with desert varnish. Thin seams of manganese-stained chalcedony are present. Certain softer rock members have a characteristic pinkish cast, suggesting the presence of manganese carbonate in the limestone. These strata weather to speckled surfaces with black manganese oxide disseminated throughout. Where joint planes and minor fissures were open to circulation of ground water, they are filled with a mixture of calcite and manganese dioxide.

Manganese Deposits:- The manganese ore body on the Wild Cat claim shows little evidence on the surface to distinguish it as being richer in manganese oxide than other outcrops in the vicinity. The ore body has been developed down the eastward dip of about  $45^{\circ}$  for a distance of approximately 200 feet. Most of the ore was found mushrooming out from a small insignificant fissure that strikes N.  $75-55^{\circ}$  E. A dense fossiliferous limestone bed forms the footwall. Shaly clay-like altered lime beds constitute the zone in which the manganese was deposited. At depth the strata dip at a steeper angle than those exposed in the first 100 feet from the surface. The change in dip steepens the beds approximately  $10^{\circ}$ . This change appears to be associated with a minor fault zone parallel with the front of the range.

The "Saddle Reef" caused by the change in dip has been a favorable area for manganese deposition. This is possibly due in part to the additional fracturing and more porous nature of the rocks, and in part to the

impervious nature of the residual clay of the hanging wall which has held solutions longer at this place. Drifts have been extended for some distance to the south and for a short distance to the north at the intersection of this zone with the manganese ore shoot. This work encountered good manganese ore, and it is believed that other bodies may be opened by further explorations to the north and south along this zone.

The deposition of manganese in these areas appears to have filled open water courses. The ore consists chiefly of porous to compact masses of psilomelane covered by botryoidal surfaces and colloform crusts. "Wad", the black earthy oxide of manganese, is also prominent. All manganese ore shipped from these stoops was about 48% in grade. Some of the ore contained more than 60% manganese and was used by the Midvale Glass Company during its short operation in the early 1930's.

To the north of the main workings across a small drainage gully, an open trench has been prolonged northward into a cavernous stope in siliceous limestone. The manganese here occurs chiefly as psilomelane filling joints from one to four inches in width. Occasionally, masses of this material approach shipping ore. An area several feet wide and exposed for some distance along the strike of the beds is highly impregnated with manganese of this character. This zone is stratigraphically some 20-50 feet beneath the horizon described in the foregoing paragraph. Several small prospects expose pockets of manganese ore, usually in the bottom of small ravines where altered limestone and shale beds form either or both the foot and hanging walls of the bedded veins. The location of these prospects may be due to the better exposure in the bottom of ravines of a manganese-rich

zone otherwise obscured by soil and rock mantle, or it may be due to the selective etching by the surface runoff along minor east-west fissure zones that are less resistant to erosion and which facilitated concentration of the manganese-bearing solutions.

Production:- Thus far, shipments of manganese ore have been made only from the Wild Cat claim. Approximately 250 tons were shipped prior to the examination made by the writers. Four cars of ore were purchased by the Columbia Steel Plant at Ironton, Utah, one car was delivered to the Colorado Fuel & Iron Company of Pueblo, Colorado, and approximately 25 tons were purchased by the Midvale Glass Company at Midvale, Utah.

During 1943, four truckloads of ore were shipped to the Metals Reserve stockpile at Delta, Utah. The ore averaged 44 percent manganese. A typical analysis of the manganese ore accepted at Delta is as follows:

Manganese . . . . .	43.62%
Iron . . . . .	1.47%
Silica . . . . .	6.30%
Alumina . . . . .	2.10%
Phosphorus . . . . .	none
Zinc . . . . .	none

Origin:- Three possibilities may account for the source of the manganese-bearing solutions that formed the manganese deposits. They may have been derived from (1) syngenetic manganese in the limestone beds, (2) ascending hydrothermal solutions, or (3) the weathering of a mangariferous volcanic tuff. In the latter hypothesis it would be necessary to postulate a thick blanket of tuffaceous material covering the higher regions of the Lake Mountains, and to assume that the tuff occupied this position long enough to

have been thoroughly leached of its manganese. These specialized conditions permitting manganese from such a source are not favored by the writers. The second possibility is scarcely more tenable since little evidence is discernible of hydrothermal alteration or other mineralization that would have accompanied hypogene solutions ascending along joint planes and up the dip of the limestones. The first premise, favored by the authors, is that considerable manganese carbonate was precipitated with the limestone beds or became incorporated in the limestone by paragenesis soon after their deposition -- and that carbonic acid and calcium bicarbonate from supergene percolating waters reacted with these beds during weathering processes, concentrating the manganese along joint and bedding planes more pervious to these solutions.

The fact that these deposits contain wider and richer veins of manganese near the surface than at depth, indicates that the concentration of manganese has taken place at or near the surface. Part of the manganese may have formed directly from ordinary ground water following the water table near the surface, migrating downward along the joint planes. However, the chemistry of manganese oxide formation is more adequately explained if it is assumed that the manganese (1) was leached from higher areas of the range, (2) percolated down through cracks and joints in the limestone, and (3) later reappeared on the lower flanks, being forced upward along the dip under artesian pressure. Clarke<sup>1/</sup> has shown that manganese carbonate will stay in solution longer and is more stable than iron carbonate. Manganese

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<sup>1/</sup> Clarke, Frank Wigglesworth, The Data of Geochemistry, 4th Edition, U. S. Geol. Survey Bull. 695, pp. 533-4, 1920.

sulphates are readily soluble and will remain in solution in the presence of calcium oxide unless free oxygen is simultaneously encountered. Thus, as the manganese solutions reach the surface where free oxygen is abundant, the available manganese becomes further oxidized and precipitates as the stable manganese dioxides,  $MnO_2$ , or related forms.

Recommendations:- The wide-spread occurrence of manganese in the limestone of this area indicates that other deposits similar to the one developed on the Wild Cat claim may be anticipated. They should be developed by following ore shoots down dip to where the concentration has been greatest. Where cross-breaks or other local structural conditions have enlarged the ore-bearing areas laterally along the strike of the beds, they should be prospected by drifts with the hope of encountering additional ore shoots. These could then be stoved upward at relatively low cost. The conditions observed do not promise large scale ore deposits, and as a consequence new development must be under careful supervision if profits are to be obtained.

The Roger Cedarstrom Calcite Mine.

Introduction:- The Roger Cedarstrom Calcite Mine is described because of the importance of calcite to the local poultry and dairy industries. The high-purity calcite produced from the Cedarstrom Mine together with deposit in the Cedar Mountains of Tooele County furnishes the needs of the poultry and livestock industries of Utah. Prior to the opening of these two calcite properties, oyster shells were shipped from the southern Gulf states. Easily digestible calcium carbonate ( $CaCO_3$ ), either aragonite or calcite,

fills a nutritional requirement for poultry and certain livestock, especially when the normal feed is low in calcium. Bone meal can and is used for this requirement, but when phosphorus needs have been supplied (from bone meal or other digestible calcium phosphates), the additional calcium requirements can then be supplied more cheaply from calcium carbonates than from calcium phosphates. Chickens cannot maintain daily hard-shell egg production unless constantly fortified with extra calcium. The addition of a small amount of calcite "flour" to the rations of steers being fattened in the "corn belt" lessens the amount of bone meal otherwise required to make satisfactory gains.

Location and Mineral Deposits:- The Roger Cedarstrom Calcite Mine is on the northeast flank of the Lake Mountains, approximately 14 miles southwest of Lehi, in sec. 30, T. 6 S., R. 1 E., SLBM. The property is covered by 5 claims consisting of about 20 acres each. Large vertical veins of coarsely crystalline calcite transect a massive bedded, fine-grained, blue-gray limestone. The limestone beds are nearly horizontal and are estimated to be 500 feet in thickness. The largest calcite vein is 12 feet thick, and has been exposed by a long open cut and an incline shaft from which the vein system has been explored to a maximum depth of 300 feet. Within this zone cave openings are abundant. They are usually vertical pipe-like openings of irregular form, and some attain considerable size. The walls of the caves are covered with small stalactitic growths of calcium carbonate. The strong air currents issuing from these openings are indicative of their interconnections at depth with other openings not discernible in the immediate vicinity of the mine.

Production:- The mine has been in operation for a period of 29 years and is credited with a production of approximately 2,000 tons of calcite per year. The raw calcite is crushed in a mill on the property to various sizes, as required by the trade. At the mine, the bulk calcite has a value of approximately \$10.00 per ton, but is marketed usually in 100-lb. bags. According to Mr. Cedarstrom<sup>1/</sup>, 85 percent of the calcite produced is purchased by Draper Poultrymen, Inc., Draper, Utah, which furnishes approximately 3,000 customers with pure calcium carbonate. This calcite is ultimately placed in the feed of approximately 1,500,000 chickens, 50,000 turkeys, 3,500 dairy cows, and 7,000 hogs.<sup>2/</sup>

Limestone Deposits of the Lakeside Lime & Stone Company.

The limestone deposits of the Lakeside Lime & Stone Company are adjacent to the Roger Cedarstrom Calcite Mine on the northeast flank of the Lake Mountains. In January, 1947, the United States Bureau of Mines prepared a confidential report on the limestone deposits of the Provo Industrial Area. This report includes a description of the limestone deposits of the Lakeside Lime & Stone Company. Permission was granted by the United States Bureau of Mines to incorporate in this circular the written description and analyses pertaining to the Lake Mountain limestone deposits. This information is herewith quoted as follows:<sup>3/</sup>

"The Lake Mountains deposit is situated in T. 6 S., R. 1 W., Salt Lake Base and Meridian, probably near the boundary line of T. 6 and 7 S....The beds are nearly horizontal in this area and the thickness, although somewhat obscured by overburden near the base of the deposit, is estimated to be in excess of 150 feet and may approach 500 feet in thickness. The limestone is fine-grained,

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<sup>1/</sup> Verbal communication with Roger Cedarstrom.

<sup>2/</sup> Verbal communication with members of the Draper Poultrymen, Inc., 1944.

<sup>3/</sup> King, W. E., Limestone for the Production of Cement in the Provo Industrial Area, Utah County, Utah; U. S. Bureau of Mines Information Report, January 1947.

uniform in texture, and is blue-gray in color. Samples 43 to 49 were taken from the ore bin, quarry adjacent to the ore bin, quarry about 1,200 feet southerly from these installations, and from outcrops in the immediate area above this quarry. The analysis indicates the possibility of a deposit of considerable dimension with a very high CaO content and sufficiently low in MgO content to be considered as a source of supply of cement rock. The Lakeside Lime & Stone Company is now producing 'burned lime' in the amount of 40 tons per day from the deposit.

"One sample, number 50, was taken on the west side of the Lake Mountains. Only the most sketchy reconnaissance was made of this side of the range but observed physical conditions suggest that other locations should be investigated prior to further work in the area."

Analyses of Lake Mountains Limestone

Sample No.	CaO	MgO	SiO <sub>2</sub>	Length feet	Remarks
43	53.0	1.15	2.4		Grab from ore bin.
44	55.1	0.4	0.7	30' face	Quarry, south of kilns.
45	55.2	0.4	0.4		Quarry, west of kilns.
46	46.4	1.85	11.3		Lower bench, quarry 1200' south of kilns.
47	51.8	1.6	2.9		Upper bench, surface material.
48	54.8	0.4	0.8		Chips from outcrop above and 50' from brink of upper quarry.
49	54.6	0.3	0.9		Chips from outcrop above No. 49.
50	42.4	0.4	20.1		West side of Lake Mountains.

Building Stone.

Two types of building stone material have been mined and marketed from the Lake Mountains. They are onyx marble for interior decorative purposes, and pumicitic volcanics for light-weight aggregates and building blocks.

Ornamental Stone:- Banded onyx marble of various colors has been mined by Mr. Cedarstrom and associates intermittently over a period of years, as the occasion demanded. Two claims of onyx marble are controlled by Mr. Cedarstrom and associates. These claims were not visited by the writers. The Boulder Dam

School at American Fork and several buildings in Salt Lake City are decorated with terrazzo<sup>1/</sup> made from the onyx marble from Cedarstrom deposits.

Banded onyx marble of a pale orange color occurs as a horizontal vein approximately 12 inches thick on the west side of the range. Outcrops are exposed on the west wall of the strike valley, described on page 8. The vein consists of large mammillary incrustations of calcium carbonate. This material readily polishes to a high luster with pleasing pattern. The deposit is small, however, and has little or no economic importance other than the possible use of the material for the manufacture of ash trays, book ends, lamp bases, and other miscellaneous ornamental objects.

Light-weight Building Stone:- The demand by the building trade of Utah for light-weight aggregates and building blocks has activated exploitation of most deposits of pumice, volcanic cinder, and perlite, favorably located with respect to industrial areas and railroad facilities. The nearness of the Lake Mountain pumice breccias to Salt Lake and Utah Valleys resulted in the location of 15 placer claims in secs. 8, 17, and 20, T. 7 S., R. 1 W., SLBM., by William H. Prince and associates in 1945. Since then approximately 15,000 tons of pumicitic material have been mined from these claims, valued at \$2.00 per ton at the property. An open-pit method of mining is employed. Bulldozers push the broken pumice onto loading ramps, where waiting trucks are loaded by gravity. By this simple procedure mining costs are held at a minimum. Mr. William H. Prince<sup>2/</sup> anticipates consumption during 1949 of 100 to 150 tons per day of Lake Mountain pumice for use in the company plant in Salt Lake City.

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<sup>1/</sup> Flooring or other decorative material composed of chips of marble, etc. set irregularly in cement and polished.

<sup>2/</sup> Verbal communication with William H. Prince of William H. Prince & Sons Block Co. Inc., Salt Lake City, Utah, November, 1948.

Pelican Point Limonite.

Introduction:- To the mineralogist, "Pelican Point" of the Lake Mountains is synonymous with limonite pseudomorphs after pyrite. The area is a type locality for museum specimens of large pyrite crystals and groups of crystals altering to limonite. Practically all of the museums and universities throughout the United States, many foreign museums, and thousands of mineral collectors have representative specimens from the Lake Mountain deposits.

Location:- The limonite occurrence is approximately 1-1/2 miles southwest of Pelican Point, a peninsula projecting eastward into Utah Lake. The deposit is accessible over a dirt road which trends southwesterly for about 2 miles from the main foothill road immediately north of the Roger Cedarstrom Calcite Mine. The crystal outcrops are covered by one full unpatented mining claim (the Lakeview) that is owned by Ernest Cedarstrom, John Hutchings, and associates, of Lehi, Utah.

Other similar pseudomorphous crystals are reported to occur in the general vicinity. One area is north of the manganese properties previously described. This area was not visited by the writers, but it is doubted that this occurrence contains the large clusters of crystals common to the Pelican Point locality. Economically, the crystals have little value except for the revenue derived from sales to collectors.

Occurrence:- The limonite pseudo crystals have been mined from several open pits in the saddle of an east-west trending spur of the Lake Mountains. The crystals occur in nearly horizontal bedding seams of a calcareous shale, and in some instances are prolific within limited areas. These rich zones are conformable with the bedding, and no evidence indicating their occurring differently is discernible except that some disseminated secondary red and



**Fig. 4** Photo Illustrating Typical Limonite Pseudomorph after Pyrite Crystal Group, Pelican Point, Lake Mountains, Utah County, Utah.

yellow iron oxides are found in nearly vertical joints.

The limonite pseudomorphs after pyrite weather to a brilliant brownish-black, and originally the saddle containing the outcrops is reported to have glistened with exposed crystals. Collectors have gathered practically all of the weathered groups, and now it is necessary to mine specimens in situ.

Crystal Habit:- The common crystalline form of the original pyrite was the cube; the pyritohedral form was comparatively rare. Individual cube crystals measuring 2-inches across a crystal face have been found, but more common are clusters of intergrown crystals. Two distinct forms of crystal growth prevail. One consists typically of large crystal aggregates composed of relatively complete cube forms; the other exists as spheroidal masses with the corners of many intergrown cubic crystals protruding. Each corner usually shows a portion of 3 euhedral faces. Remarkable examples have been found of both types, such as groups of crystals attaining a maximum width of 18 inches.

The outstanding feature of these pseudo crystals is that during the alteration of the original pyrite (the iron disulphide  $\text{FeS}_2$ ) to limonite<sup>1/</sup>, the external form of the sulphide crystals was perfectly preserved. Consequently all specimens show distinct well-developed crystal form. Many of the specimens are not completely altered to limonite, and in such instances

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<sup>1/</sup> Limonite, a name formerly given to hydrous iron oxide with the supposed formula  $2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$ , is no longer an accredited mineral species of definite chemical composition. It is a convenient field term for various hydrous iron oxides whose identity is unknown. "The substances included under the name appear for the most part to represent hardened gel masses of hydrous basic ferric oxide,  $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$  or  $\text{HFeO}_2 \cdot n\text{H}_2\text{O}$ , equivalent respectively to lepidocrocite or goethite, and, in less part, hydrous ferric oxide,  $\text{Fe}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ , equivalent to hematite". — Palache, Charles; Berman, Harry; and Fröndel, Clifford: Dana's System of Mineralogy, p. 685, New York: John Wiley and Sons, Inc., 1944.

pyrite is usually near the center of the crystals. Occasionally groups of crystals of a spheroidal habit (nodular-like masses of many crystal points) reveal the center of each individual crystal to be pyrite but the cores of the groups to be completely limonitized and weathered away leaving residual shells, the outside margins of which still show perfect crystal forms. This peculiar central alteration is probably due to more rapid decomposition along fracture planes through the center of the group, but it may also indicate selective alteration of two dimorphous minerals, i.e., marcasite and pyrite.<sup>1/</sup>

Paragenesis:- The crystals of altered pyrite in the calcareous shale are apparently the result of replacement. The iron and sulphur required for the formation of pyrite appears to have been derived from the sediments that now exist as shale. There is no evidence to substantiate an origin by igneous agencies. The crystallization of the pyrite may have occurred during deposition of the shale, but more probably it was much later, possibly during the deformation of the Lake Mountains strata. The presence of pyrite, marcasite, and other sulphides in shale, limestone, coal beds, and other sedimentary formations is well known. Usually these sulphides are in the form of small, single crystals or crystal aggregates. Less common occurrences are as nodules, lenses, and beds. Occasionally fossils are replaced by pyrite or marcasite.

Whether the original pyrite crystals of Pelican Point are the indirect product of sedimentation, or whether they are the result of meteoric precipi-

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<sup>1/</sup> Marcasite, the dimorphous equivalent of pyrite, is far more decomposable than pyrite under ordinary atmospheric conditions. The writer has a specimen of marcasite and pyrite from Ohio that consists of concretionary radiating crystals of marcasite covered by large crystals of pyrite, of which the marcasite is undergoing rapid oxidation while the pyrite remains unaltered. Should a similar marcasite-pyrite relationship be assumed for some of the large Pelican Point groups, the peculiar core oxidation is apparent.

tation, or a combination of both processes, is not known. It is doubtful that the localized concentrations of the extraordinarily large crystal groups of the Pelican Point locality can be considered syngenetic. A more plausible explanation is that the original iron was precipitated as iron sulphide due to reactions between sulphur decaying organic matter and the iron in the enclosing sediments, and that the large crystal aggregates are a reconcentration and recrystallization of this source material.

The alteration of the Pelican Point pyrite to limonite pseudomorphs after pyrite is a normal oxidation reaction still active. Normally, pyrite is leached away by the sulfuric acid produced by the oxidation of pyrite, but the acid solutions thus formed at the Pelican Point deposit are speedily neutralized by the presence of calcium carbonate, and immediately precipitate the iron content as limonite.

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