

BRIGHAM
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Normative Mineral Distributions in Utah Lake Sediments: A Statistical Analysis*

PAUL A. SONERHOLM

Amax Lead Company of Missouri; Boss, Missouri

Abstract.—A systematic study of 139 contemporary bottom-sediment samples of Utah Lake, taken at the intersection of section lines, was undertaken for the 7 elements Na, K, Ca, Mg, Si, Al, and Fe by atomic-absorption spectrophotometry. Nine normative minerals—calcite, magnesite, gypsum, quartz, clinocllore, illite, hematite, halite, and sylvite—were calculated from these data. Six normative minerals—calcite, magnesite, quartz, clinocllore, illite, and hematite—were placed into 4 groups under the following headings: total carbonate, total clay, quartz, and hematite. For each of these groups, a sixth-degree trend-surface map was made by computer.

In the majority of samples, normative carbonate (i.e., calcite plus magnesite) is the most abundant mineral, with quartz the second most abundant. The total for these two normative minerals constitutes at least 90 percent of the sample in most cases.

Carbonate is highest in the northern and southern portions of the lake, and quartz is most abundant in the midportion. The trends for total clay and normative hematite are less simple and reflect the influences of various streams entering the lake.

Sediment entering the lake from the north and west shows a high in normative hematite and quartz, whereas sediments from the south are higher in clay and lower in quartz.

A high in normative hematite lies northeast of Bird Island between two inferred faults and may be related to spring action.

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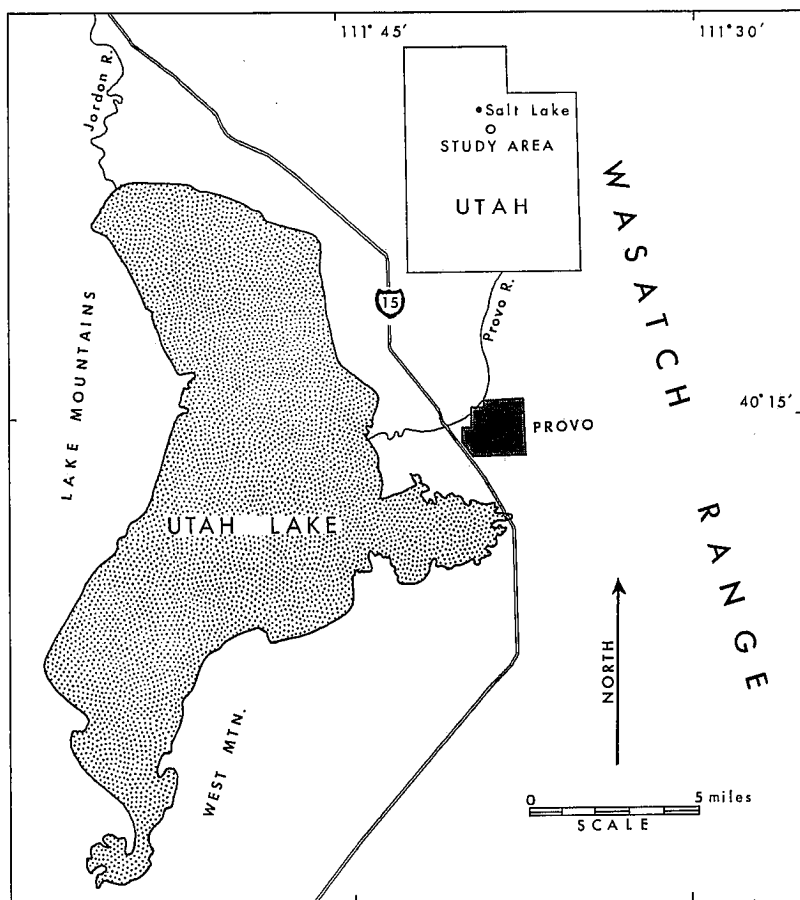
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INTRODUCTION

Location and Description

Utah Lake lies immediately west of Provo, Utah, in the lowest basin of Utah County (see Text-fig. 1). It covers 150 square miles, contains 900,000

*A thesis presented to the Department of Geology, Brigham Young University, in partial fulfillment of the requirements for the degree Master of Science, August 1974. Willis H. Brimhall, thesis chairman.



TEXT-FIGURE 1.—Index map.

acre-feet of water, loses 330,000 acre-feet of water annually through evaporation, and receives 600,000 acre-feet of water annually. Because its average depth is only 6 to 8 feet, the lake is hazardous in stormy weather: the troughs of waves may bottom out in the lake sediments and capsize a boat. The weather is usually warm enough for the ice to be off the lake by late March, although Bissell (1942) reports that work can be done through the ice before it gets too thin.

Purpose and Scope

The purpose of this paper is to determine the broad patterns of mineral distribution on the lake floor in preparation for more detailed study of the chemistry and mineralogy of the sediments. The major metals composing the uppermost 12 inches of lake sediments were quantitatively measured, and some selected normative minerals were calculated from these data. The mineral dis-

tributions were mapped by multivariate regression methods (trend-surface maps) using computer facilities at Brigham Young University.

Previous Work

The bulk of geologic work on Utah Lake consists of preliminary studies of bottom sediments by Bissell (1942) and Brimhall (1972). Several studies have been done on the water chemistry, but the samples are restricted to about 24 locations (Bradshaw, 1969).



TEXT-FIGURE 2.—Bathymetric and source map, Utah Lake, showing contour interval in feet. Surface of lake 4488 feet above sea level. Dashed lines are inferred faults.

The study by Bissell treated samples taken from 11 localities in which particle size, moisture content, organic carbon, organic content, and acid-soluble percentage were determined. The study by Brimhall dealt with recent history of Utah Lake as reflected by the chemical profile of Na, Mg, Ca, Al, and Fe.

Acknowledgments

The writer wishes to acknowledge the assistance of Dr. Willis H. Brimhall of the Department of Geology of Brigham Young University in preparing samples and adapting the trend-surface computer programs to fit the computer facilities at the Science Computation Center.

Special thanks are given to my long-suffering wife, Jan, for her support, for assisting me through college, and for typing the manuscript.

Thanks also are given to my parents and my wife's parents for their encouragement and financial assistance, both deeply appreciated.

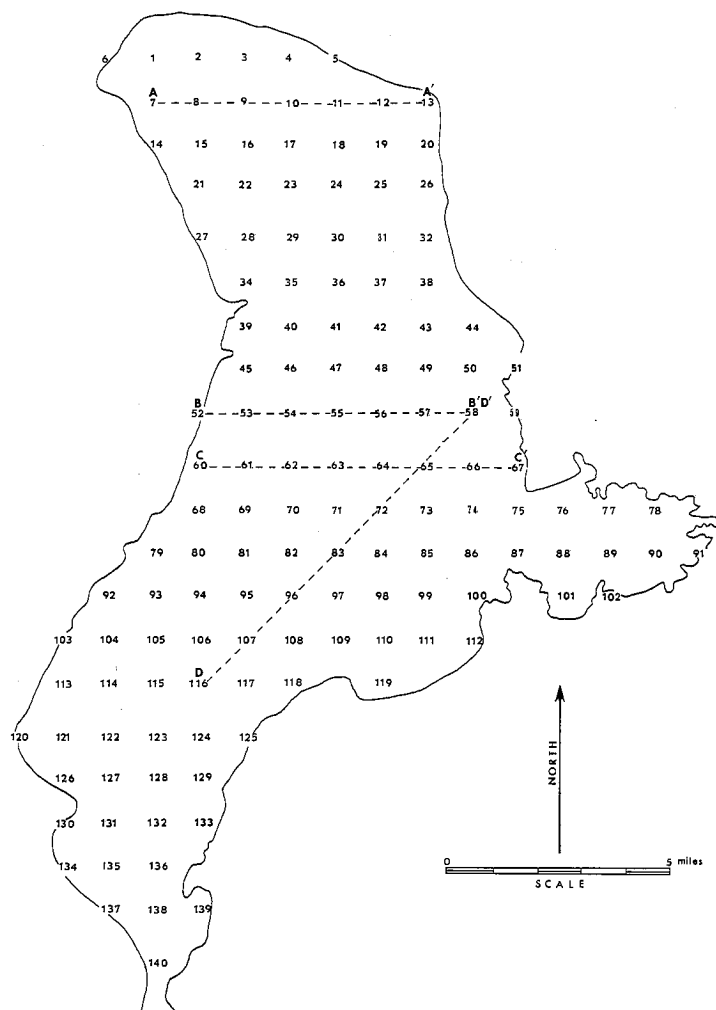
Field Methods

Core samples were taken from a boat in April and May with a Davis peat sampler, modified by Bissell (1942). One hundred thirty-nine cores were taken from as many locations in approximate 12-inch lengths on a regularly spaced gridwork of one mile that coincided with the intersections of section lines (see Text-fig. 3). As soon as each core was taken from the lake bottom, it was placed, together with a numbered label, in a double-thickness plastic bag, and the bag was sealed and numbered on the outside. Location of the sample stations was determined by calibrating the speed of the boat in feet per second at a set engine RPM and using a topographic sheet to locate landmarks on which to take a heading. The system was self correcting for drift in that a heading on a landmark kept the boat headed for the sample location rather than an imaginary magnetic point. The samples were taken on windless days to avoid the danger of capsizing in rough weather and to minimize drift. It is believed that sample locations were generally within ± 100 feet of true position since samples near and on shore, which could be located within ± 100 feet, gave the writer a chance to locate the boat position quite accurately. The error introduced in sample location was cumulative only in each separate traverse of the lake, which was from east to west, the shortest distance across the lake, and the amount of error never built up to any sizeable amount. If it had, the last stop on a sample run, which was near or on shore, would have made this readily apparent and the approximate distance easily judged.

Laboratory Methods

Each numbered sample was removed from its container, and a portion was cut from the full length. The portion was placed in a numbered glass container and heated to 200° C for four hours to drive off the free water. The sample was then crushed and screened to pass 60 mesh and a 50 gm portion was then placed in a numbered glass bottle with an airtight cap.

The crushed sample was prepared for analysis by a technique described by Brimhall and Embree (1970). A 0.3333 gm portion of the sample was mixed well with 1.67 gm of powdered anhydrous lithium metaborate and poured into a clean graphite crucible. The crucible was placed in a furnace at 1000° C for 10 to 15 minutes to fuse the sample. The molten bead was then poured into 400 ml of cold dilute HNO₃ (1:20) and stirred until dissolved. The sample



TEXT-FIGURE 3.—Sample location map. Numbers in italics represent samples in which the total mineral percentage fell outside the allowable error.

was brought to 500 ml volume and filtered. A 250 ml portion of the sample was poured into a numbered plastic bottle with an airtight cap. The samples were then at a concentration equivalent to 1 gm in 1500 ml dilution.

A standard for measuring precision of reproducibility of sample preparation was made by taking 5 gm portions of 5 of the foregoing samples, chosen at random, and mixing them well. A 0.3333 gm portion of the precision standard was processed after every 6 samples.

The samples were arranged in a tray so that (1) no sample was more than 4 determinations from a precision standard and (2) the artificial standards

were no further than every 12 determinations. All the samples and standards were analyzed on a Perkins-Elmer Model 303 Atomic-Absorption Spectrophotometer for sodium, calcium, magnesium, potassium, iron, aluminum, and silicon.

Artificial standards were formulated for the maximum expected values in the samples analyzed, or even for fractions of these values. The percentages of the elements in the standard are listed in Table 1. The weights, in grams of reagents used to prepare the standards, are listed in Table 2.

RATIONALE FOR NORMATIVE MINERALS

Direct determination of the mineral content of the lake sediments poses two experimental difficulties not easily overcome: (1) the mineral particles are

TABLE 1
COMPOSITION, IN PERCENTAGES, OF THE SEVEN SYNTHETIC STANDARDS

	STANDARD						
	1	2	3	4	5	6	7
Si	12.0	24.0	36.0	48.0	00.0	6.00	3.00
Al	6.0	12.0	18.0	24.0	00.0	3.00	1.50
Na	1.0	2.0	3.0	4.0	00.0	5.00	2.50
K	1.0	2.0	3.0	4.0	00.0	3.00	1.50
Mg	6.0	12.0	18.0	24.0	00.0	0.50	0.25
Ca	10.0	20.0	30.0	40.0	00.0	0.50	0.25
Fe	2.0	4.0	6.0	8.0	00.0	1.00	0.50

TABLE 2
WEIGHT IN GRAMS OF REAGENTS USED TO PREPARE THE STANDARDS

	STANDARD						
	1	2	3	4	5	6	7
Si							
SiO ₂	0.345	0.690	1.035	1.380	0.000	0.172	0.086
Al							
Al ₂ O ₃	0.301	0.604	0.906	1.208	0.000	0.150	0.075
Na							
Na ₂ CO ₃	0.061	0.122	0.183	0.245	0.000	0.093	0.046
K							
K ₂ CO ₃	0.047	0.094	0.141	0.188	0.000	0.066	0.033
Mg							
MgO	0.132	0.265	0.397	0.530	0.000	0.023	0.011
Ca							
CaO	0.186	0.373	0.559	0.746	0.000	0.030	0.015
Fe							
Fe ₂ O ₃	0.076	0.152	0.338	0.304	0.000	0.038	0.019

microscopic in size and do not lend themselves to easy recognition and measurement; (2) quantitative X-ray techniques could be used but are tedious to make and difficult to interpret, and the uncertainties are large.

Atomic-absorption spectrophotometry offers a rapid, inexpensive, and accurate method of determining the elemental constituents of the samples with reproducibility within the requirements for the trend-surface maps. The hypothetical or normative minerals (Table 4) chosen to be consistent with the environment of Utah Lake can easily be calculated from these data.

The normative minerals calcite, magnesite, gypsum, quartz, clinocllore, illite, hematite, halite, and sylvite were chosen to meet three requirements: (1) they must account for elements measured, (2) the formula of each must be simple enough to allow determination of its formula weight, and (3) the minerals

TABLE 3
PRECISION OF THE METHOD FOR MINERALS*

Ca	27.15 ± 0.89%	K	0.39 ± 0.02%
Si	9.98 ± 0.70%	Mg	1.35 ± 0.05%
Al	1.28 ± 0.14%	Fe	0.62 ± 0.06%
Na	0.09 ± 0.00%		

*Precision of the method, based on 24 replicate samples of Utah Lake Standards PS 001, analyzed with the unknowns. Data are in weight percent, with 90 percent confidence interval.

TABLE 4
FORMULAE OF MINERALS

MINERAL	FORMULA WEIGHT	ELEMENT	PERCENT	F.W./ELEMENT
Calcite CaCO_3	100.09	Ca	40.04	2.45
Illite $\text{K}_2\text{Al}_6\text{Si}_{13}\text{O}_{44}(\text{OH})_4$	796.60	K	9.81	10.18
		Al	20.32	4.92
		Si	21.11	4.72
Clinocllore $\text{Mg}_5\text{Al}(\text{Si}_3\text{Al})\text{O}_{10}(\text{OH})_8$	555.86	Mg	21.87	4.57
		Al	9.71	10.32
		Si	15.16	6.60
Silica SiO_2	60.09	Si	46.75	2.14
Gypsum $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$	170.16	Ca	23.50	4.25
Magnesite MgCO_3	84.32	Mg	28.85	3.47
Hematite Fe_2O_3	159.70	Fe	35.00	2.85
Halite NaCl	58.44	Na	39.35	2.54
Sylvite KCl	74.55	K	52.50	1.90

must be compatible with the environment of the lake floor. The calcite-magnesite total equals the total carbonate, which is a low magnesium carbonate; the clinocllore-illite total equals the total clay; and halite and sylvite equal the total chlorides. Quartz, gypsum, and hematite stand alone. If a complete analysis for actual composition had been made at each sample location, this study would not have been possible on the scale undertaken.

TABLE 5
DATA ON THE ELEMENTS FOR EACH SAMPLE

SPECIMEN	Si	Al	Na	K	Hg	Ca	Fe
Uls-001	9.98	1.18	0.10	0.35	1.23	27.21	0.56
Uls-002	7.67	.95	0.07	0.31	1.25	30.47	0.49
Uls-003	10.48	1.18	0.11	0.41	1.39	27.21	0.52
Uls-004	10.48	1.09	0.10	0.41	1.28	26.63	0.56
Uls-005	19.96	1.51	0.14	0.51	2.03	18.07	0.63
Uls-006	28.89	2.17	0.40	0.76	0.90	9.79	0.79
Uls-007	18.79	2.39	0.10	0.79	1.83	18.07	0.86
Uls-008	7.16	0.95	0.07	0.30	1.30	31.50	0.47
Uls-009	9.72	1.23	0.08	0.36	1.35	28.40	0.53
Uls-010	9.21	1.23	0.08	0.37	1.35	28.92	0.57
Uls-011	9.72	1.23	0.08	0.38	1.40	27.37	0.62
Uls-012	9.48	1.23	0.06	0.39	1.33	27.59	0.89
Uls-013	21.96	1.27	0.25	0.56	1.07	16.59	0.52
Uls-014	10.48	1.37	0.10	0.43	1.33	26.63	0.56
Uls-015	8.70	0.95	0.08	0.33	1.35	29.95	0.49
Uls-016	9.98	1.18	0.10	0.36	1.17	27.59	0.56
Uls-017	10.23	1.23	0.10	0.38	1.30	27.37	0.56
Uls-018	9.98	1.23	0.09	0.36	1.23	26.82	0.89
Uls-019	9.21	1.23	0.07	0.38	1.40	27.89	0.61
Uls-020	11.48	1.27	0.12	0.45	1.39	25.86	0.61
Uls-021	12.97	1.23	0.15	0.45	1.17	25.28	0.47
Uls-022	11.26	1.23	0.12	0.39	1.25	26.85	0.57
Uls-023	10.75	1.37	0.10	0.41	1.35	27.37	0.62
Uls-024	9.72	1.37	0.09	0.40	1.40	27.37	0.62
Uls-025	9.72	1.23	0.08	0.39	1.40	27.89	0.61
Uls-026	8.48	1.00	0.06	0.32	1.23	28.94	0.56
Uls-027	28.80	2.65	0.20	0.87	1.47	10.50	1.26
Uls-028	8.98	1.18	0.10	0.41	1.39	28.37	0.61
Uls-029	12.28	1.28	0.11	0.42	1.35	25.30	0.63
Uls-030	26.95	1.50	0.25	0.53	1.12	12.73	0.56
Uls-032	34.81	0.92	0.08	0.18	0.67	8.26	0.35
Uls-034	14.97	1.27	0.13	0.40	1.12	23.15	0.47
Uls-035	13.82	1.23	0.14	0.45	1.25	24.27	0.57
Uls-036	10.23	1.23	0.10	0.38	1.35	27.89	0.59
Uls-037	10.75	1.37	0.10	0.41	1.40	27.37	0.63
Uls-038	23.95	1.46	0.27	0.65	1.01	14.47	0.61
Uls-039	20.96	1.64	0.20	0.54	1.60	16.59	0.46
Uls-040	15.87	1.37	0.16	1.55	1.25	22.72	0.59
Uls-041	9.98	1.46	0.07	0.39	1.39	26.63	0.61
Uls-042	10.75	1.28	0.08	0.39	1.35	26.85	0.60
Uls-043	10.98	1.55	0.06	0.41	1.44	25.66	0.61
Uls-044	32.94	1.18	0.17	0.42	0.74	7.62	0.56
Uls-045	11.97	1.46	0.11	0.43	1.39	24.51	0.61
Uls-046	12.28	1.43	0.11	0.45	1.35	25.30	0.65
Uls-047	13.47	1.37	0.11	0.43	1.10	23.51	0.65
Uls-048	10.23	1.37	0.10	0.42	1.40	27.37	0.63
Uls-049	9.88	1.28	0.09	0.37	1.25	27.11	0.61
Uls-050	11.97	1.41	0.10	0.43	1.49	24.12	0.61
Uls-051	26.79	1.81	0.25	0.67	1.40	11.92	0.97
Uls-052	28.15	1.51	0.31	0.68	1.01	11.36	0.47
Uls-053	10.48	1.46	0.08	0.44	1.33	25.86	0.66
Uls-054	11.26	1.51	0.09	0.43	1.45	25.82	0.68
Uls-055	9.98	1.37	0.07	0.41	1.33	26.24	0.56
Uls-056	9.88	1.28	0.09	0.39	1.25	27.11	0.59
Uls-057	11.97	1.27	0.10	0.44	1.39	25.66	0.66

TABLE 5 (Continued)

SPECIMEN	Si	Al	Na	K	Mg	Ca	Fe
ULS-058	12.47	1.46	0.10	0.45	1.49	24.12	0.61
ULS-060	31.03	2.75	0.33	0.75	0.73	9.11	1.15
ULS-061	10.23	1.51	0.08	0.41	1.40	28.85	0.67
ULS-062	10.75	1.51	0.08	0.43	1.45	26.34	0.69
ULS-063	9.72	1.37	0.08	0.42	1.45	27.37	0.58
ULS-064	10.23	1.51	0.09	0.42	1.45	27.37	0.70
ULS-065	9.72	1.43	0.08	0.42	1.45	27.37	0.70
ULS-066	13.61	1.78	0.10	0.51	1.45	23.75	0.79
ULS-067	37.86	1.36	0.18	0.21	0.77	4.13	0.47
ULS-068	9.48	1.18	0.07	0.38	1.28	27.01	0.56
ULS-069	8.19	0.95	0.10	0.32	1.25	29.95	0.49
ULS-070	9.88	1.29	0.08	0.39	1.35	27.11	0.67
ULS-071	10.48	1.46	0.07	0.40	1.49	26.63	0.61
ULS-072	9.88	1.29	0.09	0.40	1.40	25.05	0.67
ULS-073	11.97	1.50	0.10	0.45	1.33	24.31	0.66
ULS-075	37.88	1.36	0.19	0.23	0.77	4.64	0.41
ULS-076	19.96	1.41	0.21	0.49	1.25	19.59	0.65
ULS-077	12.02	0.98	0.08	0.30	1.10	25.43	0.49
ULS-078	21.65	1.27	0.16	0.39	2.83	14.39	0.63
ULS-079	9.72	0.90	0.10	0.35	1.30	28.40	0.47
ULS-080	8.70	1.15	0.07	0.34	1.35	28.92	0.55
ULS-081	8.70	1.23	0.08	0.37	1.35	28.92	0.59
ULS-082	9.72	1.28	0.07	0.38	1.45	27.89	0.61
ULS-083	10.23	1.28	0.07	0.40	1.40	27.37	0.63
ULS-084	9.72	1.23	0.09	0.38	1.40	27.37	0.61
ULS-085	11.77	1.37	0.10	0.45	1.45	25.82	0.70
ULS-086	13.82	1.78	0.12	1.58	1.45	22.72	0.81
ULS-087	29.10	1.67	0.17	0.58	0.86	11.99	0.76
ULS-088	27.95	1.37	0.17	0.50	0.96	11.19	0.47
ULS-089	13.97	1.27	0.11	0.40	1.01	23.15	0.56
ULS-090	15.39	1.27	0.11	0.41	0.73	22.55	0.61
ULS-091	26.94	1.96	0.11	0.68	0.49	12.95	0.84
ULS-092	9.00	0.99	0.09	0.34	0.29	29.12	0.51
ULS-093	8.98	1.00	0.08	0.34	0.28	28.94	0.37
ULS-094	7.63	0.99	0.07	0.32	1.25	30.63	0.53
ULS-095	8.93	1.37	0.06	0.36	1.49	27.79	0.66
ULS-096	9.78	1.34	0.09	0.41	1.40	27.11	0.70
ULS-097	8.98	1.23	0.09	0.35	1.39	27.59	0.61
ULS-098	8.80	1.09	0.10	0.36	1.35	28.12	0.59
ULS-099	11.48	1.18	0.11	0.40	1.28	25.08	0.56
ULS-100	33.78	0.81	0.08	0.20	0.87	8.78	0.49
ULS-101	24.69	1.31	0.14	0.50	1.15	15.33	0.60
ULS-102	22.06	1.51	0.25	0.51	1.32	16.18	0.69
ULS-103	23.96	2.62	0.28	1.03	2.20	11.07	1.20
ULS-104	7.63	0.89	0.07	0.29	1.25	31.13	0.49
ULS-105	8.41	1.19	0.08	0.36	1.35	28.62	0.57
ULS-106	9.39	1.29	0.08	0.38	1.40	28.12	0.66
ULS-107	9.19	1.29	0.08	0.40	1.35	27.11	0.64
ULS-108	10.10	1.41	0.09	0.42	1.50	26.40	0.65
ULS-109	11.74	1.44	0.12	0.44	1.50	25.10	0.70
ULS-110	12.91	1.49	0.12	0.45	1.40	24.60	0.66
ULS-111	14.71	1.51	0.12	0.50	1.45	22.14	0.74
ULS-112	33.78	1.10	0.08	0.20	0.87	8.78	0.47
ULS-113	8.61	0.89	0.09	0.32	1.21	30.12	0.47
ULS-114	8.61	1.14	0.09	0.36	1.40	29.12	0.47
ULS-115	9.48	1.27	0.07	0.40	1.33	26.44	0.56
ULS-116	9.98	1.24	0.08	0.38	1.35	27.11	0.61
ULS-117	8.02	1.04	0.09	0.32	1.25	29.62	0.51
ULS-118	11.49	1.39	0.10	0.42	1.35	24.98	0.67
ULS-119	31.31	1.39	0.23	0.63	0.77	8.53	0.24

TABLE 5 (Continued)

SPECIMEN	Si	Al	Na	K	Mg	Ca	Fe
ULS-120	10.98	1.09	0.11	0.34	1.33	27.01	0.61
ULS-121	9.78	1.09	0.10	0.38	1.35	27.61	0.57
ULS-122	7.24	0.94	0.08	0.28	1.16	31.13	0.47
ULS-123	9.19	1.09	0.09	0.34	1.40	28.62	0.59
ULS-124	9.19	1.09	0.09	0.35	1.35	28.62	0.55
ULS-125	13.47	1.27	0.11	0.44	1.49	23.73	0.66
ULS-126	10.76	1.19	0.13	0.39	1.25	26.61	0.55
ULS-127	9.78	1.09	0.10	0.34	1.25	28.62	0.53
ULS-128	10.75	1.23	0.10	0.41	1.40	26.85	0.59
ULS-129	10.37	1.09	0.11	0.38	1.25	26.61	0.53
ULS-130	12.11	1.44	0.15	0.50	1.74	23.60	0.64
ULS-131	10.76	1.29	0.10	0.42	1.40	26.61	0.66
ULS-132	10.96	1.39	0.10	0.42	1.35	25.60	0.68
ULS-133	13.89	1.29	0.14	0.44	1.35	23.09	0.64
ULS-134	15.47	1.09	0.18	0.44	1.33	22.95	0.61
ULS-135	11.94	1.14	0.14	0.39	1.25	26.11	0.57
ULS-136	13.97	1.27	0.10	0.42	1.44	23.35	0.61
ULS-137	15.65	1.39	0.16	0.50	1.25	21.09	0.72
ULS-138	14.28	1.19	0.15	0.42	1.16	23.09	0.55
ULS-139	18.79	1.39	0.19	0.55	1.35	18.57	0.64
ULS-140	17.47	1.37	0.19	0.51	1.39	19.49	0.61

TABLE 6
PRECISION OF THE METHOD FOR ELEMENTS*

Ca	27.15 ± 0.89%	K	0.39 ± 0.02%
Si	9.98 ± 0.70%	Mg	1.35 ± 0.05%
Al	1.28 ± 0.14%	Fe	0.62 ± 0.06%
Na	0.09 ± 0.00%		

*Precision of the method, based on 24 replicate samples of Utah Lake Standard PS 001, analyzed with the unknowns. Data are in weight percent, with 90 percent confidence interval.

Through analysis of a 0.3333 gm portion of precision standard PS-001 it was found that 99.1 percent of the calcium is in the acid-soluble form, making calcite the logical choice. The insoluble calcium was allocated to gypsum rather than to clay for ease of calculation. In the same test for acid-soluble calcium it was also determined that 70 percent of the magnesium was in acid-soluble form, and magnesite was chosen to account for it. Clinocllore ($Mg_5Al(Si_3Al)O_{10}(OH)_8$) was chosen to account for the insoluble magnesium because it is a simple iron-free clay that would use the magnesium exclusive of the other clay.

Illite ($K_2Al_6Si_3O_{14}(OH)_4$) was chosen to account for the insoluble potassium and the aluminum left after calculation of the clinocllore.

Iron was placed in hematite as a convenience, there being too little to allow for an iron-bearing clay and there being a source of hematite near the lake.

Some potassium and sodium determined in the soluble form were placed in chlorides because they accounted for such a small percent, and they were not used to construct a map.

The remaining silicon was placed in quartz, quartz sand being abundant in the lake.

Although the normative minerals thus calculated are not wholly compatible with the actual mineralogy (the clays are probably montmorillonites), it is believed that the total carbonate (calcium and magnesium) is a good measure of the low magnesium calcite actually present in the sediment. The total clay (illite plus clinocllore) is believed to be a good accounting of the elements that make up the clay, and the calculated quartz and hematite is believed to be a good measure of the actual quartz and iron oxide present in the sediments.

The total percentage of minerals thus calculated is close to 100. Samples that totaled less than 95 percent and greater than 102 percent were rerun or rejected from the finished data. The rejects accounted for fewer than 3 percent of the samples collected. Precision of the method is given in Table 3.

DATA PROCESSING

The atomic-absorption data were recorded on a strip-chart recorder. Values of the synthetic standards derived from these data were used to construct a set of curves that bracket samples. The data on each sample from the 7 elements were keypunched onto computer cards, and the coordinates of every sample were keypunched on additional cards that were added to the program for calculating the normative minerals. The program processed the data and for each sample wrote additional cards used to construct the 4 trend-surface maps: (1) percentage total carbonate, (2) percentage quartz, (3) percentage total clay, and (4) percentage hematite.

The normative minerals, gypsum, and total chlorides were not used to make maps because the data for them are subject to too large an uncertainty. The gypsum is calculated as 0.9 percent of the total calcium in each sample. This set percentage was the percentage of acid-insoluble calcium in the precision standard and was extrapolated to all samples. The total chlorides represent the potassium and sodium remaining after formation of illite and most often are zero. If gypsum and total chlorides data are to be used in maps, a separate determination for the acid-insoluble calcium and soluble potassium and sodium would have to be made for each sample.

DETERMINATION OF THE AMOUNTS OF SOLUBLE CALCIUM AND MAGNESIUM IN THE LAKE SEDIMENTS

Through a chemical determination on the precision standard, 0.9 percent of the calcium was determined to be in an acid-insoluble form and thus was allocated to gypsum. During the same test, it was found that 30 percent of the total magnesium was in an acid-insoluble form and thus allocated to the clay clinocllore.

To determine the insolubles, a 0.3333 gram sample of the precision standard was taken and leached with cold dilute HCl (1:20), adding acid until the evolution of bubbles ceased. At this point it was assumed that the carbonates were totally dissolved. The sample was centrifuged three times with distilled water to remove all solubles. The acid and rinsings were added together, brought to 500 ml volume, bottled and labeled. The residue was dried at 200° C for one hour, mixed well with 1.67 mg of lithium metaborate, fused, and treated as a regular sample. The diluted dissolved residue was bottled and labeled. Through analysis of the two standards, it was possible to determine the percentage of calcium and magnesium in each portion of the standard.

RESULTS AND DISCUSSION

General Description of Utah Lake

Utah Lake, as illustrated in Text-figure 2, can be roughly described as a north-south rectangle, flexed concave to the west and about 7 by 20 miles. Major streams include Dry Creek on the midnorth, American Fork River on the northeast, Spanish Fork River on the mideast, Provo River about a third of the way down on the east side, and several intermittent streams along the mid third of the west side. Jordan River, on the northwest, is the natural exit.

Two topographic highs are adjacent to the lake. The Lake Mountains lie in the mid third of the west side, and West Mountain lies in the lower quarter of the east side. A single small island (Bird Island) exists about a third of the way from the south end and about one-half mile east of the center line and the deepest part of the lake (about 12 feet). The average depth of the lake is 6 to 8 feet, depending on spring runoff.

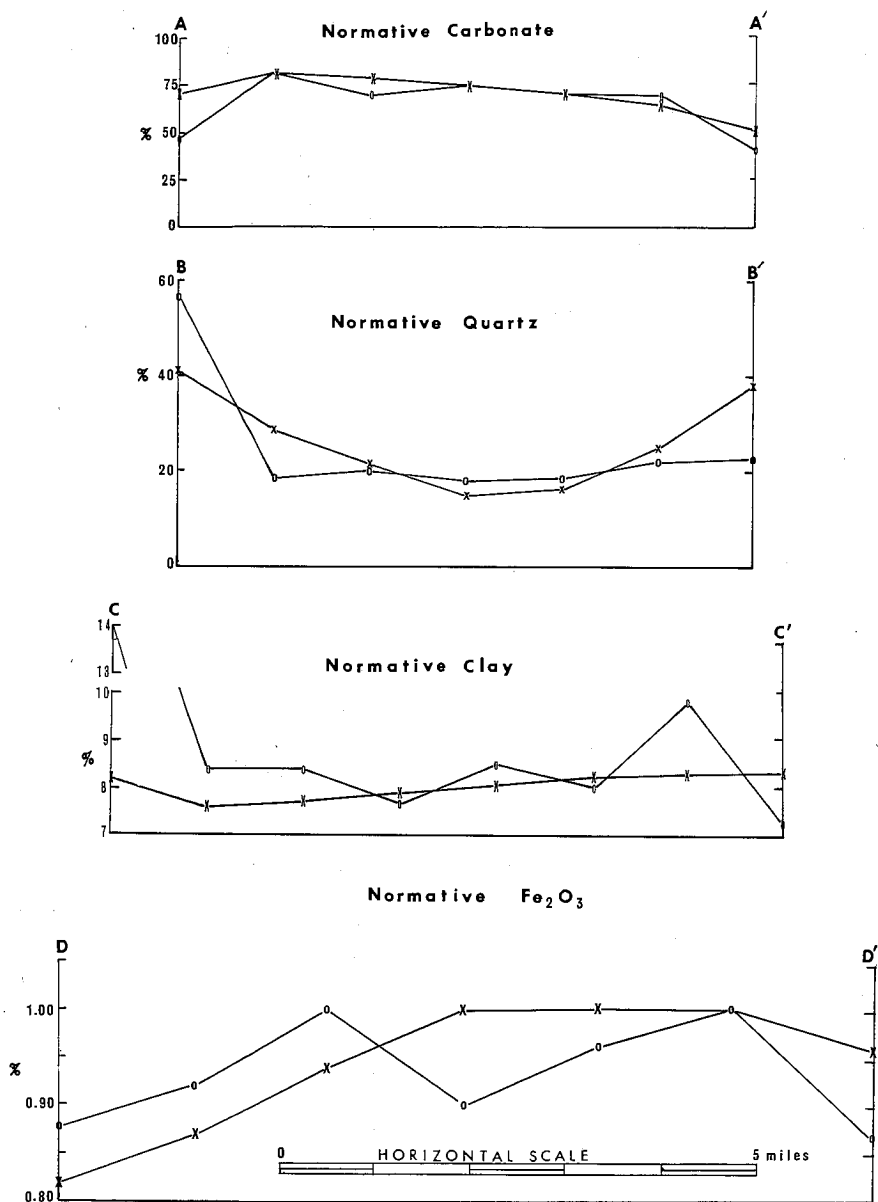
Total Normative Carbonate

Statistical data on total normative carbonate are given in Table 4. The mean value is 62 percent, and the standard deviation is 20 percent. The coefficient of correlation, 78 percent, refers to the correlation obtained by simple linear regression on the values of carbonate calculated from the trend surface and values actually observed. Such a coefficient is useful in measuring the degree to which the calculated surface corresponds to the observed data points. The coefficient of determination, 61 percent, is the coefficient of correlation squared.

Total carbonate in the bottom sediments of Utah Lake is illustrated by the contour map in Text-figure 5. The trend map indicates a high concentration of carbonate (70 to 80 percent of the total sediment) following a broad north-south line through the middle of the lake. With the exception of the northwest section, the highs are farthest from the sources of clastics and include the deepest portion of the lake, which is just northwest of the mouth of Spring Creek (see Text-fig. 2). The lowest concentrations are in the areas nearest the stream mouths (e.g., Provo River 30 to 35 percent, Hobbie Creek 35 percent, and Spanish Fork River 35 percent) and thereby indicate the influence of the clastics that dilute the carbonate.

The high concentration of carbonate (80 percent) in the northwest section may be caused by (1) mineralization by Saratoga Springs and subsequent eastward movement of the mineralized water before precipitation or (2) a bottle-neck effect, in which water moving toward the major exit and therefore into shallower areas experiences an accompanying rise in temperature and subsequent increased concentration of minerals through evaporation. Cross section A-A' in Text-figure 4 further illustrates the high in the northwest section of the lake and the smoothing effect of the trend-surface methods. Text-figure 2 illustrates the major sources of solid and dissolved material for the lake. There appears to be no evidence of streams building carbonate clastic deltas and no relation of lake depth to carbonate highs and lows, except that because the deepest portions of the lake are furthest from shore the clastics there comprise a lower percentage of the total sediment.

About two miles north of the mouth of Spring Creek is a small tufa cone called Bird Island, which appears to be related to inferred faulting (Stokes, 1962). Tufa also exists along the beach to the west of the mouth of Spring Creek but, being small in comparison with the rest of the map, fails to affect

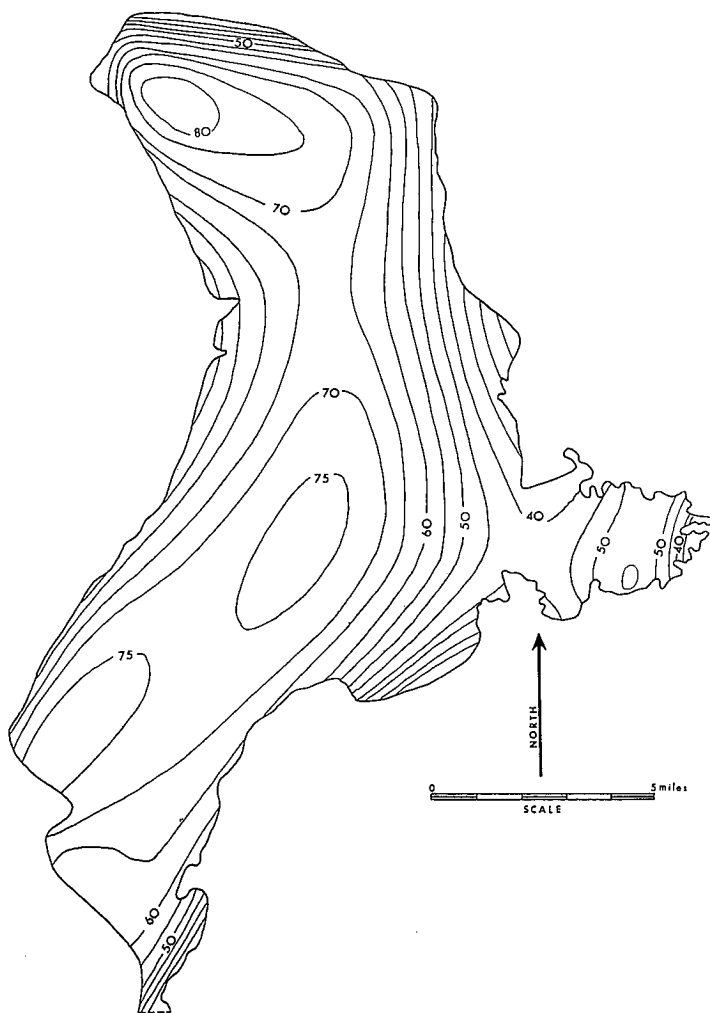


TEXT-FIGURE 4.—Cross sections as shown on Text-figure 3: (x) computer-fitted data, (o) raw data.

the overall trend. The highs in the southwest section of the lake are apparently due to the scarcity of clastic sediments explained by the absence of major streams (precluding the addition of clastics to any significant degree).

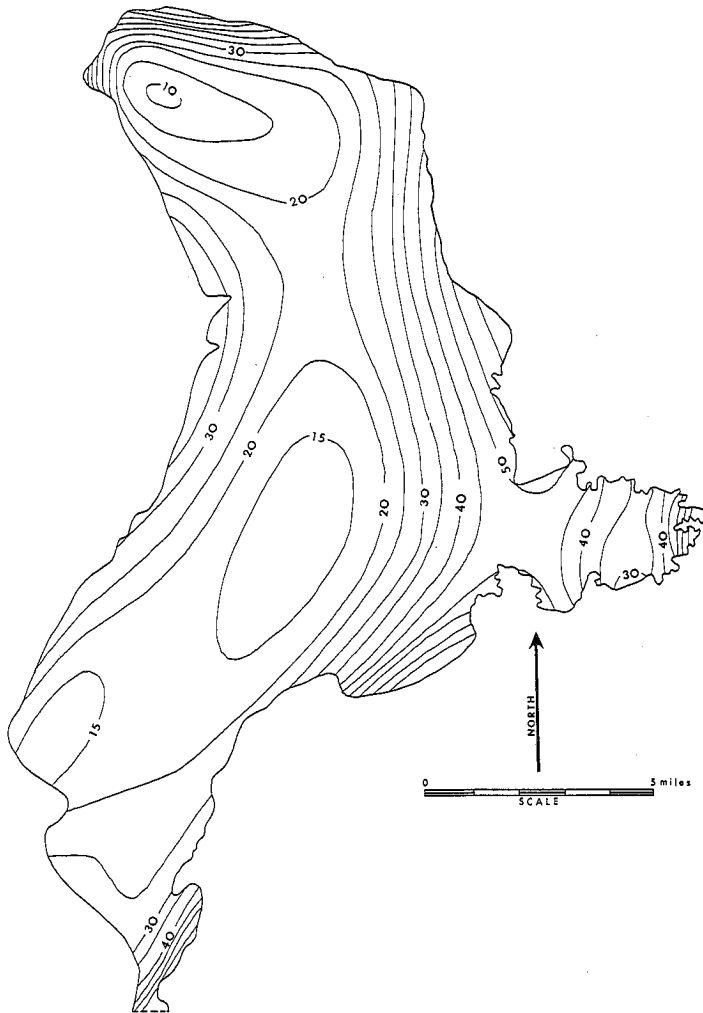
Total Normative Quartz

Statistical data for the normative quartz are as follows: the mean value is 27 percent; the standard deviation is 19 percent; the coefficient of correlation is 77 percent; and the coefficient of determination is 59 percent.



TEXT-FIGURE 5.—Normative carbonate, Utah Lake. Degree 6 trend surface; contour interval 5 percent.

Normative quartz in the bottom sediments of Utah Lake is illustrated by Text-figure 6. General trends indicate an inverse relationship with the carbonate because the sum of the quartz and carbonate at any location accounts for greater than 90 percent of the sediment. The trend map indicates a low concentration of quartz (10 to 20 percent) following a broad north-south line through the middle of the lake. The highs are nearest the mouths of streams entering the lake (e.g., Dry Creek 55 percent, American Fork River 30 percent, Provo River 55 percent, and Spanish Fork River 55 percent).



TEXT-FIGURE 6.—Normative quartz, Utah Lake. Degree 6 trend surface; contour interval 5 percent.

The prevailing winds from the north and southwest apparently set up longshore currents which work the quartz up and down the shores and wash out the small particles, including the carbonate, and produces higher quartz values along the north and west shores. Quartz from the Lake Mountains is carried into the lake by intermittent streams and has contributed much less material—as shown by the 35 percent high along the west shore—even though individual samples have shown very high quartz (up to 60 percent). The carbonate high in the northwest section masks the quartz supplied by the intermittent streams from the Lake Mountains, but Dry Creek and American Fork are far enough away from this area to reflect their contributions.

Because the greatest amount of quartz lies north, south, and west of the mouth of the river, it appears that Provo River is the major supplier of quartz on the lake. Cross section B-B' in Text-figure 4 illustrates the quartz high as it extends from the mouth of Provo River westward into the middle of the lake. The quartz high (60 percent), in the eastern bay on the lake, is quickly masked by the high in carbonate. The quartz low (25 percent), just west of Spring Creek, may be a reflection of the tufa that forms the beach and banks out from the shore. The lack of high quartz values along the west side of the West Mountain is probably due to high carbonate deposition.

Total Normative Clay

Statistical data for normative clay are as follows: the mean value is 7.5 percent, and the standard deviation is 2 percent; the coefficient of correlation is 58 percent, and the coefficient of determination is 33 percent.

Normative clay in the bottom sediments of Utah Lake is illustrated by Text-figure 7. The general trends indicate clay highs extending into the lake from the mouths of the streams and rivers (e.g., Dry Creek 9.5 percent, American Fork 9 percent, Provo River 8.5 percent, and Spanish Fork 8.5 percent). The few prominent clay lows appear to be reflections of carbonate highs (e.g., the northwest area 6.5 percent, the middle of the lake 7.5 percent, and the southwest area 6.5 percent).

The most prominent features of the clay deposition are lobes into the lake, such as the one extending southwest from Provo River about 4 miles. This lobe is further illustrated by cross section C-C' in Text-figure 4. Because the quartz does not form lobes as does the clay, it is suspected that particle size may be responsible. Either the clays are unaffected by wave action, or they are affected by a chemical change in the lake. Another possibility is that a chemical change from stream water to lake water causes a precipitation of the clay by destroying the effectiveness of the dispersing agent in the stream water.

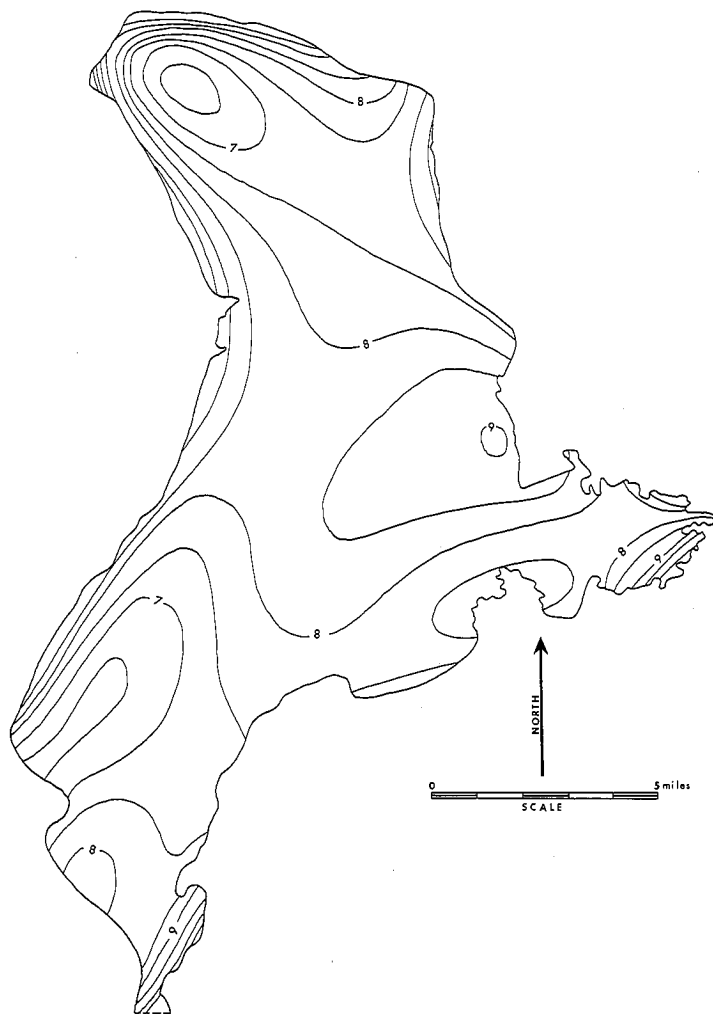
The area just west of West Mountain is peculiar in that either there is no clay entering the lake from West Mountain, or the amount is so small as to be completely overshadowed by the carbonate. Because clay is being brought into the lake from the West Mountain further to the south, the latter reason is favored.

A clay low 4 miles west of Spring Creek and another in the northwest (both 6.5 percent) correspond to carbonate highs and quartz lows. Both areas, which reach 8.5 percent near shore, are fed by intermittent streams, which probably explains the low so near shore.

Total Normative Hematite

Statistical data on total normative hematite are as follows: mean value 0.87 percent, standard deviation 0.23 percent, coefficient of correlation 49 percent, and coefficient of determination 24 percent.

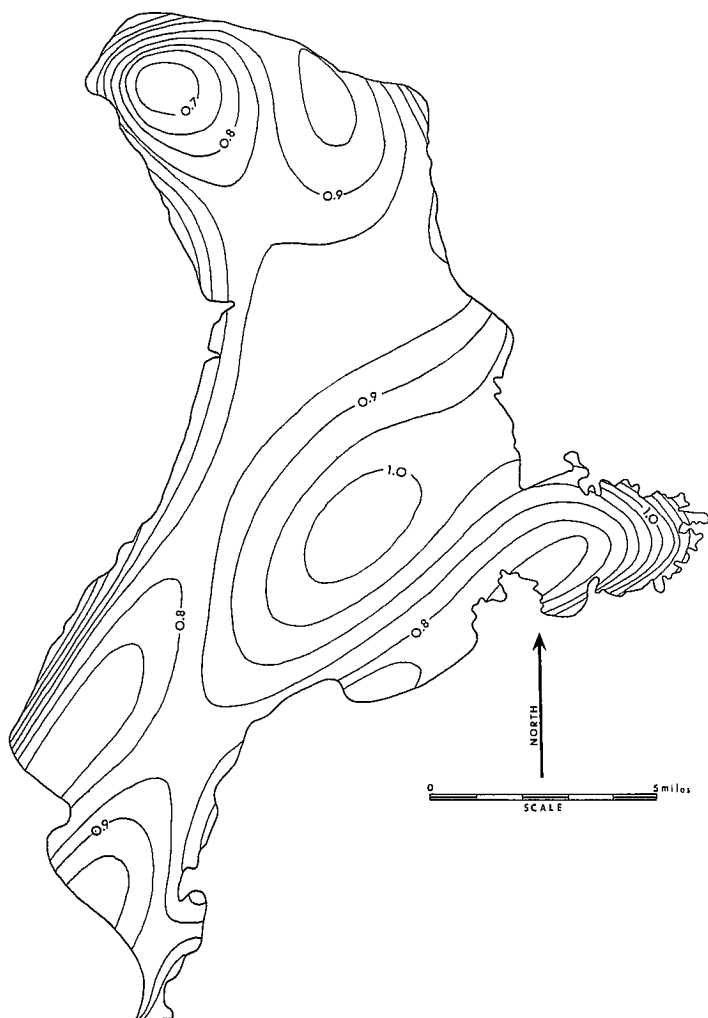
Total normative hematite as it occurs in the bottom sediments of Utah Lake is illustrated in Text-figure 8. The trend map indicates a hematite high of 0.85 percent running up the east side of the lake, with three peaks imposed on it: in the northeast, a 0.95 percent peak where American Fork River enters the lake; in the middle, a 1.0 percent peak 3 miles southwest of Provo River; and



TEXT-FIGURE 7.—Normative clay, Utah Lake. Degree 6 trend surface; contour interval 0.5 percent.

in the southwest, a 0.95 percent peak which corresponds to a quartz high and a carbonate low. The hematite high southeast of Provo River is further illustrated by cross section D-D' in Text-figure 4. Hematite lows existing in the northwest, southwest, and mideast correspond to carbonate highs and reflect dilution. No discernible hematite high was detected near the Geneva Steel plant on the east northeast side of the lake.

While the hematite lows are probably due to dilution by carbonate, the highs may be the result of dissolved iron in spring-fed water or clay-sized particles in stream water that precipitate when they reach the change in environment of



TEXT-FIGURE 8.—Normative hematite, Utah Lake. Degree 6 trend surface; contour interval 0.05 percent.

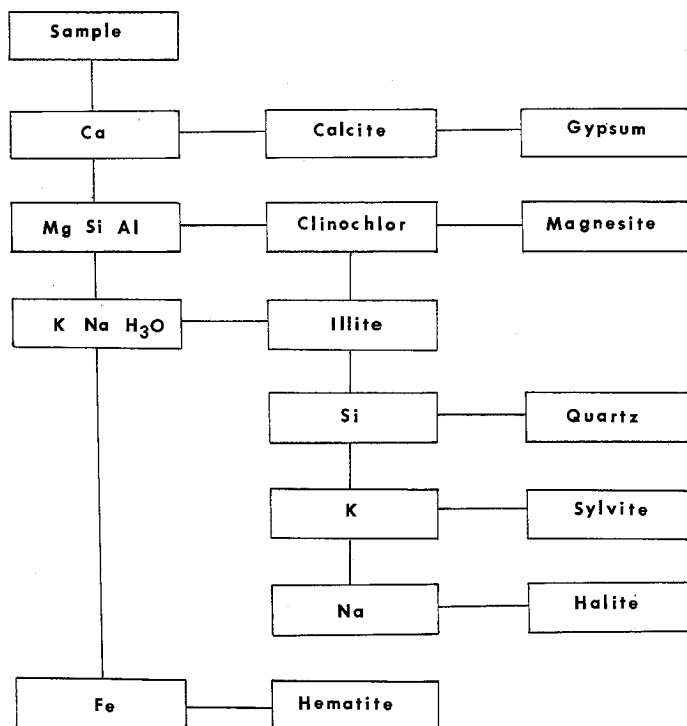
the lake water. There is also the possibility that the hematite high north of Bird Island is due, in part, to mineralized water from inferred faults in the vicinity (Text-fig. 2).

FUTURE WORK

Three areas on the lake that indicate the need for further, more detailed study are recognized. The most conspicuous area is in the northwestern section and appears high in carbonate and low in the other three minerals. This may be related to the Saratoga Mineral Springs; or, because the only outlet on the lake is at the Jordan River, the drawing of mineral-saturated water into the shallows at the north end of the lake may accelerate precipitation.

The high may be the result of detritus from the Lake Mountains, which are mostly limestone. A particle-size study would readily determine this, but if the high were caused by detritus from the Lake Mountains, the map percentages should show a tongue of carbonate extending from the shore to the present high.

The next major area of interest is in the southwestern section of the lake about five miles west of the mouth of Spring Creek and shows as a carbonate high. Because the topographic gradient is low (the nearest hills that drain into this area are several miles to the southwest, and this area is quite shallow), the chemical-precipitated calcite predominates. And, although there are no maps



TEXT-FIGURE 9.—Flow chart.

indicating springs in this area, it is possible that this is the groundwater-discharge area for the valley and mountains to the southwest.

The third most obvious area of interest is a high in clay and iron extending from Provo River to the southwest for several miles. The clay and iron form a lobe into the lake and apparently are not affected by the currents that keep the quartz concentrated along the shores.

The iron may be a result, not only of river sediment, but also of mineralized springs. If the iron in the river is in a fine fraction of the clastics, it may be precipitating as a result of a change in the temperature or pH. It may be that the iron is a result of iron-bearing mineral waters that are brought in by springs along the inferred structure and that cross the high. Examination of the data seems to indicate that both factors enter the picture: there is a trend of high to low from the river to the southwest, and there is a peak in the observed data southwest of Bird Island in an area of known mineral springs.

APPENDIX

Computer Program for Normative Minerals

```

FORTRAN SYSTEM -- VERSION 03/28/65 - CORRECTION LEVEL 03/28/65
C      DATA LINR/4H9999/
      DATA LINR(4H9999)
00001  4      READ(5,1) SPID1,SPID2,L,SI,AL,ANA,AK,AMG,CA,FE,X,Y
00002  1      FORMAT(2A4,1X,I1,7F10.2/10X,2F10.0)
00003          IF(L.EQ.9) GO TO 100
00004          X=4.70*X
00005          Y=4.70*Y
00006          WRITE(6,2) SPID1,SPID2,SI,AL,ANA,AK,AMG,CA,FE
00007  2      FORMAT(1H ,2A4,2X,$SPECIMEN IDENT$/
*          1H ,10X,F10.2,2X,$SILICONS/
*          1H ,10X,F10.2,2X,$ALUMINUMS/
*          1H ,10X,F10.2,2X,$SODIUMS/
*          1H ,10X,F10.2,2X,$POTASSIUMS/
*          1H ,10X,F10.2,2X,$MAGNESIUMS/
*          1H ,10X,F10.2,2X,$CALCIUMS/
*          1H ,10X,F10.2,2X,$IRONS/)
00008          CAGYPS=0.009*CA
00009          GYPS=4.30*CAGYPS
00010          WRITE(6,12) GYPS
00011  12      FORMAT(1H ,10X,F10.2,2X,$PERCENT GYPSUMS/)
00012          CA=CA-CAGYPS
00013          CALCIT=2.50*CA
00014          WRITE(6,3) CALCIT
00015  3      FORMAT(1H ,10X,F10.2,2X,$PERCENT CALCITE$/
00016          CARBMG=0.70*AMG
00017          AMGSTE=CARBMG*3.50
00018          WRITE(6,5) AMGSTE
00019  5      FORMAT(1H ,10X,F10.2,2X,$PERCENT MAGNESITE$/
00020          AMG=AMG-CARBMG
00021          CLCHLR=4.57*AMG
00022          SI=SI-0.15*CLCHLR
00023          AL=AL-0.097*CLCHLR
00024          WRITE(6,6) CLCHLR
00025  6      FORMAT(1H ,10X,F10.2,2X,$PERCENT CLINOCHLOR$/
00026          AILLTE=4.92*AL
00027          SI=SI-0.21*AILLTE
00028          AK=AK-0.098*AILLTE
00029          IF(AK.LT.0.) ANA=ANA+AK
00030          IF(AK.LT.0.0.AND.ANA.LT.0.0)H2O=-1.0*(AK+ANA)
00031          IF(AK.LT.0.0.AND.ANA.LT.0.0)WRITE(6,14)H2O
00032  14      FORMAT(1H ,10X,F10.2,2X,$PCT K+ AND NA+ REPLACED BY H3O+$/
00033          WRITE(6,7) AILLTE
00034  7      FORMAT(1H ,10X,F10.2,2X,$PERCENT ILLITE$/
00035          QUARTZ=SI*2.14
00036          IF(AK.LT.0.0)AK=0.0
00037          IF(ANA.LT.0.0)ANA=0.0
00038          AKCL=AK*1.90
00039          ANACL=2.54*ANA
00040          TOCLOR=AKCL+ANACL
00041          WRITE(6,18) TOCLOR
00042  18      FORMAT(1H ,10X,F10.2,2X,$PERCENT TOTAL CHLORIDES$/
00043          FE2O3=FE*1.43
00044          WRITE(6,8)QUARTZ,AKCL, ANACL,FE2O3

```



```

00045  8  FORMAT(1H ,10X,F10.2,2X,$PERCENT QUARTZ$/
*      1H ,10X,F10.2,2X,$PERCENT KCL$/
*      1H ,10X,F10.2,2X,$PERCENT NACL$/
*      1H ,10X,F10.2,2X,$PERCENT FE2O3$/
00046  TOCARB=CALCIT+AMGSTE
00047  WRITE(6,9) TOCARB
00048  9  FORMAT(1H ,10X,F10.2,2X,$TUTIAL CARBONATES$)
00049  TOILAY=CLCHLR+AILLTE
00050  WRITE(6,10) TOCLAY
00051  10  FORMAT(1H ,10X,F10.2,2X,$PERCENT TOTAL CLAYS$)
00052  TOMIN=CALCIT+AMGSTE+CLCHLR+AILLTE+AKCL+QUARTZ+ANACL+FE2O3+GYPS
00053  WRITE(6,11) TOMIN
00054  11  FORMAT(1H ,10X,F10.2,2X,$PERCENT TOTAL MINERALS$///)
00055  IF(TOMIN.GT.102.0.OR.TOMIN.LT.95.0) WRITE (6,13)
00056  13  FORMAT(1H , $TOTAL MINERALS OUTSIDE LIMITS. SAMPLE REJECTED$///)
00057  IF(TOMIN.GT.102.0.OR.TOMIN.LT.95.0) GO TO 99
00058  WRITE(7,15) SPID1,SPID2,Y,X,TOCARB
00059  WRITE(7,15) SPID1,SPID2,Y,X,TOCLAY
00060  WRITE(7,15) SPID1,SPID2,Y,X,FE2O3
00061  WRITE(7,15) SPID1,SPID2,Y,X,QUARTZ
00062  15  FORMAT(2A4,2X,3F10.2)
00063  WRITE(7,16)LINR
00064  16  FORMAT(A4)
00065  99  GO TO 4
00066  100 CALL EXIT
00067  END

```

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