The Holocene Ridgeland Formation And Associated Decker Soil (New Names) Near Great Salt Lake, Utah

GEOLOGICAL SURVEY BULLETIN 1457-C

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By RICHARD VAN HORN

CONTRIBUTIONS TO STRATIGRAPHY

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Two new units of Holocene age that are associated with ancient Lake Bonneville are named and described

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ILLUSTRATIONS

METRIC-ENGLISH EQUIVALENTS

[SI, International System of Units, a modernized metric system of measurement]

SI unit		U.S. customary equivalent	
Length			
millimeter (mm)	=	0.039 37	inch (in)
meter (m)	=	3.281	feet (ft)
	=	1.094	yards (yd)
kilometer (km)	=	0.621 4	mile (mi)
	=	0.540 0	mile, nautical (nmi)
Area			
centimeter^2 (cm^2)	=	0.155 0	inch^2 (in^2)
meter^2 (m^2)	=	10.76	feet^2 (ft^2)
	=	1.196	yards^2 (yd^2)
	=	0.000 247 1	acre
hectometer^2 (hm^2)	=	2.471	acres
	=	0.003 861	section (640 acres or 1 mi^2)
kilometer^2 (km^2)	=	0.386 1	mile^2 (mi^2)
Volume			
centimeter^3 (cm^3)	=	0.061 02	inch^3 (in^3)
decimeter^3 (dm^3)	=	61.02	inches^3 (in^3)
	=	2.113	pints (pt)
	=	1.057	quarts (qt)
	=	0.264 2	gallon (gal)
	=	0.035 31	foot^3 (ft^3)
meter^3 (m^3)	=	35.31	feet^3 (ft^3)
	=	1.308	yards^3 (yd^3)
	=	264.2	gallons (gal)
	=	6.290	barrels (bbl) (petroleum, 1 bbl=42 gal)
	=	0.000 810 7	acre-foot (acre-ft)
hectometer^3 (hm^3)	=	810.7	acre-feet (acre-ft)
kilometer^3 (km^3)	=	0.239 9	mile^3 (mi^3)
Volume per unit time (includes flow)			
decimeter^3 per second (dm^3/s)	=	0.035 31	foot^3 per second (ft^3/s)
	=	2.119	feet^3 per minute (ft^3/min)

SI unit		U.S. customary equivalent	
Volume per unit time (includes flow)—Continued			
decimeter^3 per second (dm^3/s)	=	15.85	gallons per minute (gal/min)
	=	543.4	barrels per day (bbl/d) (petroleum, 1 bbl=42 gal)
meter^3 per second (m^3/s)	=	35.31	feet^3 per second (ft^3/s)
	=	15 850	gallons per minute (gal/min)
Mass			
gram (g)	=	0.035 27	ounce avoirdupois (oz avdp)
kilogram (kg)	=	2.205	pounds avoirdupois (lb avdp)
megagram (Mg)	=	1.102	tons, short (2 000 lb)
	=	0.984 2	ton, long (2 240 lb)
Mass per unit volume (includes density)			
kilogram per meter^3 (kg/m^3)	=	0.062 43	pound per foot^3 (lb/ft^3)
Pressure			
kilopascal (kPa)	=	0.145 0	pound-force per inch^2 (lbf/in^2)
	=	0.009 869	atmosphere, standard (atm)
	=	0.01	bar
	=	0.296 1	inch of mercury at 60°F (in Hg)
Temperature			
temp kelvin (K)	=	[temp deg Fahrenheit (°F) +459.67]/1.8	
temp deg Celsius (°C)	=	[temp deg Fahrenheit (°F) −32]/1.8	

THE HOLOCENE RIDGELAND FORMATION AND ASSOCIATED DECKER SOIL (NEW NAMES) NEAR GREAT SALT LAKE, UTAH

By Richard Van Horn

ABSTRACT

The lacustrine Ridgeland Formation (new name) was deposited during a low stage of Lake Bonneville in northwest Utah and was graded to the Gilbert shoreline. The Gilbert shoreline is about 15 m higher than the level of Great Salt Lake in 1977. The Decker Soil (new name) formed on the Ridgeland Formation and older formations and soils exposed at that time. The Ridgeland probably was deposited during the Holocene in early Neoglacial time. The lake cycle that produced this formation and soil indicates climatic changes that may be pertinent to understanding the modern changes in Great Salt Lake.

INTRODUCTION

The Ridgeland Formation and Decker Soil, of Holocene age, are herein named. The Ridgeland Formation named for the Ridgeland Canal is of lacustrine origin and is in the upper part of the Lake Bonneville Group (Gilbert, 1875, p. 89; Hunt and others, 1953, p. 17) and at present is only known to exist in the vicinity of Great Salt Lake, Utah. (See fig. 1.) The Decker Soil is named for Decker Creek that begins near the type locality and flows into Decker Lake located approximately 2 km southeast of the former Utah Central Airport. It is typically formed on the Ridgeland Formation but is much more widespread than the Ridgeland because it also formed on all exposed older soils and formations. The reason for naming these thin units is to ease communication in describing the late history of Lake Bonneville and the early history of its successor, the Great Salt Lake.

Lake Bonneville was a large lake of late Pleistocene and Holocene age that occupied much of northwestern Utah. It has a very complicated history that includes several cycles that resulted in three prominent and

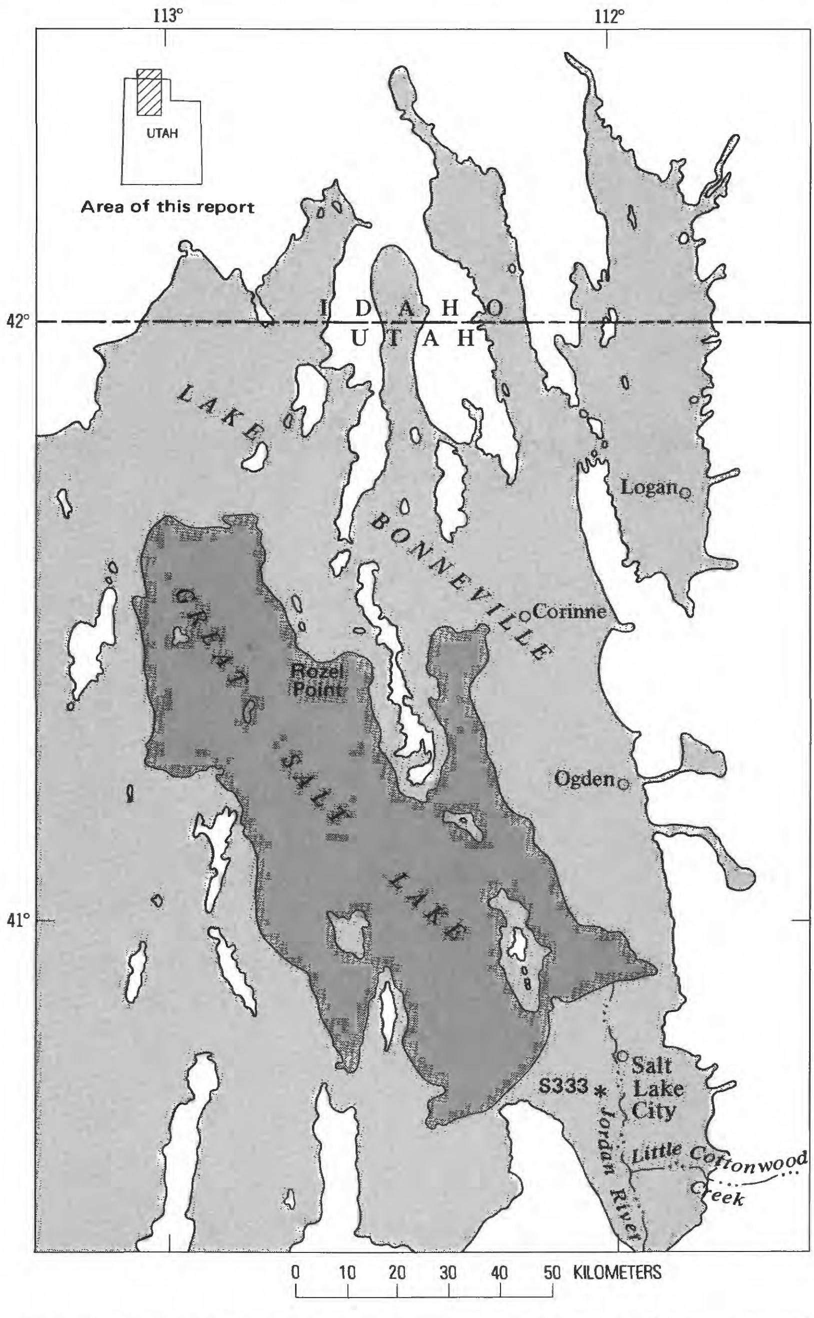

FIGURE 1.—Great Salt Lake (dark stipple) and vicinity, showing localities mentioned in the text. Heavy line is Bonneville (highest) shoreline of Lake Bonneville (light stipple). Star shows location of measured type section (S333) of the Ridgeland Formation and of the Decker Soil.

well-marked shorelines—the Bonneville, Provo, and Stansbury shorelines. The Bonneville shoreline marks the highest level attained by the lake, and in the Salt Lake City area it is about 1,579 m (5,180 ft) above sea level. When the lake stood at this level it was about 310 m deep. A much less prominently developed shoreline that is about 1,292 m (4,240 ft) above sea level in the Salt Lake City area is called the Gilbert shoreline (Eardley and others, 1957, p. 1161).

DEFINITION AND DESCRIPTION

The Ridgeland Formation is a lake deposit that formed in late Holocene time after the development of the Midvale Soil. The Ridgeland was deposited during a cycle of Lake Bonneville that started when the lake was at an unknown altitude lower than 1,292 m (4,240 ft), continued as the lake rose to the altitude where the Gilbert shoreline was formed, and then fell to some unknown level. The deposits are principally silt and fine-grained sand, but may contain clay, oolites, brine shrimp fecal pellets, ostracods, gastropods, brachiopods, and Foraminifera. The known deposits of the Ridgeland formed as bay bars, offshore bars, and lake-bottom deposits.

The Decker Soil is an immature soil that has developed since Lake Bonneville stood at the Gilbert shoreline. The Decker Soil formed on the Ridgeland Formation as the water of Lake Bonneville slowly evaporated and retreated from the Gilbert shoreline.

RIDGELAND FORMATION

The Ridgeland Formation is light-gray to dark-brown silt or clay that is 15–190 cm thick. At the type section the deposit is silt that probably was deposited by east-trending lake currents in a relatively narrow zone near the shore. East and south of the type section are several southeast-trending deposits of silt and sandy silt as much as 700 m long and 50 m wide. These appear to be offshore bars. Farther north, on the delta of the Jordan River, the Ridgeland Formation is principally clay and was deposited in relatively still water. On the north side of Great Salt Lake several offshore and bay bars of Ridgeland Formation are composed of sandy silt that locally is pebbly.

At several places the Ridgeland overlies the Midvale Soil. At these places the Midvale Soil is from 10 to 45 cm thick, which is thinner than most exposures of Midvale Soil exposed at the surface.

DECKER SOIL

The Decker Soil ranges from dark gray to light gray in color and from silt to clay in grain size. It is similar in composition to the underlying

Ridgeland Formation. The soil is generally 5–20 cm thick, but locally it may be as much as 30 cm thick.

The Decker Soil is an immature soil and consists of an A horizon enriched in organic material that gives it a color darker than the underlying parent material. There does not appear to be any significant downward dislocation of clay or calcium carbonate from the A horizon into the underlying parent material.

The recognized extent of the Decker Soil has the same distribution as the Ridgeland Formation. The Decker Soil has been recognized below the Gilbert shoreline in the Salt Lake City area and also in the desert north of the Great Salt Lake. It is thinner in the desert area than in the Salt Lake City area. The thickest development seen is in deposits on the Jordan River delta 5 km northwest of Salt Lake City.

The Decker Soil has been recognized only where formed on the Ridgeland Formation, but presumably it also formed on other deposits and soils that were exposed at the land surface after Lake Bonneville started retreating below the Gilbert shoreline for the last time. The only place a deposit is known to overlie the Decker Soil is 20 km northwest of Corinne adjacent to Utah Highway 83. Here, a natural levee of Salt Creek overlies the Decker.

TYPE SECTION

The type section of the Ridgeland Formation and of the Decker Soil is exposed in the west bank of the Ridgeland Canal in the SW¼SE¼ sec. 20, T. 1 S., R. 1 W., Salt Lake Meridian in the Salt Lake City South, Utah 7.5-minute quadrangle of the U.S. Geological Survey. (See figs. 1 and 2 and measured section S333.) The section lies between the Ridgeland Canal and Vespa Drive at Salt Lake City coordinate 3440 West, 2575 South. The outcrop is best approached from the east by way of the south runway of the former Utah Central Airport. Figure 2*A* shows the outcrop as viewed from this approach.

SECTION S333.—*Type Ridgeland Formation and Decker Soil and underlying units*

[Measured in the west bank of the Ridgeland Canal in the SW¼SE¼ sec. 20, T. 1 S., R. 1 W. ML, CL, and SM are letter symbols of Unified Soil Classification (U.S. Bur. Reclamation, 1960, p. 379–400]

	Thickness in centimeters
9. Artificial fill and spoil from canal. Medium-gray silt-size fragments of clay. Unconformable contact with underlying unit 8	0–90
8. Soil A horizon of the Decker Soil formed on Ridgeland Formation. Dark-gray, massive, calcareous, tastes slightly salty, silt (ML). Locally contains long cylindrical, partly cemented worm(?) casts. Grades into underlying unit 7	18
Total, Decker Soil	18

SECTION S333.—*Type Ridgeland Formation and Decker Soil and underlying units*—Continued

	Thickness in centimeters
7. Ridgeland Formation. Medium-gray, massive, calcareous, tastes slightly salty, silt (ML). Contains small gastropods, ostracods, brine shrimp(?) pellets, nonmarine mollusks, and, according to P.B. Smith of the U.S. Geol. Survey (written commun. Aug. 2, 1971), Foraminifera. Undulating, sharp, unconformable contact with underlying unit 6	51
Total, Ridgeland Formation	51
6. Midvale Soil. Very dark gray, very calcareous, does not taste salty, slightly sandy silt (ML). Contains a few animal burrows. Gradational contact with underlying unit 5	33
Total, Midvale Soil	33
5. Draper Formation. Very light gray, very calcareous, tastes salty, silty clay (CL). Upper part has platey structure. This unit may be a Cca soil horizon (zone of calcium carbonate accumulation). Grades into underlying unit 4	59
4. Draper Formation. Medium-gray, calcareous, no salty taste, clay (CL). Contains some small round openings like root holes. Grades into underlying unit 3	33
3. Draper Formation. Light-brown with medium-gray mottles, calcareous, no salty taste, clay (CL). Contains a few 0.1-cm-thick and 13-cm-long lenses of very fine grained sand. Has sharp even contact with underlying unit 2	59
2. Draper Formation. Light-gray, calcareous, uniform grain size, silty, very fine grained sand (ML-SM). Contains gastropods, ostracods, and sparse mica. Has sharp even contact with underlying unit 1	3
1. Draper Formation. Medium-gray, calcareous, no salty taste, silty clay (CL). Contains a few 0.1-cm-thick very fine grained sand lenses. Base not exposed	60
Total, Draper Formation	214

Samples from units 8, 7, 6, and 1 were examined by R.M. Forester of the U.S. Geological Survey (written commun. June 14, 1977) who recognized the following organisms, mostly ostracodes.

Unit 8 contained (abundance not given):

Candona rawsoni Tressler, 1957.
Cyprinotus glaucus? Furtos, 1933.
Eucypris serrata (Muller, 1900).
Candona caudata Kaufmann, 1900.
Cyclocypris ampla Furtos, 1933.
Limnocythere illinoisensis Sharpe, 1897.
Foraminifera(?).

Unit 7 contained:

Ilyocypris biplicata (Koch, 1838)	Abundant.
Ilyocypris gibba (Ramdohr, 1808)	Rare.
Limnocythere illinoisensis Sharpe, 1897	Rare.
Cytherissa lacustris? (Sars, 1863)	Rare.
Cyprinotus glaucus? Furtos, 1933	Rare.
Candona rawsoni Tressler, 1957	Common.

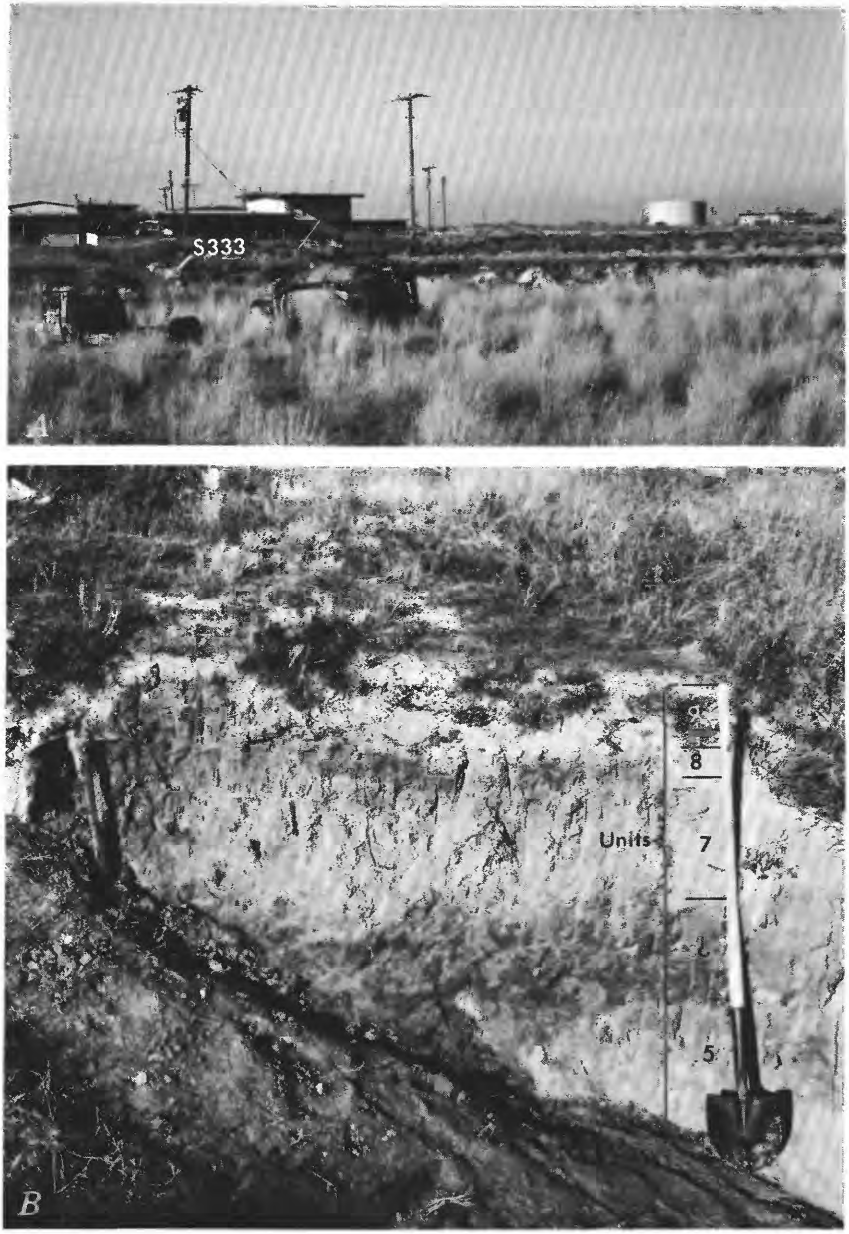

FIGURE 2.—Location of measured type section (S333) of the Ridgeland Formation and of the Decker Soil in a cut perpendicular to the bank of the Ridgeland Canal. *A*, The cut is visible between the truck body and the concrete mixer. View is to the west from the former Utah Central Airport. *B*, From the top down are artificial fill (unit 9), Decker Soil (unit 8), Ridgeland Formation (unit 7), Midvale Soil (unit 6), and Draper Formation (unit 5). The shovel is 150 cm long. View is to the north.

Unit 7.—Continued.

Candona adunca Lister, 1975 .... Rare.
Potamocypris? sp .... Rare.
Cypridopsis vidua (Muller, 1776) .... Rare.
Eucypris serrata (Muller, 1900) .... Rare.
Physocypris pustulosa Sharpe, 1897 .... Rare.
Cyclocypris ampla Furtos, 1933 .... Rare.
Cyprideis sp. (Juv) .... Rare.
Chara sp. (charophyte) .... Rare.
Foraminifera(?).

Unit 6 contained:

Candona rawsoni Tressler, 1957 .... Abundant.
Ilyocypris biplicata (Koch, 1838) .... Rare.

Unit 1 contained:

Limnocythere illinoisensis Sharpe, 1897 ...... Abundant.
Candona caudata Kaufmann, 1900 .... Common.
Candona adunca Lister, 1975 .... Rare.
Candona sp. (Juv) .... Rare

Forester stated:

The above assemblages of ostracodes occur throught much of the Quaternary. The exact ranges of the majority of these species have not been determined with any real confidence due to a general lack of study. The approximate 2,000-year date associated with the Ridgeland Formation (represented by these samples) is supported but not confirmed by these ostracode species.

The depositional environment suggested by these assemblages is one ranging from a fresh water to slightly saline lake. The vast majority of the ostracodes noted above are fresh water species, but all can tolerate slight salinities—many are known from salinities up to 5 parts per thousand. *Cyprideis* sp. which occurs in unit 7 is both an estuarine and hypersaline species. These specimens are noded, however, which is typical for very low salinity conditions. The presence of several species of *Candona* in the various samples suggests that the temperature was as low as 0 to 5 degrees Celsius during part of the year. The occurrence of *Cyclocypris* and *Physocypris* and to a lesser extent *Cypridopsis* suggests a very shallow depositional environment—probably no more than 2 to 3 meters of water. The *Chara* sp. would support a pH of 7 or more and fairly hard water. The occurrence of so-called foraminifera is not confirmed beyond a reasonable doubt. There are a number of agglutinated tubes present in both samples U7 and U8, which could be thecamoebians or basically fresh water foraminifera. These tubes could also be casings surrounding certain types of insect larvae. If they are foraminifera they do not support a high salinity for this environment.

J. P. Bradbury of the U.S. Geological Survey (written commun., Sept. 19, 1977) recognized the following organisms.

Samples S–333 U–1, U–6, and U–8 were barren of diatoms.

Sample S–333 U–7 was assigned USGS paleobotany locality number D5755. This sample contains a sparse diatom flora. Most specimens are fragmented. The following species were identified.

Amphora ovalis v. *lybica*
Amphora ovalis v. *pediculus*
Biddulphia laevis
Cocconeis pediculus
Cymbella triangulum?
Diploneis smithii
Epithemia argus
E. adnata
Fragilaria construens
Fragilaria construens v. *venter*
Gomphonema sp.
Gyrosigma sp.
Hantzschia amphioxys
Navicula cincta?
Navicula mutica
Navicula mutica v. *cohnii*
Nitzschia amphibia
Pinnularia borealis
Synedra ulna

Plant phytoliths, chrysophycean cysts and sponge spicules are also present.

The most common diatom fragments are those of *Biddulphia laevis*. This diatom commonly lives attached to the substrate in slightly saline rivers, lakes, and estuaries, although it can tolerate salinities approaching that of sea water. It is present in the Cache La Poudre and St. Vrain Rivers in Colorado and in several rivers in the Great Plains States of Wyoming, Kansas, Missouri, Nebraska, and Oklahoma. The specific conductance of the Colorado and Missouri localities is generally between 700 and 1800 micro mhos per cm. (a salinity about $\frac{1}{25}$ of seawater). In addition I have seen the species in large lakes such as Lake Valencia, Venezuela which has conductivity values between 1700 and 1800. Frequently the water in which this species lives has a high organic content and is turbid. Many of the other species found in this sample are tolerant or prefer water with some dissolved solids, and it is possible that they lived in association with *Biddulphia laevis*.

However, the common presence of specimens of *Hantzschia amphioxys, Pinnularia borealis* and of *Navicula mutica* and its variety *cohnii* suggests that the sample is a mixed diatom assemblage. These are common soil diatoms, which can live in moist subaerial habitats, although they are not unknown from alkaline lakes and rivers. In general these specimens are unfragmented, and it is probable that they lived in subaerial habitats not too far removed from the site of deposition. I suspect that the *Biddulphia laevis* fragments may be reworked from higher deposits surrounding Great Salt Lake when the lake was brackish, but neither highly saline as it is today nor fresh as it must have been when it produced the Bonneville and Provo shorelines.

In general, diatom samples from the shoreline terraces are difficult to interpret because the sediment can contain diatoms reworked from higher lacustrine deposits. In addition, samples from sediments derived largely from soils or subjected to soil-forming processes frequently contain some potentially non-lacustrine diatoms that could complicate paleolimnological interpretation. In the case of S–333 U–7, there is no guarantee that any of the diatoms encountered lived at the time the terrace of the Ridgeland Formation was formed. Nevertheless, it is encouraging that they are preserved and if proper lacustrine sediments are found, diatoms will very likely provide a detailed paleolimnological history for Great Salt Lake.

GEOLOGIC HISTORY

Lake Bonneville has undergone numerous advances and retreats in response to climatic changes during the latter part of the Pleistocene. There were several major high lake levels with intervening periods of desiccation to near dryness from 1,000,000 to 30,000 years ago, when the Alpine Formation was deposited. During the succeeding 20,000 years, the lake refilled and the Bonneville Formation was deposited—the lake advanced to its high level twice; then the lake retreated to some unknown low level between these advances. After the second advance to the high level, the lake overflowed and rapidly eroded an outlet channel more than 100 m deep. The lake then desiccated and retreated to some unknown level. This was followed by filling almost to the level of the outlet channel and the Draper Formation was deposited. Three moderately deep lake cycles are recorded by the Draper Formation in the succeeding 5,000 years.

The presence of the Ridgeland Formation and the succeeding Decker Soil implies still more climatic changes. Lake Bonneville must have desiccated to some unknown but low level following deposition of the Draper Formation. The Midvale Soil developed on the Draper during and after the lake retreat to that low level. In response to a subsequent climatic change, the lake rose to the level at which the Gilbert shoreline then formed. During this rise, which climaxed at a standstill at the Gilbert shoreline, and the following period of desiccation when the lake again fell, the Ridgeland Formation was deposited. As the lake receded from the Gilbert shoreline, the Decker Soil began to form on the Ridgeland and on all other formations and soils exposed at the land surface. Where the Decker Soil developed on virgin parent material it formed a weak immature soil. Where it developed on an older soil, such as the Midvale, it increased the degree of development of the older soil. This sequence of events fits the climatic theory of Eardley, Gvosdetsky, and Marsell (1957, p. 1189).

AGE

The precise age of the Ridgeland Formation is not known. It is post-Midvale Soil (altithermal) and therefore is younger than 4,000 years. The high levels of older stages of Lake Bonneville just south of Salt Lake City have coincided with the maximum glacial advances at Little Cottonwood Canyon (Morrison, 1965, p. 53). It is likely that the same is true for the younger stages of Lake Bonneville. If so, the Ridgeland correlates with one of the advances of the Neoglaciation which started about 4,000 years ago and continued to about 1850 A.D.

Several workers in the Rocky Mountains indicate that there were three glacial advances during the post 4,000 B.P. (before present) period which are now assigned to the Neoglacial. The lake rise represented by the Ridgeland may correlate with the earliest of these, which has been dated from as much as 4,500 B.P. to about 2,500 B.P. (Miller, 1973).

The rate of isostatic rebound of the land surface, after Lake Bonneville started drying up, gives a possible clue to the age of the Ridgeland Formation. The Ridgeland does not occur above the Gilbert shoreline. The Gilbert shoreline has been warped by isostatic rebound of the Bonneville basin which resulted from the loss of tremendous amounts of water from Lake Bonneville since the last time it occupied its high shore, the Bonneville shoreline (Gilbert, 1890). According to Crittenden (1967, fig. 4B), the Bonneville shoreline in the center of the lake began rising at a nearly constant rate 18,000 years ago. As he states, this is a simplification of a very complex sequence of events because of the different rates of retreat and because of several lake cycles that occurred during the past 18,000 years. The actual rebound is probably based on an exponential decay, which is not decipherable from the available information.

The following simplified calculations indicate that the Gilbert shoreline, and presumably the Ridgeland Formation, was formed during the early part of the Neoglacial. The Gilbert shoreline in the Salt Lake City area is at 1,292 m (4,240 ft) above sea level. At Rozel Point, 100 km northwest of Salt Lake City, the Gilbert is at 1,296 m (4,253 ft) or about 4 m higher. The difference is probably caused by isostatic uplift of the central part of the Bonneville basin since the Gilbert shoreline was formed. According to Crittenden (1963, fig. 3; 1967, fig. 2), the Bonneville shoreline has risen to 1,579 m (5,180 ft) altitude in the Salt Lake City area and to 1,603 m (5,260 ft) altitude in the vicinity of Rozel Point since the Bonneville shoreline was last occupied, about 18,000 years ago. This indicates that the Bonneville shoreline has rebounded 24 m higher in the vicinity of Rozel Point than it did near Salt Lake City. If the 24 m of differential elevation of the Bonneville shoreline can be assumed to have taken place at a constant rate over the entire 18,000 years, the rate of rebound between the two localities is 24÷18,000 or 0.0013 m/yr. If this rate is applied to the differential elevation of the Gilbert shoreline at these two localities it would indicate that the Gilbert was formed about 4÷0.0013 or 3,000 years ago. Similar calculations using the Provo shoreline a s a base indicate that the Gilbert shoreline was formed about 1,700 years ago.

CLIMATIC AND ENVIRONMENTAL IMPLICATIONS

Each rise of Lake Bonneville to a different shoreline may be interpreted to mean a wetter, colder, or cloudier environment, which would provide more water to the lake either by increased precipitation, less evaporation, or a combination of both. Each falling of the lake could represent a return to the reverse of the above.

A better understanding of the late history of Lake Bonneville and the early history of Great Salt Lake is needed if we are to try to predict the rise and fall of Great Salt Lake, which may have serious economic consequences on the human population and land use in the vicinity of the lake.

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