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LAKE BONNEVILLE STRATIGRAPHY AT THE OLD RIVER BED, UTAH

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ABSTRACT. Stratigraphic studies at the Old River Bed, Utah, show that the yellow clay of Gilbert (1890, U.S. Geol. Survey Mon. 1) is a fine-clastic, deltaic, or underflow fan facies and that the white marl is an open-water chemical lacustrine facies deposited in shallow to deep water. At the Old River Bed, the yellow clay was deposited early in the transgressive phase of the last major deep-lake cycle in the Bonneville basin, referred to as Lake Bonneville. The white marl was deposited in Lake Bonneville during the long ensuing period of deep-water stages mostly higher than the Stansbury Shoreline. Regressive-phase deposits overlie the white marl. Two disconformities, one within the yellow clay and one between the yellow clay and the white marl, were caused by two fluctuations in lake level, which together comprise the Stansbury oscillation having a maximum total amplitude of about 60 m. The Stansbury Shoreline was formed during the Stansbury oscillation. At low altitudes in the Old River Bed area the yellow clay and white marl are conformable, and the contact between them is gradational.

A facies interpretation of the Bonneville beds at Gilbert's type locality allows for a simpler reconstruction of lake history than has been proposed in the past for the exposures in this area. The yellow clay and the white marl are separate facies of the Bonneville Alloformation and represent the changing depositional environments in a small area during different phases of a single major lacustrine cycle, the Bonneville Episode.

INTRODUCTION

The Old River Bed was recognized by Gilbert (1890, p. 181-184) as an abandoned river channel carved in fine-grained deposits of Lake Bonneville by discharge flowing northward from the Sevier Desert into the Great Salt Lake Desert (fig. 1) late in the regressive phase of the lake. The Sevier Desert basin is separated from the Great Salt Lake basin by a low divide, referred to in this paper as the Old River Bed threshold (fig. 1). Gilbert (1890) described the exposures in the Bonneville beds at the Old River Bed and established a type section here. In his (1890, p. 189-190) words:

> The deepest section of the lake beds, or more strictly the section representing the largest fraction of the Bonneville Period, is exposed in the walls of the Old River Bed near the point where it is crossed by the Overland Stage-road. It has some title to be regarded as the typical section . . .

Gilbert (1890, p. 189) referred to the type section as the "Lower River Bed" section. Stratigraphic descriptions at two other localities supplemented Gilbert's observations at the type section. One of these was along the Old River Bed and was referred to as the "Upper River Bed" section

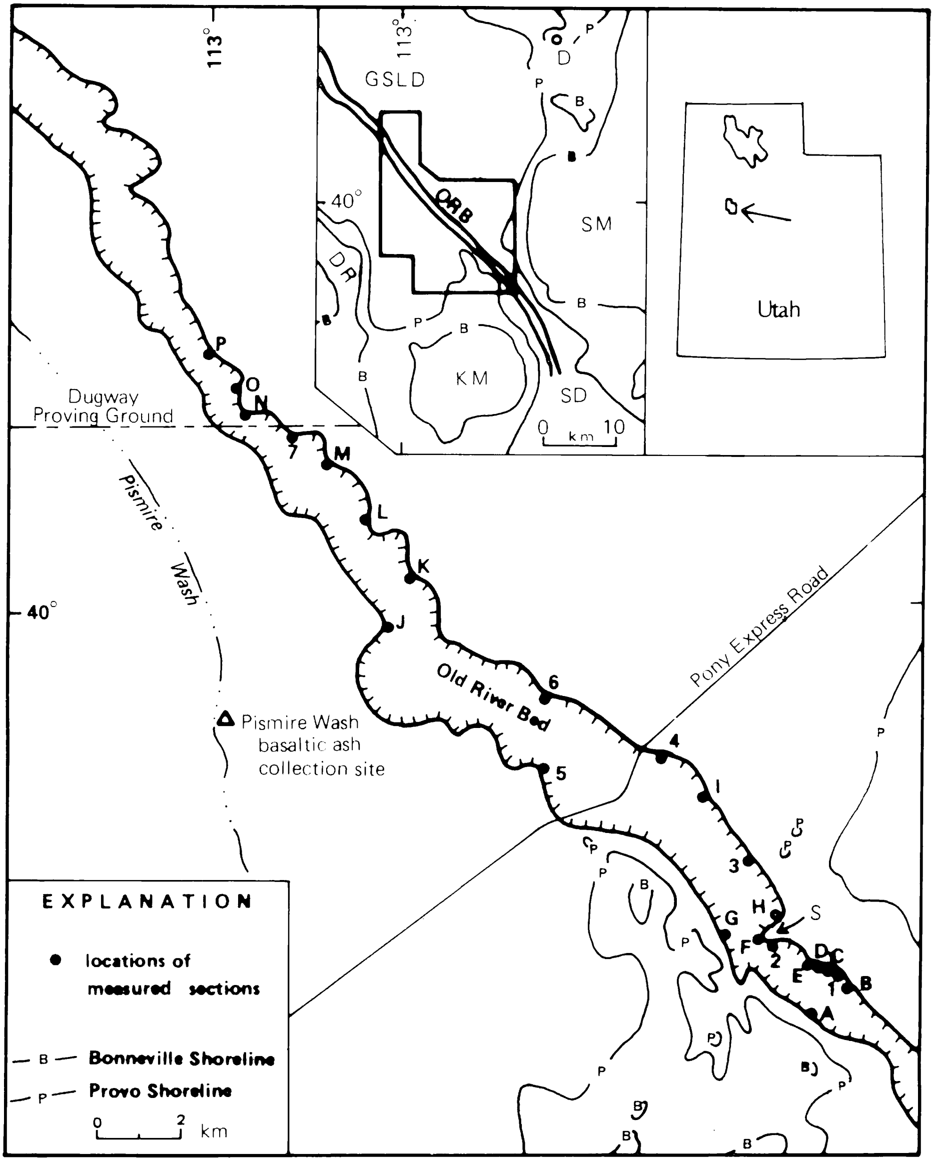

Fig. 1. Location of Old River Bed and of measured sections along the margins of the Old River Bed channel. D = Dugway, DR = Dugway Range, GSLD = Great Salt Lake Desert, KM = Keg Mountain, ORB = Old River Bed, S = The Shutoff, SD = Sevier Desert, SM = Simpson Mountains. The Old River Bed threshold is at the southern end of the Old River Bed channel.

(Gilbert, 1890, p. 196). "It is connected by continuous outcrop with the Lower River Bed, where the type section of the lake sediments is exhibited; but there is no such connection with Lemington, forty miles away" (Gilbert, 1890, p. 196). The third section, at Leamington, Utah, will be discussed in a separate publication.

Gilbert (1890, p. 190) defined two stratigraphic units in the Old River Bed area, the yellow clay and the white marl, each of which he thought represented deep-water deposition, and which he suggested were separated by a major unconformity. The two-component Bonneville stratigraphic model established by Gilbert was expanded and refined by many subsequent workers. Hunt, Varnes, and Thomas (1953) defined the Alpine and Bonneville Formations, which formed the nomenclatural basis for much of the later stratigraphic work in the Bonneville basin, including the efforts of Eardley, Gvosdetsky, and Marsell (1957), Bissell (1963), and Morrison (1965, 1966). Varnes and Van Horn (1961) correlated the yellow clay and white marl at the Old River Bed with the Alpine and Bonneville Formations, respectively.

Although Morrison (1975) suggested that the Alpine Formation was deposited prior to the last interglaciation, the concept that the Wisconsin through early Holocene history of Lake Bonneville involved two or more major cycles was the dominant viewpoint until at least the late 1970s. More recent work shows that the early to middle Wisconsin (formerly "Alpine") lake in the Bonneville basin rose no higher than 1340 m in altitude (Scott and others, 1983; Oviatt, McCoy, and Reider, in press), and that there was only one major lacustrine cycle during the last 30,000 yrs (Currey, Oviatt, and Plyler, 1983; Scott and others, 1983; Spencer and others, 1984).

In this paper the term Lake Bonneville refers only to the last deep-lake cycle, which lasted from about 32,000 to 10,000 yr B.P. (Scott and others, 1983; Currey and Oviatt, 1985). Deposits of older lake cycles (Morrison, 1966; Eardley and others, 1973; Scott and others, 1983; Oviatt, McCoy, and Reider, in press) are not the subject of this paper. Although the presence of pre-Bonneville deposits in the Old River Bed area has been mentioned briefly in the literature (Morrison, 1966, p. 84), the locations and descriptions of the exposures have not been published. The area has also been studied in varying detail by others (Ives, 1951; Varnes and Van Horn, 1961; McCoy, ms).

Gilbert's Lower River Bed section was located somewhere near my section 6 (fig. 1), and Varnes and Van Horn (1961) also described a section at this locality. Gilbert's Upper River Bed section was located at what is now called the Shutoff (fig. 1). Detailed descriptions of the numbered stratigraphic sections in figure 1 are given in Oviatt (ms).

This paper documents evidence that at Gilbert's type locality of the Bonneville beds the yellow clay was deposited in shallow water during the same major lacustrine cycle as the white marl. By viewing the yellow clay and the white marl as distinct facies representing the changing physical, chemical, and biologic environment of a lake that fluctuated in a closed basin for most of its history, it is unnecessary to call for major changes in lake level to explain every lithologic change in the stratigraphic record. In addition, the utility of allostratigraphic classification (North American Commission on Stratigraphic Nomenclature, 1983, p. 865-867) is illustrated at the Old River Bed. Under the new stratigraphic code, the yellow clay and the white marl are best considered to be facies of the Bonneville Alloformation as defined by Currey, Oviatt, and Czarnomski (1984). These units should eventually be formally defined as allomembers of the Bonneville Alloformation.

YELLOW CLAY

Description.—At the base of the Lake Bonneville deposits at the Old River Bed, the yellow clay consists of massive, to finely bedded to laminated silt, silty clay, and interbedded clayey and silty fine sand. Individual beds in the yellow clay are flat-lying and laterally continuous for tens of meters. The unit generally increases in sand content to the south suggesting that the sand source was in this direction. It ranges in total thickness from 0 to over 15 m. A pebbly sand fluvial channel-fill unit, which was previously recognized by Varnes and Van Horn (1961), separates the yellow clay into lower and upper parts (fig. 2). In the area south of the Pony Express-Overland Stage-road each yellow-clay unit is generally an upward-fining sequence characterized by sandy fluvial beds at the base, which grade upward into fine-grained marsh deposits and fine-grained lacustrine deposits. Cross-bedding and climbing ripples in some sand beds indicate currents flowing toward the north.

The lower yellow clay overlies bedrock, colluvial slopes, and alluvial fans. At section G (figs. 2 and 3) the lower yellow clay overlies and interfingers with locally derived coarse alluvium. No transgressive beach deposits have been observed at the base of the lower yellow clay. Bedding in its lower part is horizontal, or has a maximum initial dip of 5° adjacent to steep slopes, and the bedding abuts against the underlying bedrock hills or slopes (fig. 3).

Ostracodes from the lower and upper yellow clay are forms typical of marsh/pond and marginal lacustrine environments and indicate fresh Ca^{2+}–(Mg^{2+})–SO_4^{2+}–HCO_3^-–dominated water (R. M. Forester, 1983 and 1986, written commun.). Impressions of leaves, stems, and roots, probably of *Ruppia maritima*, a marsh plant (B. J. Albee, 1983, written commun.), are present in both the lower and upper yellow clay. Molluscs are common in some beds, particularly those interpreted as marsh deposits.

At low altitudes (fig. 2, secs. N, O, and P) the lower yellow clay is conformable and vertically gradational with the white marl over an interval of about 1 m. At higher altitudes, however, two disconformities are evident — one within and one at the top of the yellow clay (Varnes and Van Horn, 1961; Oviatt, ms). The lower disconformity is marked by fluvial channel entrenchment, as at sec. 6, or by slight oxidation and root tubules at the top of the lower yellow clay, as at sec. 5 (fig. 2). The upper disconformity is locally marked by oxidation and root tubules and every-

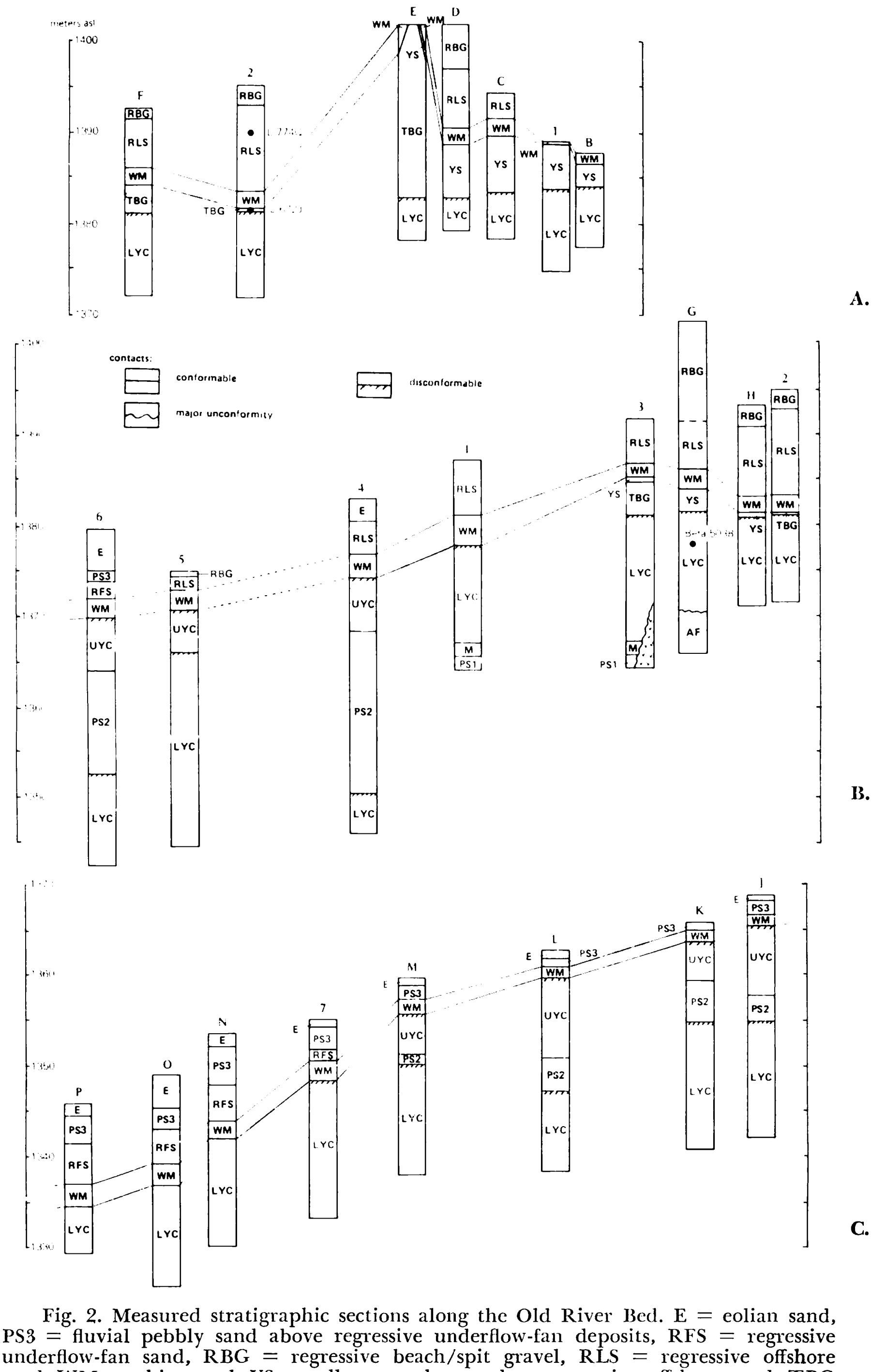

Fig. 2. Measured stratigraphic sections along the Old River Bed. E = eolian sand, PS3 = fluvial pebbly sand above regressive underflow-fan deposits, RFS = regressive underflow-fan sand, RBG = regressive beach/spit gravel, RLS = regressive offshore sand, WM = white marl, YS = yellow, poorly sorted, transgressive offshore sand, TBG = transgressive beach/spit gravel, UYC = upper yellow clay, PS2 = fluvial pebbly sand of channel fill within yellow clay, LYC = lower yellow clay, M = marsh sediments, PS1 = fluvial pebbly sand at base of lower yellow clay, AF = alluvial-fan gravels, V = Tertiary volcanic bedrock. Horizontal scale approximate.

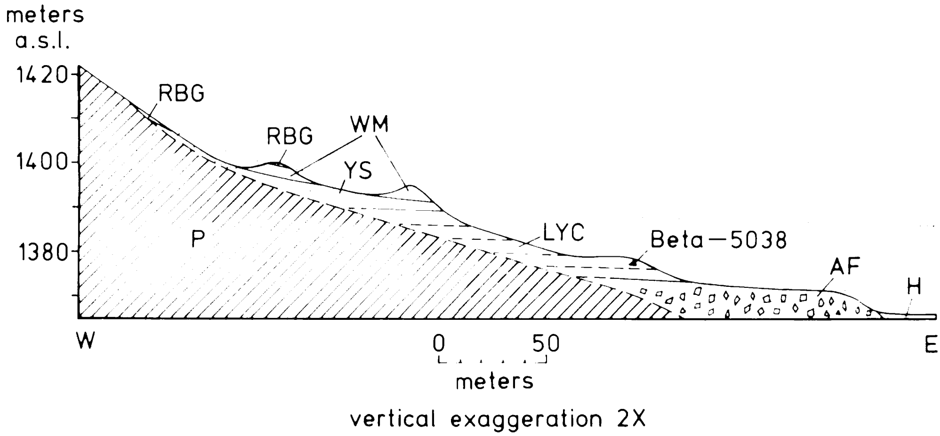

Fig. 3. Measured topographic profile and stratigraphic section at sec. G on the west side of the Old River Bed. H = Holocene alluvial fill, RBG = regressive beach/spit gravel, WM = white marl, YS = yellow, poorly sorted, transgressive offshore sand, LYC = lower yellow clay, AF = alluvial fan gravels, P = Paleozoic carbonate bedrock.

where is indicated by either a thin bed of well-sorted sand or well-sorted and rounded, locally derived gravel interpreted as beach deposits. South of the Pony Express road (fig. 1) the sand at this contact contains abundant gastropod shells (*Amnicola*). At sec. A (fig. 1) large algal tufa heads up to 1 m in diameter at the top of the lower yellow clay mark the disconformity and are overlain by the layer of gastropod-rich beach sand.

Interpretation.—All these stratigraphic, sedimentologic, and paleontologic characteristics suggest deposition of both the lower and upper yellow clay in shallow water. None of my observations and none of the observations of previous workers (Gilbert, 1890; Ives, 1951; Varnes and Van Horn, 1961) suggest deposition in deep water, and therefore I reject that hypothesis.

The available evidence suggests that the yellow clay was deposited in a shallow, fresh water, clastic depositional environment best characterized as deltaic. The massive to laminated silts and interbedded sands are similar to those of the underflow fans that formed in Lake Agassiz (Fenton and others, 1983), and I have adopted that term here (fig. 2). Silt- and sand-laden density currents that deposited the yellow clay were derived from a river flowing northward from the Sevier Desert basin into the shallow lake in the Old River Bed area early in the transgressive phase of Lake Bonneville.

Fresh-appearing, articulated *Sphaerium* shells from the lower yellow clay (fig. 2, sec. G) yielded a radiocarbon date of 23,190 ± 1360 yr BP (Beta-5038). This must be regarded as a minimum age because of the possibility of contamination by "young" carbon. However, the date is accepted here for two reasons. First, amino-acid analyses on *Sphaerium* shells from the same locality support the interpretation that the yellow clay was deposited during the last major lacustrine cycle (W. D. McCoy, 1984, written commun.). The average ratio of alloisoleucine to isoleucine (aIle/Ile) in the total hydrolysate of the *Sphaerium* shells is 0.076 ± 0.005 (AGL 189). *Sphaerium* amino-acid ratios are consistently similar to *Lymnaea* ratios in shells from deposits of the same age, indicating that the genus *Sphaerium* is useful in aminostratigraphy (W. D. McCoy, 1984 and 1986, personal commun.; Oviatt, McCoy, and Reider, in press). The average aIle/Ile ratio for *Lymnaea* from the Bonneville Alloformation is 0.11 ± 0.03 (McCoy, ms). Therefore, the amino-acid analysis on *Sphaerium* from the yellow clay indicates that the yellow clay dates from the last, Bonneville, lake cycle.

The second reason for accepting Beta-5038 is that when plotted on a time-altitude diagram, the date falls in an expected and reasonable position relative to other radiocarbon dates from Lake Bonneville deposits, including wood dates (Currey and Oviatt, 1985). Considering these lines of reasoning, the cautionary statement, that radiocarbon dates on shell must be considered to be minimum dates, is an insufficient reason to reject Beta-5038. The physical stratigraphic, radiometric, and amino acid data all converge on one conclusion: that the lower and upper yellow clay and the white marl were deposited during a single major lacustrine cycle.

STANSBURY OSCILLATION

The entrenched channel within the yellow clay and the associated disconformities are interpreted as evidence for two lake-level fluctuations having a maximum total amplitude of 45 to 60 m between approx 22,500 and 21,500 yr BP (Oviatt, ms; Currey and Oviatt, 1985). Based on the mapped extent of the disconformities (fig. 2; Oviatt, ms), the altitudinal limits of the two fluctuations at the Old River Bed are as follows. During the first transgression, the lake rose to an altitude slightly higher than 1385 m but no higher than the Old River Bed threshold at about 1400 m. If it had transgressed higher than the Old River Bed threshold, the supply of fine-clastic sediment carried by river currents from the Sevier Desert would have been cut off, and an open-water marl facies would have been deposited in the Old River Bed area. There is no evidence that this happened.

During the first regression the lake dropped to an altitude between 1340 and 1345 m. This is shown by the disconformity between the lower yellow clay and the white marl at sec. 7 and the conformable and gradational contact between the two units in secs. N, O, and P (fig. 2).

The second transgression reached a minimum altitude between 1375 and 1385 m, based on the upper limit of exposures of upper yellow clay and a maximum of about 1400 m. It did not exceed the Old River Bed threshold.

The second regression dropped the lake again to an altitude between 1340 and 1345 m. The lowest traceable limit of fluvial entrenchment during the two regressions is between 1345 and 1350 m. If the lake had regressed to a level at or below the floor of the Great Salt Lake desert, which has a modern altitude of about 1310 m, a channel comparable to the modern Old River Bed channel would have been cut, and there would be a disconformity between the lower yellow clay and the white marl at all altitudes above 1310 m.

During the final transgression through the Old River Bed area, the lake exceeded the Old River Bed threshold, began to deposit marl over the yellow clay, and continued transgressing toward the Bonneville Shoreline (Currey and Oviatt, 1985).

The two fluctuations in lake level were climatically controlled and comprise the Stansbury oscillation (Currey, Oviatt, and Plyler, 1983; Oviatt, ms), during which the Stansbury Shoreline was formed elsewhere in the basin. On the north end of Camels Back Ridge, 8 km north of sec. P (fig. 1), the Stansbury Shoreline occurs as a zone of tufa-cemented gravel on hillslopes between altitudes of 1350 to 1360 m. This is a typical expression of the Stansbury Shoreline in the Bonneville basin. The altitude of the Stansbury Shoreline in this area corresponds well with the lower limits of the disconformities in the Old River Bed sections.

In my interpretation, the tufa-cemented gravel at the Stansbury Shoreline was deposited in the shore zone when the lake became concentrated in $CaCO_3$ during the two fluctuations in lake level. This interpretation is consistent with the work of Spencer and others (1984, p. 331), who detected geochemical evidence in cores of Lake Bonneville sediments for stillstands or fluctuations, during which the lake water became concentrated, and aragonite and Mg-calcite were precipitated (their unit III d). During periods of rising water level, calcite was the dominant carbonate precipitate (Spencer and others, 1984). The ostracodes from unit III d sediments suggest that the lake became concentrated at about the level of the Stansbury Shoreline during the transgressive phase of the lake (Spencer and others, 1984, p. 331).

Other support for the Stansbury oscillation hypothesis comes from Stansbury Island in the Great Salt Lake (Currey, Oviatt, and Plyler, 1983, p. 66-69). On Stansbury Island a wedge of Stansbury shore gravel thins and grades downslope into two thin sand beds separated by about 10 cm of sandy marl. The wedge of gravel and the two sand beds are underlain by over 1 m of marl and overlain by a similar thickness of marl. This section suggests that three relatively deep water phases, during which marl was deposited, were separated by two relatively shallow-water phases, during which gravel and sand were deposited at this site. The middle deep-water phase was short relative to the other two.

Gastropods collected from the downslope end of the gravel wedge yielded a radiocarbon date of 20,710 ± 310 yr BP (Currey, Oviatt, and Plyler, 1983). Thus, the physical stratigraphic evidence at this site, that the Stansbury Shoreline formed during the transgressive phase of Lake Bonneville, is supported by the radiometric evidence. Furthermore, the data from Stansbury Island are consistent with the stratigraphic, geomorphic, and radiometric data from the Old River Bed and other areas.

Therefore, the following conclusions can be drawn. (1) The Stansbury Shoreline was formed during the transgressive phase of Lake Bonneville between about 22,500 and 21,500 yr BP (Currey and Oviatt, 1985). (2) The Stansbury Shoreline formed as the result of two fluctuations in lake level having a maximum total amplitude of 60 m. (3) During the fluctuations, the lake water became concentrated, thus resulting in a change in the geochemical record in the bottom sediments (Spencer and others, 1984) and in the precipitation of large volumes of tufa in the shore zone. (4) The yellow clay at the Old River Bed is in part the Stansbury-age delta of the major river draining the Sevier Desert.

WHITE MARL

Description.—The white marl consists of chemically precipitated clay- and silt-sized grains of calcium carbonate with varying amounts of detrital material. It is typically very finely but crudely bedded, and individual beds or subunits can be traced laterally for kilometers. Detrital sand is more common in the southern sections where slopes are steeper and shorelines were nearby even during high stages.

The white marl blankets underlying topography, which includes the flat upper surface of the yellow clay underflow fan, gravel spits and beach ridges, and colluvial or bedrock slopes (fig. 3). Initial dips range from 0° to 32°.

Ostracodes in the white marl indicate open-lake, shallow- to deep-water environments (R. M. Forester, 1983, written commun.). Other fossils include whitefish scales and trout bones (G. R. Smith, 1984, written commun.), carbonate plant-stem encrustations, and gastropods. Dropstones, presumably derived from slabs of shore ice melting in open water, are common.

The white marl is overlain by shallow-water sands or gravels, or by underflow-fan deposits similar to the yellow clay. Deposits overlying the white marl generally comprise an upward-coarsening sequence indicating regression and are locally overlain by eolian sand (fig. 2).

Radiocarbon dates of 19,800 ± 400 yr BP (L-672J) and 11,900 ± 300 yr BP (L-774Q; Broecker and Kaufman, 1965) bracket the white marl at the Old River Bed (sec. 2, fig. 2). Although these dates must be regarded as minimum ages, they are not unreasonable compared with basin-wide syntheses of the Bonneville Alloformation (Scott and others, 1983; Spencer and others, 1984; Currey and Oviatt, 1985) and suggest about 8000 yrs of marl deposition in the Old River Bed area.

A thin layer of very fine basaltic ash found in unit c of the white marl (fig. 4) in exposures along Pismire Wash (fig. 1) is probably the same ash found in many white marl sections in the Sevier Desert (Varnes and Van Horn, 1961, 1984; Broecker and Kaufman, 1965; Oviatt, ms). Minimum limiting radiocarbon dates on gastropods and ostracodes associated with the ash average about 15,300 yr BP (Currey and Oviatt, 1985). The ash was probably erupted from Pavant Butte in the Sevier Desert (Currey, 1982; Oviatt, ms). Despite the suggestion by Varnes and Van Horn (1984) that there are two basaltic ashes commonly exposed in the Sevier Desert, there is convincing evidence for only one (Oviatt, ms; Oviatt, unpub. data).

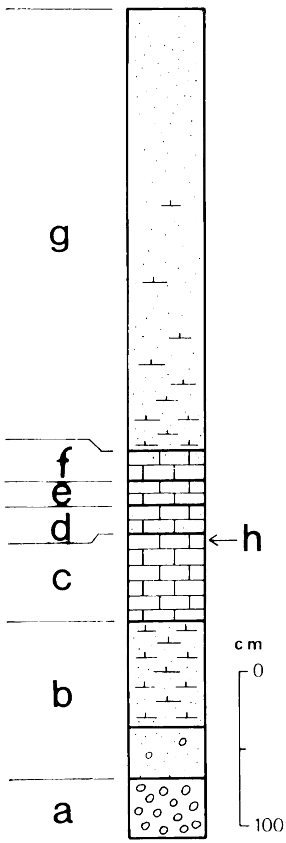

Fig. 4. Measured stratigraphic section of the white marl at sec. 3. a = transgressive beach gravels, b = transgressive offshore sand and sandy marl, c = deep-water marl, d = marker bed related to Bonneville Flood, e = Provo stage marl, f = regressive marl, g = regressive shallow-water sand, h = inferred position of Pavant Butte basaltic ash, which is not seen in this section. Measured about 0.3 km east of a partly exhumed bedrock knoll in a vertical exposure at the head of a gully.

In a typical section of white marl seven distinct lithologic units can be recognized and are lettered a-g in figure 4. Well sorted sand or gravel at the base (unit a) is overlain by unit b, which consists of poorly sorted yellow sand that locally grades up into marly sand or sandy marl. Bedding in unit b is massive in the lower part but is better defined in the upper part where it is flat-bedded to cross-bedded. The poorly sorted yellow sand of this unit varys in thickness in the Shutoff area from 0 to about 6 m and is indicated in figure 2 by YS. It directly overlies beach gravel, or in localities that are unfavorable for beach development, it overlies bedrock or other deposits. It dips parallel to the underlying slope and is conformable with unit C. Gastropods of the genus *Amnicola* are common.

In unit C the marl is generally denser than below and is grayer, although thin layers of pure white marl are locally interbedded with the gray marl. Ostracodes are abundant and large in this unit, and gastropods are absent. The bedding is fine to laminated, but individual beds or laminae have indistinct or diffuse boundaries. Unit C is about 60 cm thick.

Unit d is a widespread marker bed at the Old River Bed. It consists of laminated, relatively sandy marl containing calcium carbonate-coated ostracodes, which are interpreted as reworked. The laminae in unit d are well preserved in contrast to those in unit C. Unit d is 45 cm thick at sec. C but decreases in thickness northward and is not present north of sec. 6. The contact between units c and d is sharp and even and can be identified from a distance even on weathered outcrops. At most localities unit d is stained yellow or orange by iron oxide which probably was deposited by ground water flowing through the slightly more permeable layer.

The upper contact of unit d is gradational with unit e, which consists of relatively dense gray marl with abundant ostracodes. There is slightly more detrital sand in unit e than in unit c, but they are otherwise similar in lithology and in bedding and therefore were probably deposited in similar environments. In exposures north of sec. 6, units c and e merge and are indistinguishable.

Unit f is gradational with unit e but is distinguishable because of a marked increase in detrital sand and pebbles and by the presence of gastropods and carbonate-coated ostracodes. Small tufa heads (less than 10 cm in diam) occur at the upper contact.

Unit g overlies unit f with a sharp contact and is composed of marly sand containing gastropods and gastropod fragments, carbonate-coated ostracodes, and fragments of carbonate-encrusted plant stems. The sand is horizontally bedded to ripple-laminated.

Interpretation.—My interpretation of the white marl sequence illustrated in figure 4 is as follows. Unit a consists of beach and spit deposits. It can be traced to the south from sec. 3 into gravel comprising a well developed spit at the Shutoff. Gilbert (1890, p. 194-195) interpreted this gravel as a thick alluvial deposit, but most of the descriptive characteristics he lists and that I have observed are better interpreted as having a lacustrine origin.

Unit b represents deposition in a shallow offshore environment during the transgressive phase of the lake. The yellow sand facies is found in isolated exposures at altitudes almost as high as the Bonneville Shoreline in the Old River Bed area. Because of their similarity in color and texture, Gilbert (1890, p. 190-191) may have interpreted this facies as the yellow clay in localities distant from the Old River Bed. However, with close inspection, the yellow clay and the yellow sand are seen to be distinctly different facies.

The yellow sand is best interpreted as an offshore deposit of fine-grained sediment winnowed from the coarser debris by waves higher on the slopes. The thickest section of the yellow sand is preserved in the Shutoff area (fig. 2, secs. 1,B,C, and D) where southward-moving longshore currents carried a plume of turbid water beyond the distal end of the large gravel spit (fig. 2, TBG, sec. E).

Unit c (fig. 4) represents deposition in the deepest water while the lake was transgressing to levels higher than the Stansbury Shoreline, and during the development of the Bonneville Shoreline (about 1590 m), but prior to the Bonneville Flood. The thickness of unit c is consistent with the findings of Spencer and others (1984), who showed that the entire Bonneville cycle is represented by about 1.5 m of sediment in undisturbed cores from the bottom of Great Salt Lake. Sedimentation rates were slow, on the order of 10 cm per 1000 yrs, during unit c time. The indistinct laminations in unit c are probably related to bioturbation by benthic organisms during the slow deposition of the marl.

I interpret unit d as representing the down-current redeposition of lake-bottom deposits that had been scoured from the Old River Bed threshold area during the Bonneville Flood. See Gilbert (1890), Malde (1968), and Currey (1982) for descriptions of the Bonneville Flood. During the flood, which probably lasted less than 1 yr, water discharged through the outlet in southern Idaho at as much as 1.1×10^6 m^3/s (Malde, 1985, p. 31). Differential drawdown between the various arms of Lake Bonneville induced by the flood must have produced rapid currents in connecting passes, similar to currents in Lake Missoula (Pardee, 1942) created by catastrophic lowering of lake level. Evidence of scour and deposition of gravel bars at intra-basin passes by flood-generated currents has been noted elsewhere in the Bonneville basin (Oviatt, 1986). Unit d at the Old River Bed apparently overlies the Pavant Butte basaltic ash, which predates the development of the Provo Shoreline (Oviatt, ms).

Unit e represents deposition during the long period of overflowing lake conditions during the development of the Provo Shoreline (about 1470 m in this area). The Provo stage may have lasted for as long as 1000 yrs (Currey and Oviatt, 1985), and lake bottom environments were restabilized after the disruption caused by the Bonneville Flood.

Unit f represents deposition during the relatively rapid regression from the Provo Shoreline to the level of the Old River Bed threshold. During this period the strait between the Simpson Mountains and Keg Mountain (fig. 1) would have decreased progressively in width and depth, and the detrital input to the bottom of the strait from wave activity higher on the slopes would have increased.

Unit g represents the deposition in shallow water of reworked Bonneville lacustrine sediments from the Old River Bed threshold area. Erosion by fluvial currents began at the threshold as soon as Lake Bonneville regressed below that level (about 1400 m). Thus, the contact between units f and g marks a sharp change in depositional environment at sec. 3 that was controlled by the shape of the lake basin 20 km to the south. A sharp facies change would be recorded in this stratigraphic interval at this and nearby sites regardless of the rate of regression of the lake.

I interpret the white marl as a whole as the open-water lacustrine facies of the Bonneville Alloformation. It occurs in various forms throughout the Bonneville basin at altitudes ranging from below 1310 m to close to the Bonneville Shoreline. At the Old River Bed it was deposited on the lake bottom during a long period including the time of development of the transgressive "Intermediate shore-lines" of Gilbert (1890), the Bonneville Shoreline, and the Provo Shoreline.

CONCLUSIONS AND DISCUSSION

The following conclusions can be drawn from the interpretations presented here:

1. Neither the lower nor the upper yellow clay units at the Old River Bed were deposited during a separate, much older deep-lake cycle, as has been previously suggested (Gilbert, 1890; Varnes and Van Horn, 1961), but are shallow-water, fine-clastic, transgressive facies of the Bonneville Alloformation. It is not surprising, therefore, that Gilbert (1890, p. 200-209) was unable to formulate a compelling explanation for the difference in lithologic character between the yellow clay and white marl if, as he supposed, they were both deposited on the bottoms of deep lakes. Deposits of older deep-lake cycles are preserved elsewhere in the Bonneville basin, but most of the exposures are in modern gravel pits and were unavailable to Gilbert. None of the older (pre-Bonneville) lacustrine deposits, which in most places are separated from the Bonneville Alloformation by a strongly developed buried soil, is correlative with any of the exposed stratigraphic units I have observed at the Old River Bed.

2. Allostratigraphic classification is preferred over lithostratigraphic classification of Lake Bonneville deposits. Deposits having a gross lithologic character identical to the yellow clay are found throughout the Bonneville basin, and some have been mapped as the Alpine Formation. But lithologic similarity alone is an insufficient basis for stratigraphic correlation because depositional environments and resulting lithofacies were recurring phenomena, both temporally and spatially. Allostratigraphic classification was formulated specifically for use in situations where lithostratigraphic classification is inappropriate and where elements of geologic history are to be emphasized (North American Commission on Stratigraphic Nomenclature, 1983, p. 849, 865-867). The Bonneville Alloformation (Currey, Oviatt, and Czarnomski, 1984) is composed of many diverse lithofacies in the Old River Bed area, including the yellow clay, the white marl, beach gravel and sand, marsh deposits, fluvial sand and gravel, and offshore sand. All these were deposited during the Bonneville Episode (Currey, Oviatt, and Czarnomski, 1984; North American Commission on Stratigraphic Nomenclature, 1983, p. 870-871) and collectively represent the diverse and changing depositional environments in Lake Bonneville as it transgressed and regressed through the Old River Bed area.

3. There is no stratigraphic evidence in the Old River Bed area for a lacustrine transgression higher than 1345 m subsequent to the deposi-

tion of the white marl. If a post-white marl transgression to an altitude close to the Provo Shoreline had occurred in the Bonneville basin, such as that proposed for the Draper lake cycle (Morrison, 1965, 1966), the Old River Bed area would have been a prime depositional site.

However, no deposits that could be interpreted as the Draper Formation have been observed in this area. Although this is negative evidence, the lack of the Draper Formation is consistent with the conclusion of Scott and others (1983), who suggested that the concept of the Draper cycle should be abandoned. It is also consistent with recent reconstructions of Lake Bonneville history (Spencer and others, 1984; Currey and Oviatt, 1985) that show the lake at low levels during the previously suggested Draper time period. Therefore, recent geologic maps portraying the Draper Formation at altitudes close to the Provo Shoreline (Van Horn, 1982; Varnes and Van Horn, 1984) should be viewed with skepticism.

4. An appreciation of the geomorphology of a site is necessary in reconstructing paleoenvironments and geologic history from the stratigraphic record. For example, at localities where sediment supply was low, the white marl and related offshore sand or beach deposits are the basal lithofacies of the Bonneville Alloformation. But, where fine-clastic sediment supply was high, an underflow-fan or deltaic facies similar to the yellow clay was deposited as the basal unit. In a huge, intricate, and heterogeneous lake basin such as the Bonneville basin, complex and closely spaced facies changes should be expected and can be predicted if due attention is paid to critical aspects of the local geomorphology. An open-water facies, such as the white marl, is most likely to be mappable over broad areas of the basin, but even it changes in character laterally depending on local geomorphic, geochemical, or biological factors.

5. The Old River Bed area contains deposits typical of Lake Bonneville deposits throughout the basin (Gilbert, 1890; Oviatt, unpub. data), and it should be reconsidered as the type area for the Bonneville Alloformation. The exposures are excellent, easily accessible, and extend laterally for many kilometers, so that intertonguing relationships and facies changes within units can be readily observed. In addition, because of the low altitude of the Old River Bed area, the deposits here record events that occurred during most of the Bonneville Episode.

6. The Bonneville stratigraphic record is complex, but the complexity does not necessarily imply a complex history of major lacustrine fluctuations. This paper presents a simple interpretation of the complex stratigraphic record at G. K. Gilbert's type locality derived from facies analysis. Although my interpretations differ from those of Gilbert, I respect his genius. Gilbert's work was monumental, and considering the limitations under which he worked, his synthesis of Lake Bonneville history was incredibly accurate.

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