DRAFT SAMPLING PLAN
Lake Bonneville Shorelines Sampling Trip

July 7-10, 2005

CRONUS-Earth Project

1.0 Introduction

One of the primary tasks of the CRONUS-Earth project is to calibrate more precisely the production rates of most commonly measured in situ cosmogenic nuclides (CNs). Well-dated bedrock surfaces in Utah and southern Idaho associated with Pleistocene Lake Bonneville provide a unique opportunity achieve this goal. Wave-cut shorelines are present in a variety of rock types throughout the Lake Bonneville basin, enabling us to utilize nuclides produced from various target elements. These surfaces have been used to estimate late Quaternary cosmogenic nuclide production rates for ^{3}He (Cerling, 1990; Cerling and Craig, 1994), ^{10}Be (Gosse and Klein, 1996), ^{21}Ne (Poreda and Cerling, 1992), ^{36}Cl (Phillips et al., 1996; Stone et al., 1996; Zreda et al., 1991), ^{14}C in quartz (Lifton et al., 2001), and ^{14}C in carbonates (Handwerger et al., 1999). We plan to revisit and sample key locations in the Lake Bonneville basin to provide a consistent intercomparison of in situ CN production rates.

Below we present an overview of the lake history pertinent to our sampling locations. This is followed by summaries of the advantages and disadvantages of Lake Bonneville sites for cosmogenic nuclide production rate calibrations. We conclude by offering detailed sampling plans for each site, and a summary budget for the trip.

2.0 Lake Bonneville Overview

2.1 Lake History

Lake Bonneville began to rise above levels comparable to those of Holocene Great Salt Lake about 35 cal ka (Figure 1) (see Gilbert, 1890; Scott et al., 1983; Oviatt et al., 1992). As a closed-basin lake, it was probably in a constant state of fluctuation during its transgressive phase. The lake reached its highest stage and began overflowing into the Snake River drainage basin in southern Idaho after about 18.9 cal ka; at this level it formed the highest shoreline in the basin, the Bonneville shoreline. There is no evidence that any Quaternary lake in the basin ever reached an altitude higher than the Bonneville shoreline. The overflow threshold in unconsolidated alluvium in southern Idaho washed out catastrophically during the Bonneville flood, and the lake dropped about 100 m to a stable threshold on bedrock at Red Rock Pass, Idaho. This threshold controlled the subsequent development of the Provo shoreline, which apparently had a long (probably several thousand years) and complicated history involving at least two occupations of the shoreline separated by an undated period of lower lake levels. Post-Provo regression to near modern levels of Great Salt Lake was rapid and was probably accomplished by about 13 cal ka.

2.2 Chronology of the Bonneville shoreline, Bonneville flood, and initial Provo shoreline

The calibrated radiocarbon chronology for the development of the Bonneville shoreline and early part of the Provo shoreline is shown in Figure 1, and associated radiocarbon ages are listed in Table 1. A key radiocarbon sample for estimating the age of the earliest occupation of the Bonneville shoreline is represented by age 19, which is for a single piece of charcoal from near the top of a pre-Bonneville soil beneath a barrier spit at the Bonneville shoreline near Kanosh, UT. The charcoal and soil are approximately 6 m vertically below the crest of the spit. This is the highest reliable radiocarbon age in the basin that puts an older limit on the age of the shoreline. Age number 13 is for a tufa sample collected at the Bonneville shoreline at Stockton bar.

A conservative estimate of the age range for the Bonneville shoreline is 18.9 to 17.2 cal ka (approximate older and younger limits of ages 19, 13, and 12). It is likely that the shoreline was occupied for a shorter duration (1.7 kyr), but a higher-precision estimate is not possible with the available data. Ages 9 and 10 give an approximation for the beginning of Provo shoreline development, which, based on these two ages, could have been as early as about 17.6 cal ka. The Bonneville flood occurred between the end of Bonneville shoreline development and the beginning of Provo shoreline formation – an estimate of its age based on the data in Figure 1 is 17.4 cal ka. There is a tremendous amount of overlap in the age ranges between samples associated with the Bonneville and early Provo shorelines.

The age of abandonment of the Bonneville shoreline (i.e., the age of the Bonneville flood) can be more firmly estimated using statistical methods. Assuming that Samples 1-10 postdate the flood, and that Samples 11-19 predate it, we applied Monte Carlo techniques to the calibrated radiocarbon chronology (Samples 1-19, Figure 1, Table 1), using probability density functions from Calib 5.0 for each sample. Results of this analysis agree with the estimate in the preceeding paragraph, indicating a modal age for the flood of 17.4 cal kyr BP, with an estimated standard error of approximately 0.2 kyr. A corresponding Bayesian statistical analysis of these data confirms this conclusion. Therefore, the age at which subaerial exposure of the Bonneville shoreline began is known to better than ±1.5%, while the duration of Bonneville shoreline formation is less well-constrained.

2.3 Geomorphic development of the Bonneville and Provo shorelines

At the time of development of the depositional and erosional geomorphic features associated with the Bonneville shoreline, the lake was at or near its maximum depth, about 300 m near the present location of Great Salt Lake and west to nearly the Nevada border. As a result of the long fetch, storms probably generated tremendous wave energy that resulted in pronounced coastal geomorphology despite the relatively short duration of the lake at the Bonneville shoreline.

Depositional features at the Bonneville shoreline such as barrier beaches, bars, and spits illustrate the complexity of the lake history during this time. In many locations, several deposits in aggregate comprise the shoreline, and together suggest that the lake level was not stable or that local and regional factors altered depositional parameters. Toward the center of the lake isostatic depression due to the increasing lake load has been invoked to explain the rising set of spits at Stockton Bar (Gilbert, 1890; Currey and Burr, 1988; Figure 2). Elsewhere, the isostatic effects were of less importance and other effects such as threshold instability (e.g., downcutting at the threshold) or inconsistent overflow (and periodic drop of lake level) may have led to the complex depositional features. In addition, local geomorphology varies by local sheltering from wave energy, erodability of rock, and stream sediment input. Changes in storm dynamics, such as dominant wind directions and seasonality (since winter beaches were probably shielded by nearshore ice) may also have had effects. The depositional features at the Bonneville shoreline make clear that its history was complex, and details remain unresolved.

By contrast, erosional features at the Bonneville shoreline appear to be relatively simple. The shoreline is generally represented as a single wave-cut notch. Because the depositional features indicate relatively complex lake history, the best approach when targeting the notches is to identify the most youthful part of the notch and the part least likely to have been covered by water or nearshore sediment. These requirements indicate a sampling strategy that targets the nearest shore part of the notch. This location also can have restored cover by bedrock projected with greatest assurance.

The Provo shoreline had a longer and more complicated developmental history than the Bonneville, and may involve more than one occupation of the shoreline. Therefore, we believe that the Provo shoreline be avoided for studies involving calibration of cosmogenic isotope production.

Post-lake modifications of erosional notches include erosion by streams and cover by colluvium and eolian materials. Colluvial cover should be obvious; it is unlikely that colluvium was deposited and later removed. Eolian cover should be considered carefully. Mountains and piedmonts downwind of the Great Salt Lake desert commonly display eolian silt and fine sand, and locally ooid and silica sand, as blankets and small dunes. Locations that currently lack these features in the greater Great Salt Lake area may have been buried for part of their Holocene history.

2.4 Tabernacle Hill basalt flow

The Tabernacle Hill basalt flow was erupted after the Bonneville flood had dropped the lake from the Bonneville shoreline to the Provo shoreline, into the lake at the Provo level. This is indicated by the approximately circular planimetric shape of the flow, the uniform altitude of its outer rim, lack of shorelines higher than the Provo, and the presence of pillow structures, tufa, and boulder beaches at the altitude of the Provo shoreline around its outer rim. Therefore, the flow is older than the tufa and younger than the Bonneville flood. See Oviatt (1991) and Oviatt and Nash (1989) for more information. Tufa from the outer margin of the basalt flow has yielded a calibrated radiocarbon age range of 16.6-17.6 cal ka (age # 10; Figure 1).

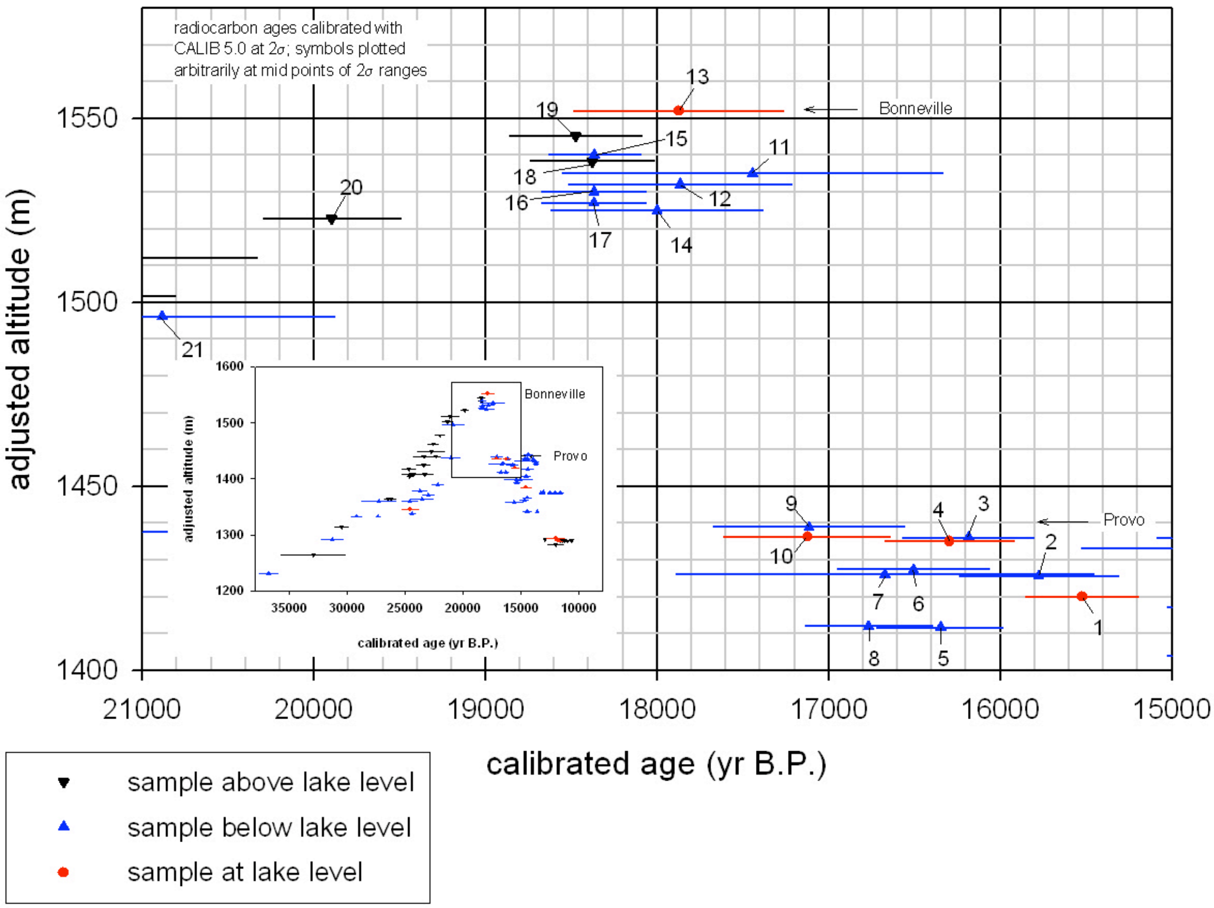

Figure 1. Calibrated radiocarbon ages for part of the Bonneville lake cycle (modified from Oviatt et al., 1992 and other sources; see Table 1 for information on the individual ages). The inset shows radiocarbon ages for the entire Bonneville lake cycle and the main figure shows an enlargement of the part of the chronology that includes the development of the Bonneville shoreline and the beginning of the Provo shoreline. Constructed by Oviatt for the CRONUS workshop (5/05). Calibrations using Stuiver et al., 2005. Altitudes are adjusted for differential isostatic rebound in the basin (Oviatt et al., 1992).

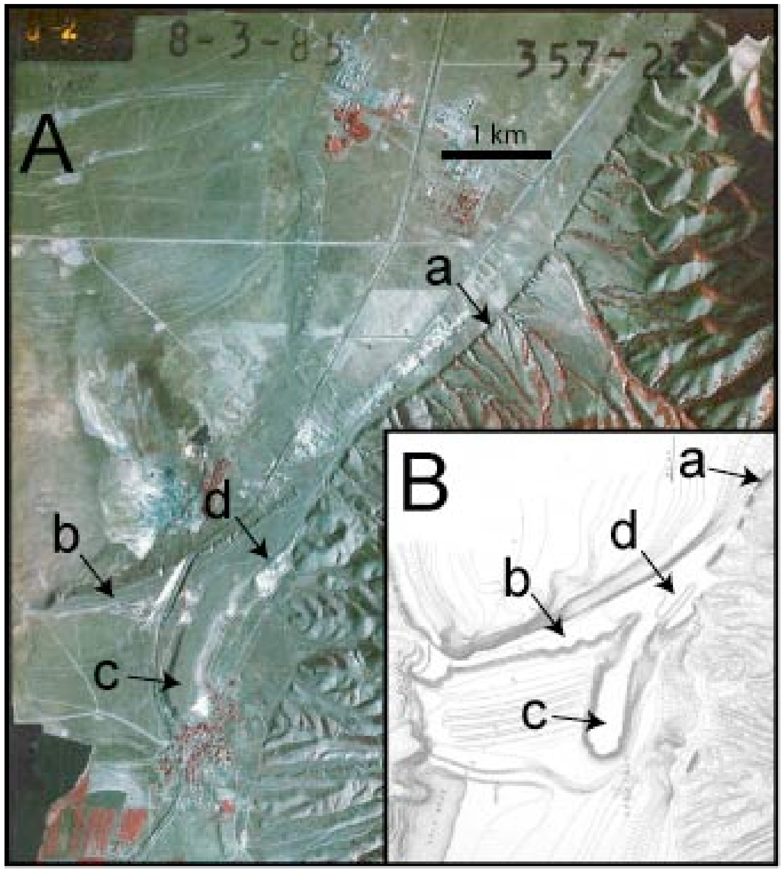

Figure 2. Bonneville shoreline geomorphology at the Stockton Bar, UT, as illustrated in a vertical aerial photograph (A) and by Plate XX of Gilbert, 1890 (B). The map and the photo are portrayed at about the same scale for comparison. In each, the lower-case letters mark: a = erosional shoreline notch at Bonneville shoreline; b, c, and d = depositional shoreline gravel spits at the Bonneville shoreline. The crest of spit c is about 9 m higher that spit b, and the crest of d is about 6 m higher than that of c (Gilbert, 1890; Burr and Currey, 1988).

Table 1 – Key ages constraining Bonneville and Provo shoreline formation

#	lab code	^{14}C	^{14}C 1σ	cal min	cal max	lake level	material	adjusted altitude (m)	stratigraphic interpretation	reference	location
1	B-153161	13110	50	15198	15847	at	gastropods	1420	backshore muddy sandy gravel	Godsey et al., 2005	25 near Alpine?
2	AA-19045	13290	115	15313	16240	up	*Fluminicola*	1426	sandy spit just below Provo shoreline	Light, 1996	Pt of Mtn
3	B-159810	13580	40	15807	16563	up	gastropods	1436	14m below Provo shoreline	Godsey et al., 2005	17 Stockton Bar?
4	B-153158	13660	50	15919	16675	at	*Stagnicola*	1435	1.5m below Provo shoreline	Godsey et al., 2005	16 Cache Valley?
5	WW4147	13705	40	15985	16713	up	*Stagnicola*	1412	sandy marl 30 m below Provo shoreline	Miller & Oviatt, unpublished	Little Mountain
6	AA-19040	13850	115	16065	16949	up	*Stagnicola*	1427	Bear River delta graded to Provo shoreline	Light, 1996	Bear River delta
7	W-899	13900	400	15456	17891	up	mollusk shells	1426	Bear River delta graded to Provo shoreline	Rubin & Berthold, 1961; Bright, 1963	W of Preston Idaho
8	WW4148	14090	40	16397	17138	up	*Stagnicola*	1412	sandy marl 30 m below Provo shoreline	Miller & Oviatt, unpublished	Little Mountain
9	AA-19059	14290	125	16559	17672	up	*Stagnicola*	1439	sand just below Provo shoreline	Light, 1996	Sand Pass camp
10	B-23803	14320	90	16640	17605	at	tufa	1436	Provo shorezone	Oviatt & Nash, 1989	Tabernacle Hill basalt flow
11	B-50770	14420	370	16334	18557	up	*Stagnicola*	1535	5m below Bonneville B1 shoreline	Godsey et al., 2005	10 Stockton Bar?
12	B-146004	14730	140	17215	18516	up	*Stagnicola*	1532	30m below Bonneville shoreline	Godsey et al., 2005	8 Stockton Bar?
13	SI-4227C	14730	100	17263	18481	at	tufa, innermost 18%	1552	Bonneville shoreline	R. Stuckenrath; Currey et al., 1983	Stockton Bar
14	B-39294	14830	160	17382	18619	up	*Stagnicola*	1525	sand 30 m below Bonneville shoreline	Oviatt et al., 1994	W flank of Simpson Mtns
15	B-169099	15060	50	18098	18632	up	*Stagnicola*	1540	6m below Bonneville shoreline	Godsey et al., 2005	5 Bear River delta?
16	B-156852	15080	90	18067	18673	up	*Stagnicola*	1530	just below Bonneville shoreline	Godsey et al., 2005	4 Callao area?
17	B-151451	15080	90	18067	18673	up	*Stagnicola*	1527	20m below Bonnneville shoreline	Godsey et al., 2005	3 W. of Stockton Bar?
18	W-5261	15100	140	18018	18742	down	wood	1538	transgressive lagoon/bar complex	Scott, 1988	MacNeish pit, No. SLC
19	B-23174; ETH-3518	15250	160	18088	18861	down	charcoal	1545	pre-Bonneville soil	Oviatt, 1991	Kanosh
20	W-4896	16770	200	19497	20297	down	wood	1523	transgressive shore zone	Scott et al., 1983	MacNeish pit, No. SLC
21	L-711C	17500	400	19878	21890	up	gastropod shells	1496	transgressive nearshore zone	Broecker & Kaufman, 1965	Leamington amphitheater

notes:

- calibrated age ranges at 2σ (CALIB5.0)
- in the lake-level column, “at” indicates lake level at or near sample altitude at time of deposition; “up” indicates lake level above sample; “down” indicates lake level below sample
- altitudes adjusted for differential isostatic rebound (see Oviatt et al., 1992)

3.0 Advantages of Lake Bonneville Shoreline Features for Calibrating CN Production Rates

The shoreline features associated with Lake Bonneville provide a number of advantages for calibrating CN production rates. First, the Bonneville highstand and subsequent Bonneville flood are well-constrained in age, bracketed by 21 radiocarbon dates. Second, a wide variety of rock types are available in the Bonneville basin, allowing analysis and intercomparison of all commonly measured CNs. Furthermore, the presence of large-scale erosional shoreline benches with well-preserved surfaces should enable samples to be collected for long-lived and stable CNs without significant prior production by fast muons. Finally, the Tabernacle Hill basalt flow was erupted into a Provo level lake and has been subaerially exposed since then. This allows us to use a Provo-age feature as a calibration point without the potential for a previous occupation of that feature by the lake.

4.0 Uncertainties in Using Lake Bonneville Shoreline Features

While the Lake Bonneville shoreline features have the advantages outlined above, one must also be aware of potentially significant aspects of the samples' exposure history which could influence the measured CN concentrations. We describe these below.

4.1 Uncertainties in isostatic corrections

Uncertainties in CN exposure history at the Bonneville-level shorelines due to differential isostatic rebound are likely small. Although there exists a 60-70 m altitudinal difference between the Bonneville-level shorelines at the center of the basin and those around the basin perimeter, the total effect of that difference on CN production over 18 kyr is about 5%. However, that assumes that the difference in altitude persisted for the entire 18 kyr. Isostatic modeling suggests that by the time the Provo shoreline was abandoned, though, the Bonneville shoreline had likely already rebounded by about 20 m at the basin center, due to the essentially instantaneous draining of nearly half of the water in the lake ((Bills et al., 1994); Bruce Bills, 2005, personal communication). The rest of the rebound likely occurred at a relatively predictable rate as the water retreated from the Provo level. Thus, the integrated effect of the isostatic rebound on the CN concentrations in the surfaces to be sampled is a slight increase in concentration which is likely much less than 5%.

4.2 Uncertainties due to prior exposure under shielded conditions

When considering erosional benches for in situ CN production rate calibration, we must consider the amount of overburden that was removed during cutting of the bench. This is particularly important for long-lived and stable CNs, since production by fast muons can extend to significant depths. We have modeled various shielding scenarios (exposure time and erosion rate of upper rock surface before bench cutting) for ^{10}Be to guide our site selection, using a site production rate of about 19 atoms/g/yr derived from (Pigati and Lifton, 2004), and an assumed landform age for the cut bench of 18 kyr (Table 2). Results suggest that production of ^{10}Be under > 40-50 m of overburden yields ^{10}Be concentrations at or below our measurement uncertainties for most likely scenarios. Even 30 m of overburden yields ^{10}Be concentrations less than 5% of those produced at the surface during subaerial exposure for exposure ages < 10^6 years. We plan to sample surficial rocks above the wave-cut notch at each erosional bench site to constrain prior exposure conditions. Furthermore, our sampling efforts will focus on the base of the cut notches to better constrain the amount of overburden.

Table 2 – Estimated uncertainties due to prior muon production under rock cover

Vertical Shielding Scenarios	Pre-Exposure Age (yr)	Erosion Rate (cm/yr)	Modeled 18 kyr Exposure Concentration (at/g)	Shielded Concentration at Start of Exposure (at/g)	% Above Unshielded Exposure %
30 m	1.0E+07	1.0E-03	3.41E+05	1.81E+04	**5.31%**
		1.0E-04	3.41E+05	3.79E+04	**11.13%**
		1.0E-05	3.41E+05	4.26E+04	**12.51%**
	1.0E+06	1.0E-03	3.41E+05	1.21E+04	**3.55%**
		1.0E-04	3.41E+05	1.57E+04	**4.60%**
		1.0E-05	3.41E+05	1.61E+04	**4.73%**
	1.0E+05	1.0E-03	3.41E+05	1.91E+03	**0.56%**
		1.0E-04	3.41E+05	1.96E+03	**0.58%**
		1.0E-05	3.41E+05	1.97E+03	**0.58%**
40 m	1.0E+07	1.0E-03	3.41E+05	9.51E+03	**2.79%**
		1.0E-04	3.41E+05	1.97E+04	**5.79%**
		1.0E-05	3.41E+05	2.21E+04	**6.48%**
	1.0E+06	1.0E-03	3.41E+05	6.32E+03	**1.86%**
		1.0E-04	3.41E+05	8.11E+03	**2.38%**
		1.0E-05	3.41E+05	8.33E+03	**2.44%**
	1.0E+05	1.0E-03	3.41E+05	9.87E+02	**0.29%**
		1.0E-04	3.41E+05	1.02E+03	**0.30%**
		1.0E-05	3.41E+05	1.02E+03	**0.30%**
50 m	1.0E+07	1.0E-03	3.41E+05	5.07E+03	**1.49%**
		1.0E-04	3.41E+05	1.05E+04	**3.07%**
		1.0E-05	3.41E+05	1.17E+04	**3.43%**
	1.0E+06	1.0E-03	3.41E+05	3.36E+03	**0.99%**
		1.0E-04	3.41E+05	4.30E+03	**1.26%**
		1.0E-05	3.41E+05	4.41E+03	**1.29%**
	1.0E+05	1.0E-03	3.41E+05	5.23E+02	**0.15%**
		1.0E-04	3.41E+05	5.38E+02	**0.16%**
		1.0E-05	3.41E+05	5.39E+02	**0.16%**

4.3 Uncertainties due to water depth

Previous work at the Bonneville shoreline at Promontory Point, UT, indicated that a difference of about 17 m exists between the bedrock bench and the top of fine-grained estuarine deposits indicating the high water level in the lake (Lifton, 1997). While the duration and average depth of cover by the water are unknown, constraints can be placed on these values by the data in Table 1 and Figure 1. We have modeled various scenarios for ^{10}Be based on these data, using a site production rate of about 19 atoms/g/yr derived from (Pigati and Lifton, 2004), and an assumed total landform age of 18 kyr (Table 3). While the maximum possible cover depth and duration yield CN concentrations in the bedrock approximately 11% lower than full subaerial exposure, more likely scenarios yield differences between subaerial and submerged/subaerial exposure of about 5% or less.

Table 3 – Potential Production Underwater for various possible scenarios

Water Shielding Scenarios	Water Shielding Time (yr)	Subaerial Exposure Concentration* (at/g)	Production Underwater (at/g)	Total Concentration Underwater + Subaerial (at/g)	% Below Full Subaerial
17 m (Max)	2000	3.03E+05	3.07E+02	3.03E+05	**10.98%**
17 m (Max)	500	3.31E+05	7.67E+01	3.31E+05	**2.74%**
10 m (Avg?)	1000	3.22E+05	2.44E+02	3.22E+05	**5.46%**
10 m (Avg?)	500	3.31E+05	1.22E+02	3.31E+05	**2.73%**

Notes: * Subaerial exposure time is the difference between 18 kyr total exposure and the water shielding time.

4.4 Potential for loess or ash cover

As noted in Section 2.3, there exists the potential for past loess cover at each site. We will look carefully for evidence of eolian cover at each site. If such evidence is found, we will attempt to constrain the potential thickness of past cover. However, it will take intercomparisons with CN analyses from other calibration sites to say definitively whether past eolian cover might be a problem at a given site in the Bonneville basin.

The Tabernacle Hill flow may have been covered originally with an unknown amount of ash. One could argue that it probably would have washed off quickly relative to the age of the flow. However, we will look for evidence of ash cover at the site. We will also avoid sampling from the western portion of the flow affected by eolian cover.

Sampling Sites

Sampling locations are depicted on Figure 3. All sampling will conform to the CRONUS-Earth Draft Sampling Protocols developed at the CRONUS-Earth Sampling Workshop in Coeur d'Alene, ID, May 26-28, 2005. We will restrict our sampling of erosional shoreline benches to those of the Bonneville level to avoid potential Provo-level complexities (Section 2.3). We plan to collect all samples using a cutoff saw unless specifically forbidden by the landowners. Site-specific tasks are presented in outline form below.

Researchers Attending: 13

Participants attending the field trip will be Greg Balco (University of Washington), Marc Caffee (Purdue University, PRIME Lab), Thure Cerling and a graduate student (University of Utah), Robert Finkel (Lawrence Livermore National Lab, CAMS), Darryl Granger (Purdue University, PRIME Lab), Mark Kurz (Woods Hole Oceanographic Institution), Nathaniel Lifton (University of Arizona), Shasta McGee (New Mexico Tech), Kunihiko Nishiizumi (University of California Berkeley, Space Sciences Lab), Fred Phillips (New Mexico Tech), Terry Swanson (University of Washington), Claire Todd (University of Washington)

Tabernacle Hill
July 7, 2005

We plan to analyze samples from the Tabernacle Hill flow for CNs in which olivine is the target mineral.

- Nuclides Available: ^{3}He, ^{21}Ne, ^{36}Cl, ^{14}C in olivine
- Resample tufa from more than 1 location, if possible, for additional ^{14}C dating and possibly U/Th dating
- Look for evidence of ash cover in cracks in the flow
- Planned number of samples – 6? **(Waiting on requested totals from Marc C.)**
- Mass of Rock Needed – *20 kg?* **(Waiting on requested totals from Marc C.)**

Oquirrh Mountains
July 8, 2005

The focus of the Oquirrh Mountains location will be to sample carbonate bedrock (e.g., Handwerger et al., 1999), which is not available at the other CRONUS-Earth primary calibration sites. However, we will also be looking for quartz-bearing rocks as a backup for ^{26}Al, in case the Promontory Point quartzites are too rich in stable Al (preliminary analyses suggest they are). This should be feasible since Pennsylvanian/Permian carbonates, quartzites and sandstones are interbedded in this range.

An advance team will scout potential sites on the 7th. This team will be escorted by Brian Vinton of the Kennecott Utah Copper Company (801-569-7887) or an associate to the potential sampling sites. The potential Bonneville-level sites are between Black Rock Canyon and Lake Point on the north side of the range, and in and near Little Valley, west of the town of Magna. The entire group will need to attend a pre-safety meeting on July 8th, to be documented by Kennecott. All participants will be required to wear hard hats, safety glasses and steel-toed boots or steel-toed shoe covers (all to be provided by Kennecott) while on the Kennecott property.

- Nuclides Available: Carbonates – ^{36}Cl, ^{14}C; Quartz-bearing rocks – ^{10}Be, ^{26}Al, ^{21}Ne, ^{14}C, ^{36}Cl
- We will look for primary wave rounding and polishing still present in outcrops, as an indication of negligible erosion since their formation.
- Final sampling locations have not been selected at this time. As such, we will enlarge and print appropriate sections of 1:24,000 scale USGS topographic maps to cover the potential

sampling locations, supplemented by less detailed air photos. We will then use the enlarged topographic maps as a base for generating a geomorphic map of the sampling site(s).

- Sample on top of cut notch (original surface) to assess inheritance
- Survey the height to top of wave-cut notch
- Survey width of notch
- Sample at base of notch
- Sample transect on wave-cut bench, perpendicular to the notch
- Number of Samples – 4? **(Waiting on requested totals from Marc C.)**
- Mass of rock needed – *10 kg?* **(Waiting on requested totals from Marc C.)**

Promontory Point
July 9-10, 2005

The Bonneville shoreline benches at Promontory Point are among the largest in the Bonneville basin – dozens of meters wide, with between 50-100 m of overburden removed (based on topographic map estimates). They are composed of Precambrian and lower Cambrian quartzites.

We plan to sample on a patch of BLM land covering the best-developed Bonneville-level bench, but will need access through a locked gate and permission to walk across private land between the road and the bench. We have arranged to call the landowner, John Young (435-723-5846, 435-279-4641 (cell)) before coming, so that he can meet us at the gate and let us onto his property. The other landowner in the area, Sam Chournos (435-257-7369), has agreed to let us cross his land if Mr. Young does.

- Nuclides Available: ^{10}Be, ^{26}Al (Stable Al content may be too high, though), ^{21}Ne, ^{36}Cl, ^{14}C
- We will look for primary wave rounding and polishing still present in outcrops, as an indication of negligible erosion since their formation.
- Small-scale aerial photography is not available for the sampling location. As such, we will enlarge and print appropriate sections of 1:24,000 scale USGS topographic maps to cover the sampling location, supplemented by less detailed air photos. We will then use the enlarged topographic map as a base for generating a geomorphic map of the sampling site.
- Sample on top of cut notch (original surface) to assess inheritance
- Survey height to top of notch
- Survey width of notch
- Sample at base of notch
- Sample transect on wave-cut bench, perpendicular to the notch
- Number of samples – 10? **(Waiting on requested totals from Marc C.)**
- Mass of rock needed – *20 kg?* **(Waiting on requested totals from Marc C.)**

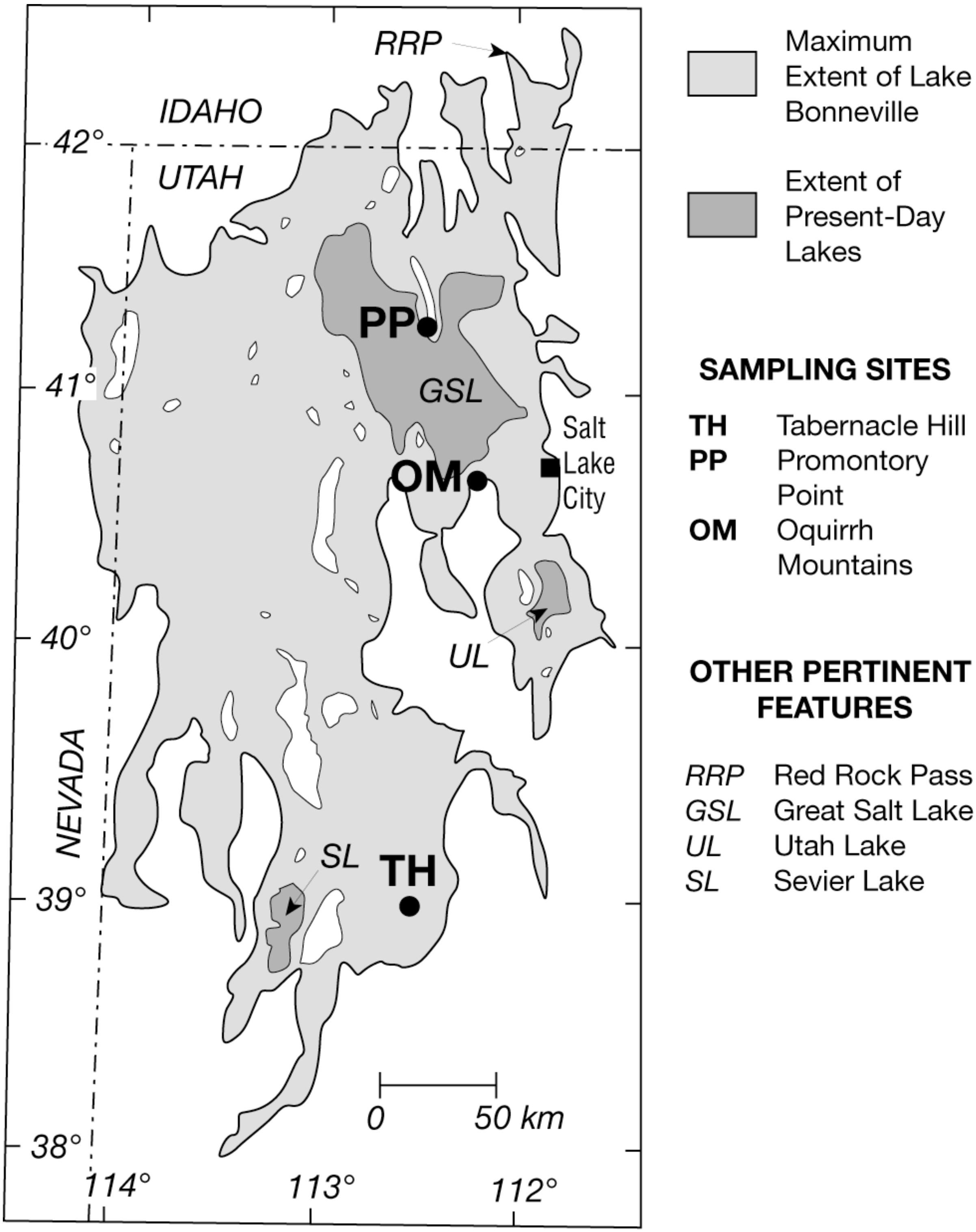

Figure 3. Vicinity map showing the maximum extent of Lake Bonneville relative to modern lakes and the sampling locations.

Contingencies

While do not anticipate our permission to cross John Young's land at Promontory Point to access the bench on BLM land there to be revoked, it remains a possibility (it has happened in the past). As such, we have applied to the State of Utah for permission to sample the Bonneville-level bedrock bench on Antelope Island as an alternate site (e.g., Doelling et al., 1990). That bench is located on a rock type similar to that on Promontory Point.

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Budget

	Airfare	Hotel (4 nights)*	Rental Car	Perdiem+	Misc. Field Exp	
Balco, Greg	$0	$400	$0	$150		
Caffee, Marc	$400	$400	$0	$150		
Thure Cerling	$0	$400	$0	$150		
Thure's Student	$0	$400	$0	$150		
Finkel, Robert	$300	$400	$0	$150		
Granger, Darryl	$400	$400	$0	$150		
Kurz, Mark	$450	$400	$0	$150		
Lifton, Nat	$320	$400	$850**	$150		
McGee, Shasta	$0	$400	$0	$150		
Nishiizumi, Kuni	$300	$400	$0	$150		
Phillips, Fred++	$0	$400	$0	$150		
Swanson, Terry	$300	$400	$0	$150		
Todd, Claire	$0	$400	$0	$150		
14 People Total						
		Assuming Individual Rooms				
Totals ->	$2,470	$5,200	$850	$1,950	$2,000	**$12,470 MAX**
		Assuming Shared Rooms Avg $100/night				
	$2,470	$2,600	$850	$1,950	$2,000	**$9,870 MIN**

Notes:

*	$100/night is probably a maximum value - rural motels will likely be less
**	Fred's car carries 5 people, Thure's car carries 4 people. Will rent a Ford Excursion for the rest
+	5 days @ $30/day each
++	Fred's son will accompany him