



Figure 1. Home to adaptable prehistoric peoples over the last 15,000 years, the Fishing Bridge Peninsula routinely gained and lost ground to a cyclically retreating and advancing Yellowstone Lake. The study area revealed a complex series of earlier shorelines, some higher, others lower, than the present-day shore at Storm Point.

CALDERA UNREST, LAKE LEVELS, AND ARCHEOLOGY: THE VIEW FROM YELLOWSTONE LAKE

A habitat restoration project prompts cooperative natural and cultural resource research

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Yellowstone National Park is rehabilitating the Fishing Bridge area on the north shore of Yellowstone Lake. This project will help maintain and protect critical habitat for the grizzly bear and preserve the quality of this diverse, local ecosystem (National Park Service 1984). During 1992-93, prior to the rehabilitation project and proposed reconstruction of the east entrance road, scientists from the NPS Midwest Archeological Center and U.S. Geological Survey conducted geoeological research on parts of the peninsula at Fishing Bridge. Although compliance legislation (Section 106 of the National Historic Preservation Act) mandated the research before the two projects could begin, we hoped to use this opportunity to learn more about the complex interactions of lakeshore level changes over time and prehistoric human adaptation to these changes (fig.1). We also hoped to use new techniques in geochemistry and immuno-

logical research to learn more about obsidian artifacts found within the study area and at other park sites. The following overview illustrates how geological and archeological observations can be integrated to interpret cultural remains and explain human adaptations to changing lake levels.

We assembled a team, including several researchers already familiar with Fishing Bridge, to provide expertise on local and regional paleoenvironmental patterns, mobility and subsistence patterns, landform history, and other topics. While preliminary, our work complements former studies in assessing the environmental circumstances that prehistoric humans lived with and adapted to.

FLUCTUATING LAKE LEVELS

Central to understanding Yellowstone Lake level fluctuations and their effects on prehistoric humans in the Fishing Bridge area is the relationship between lake levels and caldera rise and subsidence at LeHardy

Rapids on the Yellowstone River. Located 5 km (3 mi) downstream from the Yellowstone Lake outlet at Fishing Bridge, LeHardy Rapids is a bedrock threshold that controls the level of Yellowstone Lake by acting as a dam; the intervening stretch of river between the outlet and the rapids is at present very flat with a total gradient of only about one-quarter meter (less than a foot). From 1923-85, the Yellowstone caldera rose about 1 m (3.3 ft) beneath LeHardy Rapids (Pelton and Smith 1982). Since 1985, the same area has subsided at a rate of about 2 cm (0.8 in) a year (Dzurisin et al. 1990). Explanations for these changes include magma intrusion, tectono-magmatic interaction, and—our favored mechanism—geothermal sealing and pressure buildup followed by cracking and pressure release (see Pelton and Smith 1982; Fournier 1989; Dzurisin et al. 1990).

We wondered if these changes were part of a longer-term process that could be studied by dating evidence for lake levels both above and below the present level. An early

model for lake level changes proposed by Richmond (1976a, 1976b) argues for a progressive, gradual lowering from late Pleistocene through Holocene time (approximately 15,000 years ago through the present). He outlines two general ages for shorelines: a middle set of terraces 15.2-16.8, 12.2-13.7, and 9.1-10.6 m (50-55, 40-45, 30-35 ft, respectively) above present-day Yellowstone Lake formed between 5,000-8,000 years ago and a lower set of terraces 7.6, 4.6, and 3.0 m (25, 15, and 10 ft, respectively) above the lake formed more recently.

Archeological and geomorphological information gathered since Richmond's work suggests that lake history is more complicated. For example, Reeve (1989) looked at the distribution of late Pleistocene-early Holocene projectile points. He found that 10,000-8,000 years B.P., projectile points were common on shorelines that Richmond's chronology indicated should be younger than 5,000 years old. Hamilton (1985) recognized lower-than-present lake levels, and later specified that Yellowstone Lake was below its present level from approximately 9,200-5,400 years ago. He and Bailey (1990) also postulated that the lake was 5 m (16.4 ft) below present around 1600 A.D.

The ages we determined are at least twice as old as those suggested by most previous researchers (Richmond 1976a, 1976b; Meyer and Locke 1986; Locke and Meyer 1994). Shoreline ages have been quite difficult to determine with accuracy, because most are based on radiocarbon samples that are younger than the associated shoreline, and thus represent only minimum ages. We affirm the conclusion of Meyer and Locke (1986:20) that the "history of lake levels is apparently more complex than a simple decline over time."

In order to resolve dating problems like those raised by Reeve (1989) and to understand the impacts and implications of both higher- and lower-than-present lake levels on human habitation, we needed to better define the history of geomorphic changes. Using geomorphic studies and archeological excavations, we have identified, described, and precisely mapped relict landforms that record a cyclical pattern of uplift and subsidence on the north shore of Yellowstone Lake since deglaciation approximately 15,000 years ago. Each of these cycles created significant changes in

the local landforms, environments, and resources available to humans who lived in the area.

CYCLES OF UPLIFT AND POSSIBLE SUBSIDENCE

The current uplift and backflooding cycle observed over most of this century has been going on for about 3,000 years. Backflooding has converted the 5 km (3 mi) segment of the Yellowstone River (from its mouth at Yellowstone Lake to the bedrock threshold at LeHardy Rapids) from a once vigorously flowing river into the present wide pool. Using hand coring techniques, we found river gravels 4 km (2.5 mi) upstream from Le Hardy Rapids that are now submerged beneath 4 m (13.1 ft) of mud and sand that started accumulating about 2,700 yr B.P. When deposited by the faster-flowing Yellowstone River, these gravels were several meters higher than the bedrock threshold at LeHardy Rapids. However, the uplift centered at LeHardy Rapids has been enough so that these gravels are actually lower than the bedrock threshold. We estimate that this river segment was tilted back toward the lake approximately 5 m (16 ft) in the last 3,000 years.

Additional evidence for tilt and increase in the level of Yellowstone Lake comes from a submerged valley located 21 km (13 mi) southeast of Fishing Bridge, near West Thumb. A core sample from 5 m (16.4 ft) below the present lake level has an age of 2,800 years B.P. When deposited, the sample material was part of a wetland adjacent to Yellowstone Lake. This shows that Yellowstone Lake here has also risen approximately 5 m in the last 3,000 years, and is consistent with our findings near Fishing Bridge.

Evidence that may define the next older uplift cycle is difficult to unravel, because Yellowstone Lake levels then were close to the present level. However, weakly developed soil and mid-Holocene (approximately 5,000 year old) artifacts observed within a meter (3.1 ft) above the current beach suggest that lake levels were near present levels approximately 5,000 years ago and were probably lower thereafter.

The next older uplift and backflooding cycle is recorded by an S-shaped meander 0-3 m (0-10 ft) above the Yellowstone River. West of the present river, the meander backflooded and Yellowstone Lake built a

spit across it (Meyer and Locke 1986; Locke and Meyer 1994). East of the present river, a charcoal sample from between the river gravels and lake deposits shows that backflooding of the once vigorously flowing river was under way by 8,200 yr B.P. This backflooding cycle ended between 6,800-6,680 years ago when the lake level was as high as the prehistoric shoreline that is now preserved at the Fishing Bridge Museum (fig. 2, page 30). The amount of backflooding is the same as that determined for the current uplift cycle (beginning 3,000 years ago) and we think indicates a similar amount of uplift at LeHardy Rapids.

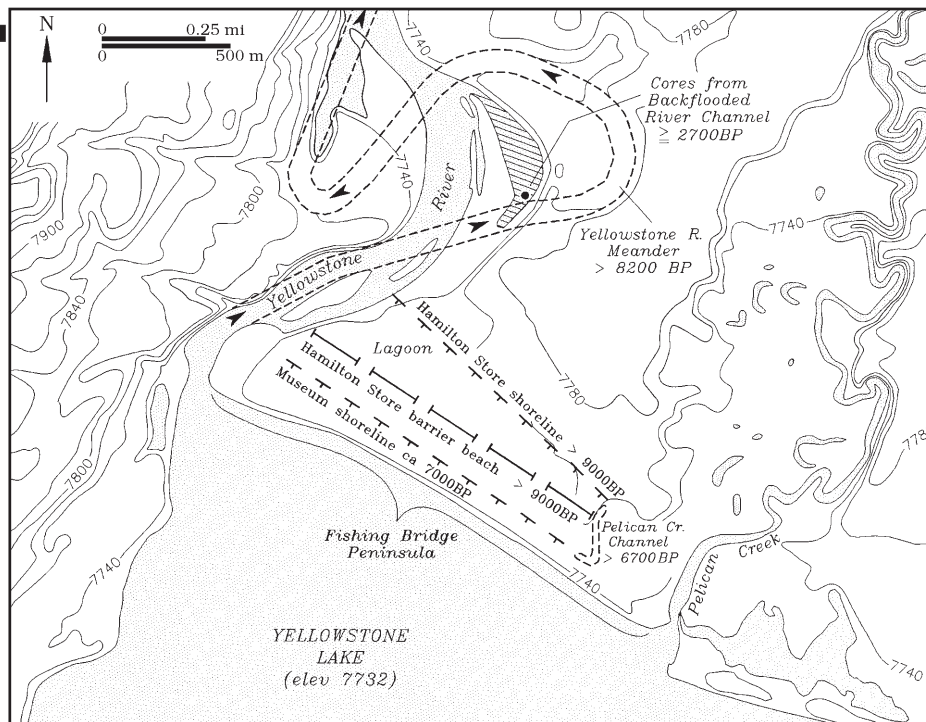
At least three river terraces formed after the glaciers melted and suggest that three additional backflooding cycles may have occurred between 8,500-15,000 years ago. The youngest of these three river terraces ties in with the shoreline at the Hamilton Store level (fig. 2, page 30). Ages determined on charcoal buried beneath dune sand indicate that this shoreline is at least 9,000 years old. In association with this shoreline, we also found Cody Complex artifacts dated between 8,750 and 10,060 B.P. (fig. 3a, page 31) that were used by people who occupied the area then (Frison 1991:table 2.2).

A geologic complexity with the Fishing Bridge area is additional tilting that is distinct from the uplift and subsidence of the central part of the caldera. Meyer and Locke (1986) show that the prehistoric shoreline at Hamilton Store (9,000 years B.P.) is downwarped 3 m (9.8 ft) within 1 km (0.6 mi) of Fishing Bridge, but that the Museum shoreline (about 7,000 years old) is not downwarped. An offshore graben (depressed crust bounded by faults) trends towards Fishing Bridge (Otis et al. 1977; Kaplinski 1991) and might be responsible for this downwarping. However, neither we, nor other researchers have found evidence for extension of this graben on shore.

In summary, we suggest that the central part of the Yellowstone caldera has been uplifting and probably subsiding cyclically. This *heavy breathing* has breathed several thousand years long. For the pattern of uplift and subsidence measured this century, that part between the center of uplift near Le Hardy Rapids and Fishing Bridge measures only the crestal one-fourth of the total span. If the past patterns paralleled

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Figure 2. Map of Fishing Bridge Peninsula showing prehistoric shorelines and beaches of Yellowstone Lake, some older courses of the Yellowstone River, and contours (in feet above mean sea level).



those observed this century, the 5 m uplift of Le Hardy Rapids relative to Fishing Bridge is only one-fourth of the total uplift. If so, the total uplift for at least two of the cycles was about 20 m. Thus, the heavy breathing of the central part of the Yellowstone caldera has breaths of about 20 m spaced at intervals of perhaps 1,000-4,000 years.

Native American inhabitants of the Fishing Bridge peninsula around 10,000 years ago probably encountered landforms similar to those found at the mouth of Pelican Creek today (see fig. 1). The Hamilton Store shoreline was an active barrier beach, with a shallow lagoon immediately to the north. North of the lagoon, emergent beaches collected windblown sand, and several spits also extended westward into the lagoon.

At around this time, pollen records indicate that the lakeshore was dominated by open grasslands or steppe species. Common members included sagebrush, various grasses of the family Poaceae, sedges, and other herbs. Between 10,500 and 9,000 years ago, lodgepole pine (*Pinus contorta*) began to dominate forests in response to warming and has remained the dominant overstory species ever since (Whitlock 1993). Understanding climate and vegetative change is important for modeling population dynamics of human prey species, such as deer, bison, elk, and bighorn sheep.

OBSIDIAN USE

In addition to understanding the Fishing Bridge area paleoenvironment, our research also emphasized settlement and subsistence patterns and tool stone acquisition. Native Americans produced an abundance of stone tools from obsidian obtained from local volcanic exposures (Davis et al. 1992). Geochemical studies over the past 30 years have shown that volcanic flows have distinct chemistry, and by comparing trace elements of known geologic sources with those of prehistoric tools, researchers can develop procurement strategies of tool stone.

Earlier geochemical studies suggested that humans used only local Yellowstone Plateau obsidians in the manufacture of stone tools (e.g., Wright and Chaya 1985). However, over the last 10 years, improvements in trace element analyses and a greater knowledge of regional sources of volcanic glass have increased the number of source areas in the archeological record (Nelson 1984). Our studies have documented at least 10 distinct geochemical types among obsidian projectile points and tools found in Yellowstone. Although Obsidian Cliff is by far the most significant source, a substantial number of nonlocal sources occur (30%), some as far away as 280 km (174 mi) to the southeast in Idaho (Cannon and Hughes 1993). For instance, Paleo-Indian points were manufactured from a greater diversity of sources, and from sources at greater distance than for other

time periods. This pattern would suggest greater mobility of these groups, which is consistent with other Paleo-Indian studies elsewhere in the west.

BLOOD RESIDUE ANALYSIS

Middle Rocky Mountain archeological sites are noted for poor preservation of organic materials. This has limited archeologists' abilities to understand subsistence patterns by direct evidence, such as the discarded remains of food items. However, recent studies have demonstrated that biochemical and immunological meth-

ods have the potential to identify animal species from residues (i.e., blood and tissue) remaining on stone tools (Newman 1990) and in soils (Newman et al. 1993). These techniques have direct implications for reconstruction of prehistoric subsistence patterns, tool use, and paleoenvironmental studies.

We used a modified version of crossover immunoelectrophoresis analysis. This technique was developed by the Royal Canadian Mounted Police Serology Laboratory (Ottawa) and the Centre of Forensic Sciences (Toronto) for identification of blood residue in criminal investigations. We used the technique to analyze stone tools for prehistoric blood residue (fig. 3a-g, page 31). The process returned positive anti-sera reactions for bison, deer, elk, sheep, rabbit, bear, cat, and canid for 23 of 78 analyzed artifacts (Cannon 1995). Diversity of faunal species, in contrast to the bison-dominated plains economy, has been a hallmark of prehistoric mountain economies (Frison 1991).

SUMMARY

We have begun piecing together a very exciting record of geomorphic and tectonic change, which has directly influenced settlement and subsistence of prehistoric groups living on the Fishing Bridge peninsula for millennia. Environmental and vegetative changes continually provided hunter-gatherers living in the Yellowstone area new opportunities and challenges. The

challenge to archeologists and other Quaternary researchers is to decipher these patterns from the limited evidence we are presented. Our analyses are still ongoing, but our preliminary results are encouraging. We plan to publish a final report on our findings later this year.

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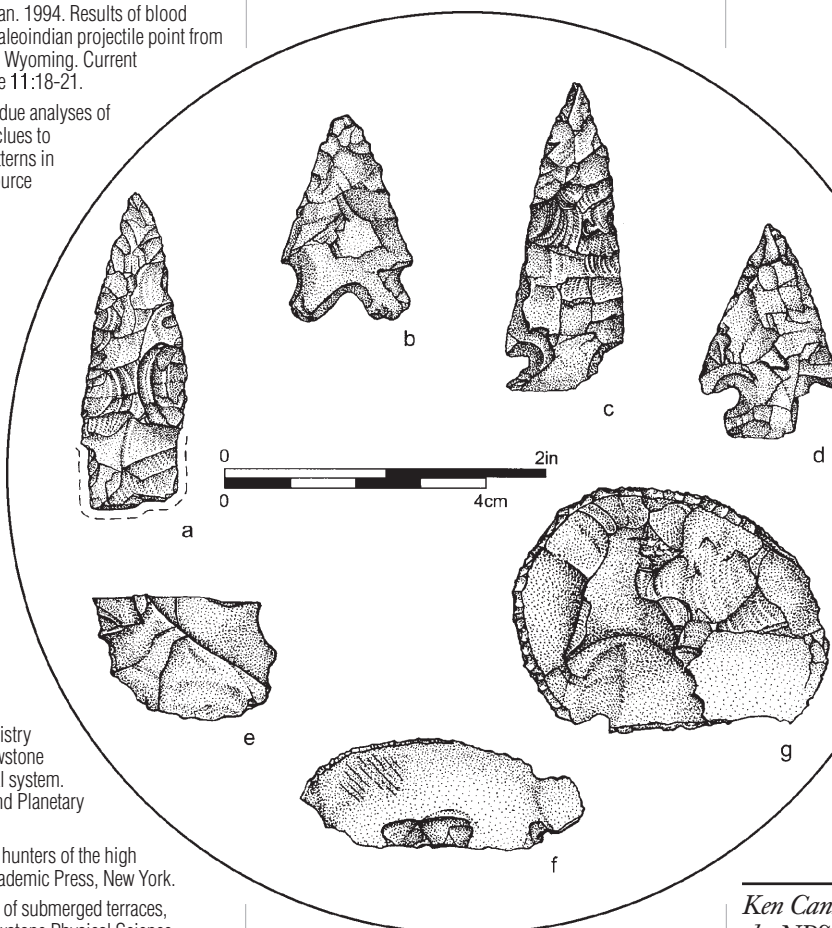


Figure 3. Flake stone tool artifacts from sites around the lakeshore that produced positive anti-sera reactions: (a) chalcedony Cody-like (ca. 9,000 years b.p.) projectile point that tested positive for rabbit anti-sera; (b) basalt Oxbow (ca. 5,000 years b.p.) projectile point; (c) chert Avonlea-like (ca. 2,000 years b.p.) projectile point that tested positive for deer anti-sera; (d) chert corner-notched projectile point basalt that tested positive for bear anti-sera; (e) retouched basalt flake that tested positive for deer and elk anti-sera; (f) chert retouched flake that tested positive for canid; (g) chert scraper that tested positive for deer anti-sera.