Preliminary Bathymetry of Shoup Basin and Late Holocene Changes of Shoup Glacier, Alaska

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	by	To obtain
foot (ft)	0.3048	meter
mile (mi)	0.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per year (ft/yr)	0.3048	meter per year
fathom	1.829	meter

VERTICAL DATUM

Sea Level: In this report. "sea level" refers to the National Geodetic Vertical Datum of 1929-A geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Preliminary Bathymetry of Shoup Basin and Late Holocene Changes of Shoup Glacier, Alaska

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Abstract

Shoup Glacier is a retreating, tidewater-calving glacier in northeast Prince William Sound, Alaska. Historical records, vegetation distribution, and sediment depth in Shoup Bay indicate that the glacier reached a late Holocene maximum at the mouth of Shoup Bay prior to 1750. When first observed around 1900, the terminus was stable on a series of shallow, bedrock obstructions between Shoup Bay and Shoup Basin, 2 miles from the late Holocene maximum. Shoup Glacier receded into tidewater in 1957 and in the following 33 years retreated 1.3 miles to expose Shoup Basin, a deep (more than 350 feet) basin with virtually no sediment accumulation. Shoup Glacier is expected to stabilize at the head of Shoup Basin shortly after the year 2000 and will not readvance if present climatic conditions continue.

INTRODUCTION

The U.S. Geological Survey (USGS) has published a series of reports that integrate historical studies with bathymetry and the field data collected during the 1970's and 1980's in Alaskan fiords that contain tidewater glaciers. Although these data are used to speculate on late Holocene glacier advance/retreat history, the reports are preliminary and are meant to be a guide for further or more detailed research. Reports in this series currently cover Aialik Bay (Post, 1980a), Blackstone Bay (Post 1980b), McCarty Fiord (Post, 1980c), and Northwestern Fiord (Post 1980d).

This report presents preliminary bathymetry and observations of Shoup Bay, Shoup Basin, and Shoup Glacier obtained in 1982 aboard the USGS research vessel *Growler.* Other data are from USGS aerial photography and historical references.

Setting and History

Shoup Bay is located 8 mi west of Valdez, on the north side of Port Valdez in Prince William Sound (plate 1). A morainal shoal with a maximum depth of 15 ft below high tide encloses the entrance to the fiord. Two miles from the moraine, the bay heads in several bedrock obstructions and a sequence of moraines, outwash, and tidal flats. These impound a tidal basin into which Shoup Glacier terminates 3.3 mi from the mouth of the bay. Due to a cold microclimate, timber is sparse in the Shoup Glacier valley.

Shoup Glacier originates in the Chugach Mountains at an altitude of approximately 7,000 ft and flows 18 mi to Shoup Basin. About 1 mi from the 1990 terminus, the southwest-flowing glacier makes a 130-degree turn to the east around a bedrock peninsula and over an icefall. This bend has caused the glacier to be

"...erroneously represented upon several maps as made up of two glaciers which coalesce" (Tarr and Martin, 1914, p. 249). A broad band of morainal debris covers the western edge of the glacier, but the remaining ice is relatively clean. The glacier has a surface area of approximately 60 mi^2 and an accumulation-area ratio (AAR) of 0.61. The equilibrium line altitude (ELA) is approximately 3,400 ft. The distribution of surface area with respect to altitude is shown in figure 1.

In the early 1900's, Shoup Glacier was called "Canyon Creek Glacier" and was a source of ice for nearby Valdez and Fort Liscum (Grant and Higgins, 1913, p. 15). Many gold prospects were located in this vicinity. The Cliff Mine, the most productive mine in Port Valdez area, was located about 0.5 mi east of Shoup Bay (fig. 2) and operated from 1906 to 1915 (Johnson, 1915). Many mines were located in the Shoup Glacier valley, and a trail extended up the glacier to claims at the Cameron-Johnson Camp, Rambler Camp, and Gold King Camp (fig. 2). The latter mine was located 8 mi from tidewater, 3,750 ft above sea level on a nunatak "...rising out of Columbia Glacier" (Johnson, 1915). None of these mines are presently active.

Acknowledgments

Many thanks to Andrew Fountain (USGS), who was instrumental in obtaining funds for this phase of the project and who handled all the logistics and paperwork involved in the publication. We are indebted to Kristi Wallace who prepared all the figures and plates for publication. The authors also would like to thank Andrew Fountain, Steve Porter (University of Washington), Terry Swanson (University of Washington) and Glen Thackray (University of Washington) for constructive and helpful reviews.

BATHYMETRY

Shoup Bay was surveyed by the U.S. Coast and Geodetic Survey (1966) (now National Oceanic and Atmospheric Administration). Results from this survey were enlarged and adjusted to fit the current maps, and soundings were converted to feet and transferred to plate 1.

Soundings indicate that Shoup Bay is a steep-walled, flat-bottomed basin with a depth of approximately 200 ft. The low relief of the basin floor suggests that considerable sediment has accumulated (plate 2). The mouth of the bay is enclosed by an arcuate terminal moraine and has a maximum water depth of 15 ft (fig. 3). South of the shoal in Port Valdez, depths drop rapidly to approximately 800 ft, and bedrock may be as deep as 1,975 ft (Von Huene and others, 1967). Located 1,800 ft above the floor of Port Valdez, Shoup Bay is a hanging valley that formed during more extensive Pleistocene glaciation (Tarr and Martin, 1914).

At the head of the bay, several bedrock and sediment obstructions form a second shoal that impounds a tidal basin. In August 1982, a dory party from the USGS research vessel *Growler* collected bathymetry data in this recently exposed basin with a Ross SL600 depth recorder (plate 1). In 1990, Valdez residents John Cotter and Dave Janka (unpub.data, 1990) collected additional data in the part of the basin subsequently uncovered by the retreating glacier (plate 1). Soundings in the deepest part of the basin indicate that depths exceed 350 ft.

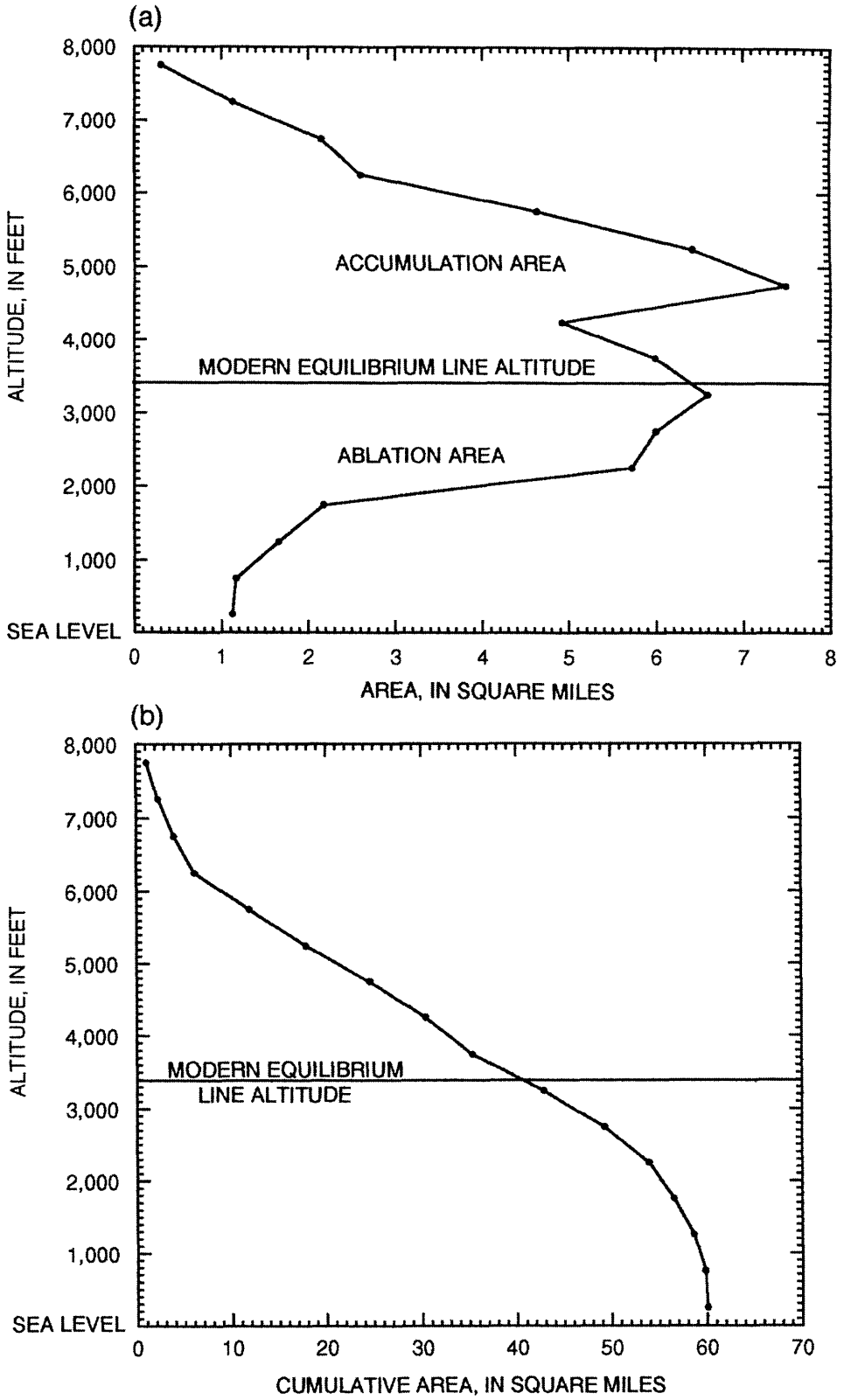

Figure 1. (a) Area-altitude graph and (b) cumulative area-altitude curve for Shoup Glacier. The equilibrium line altitude (ELA) is also shown to illustrate the division between the accumulation and ablation areas.

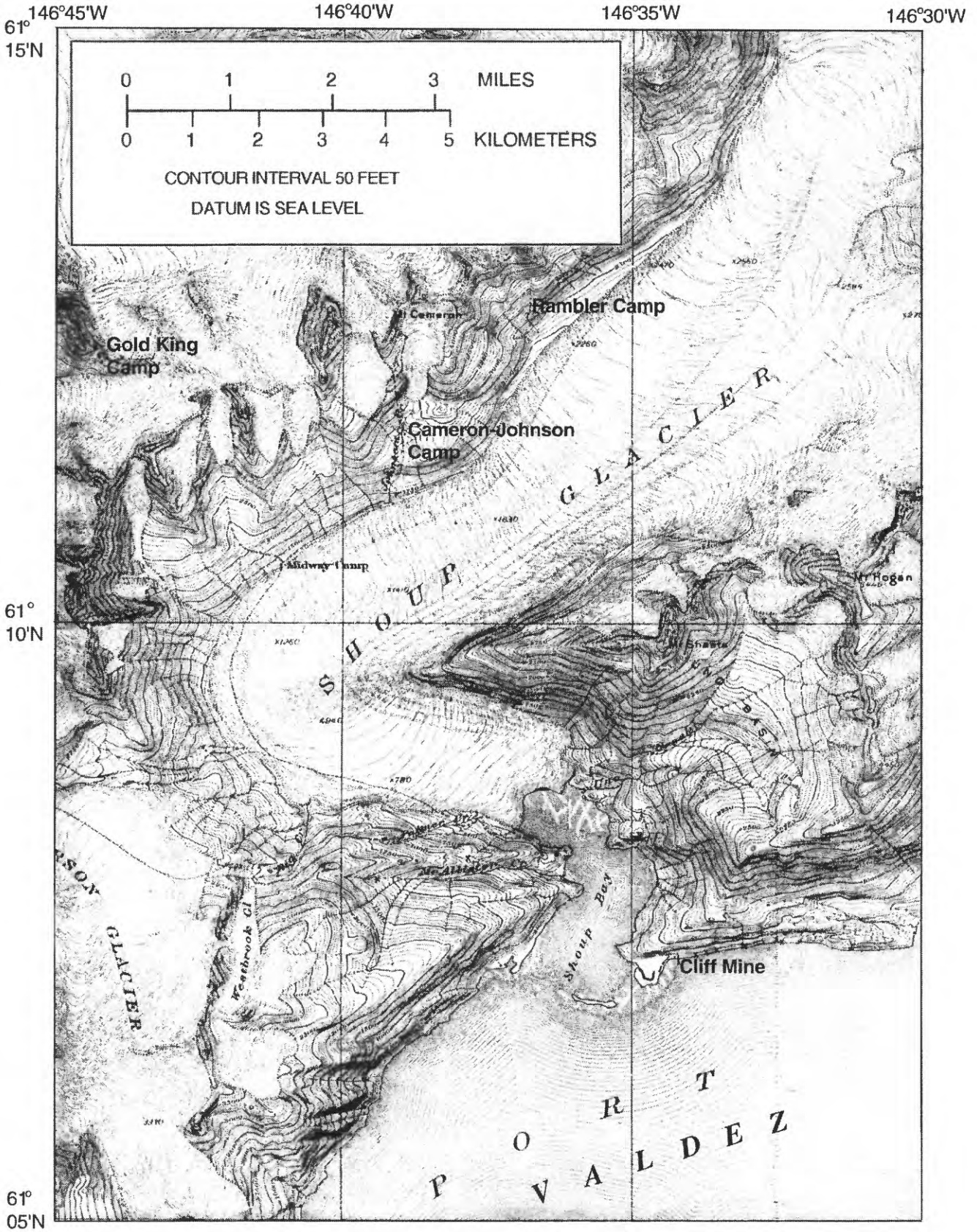

Figure 2. Topographic map of Shoup Bay and Shoup Glacier showing 1916 terminus position (from U.S. Geological Survey, 1930).

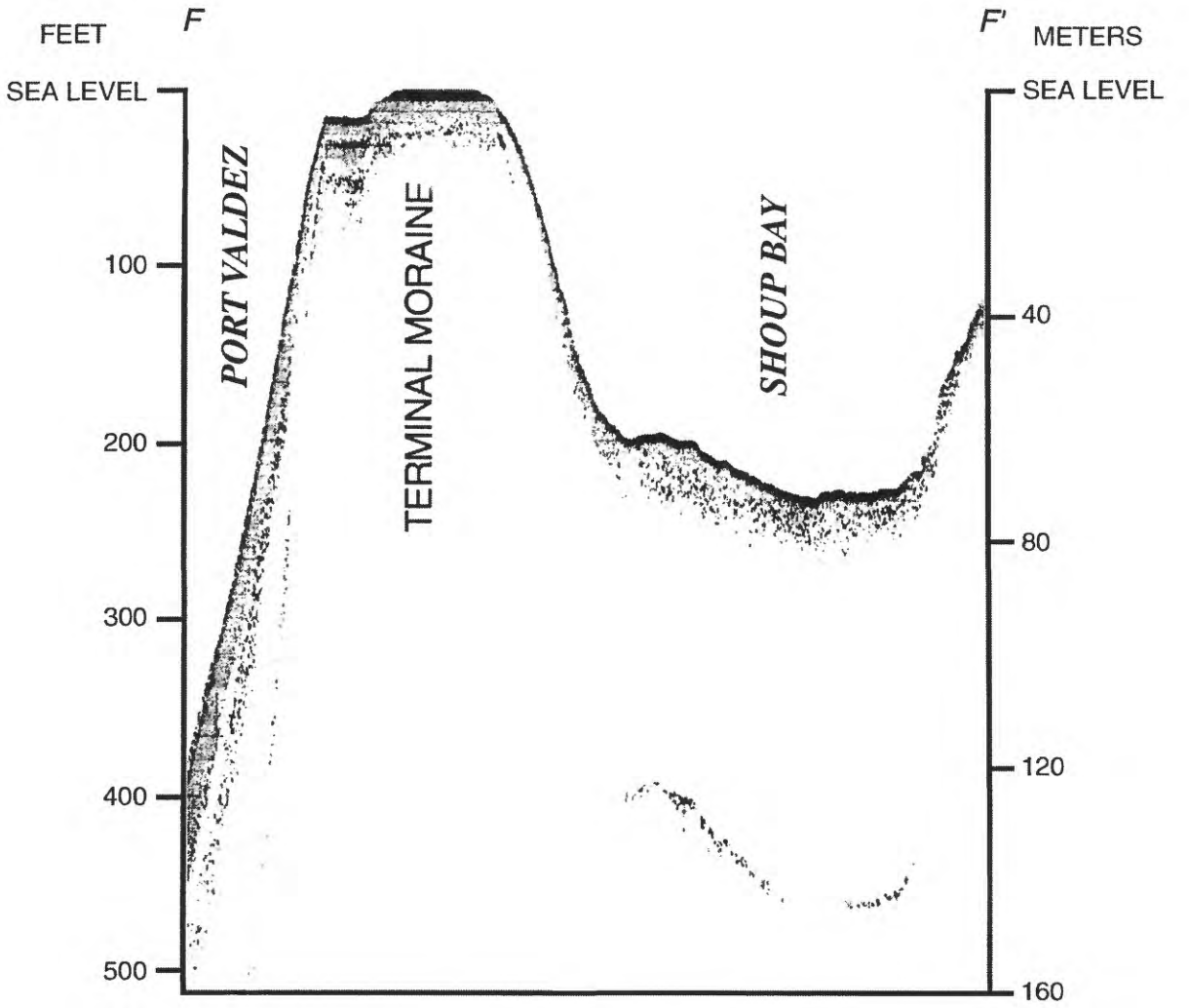

Figure 3. Depth-recorder chart showing bottom profile from Port Valdez, across the late Holocene terminal moraine, and into Shoup Bay. (The horizontal scale of the depth-recorder chart is a function of the velocity of the U.S. Geological Survey (USGS) research vessel *Growler.* Because velocity changed as the vessel crossed the moraine, the horizontal scale in not constant.) Line of section F–F' is shown in plate 2.

LATE HOLOCENE HISTORY OF SHOUP GLACIER

The morainal shoal at the mouth of Shoup Bay is inferred to mark the maximum Holocene extent of Shoup Glacier. No direct evidence indicating the age of this moraine has yet been found; however, historical records imply that the glacier has not recently reached this extended position. Although Vancouver's survey party under Lt. Whidbey sailed into Port Valdez in 1794, they failed to mention the presence of Shoup Glacier (Vancouver, 1798). More than 100 years later, Grant and Higgins (1913, p. 17) stated, "...[based on the vegetation] it seems improbable that the glacier has extended to the entrance of Shoup Bay within the last 100 years." Recent observations of vegetation cover support this conclusion. Dated fluctuations of other tidewater glaciers in the Prince William Sound area (Post, 1980d; Porter, 1989; Wiles and Calkin, 1993) indicate that Shoup Glacier may have begun advancing into

tidewater 2,000 to 1,500 years ago and stabilized at the mouth of the bay between 1,500 and 1,000 years ago. It is unknown whether the glacier would have remained extended since that time or retreated and readvanced to reach the mouth of the bay at a later date. In either case, historical and botanical evidence and thick sediment deposits in Shoup Bay imply that retreat off the shoal began sometime prior to 1750. A reconstructed profile of the late Holocene maximum of lower Shoup Glacier is shown in figure 4.

After receding off the terminal moraine, the glacier retreated 2 mi to the head of Shoup Bay. On the basis of other glaciers receding in deep water, this retreat would have been relatively rapid and may have occurred within a few decades (Post, 1980d). Following retreat, the terminus of Shoup Glacier stabilized on a bedrock shoal, where it was first described by Schrader in 1898 (Schrader, 1900). While in this stable position, the glacier built a second moraine and a proglacial outwash delta and deposited at least 100 to 200 ft of fine-grained sediment and ice-rafted debris in Shoup Bay (plate 2 and fig. 4). When observed in 1905, 1908, 1909 (figs. 5 and 6), and 1916 (plate 1 and figs. 2 and 4), the glacier was in virtually the same position as in 1898. Tarr and Martin (1914) observed "...the western half mile of the glacier ends in the bay, though in very shallow water, while the eastern quarter mile has a delta of outwash gravels and clay in front of it..." (p. 249), and "...willow, alder, and cottonwood, mature but perhaps not more than twenty to thirty years old, grow almost up to the very edge of the glacier." (p. 253). Grant and Higgins (1913, p. 17) surmised, "The glacier front

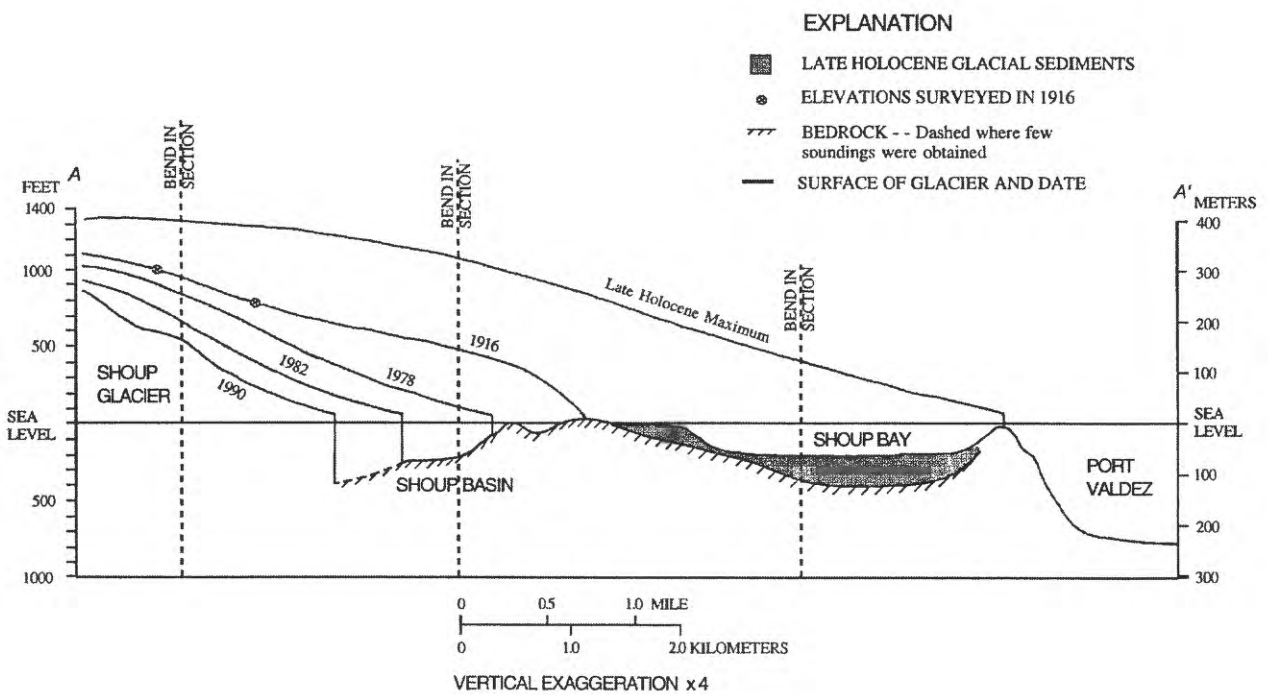

Figure 4. Longitudinal profile of lower Shoup Glacier, Shoup Basin, and Shoup Bay. Ice thickness is inferred for the late Holocene maximum and plotted for the 1916, 1966, 1978, and 1990 terminus positions on the basis of historical mapping and aerial photography. Line of section A–A' is shown in plate 2.

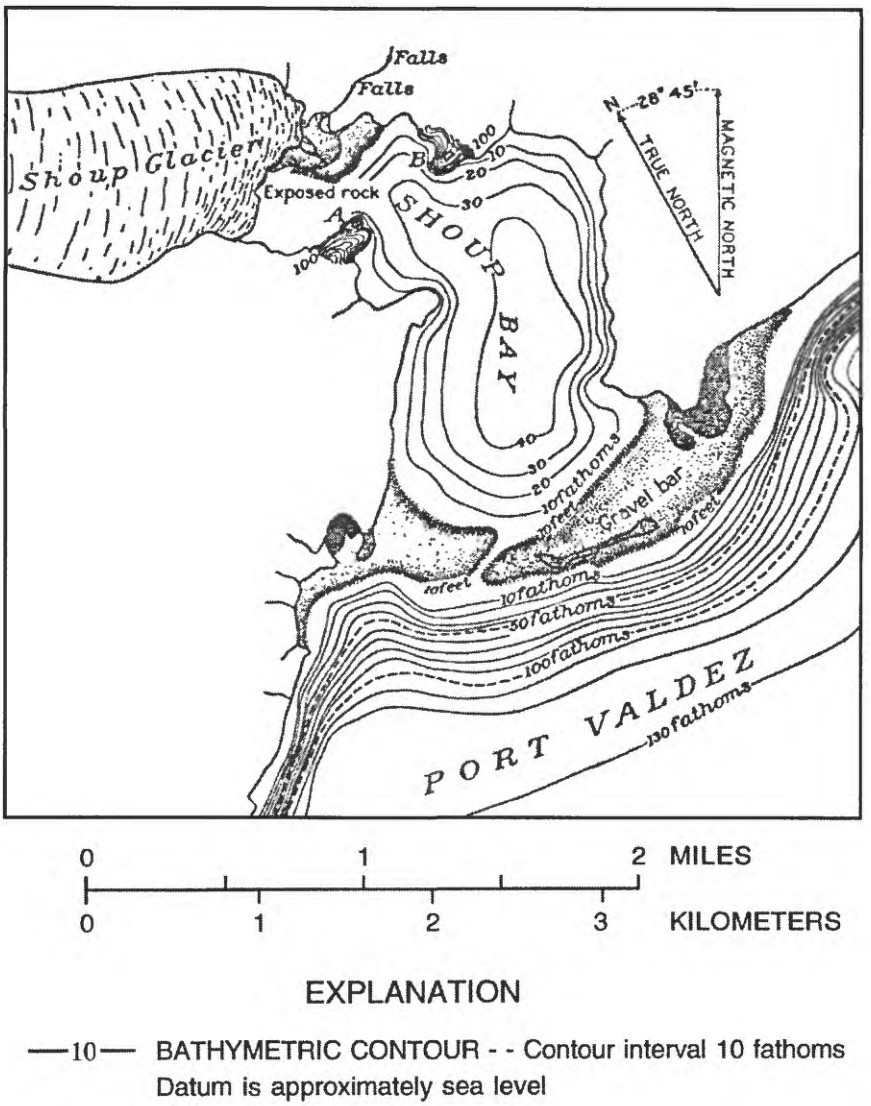

Figure 5. Bathymetric map of Shoup Bay and Port Valdez, July 16, 1909 (modified from Grant and Higgins, 1913).

is now close to its maximum extension in the last 15 and probably 50 years." The outwash delta continued to grow until the terminus only reached tidewater at high tide (Field, 1975). All geologic evidence seems to indicate that Shoup Glacier terminated in this vicinity since at least 1850.

While on the shoal, the terminus of the glacier fluctuated about 350 ft, sometimes advanced and forming push moraines (Grant and Higgins, 1913). Trimlines and survey photographs from the 1930's indicate that ice thickness was decreasing during this interval of terminus stability. According to Field (1975, p. 366), the ice surface was lowered "...on the order of 100 m. [330 ft] in the lower part of the glacier..." between 1898 and 1957.

In 1957, after more than 100 years of relative stability, the terminus again began to retreat. Once the glacier receded off the shoal and into deep water, retreat was controlled by water depth (Brown and others, 1982). The

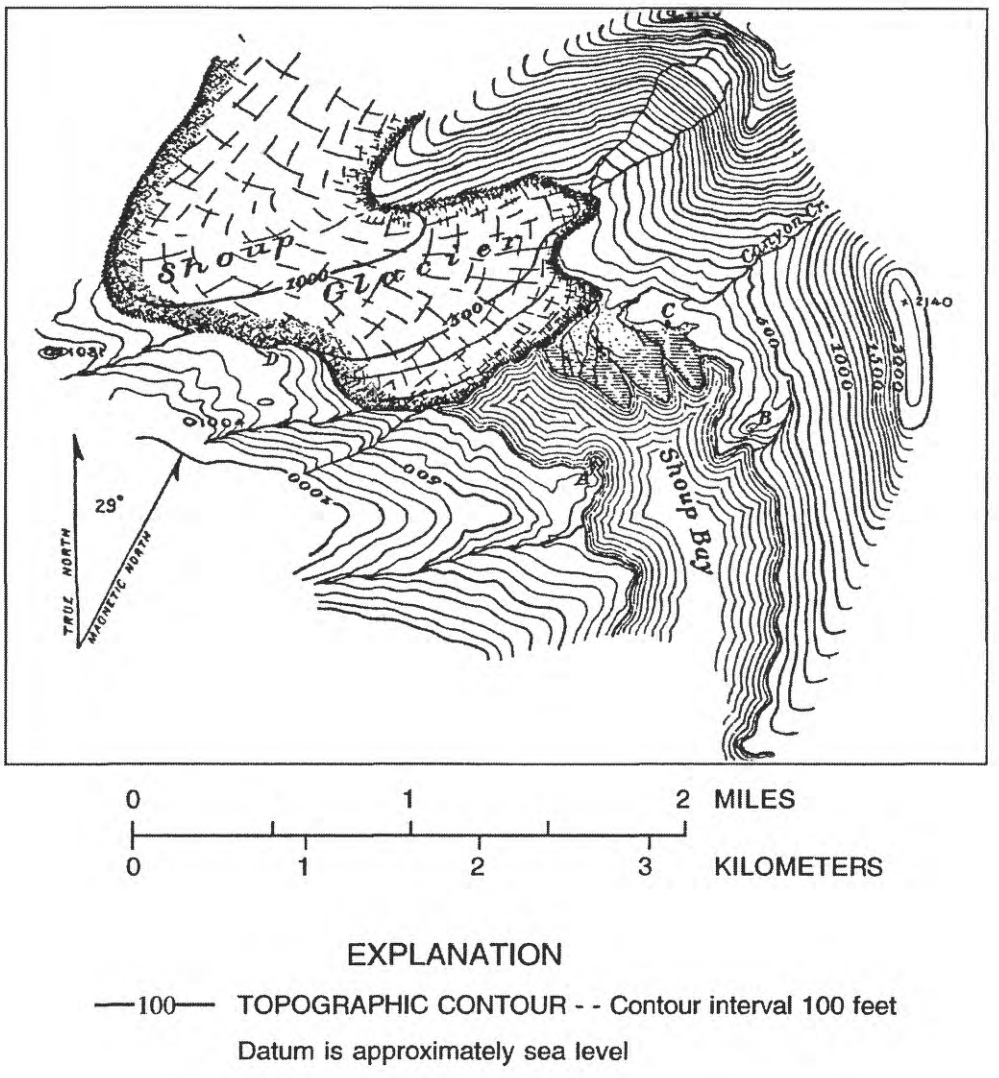

Figure 6. Topographic map of Shoup Glacier and adjacent areas, 1909 (modified from Tarr and Martin, 1914).

retreat rate increased once the terminus was in water deeper than about 35 ft (fig. 7). However, retreat rates do not correlate well with water depths across the basin, indicating that other factors affect calving rates along the terminus. Between 1957 and 1990, the glacier retreated approximately 1.3 mi, exposing a tidal basin more than 350 ft deep. Trimlines and exposed bedrock at the western base of the icefall indicate that the rate of thinning has accelerated during the last 30 years. The reconstructed profiles of lower Shoup Glacier in 1978, 1982, and 1990 are shown in figure 4.

Aerial photography reveals a series of late Holocene lateral moraine benches along the west margin of the glacier about 1.3 mi west of the 1990 terminus. These moraines may correlate with the terminal moraine at the mouth of the bay and the 19th-century moraine.

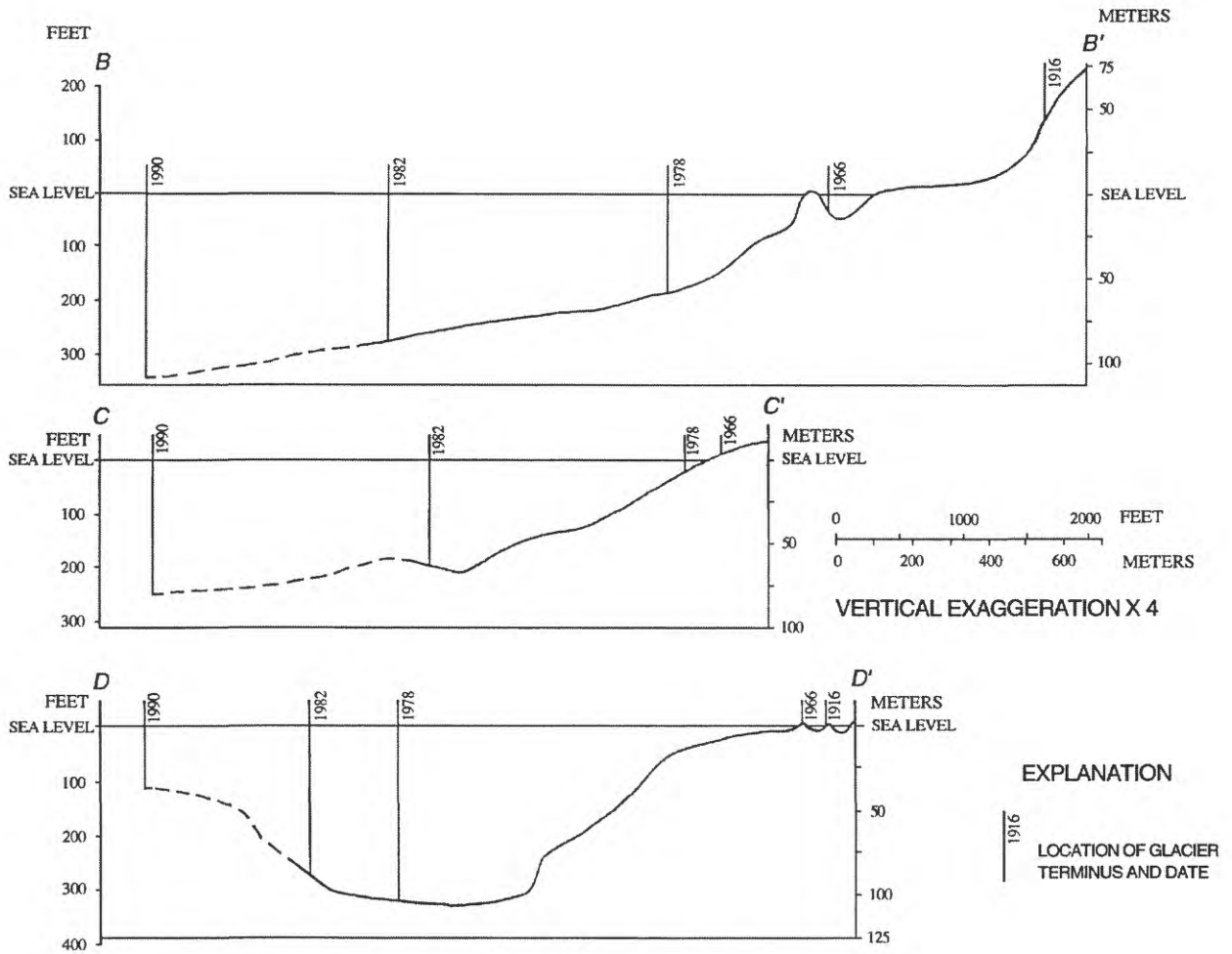

Figure 7. Sections across the north (*B–B'*), central (*C–C'*), and south (*D–D'*) regions of Shoup Basin showing location of glacier terminus. Bottom profile is dashed between 1982 and 1990 terminus position due to limited data. Lines of section are shown in plate 2.

Since Shoup Glacier has retreated off the morainal shoal, most of the sediment produced by the glacier has been deposited in Shoup Basin. Lateral streams on the southwestern side of the glacier are discharging a large percentage of the debris entering the basin. Because little morainal debris is visible on the glacier, sedimentation of ice-rafted debris is presumably low. Sounding lines obtained in 1982 reveal irregular bottom topography (fig. 8), implying that very little sediment has accumulated in the deepest area of the basin since the ice retreated.

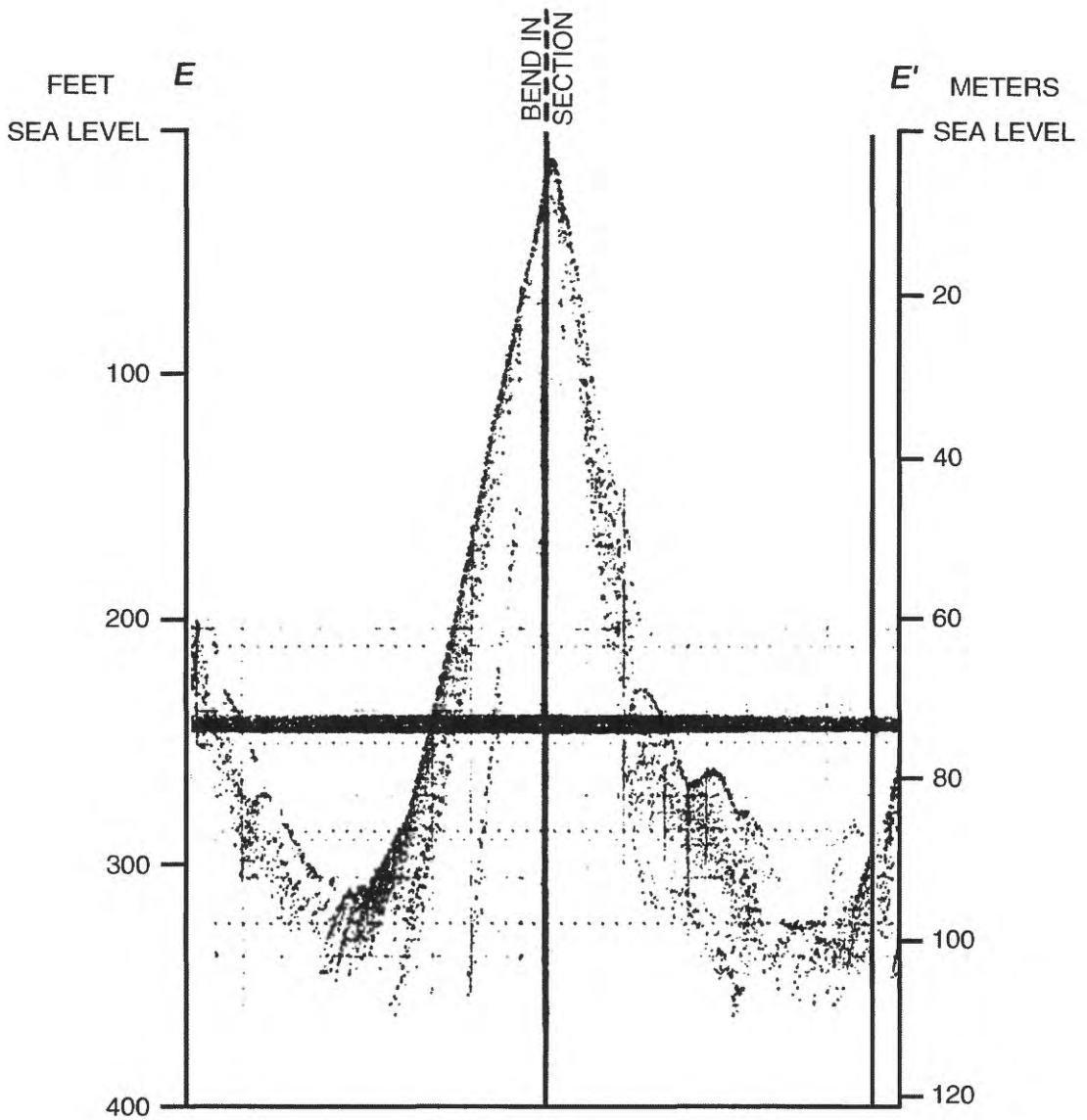

Figure 8. Depth-recorder chart showing bottom profile across Shoup Basin. (The horizontal scale of the depth-recorder chart is a function of the velocity of the U.S. Geological Survey research vessel *Growler.* Because velocity was variable, the horizontal scale is not constant.) Line of section *E–E'* is shown in plate 2.

CONCLUSIONS

If present conditions persist, Shoup Glacier will likely continue to retreat until the terminus reaches the head of Shoup Basin. Based on the topography of the glacier, recession to the head of tidewater will be less than about 0.5 mi west of the 1990 terminus. At the current rate of retreat (200 ft/yr) Shoup Glacier should stabilize shortly after 2000. At that time, the AAR of the glacier will be about 0.65, which indicates a state of equilibrium. Readvance into the basin is unlikely, for this would require a more positive mass balance that presently exists (that is, lowering the ELA) and the construction of a terminal moraine to minimize calving.

REFERENCES CITED

Brown, C.S., Meier, M.F., and Post, Austin, 1982, Calving speed of Alaska tidewater glaciers, with application to Columbia Glacier: U.S. Geological Survey Professional Paper 1258-C, p. C1-C13, 4 pls.

Field, W.O., 1975, Glaciers of the Chugach Mountains, *in* Field, W.O., ed., Mountain glaciers of the Northern Hemisphere, vol. 2: Hanover, N.H., U.S. Army Cold Regions Research and Engineering Laboratory, p. 299-492.

Grant, U.S., and Higgins, D.F., 1913, Coast glaciers of Prince William Sound and Kenai Peninsula, Alaska: U.S. Geological Survey Bulletin 526, 75 p.

Johnson, B.L., 1915, The gold and copper deposits of the Port Valdez district, *in* Brooks, A.H., ed., Mineral resources of Alaska—Report on progress of investigations in 1914: U.S. Geological Survey Bulletin 622, p. 140-188.

Porter, S.C., 1989, Late Holocene fluctuations of the fiord glacier system in Icy Bay, Alaska, U.S.A.: Arctic and Alpine Research, v. 21, p. 364-379.

Post Austin, 1980a, Preliminary bathymetry of Aialik Bay and neoglacial changes of Aialik and Pederson Glaciers: U.S. Geological Survey Open-File Report 80-423, 1 sheet.

Post Austin, 1980b, Preliminary bathymetry of Blackstone Bay and neoglacial changes of Blackstone Glacier: U.S. Geological Survey Open-File Report 80-418, 2 sheets.

Post Austin, 1980c, Preliminary bathymetry of McCarty Fiord and neoglacial changes of McCarty Glacier: U.S. Geological Survey Open-File Report 80-424, 4 sheets.

Post Austin, 1980d, Preliminary bathymetry of Northwestern Fiord and neoglacial changes of Northwestern Glacier: U.S. Geological Survey Open-File Report 80-414, 2 sheets.

Schrader, F.C. 1900, A reconnaissance of a part of Prince William Sound and the Copper River District, Alaska, *in* Explorations in Alaska in 1898: U.S. Geological Survey 20th Annual Report, 1898-99, Part 7, p. 341-423.

Tarr, R.S., and Martin, Lawrence, 1914, Alaskan glacier studies of the National Geographic Society in the Yakutat Bay, Prince William Sound, and lower Copper River Regions: Washington, D.C., National Geographic Society, 498 p.

U.S. Coast and Geodetic Survey (now National Oceanic and Atmospheric Administration), 1966, Alaska, Prince William Sound, Port Valdez: National Oceanic and Atmospheric Administration, Register No. H-8900, 1 sheet, scale 1:20,000.

U.S. Geological Survey, 1930, Alaska, Prince William Sound Region, Valdez and Vicinity: U.S. Geological Survey, Alaska Sheet #29, 1 sheet, scale 1:62,500.

Vancouver, George, 1798, A Voyage of discovery to the North Pacific Ocean and round the world, vol. 3: London, (facsimile edition reprinted by N. Isreal, Amsterdam, 1967), 506 p.

Von Huene, Roland, Shor, G.G., Jr., and Reimnitz, Erk, 1967, Geological interpretation of seismic profiles in Prince William Sound, Alaska: Geological Society American Bulletin, v. 78, p. 259-268.

Wiles, G.C., and Calkin, P.E., 1993, Neoglacial fluctuations and sedimentation of an iceberg-calving glacier resolved with tree rings (Kenai Fjords National Park, Alaska): Quaternary International, v. 18. p. 35-42.