Megafloods on the Santa Cruz River, Southern Argentina

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49° 48’

50° 12’

Lago Argentino

Condor Cliff

Cerro Fortaleza

Río Santa Cruz

Isla Pavón

ATLANTIC OCEAN

70° 00’

69° 00’

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ABSTRACT

The Santa Cruz River basin of Patagonia in southern Argentina displays numerous landforms that together indicate a landscape severely impacted by more than one Pleistocene megaflood. In the upper drainage basin (longitude 71.6 to 71.3w), paleolacustrine landforms (raised beaches, bars, spits, lagoons and deltas) and stratigraphy (widespread silt and clay deposits) demonstrate that "Paleolago Argentino" was a large, 75-m-deep, glacial lake at 250 m elevation above present sea level. These ancient lakes were up to 70 m higher than present Lake Argentino. The variety of lacustrine landforms can be seen in aerial view, but such landforms are best appreciated individually on the ground in the field.

Evidence in the upper Santa Cruz River basin indicates that multiple Pleistocene glacial lakes existed upon this southern Patagonian landscape. Lake evidences are displayed especially well at longitude 71.6 to 71.3 west. Paleolacustrine landforms (raised beaches, bars, spits, lagoons and deltas) and stratigraphy (widespread silt and clay deposits) demonstrate that "Paleolago Argentino" was a large, 75-m-deep, glacial lake at 250 m elevation above present sea level. These ancient lakes were up to 70 m higher than present Lake Argentino. The variety of lacustrine landforms can be seen in aerial view, but such landforms are best appreciated individually on the ground in the field.

Lacustrine landforms are juxtaposed upon the terminal moraine complex from the Arroyo Verde glaciations. Moraines acted as the dam, or likely, multiple dams for great glacial lakes. The basin upstream of the moraines was occupied by lakes as the ice retreated. Breached Arroyo Verde 2 terminal moraine (longitude 71.2 west) is bounded downstream by a spillway that is entrenched in Arroyo Verde proglacial deposits.

Breached Arroyo Verde 2 terminal moraine (longitude 71.2w) is bounded eastward (downstream) by a spillway that is 2.5 km wide and over 90 m deep. The spillway (longitude 71.1’w) is entrenched in Arroyo Verde glacial and proglacial deposits. Flood gradients within the spillway were 4 m per km (*s* = 0.004), high enough to allow supercritical flow. Spillway roughness did not suppress supercritical flood flow. In situ reworked glaciofluvial deposits occupy that former spillway during the present lowstand of the landscape and the river. Floods of various discharges have winnowed fine sediment from this 2.5-km-wide channel leaving the coarse lag deposit.

Eastward of the spillway, within the widening valley, paired terraces are covered by abundant "gravel hills" (longitude 71.1 to 70.7 west). "Gravel hills" were mapped by Strelin and Malagnino (1996) along 20 km of the river terrace surfaces west of Condor Cliff. These hills are composed of 0.3-m-diameter boulders displaying dune bedforms with lengths of more than 10 m and heights of up to 3 m. Andrea Pacifici (2009) described these landforms as trains of large straight-crested fluvial dunes beneath Condor Cliff (longitude 70.7 west) comparing them to dunes on Mars. Larger dunelike bedforms lie on channel margins or on elevated terraces within the lower Santa Cruz River valley (longitude 70.1 to 69.0 west). A large transverse bar within the floodplain at Rincon Grande (longitude 70.1 west) may represent supercritical flow and upstream accretion in the fashion of an antidune. Otherwise, as described by Carling et al. (2009), boulder dunes are anticipated terrace bedforms deposited by subcritical flow, especially in the waning stages of megafloods. Oblique view below shows the straight-crested dunes described by Pacifici (2009) at longitude 70.9 west on the higher terrace on the south side of the Santa Cruz River. Here is a train of dunes, each boulder dune having a wave length of ~60 m.

One megaflood overtopped the eastward-diminishing basalt cliff on the north side of the channel at Rincon Grande (longitude 70.1 west). Here the megaflood overtopped the basalt cliff depositing cobbles on top of the basalt platform. The highest elevation of the spillover deposit indicates the depth of the biggest megaflood. Polymictic assemblages of cobbles occur at elevation up to 210 m above present sea level, 130 m above today’s adjacent river. Higher basalt platforms do not have polymictic cobble deposits. The ramp of flood cobbles on the slope at the river bend transitions with increasing elevation to the spillover deposit. These spillover cobbles indicate that one megaflood was 100-m deep and 10-km wide. Flood discharge can be estimated from the Manning Equation using channel cross-sectional dimensions, channel roughness, and channel slope. The Manning parameters at Rincon Grande allow us to estimate this megaflood’s mean flood flow velocity at over 5 m/sec and discharge at 5 million m³/sec. This discharge estimate compares well to a similar discharge estimate obtained from the megaflood spillway where the flow velocity and channel gradient were much higher. Spillover deposits might be expected at the "hydraulic jump" where supercritical flow transitions abruptly to subcritical flow.

The distal path of megafloods includes enormous depositional landforms near the modern Santa Cruz River estuary. Here is where aggradation produced some of the thickest deposits within the megaflood delta. Upstream at the town of Piedra Buena, dunes up to 20 m long and 2 m high occur on top of a terrace 40 m above the present river level (longitude 69.4 to 69.3w). The biggest boulders up to 1.7 m diameter on the high Piedra Buena terrace were likely ice-rafted during a megaflood. Multiple terrace levels with coarse boulders and/or dune or antidune bedforms favor multiple megafloods. Depositional landforms containing boulders indicate megafloods with enormous bed shear stresses. Froude numbers of 0.8 to 1.2, and velocities exceeding 5 m/sec.

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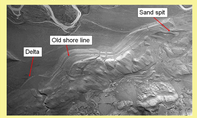
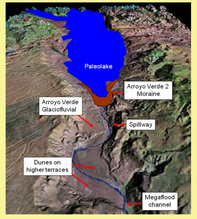
1

PLEISTOCENE LAKES



2

BREACHED MORAINE DAMS

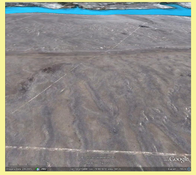


3

SPILLWAY

4

MEGAFLOOD BEDFORMS

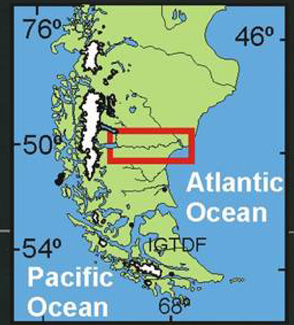


5

SPILLOVER DEPOSIT

6

DELTA DEPOSITS



0 50 km