Enduring legacy of toxic fans via episodic redistribution of California Gold Rush debris

G.K. Gilbert

Michael Bliss Singer¹,²

¹Department of Earth & Environmental Sciences, University of St Andrews
²Earth Research Institute, UC Santa Barbara

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2.5 x 10^6 m^3 of sand arrived in a single flood in 1986 and buried a rice field
Romantic vision of the California Gold Rush

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The ‘real’ California Gold Rush

1852-1884: Industrial process of hydraulic gold mining reshaped foothills of the Sierra Nevada

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~1.1 x 10^9 m^3 of sediment displaced by hydraulic mining

~1/3 as much as 1980 Mount St. Helens eruption

~7 times the volume excavated for the Panama Canal
The Yuba Fan
Length: ~40 km
Area: 120 km²
Sediment volume: $252 \times 10^6$ m³
Sediment delivery from mines created downstream problems for agriculture and navigation.

Mining was stopped in 1884 and further study was commissioned to assess mining impacts and to regulate streams affected hydraulic mining sediment.
In 1917, G.K. Gilbert showed that the riverbed elevation increased dramatically due to mining, but then progressively declined down to its former base level.

This led many to believe that the mining sediment was exhausted from the system.
B. THE "NARROWS" OF YUBA RIVER IN 1905.

The Geological Survey's gaging station is at this point. A short distance above it the deposit was sounded in 1899 and found to have a depth of 85 feet. (~25 m)
Historical terraces are the most prominent and enduring modern legacy of the mining period.
Centennial change: Longitudinal profiles (1906 and 1999)

Aggradation was succeeded by systematic degradation. Recent incision rates are slower than in the early 20th C.
Auriferous Eocene Gravels

Mercury

Up to $4 \times 10^6 \text{ kg Hg}$ lost to mining
(Alpers & Hunerlach, 2005)

Hg is 3rd on ATSDR’s 2012 toxic substance priority list

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Chinook salmon populations

The number of chinook salmon counted in the Sacramento-San Joaquin river system last fall was higher than in previous years but still below the historical average.

Historical average: 226,600

2002: 769,868
2010: 163,181

Sources: California Department of Fish and Game, National Oceanic and Atmospheric Administration; illustration from California Department of Fish and Game

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Waterfowl Flyways

Bancroft Library

dfg.ca.gov

California Waterblog
Upstream historical fan sources are highly contaminated (background HgT < 0.08 $\mu$g g$^{-1}$)
Downstream progradation of historical deposits and lowland deposition of less contaminated (diluted) sediments.
Systematic transfer of hydraulic mining sediment

What is the mechanism for this large-scale mass transfer?

Singer et al., PNAS, 2013
Large floods redistribute sediment basinwide

Extreme floods capable of eroding terraces occur about once a decade.

Singer et al., PNAS, 2013
Most exported Hg is stored in lowlands upstream of the SF Bay-Delta. It manifests as a ~70-km-long swath of contamination from Yuba Fan into the Central Valley.

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Climate change impacts on hydrology:
Phase shifts in precipitation + ‘atmospheric rivers’

Regional trends toward smaller ratios of snow to total precipitation.
Increased frequency of ‘atmospheric rivers’-high concentrations of near-surface water vapor above the Pacific Ocean.
Hydrologic manifestation of climate change?

Extreme floods rise and fall more slowly in the last several decades.

Singer et al., PNAS, 2013

Climate change could bring higher Q and thereby create a heavy tailed distribution of sediment yield.
Lowland floodplains are potential hotspots for Hg methylation. Sierran Hg is associated with sulfide minerals, prone to oxidation (to mercury sulfate) during transport.

Wetting and drying may stimulate resident sulfate-reducing bacteria to methylate Hg near the sediment-water interface at very high rates, posing risk to lowland ecosystems.
Conclusions

• Vertical incision has slowed and has been replaced by event-based terrace erosion.

• This process stage of fan evolution sustains the evacuation of legacy sediment by floods, delivering toxic sediment downstream into sensitive lowlands.

• The corresponding risks to ecology/humans depend on the morphodynamic stage of anthropogenic fan evolution, synergistically coupled to the distribution of extreme floods.

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