

Mercury contamination of active channel sediment and floodplain deposits from historic gold mining at Gold Hill, North Carolina, USA

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Abstract A reconnaissance investigation of mercury contamination associated with historic gold mining in North Carolina, USA, revealed high concentrations of mercury in channel and floodplain sediments downstream from the Gold Hill mining district. The most intense period of mining activities in this region occurred in the 1840s and 1850s when mercury amalgamation was used to recover fine gold particles from milled ore. This paper evaluates mercury concentrations measured in active channel sediments and two cores recovered from historic floodplain deposits of the lower portion of Dutch Buffalo Creek. Mercury concentrations in these cores range from 0.01 to 2.2 mg/kg, with maximum concentrations more than 35 times background levels. A later peak in copper concentrations is associated with the operation of a large copper mine between 1899 and 1906. Following the most intense periods of mining, both mercury and copper concentrations decrease upcore to constant levels of about twice pre-mining background concentrations. Results suggest that vertical trends in mercury and other trace metals provide a useful tool for interpreting rates of historic floodplain sedimentation in the Piedmont of North Carolina.

Keywords Mercury · Gold mining · Floodplains · Sedimentation · Contamination

Introduction

The first documented discovery of gold in the USA occurred in 1799 along Little Meadow Creek in Cabarrus County, North Carolina (Pardee and Park 1948). This initiated the gradual exploration and development of gold mining throughout the southern Piedmont region along a belt that extended from Virginia to Alabama. The nation's first gold rush also began in North Carolina and lasted from about 1830 until the start of the Civil War (Knapp and Glass 1999) (Fig. 1). After the war, mining resumed at moderate levels that peaked in 1887 and then declined until World War I, after which mining activities declined significantly (Knapp and Glass 1999).

An integral part of the mining operations involved the extensive use of mercury to recover gold through the amalgamation process (Callahan et al. 1994). The procedure involves mixing ore containing fine gold particles with mercury. The mercury adheres to the gold creating a pasty amalgam that is heated to vaporize the mercury, leaving the gold behind. Mercury contamination of stream sediments caused by gold mining operations has been reported on a worldwide basis (e.g., Leigh 1994, 1997; Domagalski 1998; Miller et al. 1998, 2003; Ambers and Hygelund 2001; Laperdina 2002). Although mercury has been well known as an environmental pollutant for several decades, contamination caused by anthropogenic releases to the environment is a growing concern (US EPA 2003). Nriagu (1994) showed that the use of mercury amalgamation in gold and silver mining in the Americas has led to the release of unprecedented amounts of mercury into the environment, yet relatively little is known about the environmental impacts, long-term dispersal, and ultimate fate of this contaminant (Leigh 1997; US EPA 2003; Hylander and Goodsite 2006). Mercury is a major ecological and

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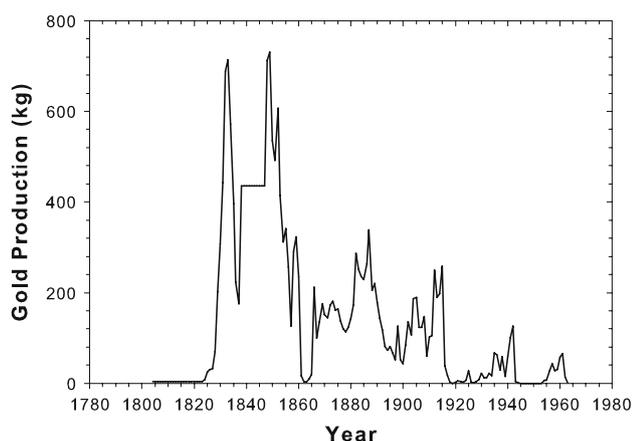


Fig. 1 Reported production of gold in North Carolina (from Knapp and Glass 1999)

health concern because it can be transformed by biological processes in aquatic environments into methylmercury which is highly bioavailable and can enter the food chain to be bioaccumulated and biomagnified in humans and biota (Beckvar et al. 1996). High concentrations of mercury in humans adversely affect the central nervous system and are particularly acute in prenatally exposed infants (Clarkson 2002). Although mercury is the most common contaminant of aquatic ecosystems worldwide (Krabbenhoft 2004), its sources, pathways, and toxicity-controlling processes are complex and relatively poorly understood (when compared to, for example, lead) (US EPA 2003; Hylander and Goodsite 2006). The purpose of this paper is to report the results of a reconnaissance investigation of mercury contamination in the Gold Hill mining district, one of the most intensely mined districts in the southern Piedmont gold belt.

Although North Carolina led the nation in gold production until 1848 and produced more gold than any other state in the southern Piedmont gold belt (Knapp and Glass 1999), few studies have investigated the environmental impacts of this mining. Both Kimberley et al. (1984) and Callahan et al. (1994) reported elevated mercury levels in some fluvial sediments in gold mining areas in North Carolina, but neither study examined mercury storage in floodplain deposits. Nevertheless, Callahan et al. (1994) reported concentrations as high as 7.4 mg/kg in active channel sediment and 4.9 mg/kg in moss, suggesting that past mining activities remain a significant source of mercury to the environment. The only other work on mercury contamination from gold mining in the southern Piedmont region was Leigh's (1994, 1997) study of the downstream dispersal and storage of mercury in floodplain sediments from watersheds impacted by hydraulic mining in the Dahlonega mining district of Georgia. He found that the

highest mercury levels were found in very close proximity to mine sources and decreased rapidly downstream.

Study area

The Gold Hill mining district is located in southern Rowan and northern Cabarrus counties in the headwaters of Little Buffalo Creek (39 km²), a tributary to Dutch Buffalo Creek (254 km²) (Fig. 2). The Dutch Buffalo watershed lies within the gently rolling terrain of the Piedmont province, with elevations ranging from 140 to 270 m. The watershed is underlain by two gold-bearing terranes that contained the state's largest and most productive gold mines, the meta-volcanic and metasedimentary rocks of the Carolina slate belt in the east and the igneous intrusive rocks of the Charlotte belt in the west (Pardee and Park 1948; Carpenter 1976; Knapp and Glass 1999). The Gold Hill fault forms the contact between the Charlotte belt and the Carolina slate belt, and most of the gold-bearing deposits occur in chlorite-sericite phyllite east of the fault (Carpenter 1976). The principal ore minerals often present are chalcopyrite and pyrite with galena, sphalerite, chalcocite, and bornite (Carpenter 1976). The lodes are typically weathered to depths of 15–30 m (Pardee and Park 1948). In addition to gold, a significant amount of copper was produced (Pardee and Park 1948). Europeans settled in this area in the mid-1700s (Merrens 1964; Powell and Lefler 1973), and at the time of the initial gold mining activities, this land was occupied mainly by farmers engaged in subsistence agriculture (Knapp and Glass 1999).

Mining history

Exploitation of the Gold Hill district did not take place until 10 to 15 years after the gold rush began in the remaining states, but Gold Hill soon became the state's leading mining district and a major supplier to the US branch mint in Charlotte, North Carolina (Knapp and Glass 1999). Most historical accounts of mining in the district establish the discovery of the principal veins in 1842 (Nitze and Wilkens 1897; Laney 1910; Pardee and Park 1948; Carpenter 1976; Knapp and Glass 1999).

The miners, many of whom were veterans of the gold boom in the Charlotte region during the 1820s and 1830s, were experienced in techniques used in excavation and extraction associated with deep mining such as the use of gunpowder, railroad carts to move ore from underground, and mercury for extracting fine gold from milled ore (Knapp and Glass 1999). Nevertheless, early mining practices at Gold Hill were very rudimentary (e.g., mine shafts were little more than open pits), and pumping

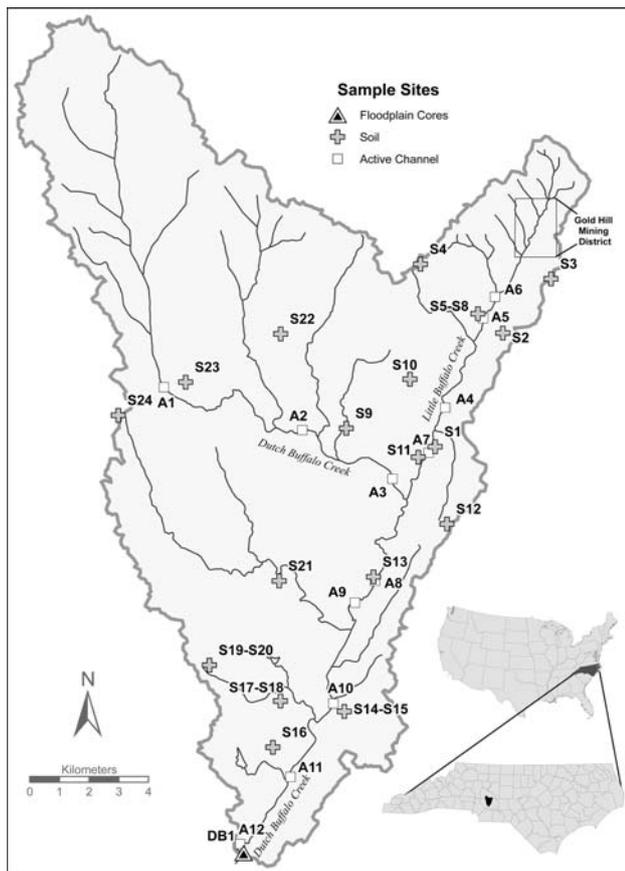


Fig. 2 Map of study area showing location of sample sites

techniques were so crude that little of the early extraction took place below the water table (Knapp and Glass 1999). Knapp and Glass (1999, p. 75) reported that a visitor to the site in 1844 observed “almost the whole surface of a ridge, some one and a half or two miles in extent, torn up by the pick and shovel of the miner.” Mining disturbances of this magnitude greatly reduced the integrity of surface soils and increased the delivery of sediment to Little Buffalo Creek by soil erosion, gullyng, and mass wasting. Excavations such as these are likely to have introduced pulses of sediment containing large amounts of mercury and copper to stream systems shortly after the onset of mining in the area in 1842. Increased sediment delivery related to mining activities was accompanied by accelerated erosion and sedimentation associated with land clearing and agricultural activities during settlement of the region.

The date that mercury amalgamation was first used in North Carolina is uncertain. In the early days, farming and gold ‘digging’ went hand in hand such that farm laborers turned to the stream bottoms during periods of inactivity (Nitze and Wilkens 1897). After placer deposits had been exhausted, the miners turned their attention to the hillsides where they sank pits and continued their primitive washing

of the diggings (Knapp and Glass 1999). These part-time miners were unlikely to have been able to afford mercury and certainly did not use it in large quantities. The use of mercury in significant amounts probably occurred after the easily acquired nuggets washed from placer deposits and surface soils were exhausted. Chilean mills were required to pulverize the vein ore containing finely disseminated gold, and mercury was used to coat the bottoms of both the Chilean mills and log rockers to amalgamate the gold (Knapp and Glass 1999). Historical accounts indicate that much of the mercury used in amalgamation was lost. For example, Emmons (1856, p. 156) reported that “On inspecting these operations when going on it is impossible to resist the conclusion that much of the gold is wasted along with the mercury.” Nitze and Wilkins (1897) estimated that the amalgamation methods used allowed as much as two-thirds of the gold to be lost with the tailings. By the mid-1850s large mining companies were using steam-powered Cornish pumps and Chilean mills, whereas small independent operators used horse- or water-powered mills to regrind and rewash waste from the larger companies (Knapp and Glass 1999). Gold Hill experienced its greatest period of productivity between 1853 and 1858, a level it never recaptured following a dramatic decline in 1859 and complete closure for the duration of the Civil War.

The mines were slow to restart after the war, and the use of mercury declined for several reasons in the 1870s and 1880s. First, the overall intensity of the mining activity decreased as much as the easily obtained gold was gone. Second, gold was more easily recovered by amalgamation above the water table where the sulfide minerals were weathered. As the mines became deeper, the miners encountered ores with a higher sulfide (and copper) content that were generally ignored as too difficult to process by amalgamation and ultimately too costly to remove the gold (Laney 1910). As the use of mercury decreased in the 1880s, interest in copper associated with sulfide ores increased. From 1899 until the mine’s closure in 1906, the Union Copper Mine produced large amounts of copper that was shipped to Perth Amboy, New Jersey, for smelting.

Methods

We chose to focus our attention on a rapid, watershed-wide reconnaissance sampling to determine mercury concentrations in soils (establishing background levels) and active channel bar sediments to assess the degree with which mercury is being remobilized from storage in floodplain deposits (Fig. 2). We restricted detailed stratigraphic analysis of floodplain deposits to two cores at the basin outlet (Fig. 3).

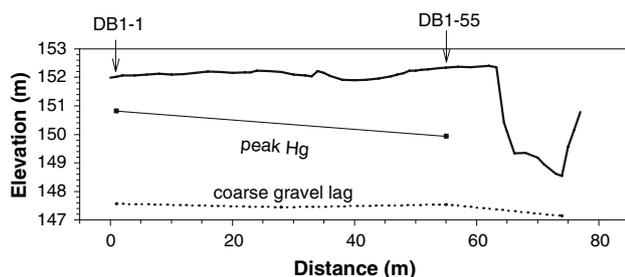


Fig. 3 Floodplain surface profile and key stratigraphic markers at site DB1

The assessment of background concentrations used 25 samples collected from soils throughout the watershed at sites not affected by mining or ore-processing activities (Fig. 2). Six of the samples were obtained from exposed B horizons while the remaining consisted of eroded A horizons. These samples were used to define the relative enrichment levels of the active channel and floodplain sediments.

A total of 36 active sediment samples were collected for physical and geochemical analysis from 12 reaches in the Dutch Buffalo watershed: four from Little Buffalo Creek below Gold Hill; three from the upper portion of Dutch Buffalo Creek which does not drain any significant gold mining areas; and five from the lower portion of Dutch Buffalo Creek below its confluence with Little Buffalo Creek. Grab samples were collected from just above the low water line during base flow on the tail ends of alternate or point bars where finer sediment sizes tend to accumulate. These deposits were recently deposited by in-channel flows and so it is assumed that the geochemical information provided by these samples reflect present-day (June 2006) conditions. In order to obtain representative information on the geochemical signal at the site, three samples were collected from three different bar tails over a reach length of 150–300 m. Samples were placed in plastic freezer-type bags and labeled in the field.

The floodplain cores collected at the basin outlet were located above the confluence of Dutch Buffalo Creek and the Rocky River, about 25 km downstream from Gold Hill (Fig. 2). The first core (DB1-55) was taken from the floodplain about 8 m from the channel bank (Fig. 3) using a 5-cm diameter, 40-cm long AMS split barrel core. This core reached a maximum depth of 480 cm and produced 53 samples. The upper part of the core was cut in 5-cm intervals or at obvious stratigraphic breaks. We increased the sampling interval to 15 cm and then 30 cm in the lower part of the core to reduce the number of samples. In order to provide some information on lateral variability, a second core (DB1-1) was collected about 60 m from the bank in a low terrace using a 2-cm diameter Oakfield-type soil probe.

The Oakfield sampling generally required longer sampling intervals (10–20 cm at stratigraphic breaks) to collect enough sediment for lab analysis. This second core reached a depth of 298 cm and produced 20 samples. Samples were placed in plastic freezer-type bags and labeled in the field.

Particle size and organic matter content were measured for all samples in the Geomorphology Laboratory at Missouri State University. Samples were pre-treated by oven drying at 60°C, disaggregated with mortar and pestle, and passed through a 2 mm sieve to remove macro-organic fragments and any small amounts of gravel contained in the samples. For core samples, the hydrometer method was used to determine the percentages of sand, silt, and clay (<4 µm) (Gee and Bauder 1986). The sand percentage (>63 µm) was determined for the active channel samples using a Sonic Sifter. Organic matter was determined for the active channel and core samples by loss-on-ignition at 600°C for 7 h.

The geochemical analyses were completed by a private commercial laboratory (ALS Chemex, Sparks, NV, USA) using an aqua regia extraction (hot 3:1 nitric–hydrochloric acids) for 34 elements. Inductively coupled plasma-atomic emission spectroscopy (ICP-AES) was used to determine concentrations for all elements except mercury which was analyzed by cold vapor atomic absorption spectroscopy (AA). The lower limit of detection for mercury was 0.01 mg/kg (Table 1). The precision of the analytical methods are certified by Chemex to be within 10% at 200 times the detection limits. Quality control data reported by the lab showed that repeated measurements of standards produced coefficients of variation less than 5% for all elements, while analysis of duplicates yielded coefficients of variation less than 8%.

Results and discussion

Table 1 summarizes trace metal concentrations in the background samples. Concentrations in samples collected from B horizons were similar to those collected at the soil surface. Mean background concentrations for mercury were 0.05 mg/kg with a maximum value of 0.13 mg/kg. These concentrations are consistent with those reported by the National Geochemical Survey for Cabarrus County (USGS 2004) and in several other studies showing that natural levels in soil generally do not exceed 0.1 mg/kg (Reimann and Caritat 1998; Xinmin et al. 2006).

Metal concentrations in the active channel sediments along lower Dutch Buffalo Creek are enriched in mercury, copper, lead, and zinc (Table 2). Contaminants in the channel sediments at these sites are likely derived from the erosion of mine wastes and remobilization of metals stored in floodplain deposits. Metal concentrations are near background levels in the relatively unmined upper portion

Table 1 Summary of chemical data for background soils

Statistic	Hg (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
Mean, USGS (2004) ^a	0.04	22	14	46
Mean	0.06	35	21	77
Median	0.05	32	21	38
SD	0.03	25	13	140
Range	0.02–0.13	3–93	4–68	12–714
Lower detection limit	0.01	1	2	2

^a Mean values reported in the National Geochemical Survey for Cabarrus County

of Dutch Buffalo Creek (Fig. 4a). However, Fig. 4b shows that mercury levels do not display the typical downstream decay from the mine source at Gold Hill because concentrations are unexpectedly low in the most intensively mined portion of the watershed along Little Buffalo Creek. Although we lack the sampling density to provide a definitive explanation, we may speculate that this pattern could be the consequence of several factors. It is possible that mercury levels in this upper reach closest to Gold Hill are being diluted by an influx of uncontaminated sediment, or that contaminated sediments that still remain have been stabilized or otherwise made unavailable for remobilization by channel erosion. High mercury levels in lower Dutch Buffalo Creek may represent a contaminated slug of sediment that has been moving downstream. We also recognize that active channel site A10 is located near Barrier’s Mill, which suggests the possibility that a mill dam may have

Table 2 Summary of chemical data for active channel sediments

Statistic ^a	Hg (mg/kg)	Cu (mg/kg)	Pb (mg/kg)	Zn (mg/kg)
<i>Upper Dutch Buffalo Creek</i>				
Mean	0.01	14	7	68
Median	0.01	13	7	22
SD	0.01	4	2	146
Range	0.01–0.03	8–20	5–10	10–457
<i>Little Buffalo Creek</i>				
Mean	0.02	17	7	26
Median	0.01	14	8	26
SD	0.02	9	2	7
Range	0.01–0.06	9–35	3–12	17–44
<i>Lower Dutch Buffalo Creek</i>				
Mean	0.57	146	35	106
Median	0.35	140	28	96
SD	0.48	81	29	45
Range	0.02–1.65	27–259	8–130	41–187

^a One sample from Upper Dutch Buffalo Creek had an Hg concentration below the lower detection limit of 0.01 mg/kg. For the purpose of calculating statistics, we assumed its value was 0.01 mg/kg

influenced the distribution of mercury-contaminated sediment along this reach. The abrupt decrease in channel gradient below the confluence of Little Buffalo Creek and Dutch Buffalo Creek may produce substantially lower values for stream power that can favor sediment storage in the lower reach (Lecce 1997). The collapse or slumping of channel banks composed of pre-mining deposits in Little Buffalo Creek may have compromised our sampling by supplying uncontaminated sediments to the channel and thereby diluting metal concentrations. Although we are unable to provide a satisfactory explanation for the low mercury concentrations in Little Buffalo Creek, the most important point is that the presence of any contaminated sediment in the active channel suggests that recent flows are currently transporting mining-related sediment from upstream sources.

Figure 5 shows that mercury and copper concentrations in the floodplain display consistent patterns in both cores. Mercury concentrations in the overbank deposits at the bottom of the cores remain constant at background levels (0.06–0.08 mg/kg) upcore before increasing by more than an order of magnitude. Peak mercury levels range from 23 (distal core) to 35 (near-channel core) times average background values. Mercury values then decrease rapidly before reaching a relatively constant level that is roughly twice background concentrations at the bottom of the core.

A similar pattern is evident for copper in the lower part of the cores. Concentrations remain fairly constant upcore at background values of about 20–35 mg/kg before increasing rapidly to a peak copper concentration that is 3 (distal core) to 6 (near-channel core) times average background values lower in each core. Peak levels of both mercury and copper occur at the same depth in each core. Copper then decreases rapidly before increasing to a second peak that is more prominent in the near-channel core than in the distal core. Copper concentrations stabilize toward the surface at concentrations about twice the background levels observed at the bottom of the cores.

Particle-size trends in the cores point to a shift in sediment supply and floodplain sedimentation following European settlement in the region. The lower portions of the cores consist of sandy lateral accretion deposits that are overlain by finer vertical accretion sediments. This transition suggests a shift from a pre-settlement system where lateral channel migration was dominant to a post-settlement system dominated by vertical accretion of finer-grained sediment. Land disturbance from first agriculture and then mining may have triggered an increase in soil erosion and the delivery of fine sediment that produced rapid aggradation on the floodplain at site DB1.

The higher post-mining background concentrations of mercury and copper in the upper portions of the cores correlate with a significant increase in silt and clay. These

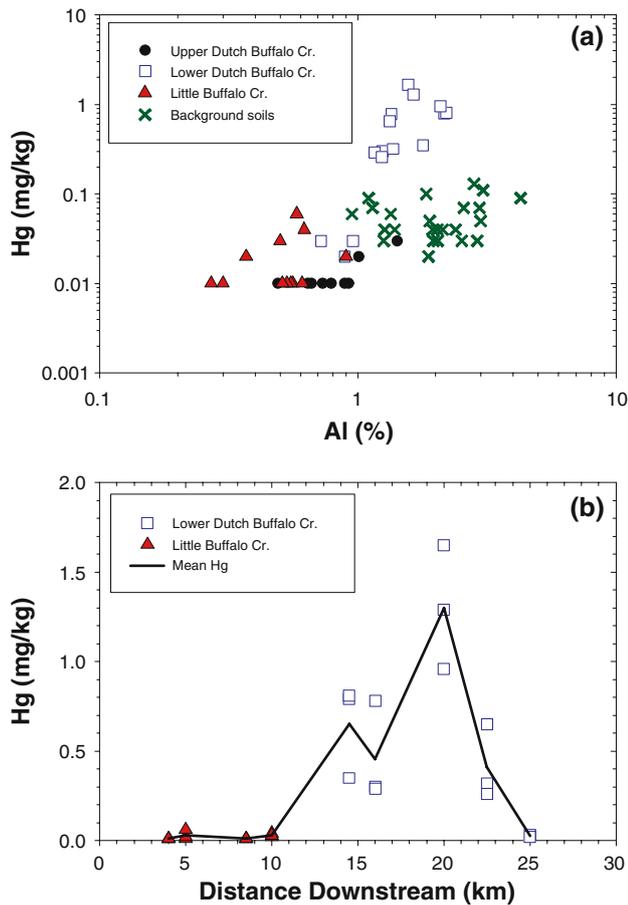


Fig. 4 **a** Mercury levels in the active channel sediments and background samples normalized by plotting versus aluminum. **b** Changes in mercury concentrations in active channel sediments downstream from Gold Hill. The *solid line* represents the mean of the three samples collected at each site

higher concentrations may also suggest that sediments contaminated by mining activities have been remobilized from upstream sources. Although it is reasonable to suspect that elevated mercury concentrations in the active channel samples in lower Dutch Buffalo Creek are supplied by the reintroduction of mercury from processes such as bank erosion, additional sampling will be needed to confirm that upstream floodplains are indeed contaminated.

Rates of floodplain sedimentation

The patterns in Fig. 5 suggest that stratigraphic trends in mercury and copper may be linked with the mining history and used to interpret the history of floodplain sedimentation in this watershed (e.g., Macklin 1985; Knox 1987; Lecce and Pavlowsky 2001) (Table 3). Although it is possible that washing of placer deposits and soils took place before the discovery of vein gold in 1842, it is unlikely that large quantities of mercury were used. The

exact timing of the introduction of mercury for use in Chilean mills is unclear, but historical descriptions suggest that the large shafts at Gold Hill were excavated quickly. Knapp and Glass (1999, p. 78) also make reference to a company organized in 1844 having invested in a steam-powered Chilean mill and mercury. Thus it is likely that large amounts of mercury were being used by at least 1845 and probably earlier.

For the purpose of estimating sedimentation rates, it is assumed that the initial increase in mercury and copper occurred when the development of the mines began in 1842. Although it is possible that there was a lag between the initiation of mining and the first deposition of contaminated sediment on the floodplain, we assume that this lag would be short because overbank floods are likely to occur every 1–2 years. The rapid increase in mercury in both cores supports the interpretation that its use was widespread and in large amounts. The rapid increase in copper is associated with the washing of weathered material rich in copper-containing sulfides. We assume that the midpoint (1856) of the 1853–1858 peak in production described by Knapp and Glass (1999, p. 85) produced maximum concentrations of copper and mercury in the cores. The second peak in copper concentrations occurs just as mercury concentrations stabilize and correlates well with the 1899 opening of the Union Copper Mine and the closing of most gold mines at Gold Hill. During this later copper mining period, little organized gold mining took place in the district, and therefore little mercury was being released to the river system at Gold Hill.

The average rate of floodplain sedimentation since mining began at Gold Hill is 1.7 cm/year at the near channel core and 1.0 cm/year at the distal core, producing an overall average of 1.3 cm/year (Table 4). The highest rates of more than 2 cm/year occurred immediately following the opening of the mines until the 1856 peak in production. Rates then decreased somewhat and stabilized with similar rates experienced in the second half of the 1800s as in the 1900s. These rates are comparable to other watersheds experiencing anthropogenic disturbance (e.g., Costa 1975; Trimble and Lund 1982; Knox 1987; Lecce and Pavlowsky 2001).

Implications

Until the present study, little data had been collected on contamination associated with gold mining in North Carolina and none on metal trends in floodplain deposits. In contrast to Leigh's (1997) finding that mercury contamination was limited to areas very near the mine source in the Dahlonega mining district in Georgia, the highly contaminated sediments near the mouth of Dutch Buffalo Creek

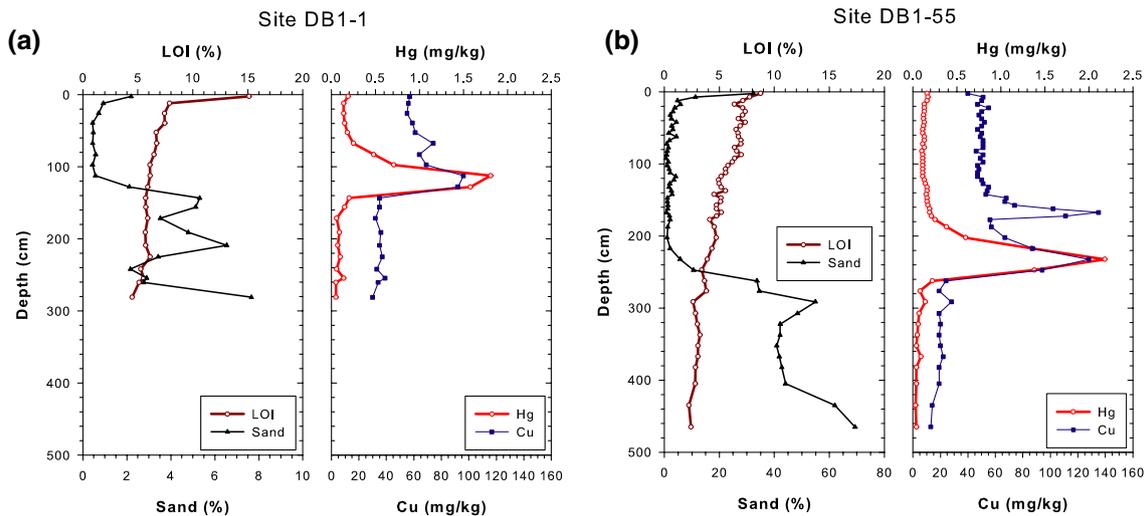


Fig. 5 Trends in grain size, organic matter, mercury, and copper at Site DB1 at the basin outlet for **a** distal (DB1-55) and **b** near-channel (DB1-1) cores

Table 3 Geochemical response to mining activities at Gold Hill

Date	Mining activity	Geochemical response
1842–1845	Gold veins discovered at Gold Hill; digging in open pits and use of mercury amalgamation in Chilean mills	Initial increase in copper and mercury
1856	Peak in gold production	Peak in mercury and copper
1899	Large-scale mining of copper begins (Union Copper Mine); decline in use of mercury as sulfides increasingly encountered with depth	Another peak in copper; mercury levels stabilize

are 20–25 km downstream from the most intensely mined areas in Gold Hill. The peak mercury concentration in the floodplain cores of 2.2 mg/kg is 35 times mean background levels. Assuming an exponential decrease in concentrations downstream from the mine source, this suggests that concentrations could be much higher farther upstream, and that there may be a substantial amount of mercury stored in floodplains throughout the watershed. In contrast, low mercury concentrations in the active channel sediments in Little Buffalo Creek imply the opposite. The next phase in this study is to explore these possibilities by expanding the study to floodplains upstream.

This study only evaluated total mercury concentrations, but given the environmental and health risks posed by

methylmercury, further study is needed to determine the form in which mercury is attached to these sediments. Although the amount of methylmercury in these floodplains is unknown, there is some evidence suggesting that floodplains may have the potential to enhance methylation. Holmes and Lean (2006) showed that rates of mercury methylation in sediments correlate with conditions favorable for sulfate reduction, thus wetlands can be considered to be important sources of methylmercury. Stamenkovic et al. (2004) found that streambank sediments had higher methylmercury concentrations, suggesting that floodplain sediments may be important sites of mercury methylation due to periodic wetting and drying (Roulet et al. 2001). Because floodplains are generally characterized by high levels of organic matter, high water tables, and reducing conditions, they may be important potential sources of methylmercury to downstream water bodies.

Table 4 Rates of floodplain sedimentation

Site	Sedimentation rate (cm/year)			
	1842–1856	1856–1899	1899–2006	1842–2006
Near-channel	2.1	1.6	1.6	1.7
Distal	2.9	1.0	0.7	1.0
Mean	2.5	1.3	1.2	1.3

Conclusion

Although North Carolina was the site of the nation’s first gold rush, this reconnaissance study is the first to examine

floodplain deposits in the Gold Hill mining district for the presence of mercury left behind by the amalgamation process. Results show that the floodplain at the outlet of the watershed is highly contaminated, with a peak mercury concentration (2.2 mg/kg) 25 km downstream from the original source at Gold Hill that is 35 times background levels. More than a century following the cessation of the large-scale use of mercury to amalgamate gold, active channel sediments also show evidence of mercury contamination which suggests that mercury is currently being remobilized from storage in floodplain deposits.

Distinct peaks in metal concentrations associated with mercury and copper mining enabled the history of floodplain sedimentation to be reconstructed. Average sedimentation rates exceeded 2 cm/year during the most intense period of mining between 1842 and 1856, and average more than 1 cm/year for the entire period between 1842 and 2006. This shows that both mining and subsequent agricultural activities have produced a substantial increase in soil erosion and sediment yields.

Contaminated floodplain sediments pose a significant environmental hazard. Even though the use of mercury associated with gold mining activities ceased long ago, the erosion of floodplain deposits by lateral channel migration poses a potential long-term threat to downstream water quality by continuing to reintroduce mercury to the active channel system.

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