Stream-Sediment Geochemistry in Mining-Impacted Drainages of the Yankee Fork of the Salmon River, Custer County, Idaho

Scientific Investigations Report 2009-5115

U.S. Department of the Interior
U.S. Geological Survey

FRONT COVER
Detail of a restored stamp mill at Custer, Idaho. Mills like this were used to crush ore in the 1800s and early 1900s during the hard-rock lode gold mining days in the Yankee Fork district. The cams on the rotating horizontal shaft raised and dropped the vertical hammers onto the ore, crushing it to make gold recovery easier.

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Contents

Figures

Tables 1-4

Appendix A and B

Stream-Sediment Geochemistry in Mining-Impacted Drainages of the Yankee Fork of the Salmon River, Custer County, Idaho

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Abstract

This reconnaissance study was undertaken at the request of the USDA Forest Service, Region 4, to assess the geochemistry, in particular the mercury and selenium contents, of mining-impacted sediments in the Yankee Fork of the Salmon River in Custer County Idaho. The Yankee Fork has been the site of hard-rock and placer mining, primarily for gold and silver, starting in the 1880s. Major dredge placer mining from the 1930s to 1950s in the Yankee Fork disturbed about a 10-kilometer reach. Mercury was commonly used in early hard-rock mining and placer operations for amalgamation and recovery of gold. During the late 1970s, feasibility studies were done on cyanide-heap leach recovery of gold from low-grade ores of the Sunbeam and related deposits. In the mid-1990s a major open-pit bulk-vat leach operation was started at the Grouse Creek Mine. This operation shut down when gold values proved to be lower than expected.

Mercury in stream sediments in the Yankee Fork ranges from below 0.02 ppm to 7 ppm, with the highest values associated with old mill locations and lode and placer mines. Selenium ranges from below the detection limit for this study of 0.2 ppm to 4 ppm in Yankee Fork sediment samples. The generally elevated selenium content in the sediment samples reflect the generally high selenium contents in the volcanic rocks that underlie the Yankee Fork and the presence of gold and silver selenides in some of the veins that were exploited in the early phases of mining.

Introduction

The drainages of the Yankee Fork of the Salmon River and its tributaries, the West Fork and Jordan Creek, have had a long history of both placer (beginning in 1873) and hard-rock (beginning in 1879) mining. A major modern hard-rock mine at the recent Grouse Creek Mine was initiated as an open-pit bulk mine but was abandoned largely on the basis of reverse-circulation percussion drilling results, after reserves proved to be lower grade than initially estimated, (Allen and Hahn, 1994; Mitchell, 1997). Both historic and recent mining and stripping practices have impacted the drainages of the Yankee Fork with increased sediment loads, disruption of the flood plain by dredging, and introduction of metals, including mercury (Hg) and selenium (Se).

This reconnaissance study was undertaken by the U.S. Geological Survey at the request of the U.S. Forest Service, specifically to identify Hg and Se contents in stream sediments and suspended sediments in the Yankee Fork of the Salmon River, Idaho. Taking these data into account in designing remediation plans for the Yankee Fork will aid in creating and improving salmon-spawning habitat. Prior to mining, the Yankee Fork was one of central Idaho's most productive salmon fisheries. This report presents sampling and analytical data for the basin-wide reconnaissance stream-sediment survey, an attempt during a very low water year to acquire suspended sediment for analysis, data for some undisturbed streambank sediment, and a discussion of the results.

Regional Setting

Geology and Topography

The drainage basin of the Yankee Fork of the Salmon River consists of the main stem, which drains into the Salmon River a few kilometers downstream from Sunbeam Hot Springs, about equidistant from Stanley and Challis, Idaho (fig. 1*A*). The lower 2 kilometers of the Yankee Fork are very steep and boulder choked where the gorge is carved into resistant granitoid rocks of the Idaho batholith (Fisher and others, 1992). Generalized geology adapted from Fisher and others (1992) is shown in figure 1*B*.

North of Polecamp Flat campground, where the valley opens up to become flat-bottomed and alluvium-filled, bedrock along the east side of the valley consists of Paleozoic black and dark-gray siltites, shales, sandstones, and silty limestones of the Grand Prize formation (Hall, 1985; Fisher and others, 1992). In drainages east of the Yankee Fork, Paleozoic black shales are host to precious- and base-metal veins that contain antimony, arsenic, barite, lead, molybdenum, silver, and zinc, among other metals.

The west side of the valley from Polecat Flat to the junction with the West Fork is underlain by Cretaceous granodiorite. The valley crosses a major northeast-trending, north-side-down fault, part of the Trans-Challis fault system that forms the southern boundary of the Custer graben, at the junction with the West Fork. At the junction with Jordan Creek, the main stem of the Yankee Fork turns northeast, and follows the graben-bounding fault system. Bedrock upstream from the Jordan Creek junction consists of Tertiary mafic to silicic volcanic and volcaniclastic rocks and sedimentary rocks of the

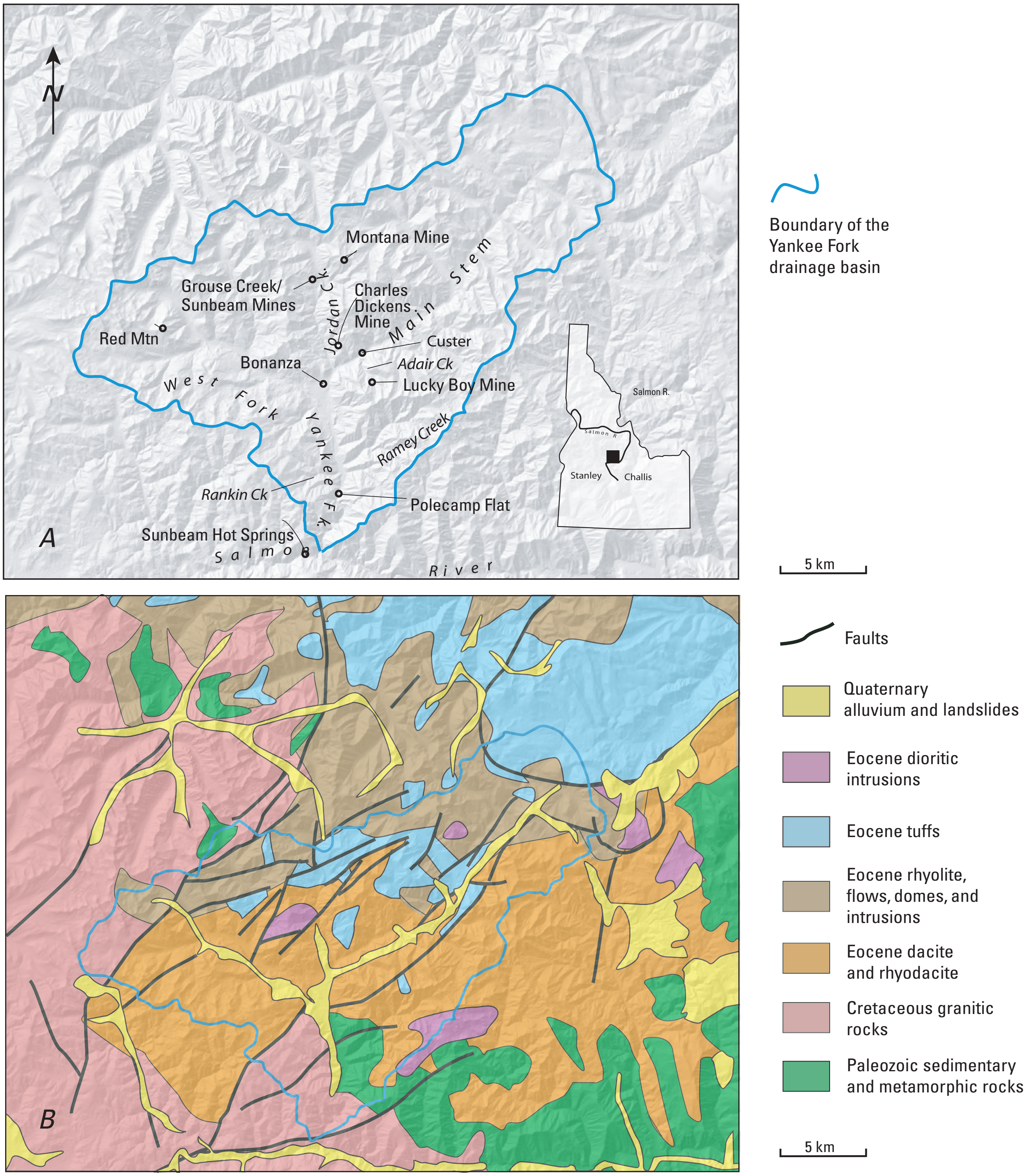

Figure 1. *A*, Yankee Fork drainage basin study area, Custer County, Idaho. *B*, Simplified geology, adapted from Fisher and others, 1992.

Challis Group (Fisher and others, 1992). The volcanic rocks of the Challis Group range in type and composition from intrusive plugs and domes, and flows and extrusive domes of basalt to rhyolite, to tuffs and breccias of variable composition. Conglomerates, sandstones, and shales are interbedded with the volcanic rocks (Allen and Hahn, 1994).

The Yankee Fork mining district is one of several in the Challis Group that hosts precious- and base-metal veins that have been mined since the 1870s. Meteoric and hydrothermal fluids emanating from and circulating through crystallizing near-surface granitic plutonic, subvolcanic intrusions, and the flows and domes carried metals and deposited them in veins and locally as disseminations in the country rock (Allen and Hahn, 1994). Commodities produced in theYankee Fork include gold, silver, lead, and zinc.

The alluvial gravels along the main stem of the Yankee Fork, from above Polecamp Flat campground to about a mile up Jordan Creek above its confluence with the Yankee Fork, were extensively dredged for gold. Side streams, including Rankin and Adair Creek along Yankee Fork and Montana Gulch off of Jordan Creek, were also placer mined, though these were too small to use the floating dredge (Dee, 1988; Yarber, 1963).

Mining History

Placer gold was discovered in 1873 in Yankee Fork at the junction of Yankee Fork and Jordan Creek (Yarber, 1963; Mitchell, 1997). By 1875 the Charles Dickens Mine was opened overlooking Jordan Creek. In 1876 the Custer Mine, working an extremely rich vein, was located on the south side of Yankee Fork above the junction with Jordan Creek.

The Custer Mill, located just upstream from the site of Custer on the Yankee Fork and operated from 1881 to 1888, used mercury amalgamation to extract gold from the ore (Yarber, 1963; Dee, 1988). Dee (1988) states that the mill operated at a capacity of 900 tons per month, that the ore was crushed and ground, and that free gold and silver were recovered as the material was passed over mercury-coated copper plates. Periodically, the mercury was scraped off the plates so that the mercury could be separated from the recovered gold and silver, which were smelted and poured into bars. The remaining ore was put through a chlorination process to remove the gold and silver not recovered by the mercury-coated plates.

The Custer Mill was taken over by the Lucky Boy Gold Mining Company in 1895 and operated until 1904. Again recovery was by mercury amalgamation. Numerous small gold and silver hard-rock mines operated in the district at various times through 1942 when gold mining was shut down due to World War II. From 1900 through 1992, recorded production for the district is 41,650 oz gold, 433,269 oz silver, 19,326 lbs of copper, 61,913 lbs lead, and 1,711 lbs of zinc. Estimates for pre-1900 gold and silver are 240,000 oz gold and 8,670,000 oz silver, giving an aggregate total of 281,000 oz of gold and 9,100,000 oz silver (Fisher, 1995).

In 1937 and 1938, the alluvial gravels of the Yankee Fork were tested for dredging, and a report was produced that claimed $11,000,000 in gold alone (more than 340,000 oz at $32/oz) could be recovered (Dee, 1988). By 1940 a floating dredge had been assembled, and it began operating in the valley. Dredging continued until 1942 when the gold mines were shut down due to World War II. Following the war, dredging resumed in 1945 and continued until 1952 (Yarber, 1963). Much of the valley bottom ground between Polecamp Flat to about a mile up Jordan Creek was dredged. The camp for the operation was located just north of the mouth of Ramey Creek, and some of the buildings are in use today as vacation homes.

The dredge operated by scooping up gravel with a 71-bucket digging ladder, which could dig to a depth of 37 feet with each bucket holding 8 cubic feet of gravel (Dee, 1988; Webber, 1994). The dredge floated in a pond of its own making, working along the margin and dropping the spoils behind as it moved forward through the gravels. On board the dredge, the gravels were washed into a trommel, a rotating pipe with holes as large as 5/8 inch, that separated the fine from the coarse material. Everything larger than 5/8 inch was dumped on a conveyor belt that exited the rear of the dredge and dumped back into the pond. The dredge dug in arcs, pinned in place by a post, so the rejected material was dumped into piles; each time the dredge moved forward it left behind a new arc-shaped mound of coarse gravel and boulders. The material finer than 5/8 inch, that passed the holes was directed to sluices where mercury-coated copper plates and mercury traps recovered the gold; the other heavy minerals, sands, and gravel were directed out the back of the dredge (Dee, 1988). The geometry of the spoils conveyor belt and the exit of the sluices from the dredge resulted in a stratigraphy such that the fines that went over the sluices and were exposed to the mercury-coated plates and traps were then largely buried by the coarse material as it exited the conveyor system.

Hecla Mining Company was granted a permit in 1992 to create an open-pit bulk-mineable gold mine, to be called the Grouse Creek Mine, at the site of the old Sunbeam Mine west of Jordan Creek. The mine began operations in 1994 and closed in 1997 after reserves proved to be lower grade than initially estimated, largely on the basis of reverse-circulation, percussion-drilling results (Allen and Hahn, 1994; Mitchell, 1997). Mitchell (1997) gives a thorough history of the Sunbeam and Grouse Creek Mine operations up through the dedication of the Grouse Creek Mine on August 10, 1995. Allen and Hahn (1994) give a complete description of geology and mineralogy of the Sunbeam and Grouse Creek deposits.

Mineral Deposits

The volcanic and sedimentary rocks underlying the Yankee Fork host a wide variety of deposit types, including various epithermal veins enriched in gold and silver and low-grade disseminated gold deposits. Placer deposits along some of the major drainages and some of the tributaries have also been exploited.

Vein Deposits

Most of the following discussion of epithermal veins in the Yankee Fork district is adapted from Fisher (1995), Fisher and others (1995a), and Allen and Hahn (1994).

The primary lode deposits in the Yankee Fork district are epithermal precious-metal veins in which gold has been the principal metal in terms of value, but in most veins silver has been more abundant. Copper, lead, and zinc have been recovered at some mines in the Yankee Fork district, most notably from the Mountain King (23,000 lbs lead), the Whynot Mine (12,500 lbs copper; 15,400 lbs lead), and Hidden Treasure (1,700 lbs zinc). The original Sunbeam Mine exploited the high-grade epithermal veins; subsequent efforts to develop the Grouse Creek Mine in the same area were targeting the lower-grade stockwork and disseminated portions of the same epithermal system (Johnson and Fisher, 1995; Allen and Hahn, 1994).

The epithermal veins contain auriferous pyrite; native gold; electrum; tetrahedrite, stephanite, and proustite (silver-arsenic sulfides); miargyrite and pyrargyrite (silver-antimony sulfides); owyheeite (lead-silver sulfide); native silver; bismuth sulfides; galena (lead sulfide); chalcopyrite (copper-iron sulfide), enargite (copper-arsenic sulfide), and sphalerite (zinc sulfide) (Allen and Hahn, 1994). Quartz is the predominant gangue mineral, along with calcite, adularia, siderite, barite, pyrite, pyrrhotite, and arsenopyrite. Selenium commonly is present at elevated levels in many epithermal gold and silver deposits, and numerous descriptions of the early mining in Yankee Fork include mention of high levels of Se, mostly in silver and gold selenide minerals associated with the deposits (Nolan, 1933; Anderson, 1949, Davidson, 1960; Davidson and Powers, 1959). Ream (1989), referring to Shannon (1926), lists naumannite (silver selenide) as occurring in several mines in the Yankee Fork District), though no specific mines are mentioned. Allen and Hahn (1994) mention naumannite as being present at the Grouse Creek and Sunbeam Mines, but no analyses are reported. No modern analyses for Se in the bedrock or ore samples are published. The mineralized veins cut Tertiary volcanic rocks and are associated with and generally subparallel to the northeast-trending Challis fault system. Alteration of the wall rocks is locally intense. Propylitic alteration (quartz-chlorite-calcite-epidote) is widespread away from the veins, whereas near the veins the wallrocks are intensely altered by silicification and argillization (clays and muscovite-sericite) (Allen and Hahn, 1994). Pyrite is common in altered rocks, and most gold occurs as fine inclusions in the pyrite.

Sediments from drainages that contain epithermal precious-metal veins or rhyolite-hosted disseminations and stockworks have elevated concentrations of gold (Au), silver (Ag), antimony (Sb), copper (Cu), lead (Pb), zinc (Zn), arsenic (As), selenium(Se), and molybdenum (Mo) (McDanal and others, 1984; McIntyre and Johnson, 1985).

Fluorspar veins cut rocks in the Yankee Fork drainage, though they have never been mined. The veins contain fluorite, with or without stibnite (antimony sulfide) in a gangue of barite, calcite, and chalcedony. Stream sediments in streams below these veins contain Mo, Au, and Ag (Fisher and others, 1995b).

Red Mountain, at the headwaters of the West Fork, is a low-grade stockwork and disseminated Mo prospect that is similar to, but younger and much lower in both tonnage and grade than the Mo deposits at Thompson Creek 25 miles to the east. The rocks are hydrothermally altered and weathered. Reddish iron oxides, produced from the weathering or iron-bearing sulfides, principally pyrite, account for the color and the name of the mountain. The core of the deposit is a stockwork of silicified veins containing pyrite, molybdenite, arsenopyrite, and chalcopyrite; the core is surrounded by broad zones of argillic (predominantly clays and chlorite) and sericitic (predominantly white mica) alteration (Kiilsgaard and Bennet, 1995). Stream sediments in drainages below such stockworks are elevated in Mo and Cu (Kiilsgaard and Bennet, 1995).

Placer deposits

The placer deposits in Yankee Fork are among the largest known in central Idaho, having produced over 29,000 oz of gold and 16,000 oz silver from 6.67 million cubic yards of spoils. Additionally, the pilot dredging operations at Jordan Creek recovered 7,600 oz gold and 4,900 oz silver from 520,000 yards of spoils.

The dredge utilized a sluice and riffles as well as mercury-coated copper plates and mercury traps to recover fine gold (Dee, 1988). The Yankee Fork operations were notably inefficient; the dredge could not reach the best pay streaks, which are located just above bedrock (Fisher and Johnson, 1995b). Large areas of alluvium along Yankee Fork were not dredged, and Choate (1962) estimated that only 60 per cent of the gold that was dredged was recovered due to low efficiency of the dredge.

Tributaries to the Yankee Fork that were placered by hand and small mechanized operations include Rankin Creek and Adair Creek (Dee, 1988). These drainages contained extremely large boulders that made placer and hydraulic operations difficult.

Jordan Creek also contained rich placers downstream from the Estes Mountain and Sunbeam (Grouse Creek Project) Mines. Nuggets as large as 32 oz have been reported (Dee, 1988). Most notable of the tributaries to Jordan Creek to be placered include Red Rock Gulch and Montana Gulch. The gold accumulated on short, step-like terraces along the steep and narrow gulches (Dee, 1988). The use of mercury for gold recovery in these placers is not recorded.

Sampling and Geochemistry

Previous Work

As part of the National Uranium Resource Evaluation (NURE) program run by the USGS, stream-sediment samples were collected in many of the drainages of the Yankee Fork. The samples were analyzed for a suite of elements, including Se. Two of 20 samples collected from the Yankee Fork contained detectable Se at 1 ppm. A report by Smith (2006) is available online, and the data may be downloaded from http://tin.er.usgs.gov/of/1997/ofr-97-0492/state/nure_id.htm.

The US Geological Survey conducted a mineral resource assessment of the Challis 1 x 2 degree quadrangle in the 1990s (Fisher and others, 1995a). As part of that assessment, 488 stream sediment and pan concentrate samples were collected from the Yankee Fork drainages (McDanal and others, 1984). Analysis of the samples did not include Hg or Se determinations. The complete database may be downloaded from http://tin.er.usgs.gov/rass/sediment .

Sampling Methodology

Sample Collection

All samples were collected in 2000 and 2001 using a plastic trowel or shovel and were placed in prelabeled zipper-lock style plastic bags. Sample site locations were marked directly onto 1:24,000 scale USGS topographic maps by inspection in the field, and the latitude and longitude (in decimal degrees, NAD 1927 datum) recorded using a Military-Spec Rockwell Precision Lightweight GPS Receiver (PLGR+96) typically with a horizontal error of less than 10 meters. In situations that the GPS receiver did not give a location (too few satellites visible), the error was greater than 10 meters, or the sample location was in the middle of the stream or pond, the latitude and longitude were determined later in the office by using a spatially-registered digital raster-graphic version of the 1:24,000-scale topographic map in ArcGIS and the latitude-longitude recorded in the table. All sample locations were confirmed using ArcGIS, and the digital raster-graphic versions of the topographic maps and locations were converted to UTM Zone 11 equivalents for use in the tables and figures. Table 1 (note that all tables are found at the back of this report) lists UTM Zone 11 locations for the samples. Locations of each sample are shown on figure 2, and detailed versions are shown on figures A1-A19. The samples were maintained in a secure environment following collection and were processed at the sample-preparation laboratories of Eastern Washington University prior to submittal to the USGS Denver analytical facilities. Descriptions of the analytical methodologies used and the detection limits are discussed in a later section of this report.

Streambed Sediment

The protocol followed for this study is the same as that used by Box and others (2004) in their study of mining-impacted streams in the North Fork of the Coeur d'Alene River in northern Idaho. At each streambed-sediment sampling site, a composite of three to five subsamples from within the high water channel was collected from the upper 10 cm of sediment within 10 m of one another. One subsample was obtained from below the water's surface at the time of collection, and others were collected from undisturbed sediment above the low-water level on one side of the stream and were mostly dry at the time of collection. Most active streams contained a large proportion of material coarser than 1 cm; the sampling efforts were aimed at retrieving sand-sized (2 mm) and finer material. Subsampling in the field was restricted to discarding the pebble-, cobble-, and boulder-sized material scooped up in the sampler prior to bagging. Digital photographs of each site, looking up- and downstream, as well as a view looking down from directly overhead were taken to record the characteristics of each site. These photographs may be obtained from the senior author.

Pond Sediment

Sampling of the generally fine- to very fine-grained sediments in the "rearing ponds"-- the ponds left over from the dredging operations that are connected to the main flow mostly by later channels dug into the dredge spoils -- was also conducted for this study. Samples from the rearing ponds were collected using methods similar to those described for the active-channel samples, although the quiet and sometimes deep water occasionally required a change in sampling gear. For those sites where a plastic scoop could not be used, a stream-sediment sampling device developed by the USGS for field work in Alaska was used. The device consists of a stainless steel can (about the size of a standard 12-oz soft drink can) welded to an extendable stainless-steel pole to allow sampling in deep water. At least three subsamples were obtained at each site, filling the can with the fine-grained material for each subsample. The subsamples were composited in the plastic sample-collection bag. The locations of each sample are shown on figure 2, and detailed versions are shown in the appendix on figures A1-A19.

Undisturbed Alluvium

At the northeastern edge of one of the rearing ponds (samples 0YA028 and 1YA070; figs. 2 and A10), the original, undisturbed pre-placer mining alluvial deposits were exposed in a cut bank. Although some small animal burrows were present in the unvegetated bank, the original alluvial sedimentary structures were clearly visible. A sample of undisturbed sediment was collected for analysis during each of the two years of the study because unexpectedly high values of Se were reported for the sample collected in the first season. The sample collected in 2001 also yielded high Se, these results are discussed in a later section of this report.

Suspended Sediment

Four samples of suspended sediment were collected along Jordan Creek and Yankee Fork on May 16, 2001, which was the date of the peak flow for the water year along the main stem of the Salmon River at the nearest USGS streamflow-gauging station (USGS site 13209500 Salmon River Below Yankee Fork Near Clayton, ID http://waterdata.usgs.gov/nwis/uv?13296500, accessed January 2006). A plot of the flow recorded at that gaging station from May 1, 2000 (when the gage began recording again after a hiatus of several years) and the end of the water year 2005 is shown in

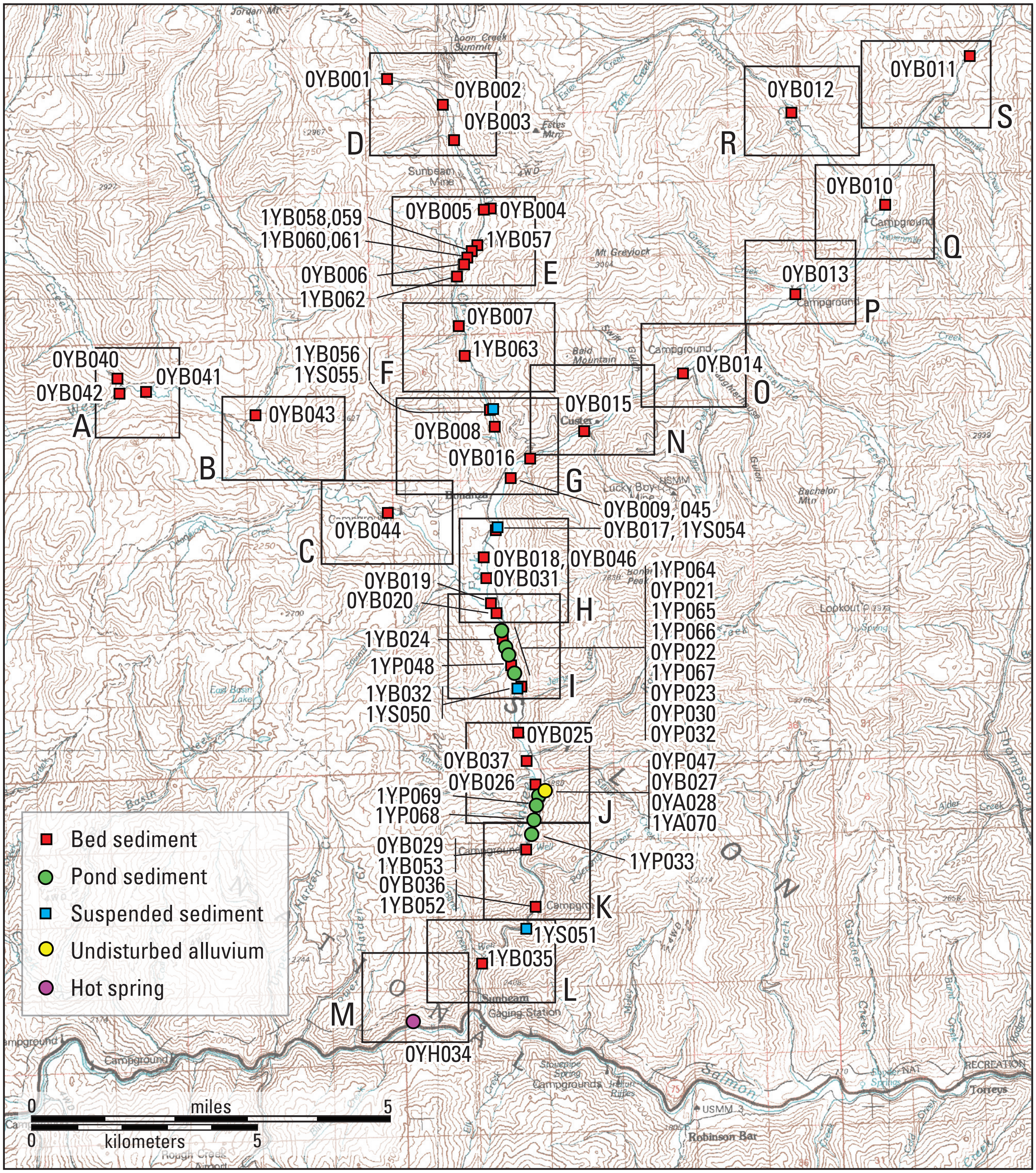

Figure 2. Generalized sample location map, Yankee Fork, Custer County, Idaho. Refer to appendix B for detailed maps for areas A-S. Base map from USGS 1:100,000-scale Challis quadrangle.

figure 3. Average flow at the streamflow-gaging station on the Salmon River was 1,231 cubic feet per second (cfs) on May 16, 2001, which was the lowest high flow for the year for the period of record. The highest average flow recorded at the gaging-station during the period recorded here was 7,110 cfs in May 2003. Though it is not known if the flow on the main stem and the flow on the Yankee Fork are directly correlated, that is, if the date of the high flow on the main stem is the same date on the Yankee Fork, the gage record indicate that the sampling date in 2001 was close to the date of the high flow on the Yankee Fork for the year, and that the high flow for the year was not very high.

Flows on May 16, 2001 were very low, the water at all sampling locations was clear, and the bottom was unobscured by suspended or moving bed-load sediment at all stations sampled. Samples were collected from the middle, highest-flow part of the channel from bridges over the stream in 1-liter, wide-mouth Nalgene bottle tied to a rope and weighted so it would sink. For each station, approximately 21 liters of water from at or near the bottom of the stream were collected and stored in 7 1-gallon zip-lock plastic bags, 3 liters per bag. The individual bags were double-bagged and the bags from each site were stored separately in plastic tubs until they arrived at the lab.

Mollusk Shells and Insect Casings

At one sample locality (0YF033; figs. 2 and A11) some unidentified mollusk shells and insect casings were collected and kept separate from the sediment sample from the same rearing pond. These were analyzed separately and the data is reported with the intermediate-sized fraction.

Sunbeam Hot Springs

Less than one mile upstream from the mouth of Yankee Fork, along the Salmon River, Sunbeam Hot Spring disgorges into the Salmon River (figs. 2 and A13). Two samples were collected from the sediments at the actively-venting, hot water discharges of the spring. One sample was collected from muds and fine sands in a hot springs pool above the highway. The second sample was collected from incipiently calcite-cemented sand and gravel from the edge of a channel that drains one of the hot spring pools. These samples were analyzed along with the other Yankee Fork samples as a comparison to the samples of the main study. The results of the analysis of these samples are presented in the tables and graphs that follow, but should not be considered as part of the study as the hot springs are not hydraulically connected with the Yankee Fork. As discussed in an earlier section, the gold and other metals in Yankee Fork were transported and deposited by ancient hydrothermal systems and hot springs, thus the geochemical values recorded in the active present-day springs provide a comparison to the values that may have existed at the time of the formation of the metallic deposits in Yankee Fork.

Sample Preparation

All samples (except those of suspended sediment) were dried in open sample bags at room temperature for a 2-week period. The samples were periodically stirred with a clean, dried plastic spatula to hasten drying time, and care was taken to avoid cross-contamination or stirring up dust. Following drying, the samples were sorted in the sample-preparation laboratory of Eastern Washington University, Cheney, Wash-

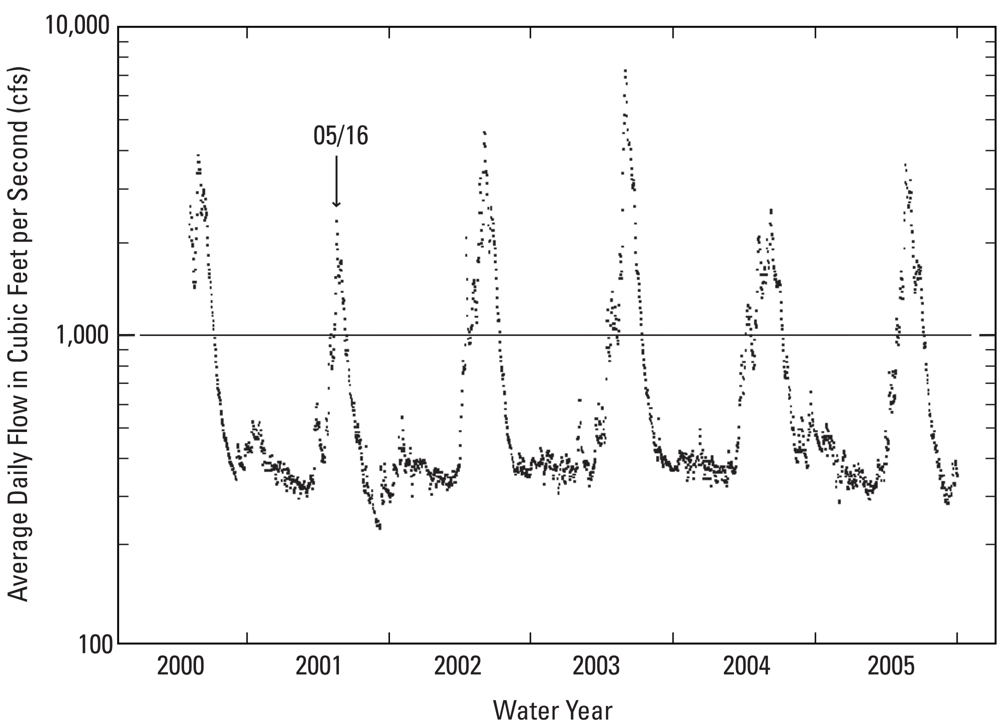

Figure 3. Average daily flow in cubic feet per second for the U.S. Geological Survey stream gaging station at Salmon River below Yankee Fork (USGS 13296500) for the water years 2000-2005. May 16, 2001, date of suspended sediment sampling on the Yankee Fork shown. Average daily flow for the Salmon River on that date is 2,310 cfs, the maximum for the water year and the lowest high flow for the time period shown. Date of maximum daily flow for Yankee Fork is unknown but probably within a day or two of the sampling date. Data downloaded from http://waterdata.usgs.gov/nwis/uv?13296500, last accessed January 2006.

ington, into different grain-size fractions (<0.063 mm, 0.063-0.125 mm, 0.125-0.25 mm, 0.25-0.5 mm, 0.5-1.0 mm, 1-2 mm, 2-4 mm, 4-8 mm, and >8 mm) using the protocol of Peacock and others (2002). Each sample was sieved for three minutes using standard wire-mesh sieves mounted on a rotary agitator. Screens were hand brushed and blown out with compressed air between each sieving. Each fraction was weighed to within 0.1 g, and its percentage of the total weight of the recovered sample was calculated (table 1). Three fractions were sent to the USGS laboratory in Denver, Colorado, for analysis: (1) fine—less than 0.063 mm (clay and silt); (2) intermediate—0.063 to 0.25 mm (very fine to fine sand); and (3) coarse—0.25 to 1.0 mm (intermediate to coarse sand). The intermediate and coarse fractions were pulverized in preparation for analysis using the procedure of Taylor and Theodorakos (2002); the fine fraction was run as received as it was already fine enough for analysis and did not require further preparation.

Samples of stream water with suspended sediment were transported to the sample-preparation laboratory after collection, where they were allowed to settle in the original sample bags for a week, after which the supernatant was decanted and its volume measured. The remaining cloudy water was centrifuged for 4 minutes, and the supernatant was decanted from the centrifuge tube and its was volume measured. The solid residues were transferred to preweighed glass sample vials and air dried for three days. After drying, the vials were reweighed, and the mass of each sample was calculated.

Due to the very low water conditions at the time of collection, very little suspended sediment was recovered. In all four samples, so little material was present that it was analyzed without attempting to split it into size fractions (table 1). For all four samples there was only enough material to analyze for Hg. Much of the solid material that was recovered was simply floating organic matter.

Chemical Analysis

Methods

Due to lack of sample volume, the suspended-sediment samples were analyzed only for Hg by the continuous-flow cold vapor-atomic absorption protocol of Brown and others (2002). The fine split of all bed sediment and other samples was analyzed for (1) Hg using the continuous-flow cold vapor-atomic absorption protocol of Brown and others (2002), (2) for Se and As using the continuous-flow-hydride generation-atomic absorption spectrophotometry protocol of Hageman and others (2002), (3) for thallium (Tl) using graphite furnace atomic absorption spectrometry protocol through a contract laboratory XRAL (see appendix B for a summary of the method), (4) for Sb by continuous flow-hydride generation atomic absorption spectrophotometry through a contract laboratory (see appendix B for a summary of the method), and (5) for 40 elements by inductively-coupled plasma-atomic emission spectrometry (ICP-AES) using the protocol of Briggs (2002). The intermediate split was analyzed using the same protocols as above for Hg, Se, and 40 elements (the 2001 samples were also analyzed for antimony by hydride-generation atomic-absorption spectrometry). The coarse split was analyzed for 40 elements using the same protocol as the other samples.

A total of 203 samples were analyzed for this study of which 9 percent were replicates of splits of streambed or pond sediment samples submitted under independent sample numbers in order to check laboratory precision. The results of the replicate split analyses are included in tables 2-4.

Additionally, at several pond locations, two samples were collected to check for within-site variation, and several sites were repeated during each of the two sampling seasons to check for year-to-year variation and to check on high Hg, Se, or As values reported during the first year of the sampling program.

Analytical Data

Table 2 lists analytical results for what is termed the “fine” fraction in this report--the grain-size fraction of each sample measuring less than 0.063 mm, including all solid material collected for the suspended-sediment samples. Table 3 lists the results for the “intermediate” fraction, the grain-size fraction measuring between 0.063 and 0.25 mm, including the shells and insect casings. Table 4 lists results for the “coarse” fraction, the fraction of the sample measuring between 0.25 and 1.0 mm. The material coarser than 1.0 mm was not analyzed.

Of the 40-element ICP-AES analyses done for this study, several elements are not reported here because all their values were near or below the detection limit. Elements detected but not reported in tables 2 through 4 include those for which all samples reported less than three times the detection limit for that element. Elements analyzed for but not detected (at the limit noted) in the fine fraction include: gold (Au, 8 ppm), bismuth (Bi, 50 ppm), cadmium (Cd, 2 ppm), holmium (Ho, 4 ppm), tantalum (Ta, 40 ppm), and uranium (U, 100 ppm). Elements not reported for the fine fraction because all values were less than three times the detection limit include silver (Ag, 2 ppm), europium (Eu, 2 ppm), tin (Sn, 50 ppm), and ytterbium (Yb, 1 ppm). For the intermediate and coarse fractions, elements not reported due to being near or below the same detection limits as above include Ag, Au, Bi, Cd, Eu, Ho, Ta, Sn, U, and Yb.

Results

Figures 4 through 7 are maps showing the values for Se, Hg, As, and Cu in the fine-fraction (<0.063 mm) sediments in the Yankee Fork drainages. The figures show that the Main Stem above Custer is relatively low in all elements plotted. Jordan Creek and the Main Stem south of Custer, downstream from where most of the mining activity in the district has occurred, has anomalously high values for all elements plotted.

The West Fork is elevated in Cu relative to the other drainages. These results are discussed further in the following sections.

Sediment Chemistry – Elemental Values by Reach

The U.S. Environmental Protection Agency (EPA), as of October 2008, has only draft aquatic life standards for Se, published in 2004 (http://www.epa.gov/waterscience/criteria/selenium/pdf/maintext.pdf). The toxicity of selenium appears to vary widely among the various species mentioned in the draft standards, and the toxicity also varies widely depending on water hardness and the oxidation state of Se. Species Mean Acute Value for Chinook salmon is reported as 15,596 (in ppm or µg/L Se, U.S. Environmental Protection Agency, 2004, p. 43).

The following discussion examines the main elements of concern in each size fraction by stream reach or sampling environment. Plots of the elemental values (figs. 8 and 9) are presented with UTM N as the x variable because all streams drain broadly to the south; therefore the West Fork, Jordan Creek above and below Grouse Creek Mine, and the Main Stem above and below the town site of Custer can be compared, and the locations of the pond sediments in their correct

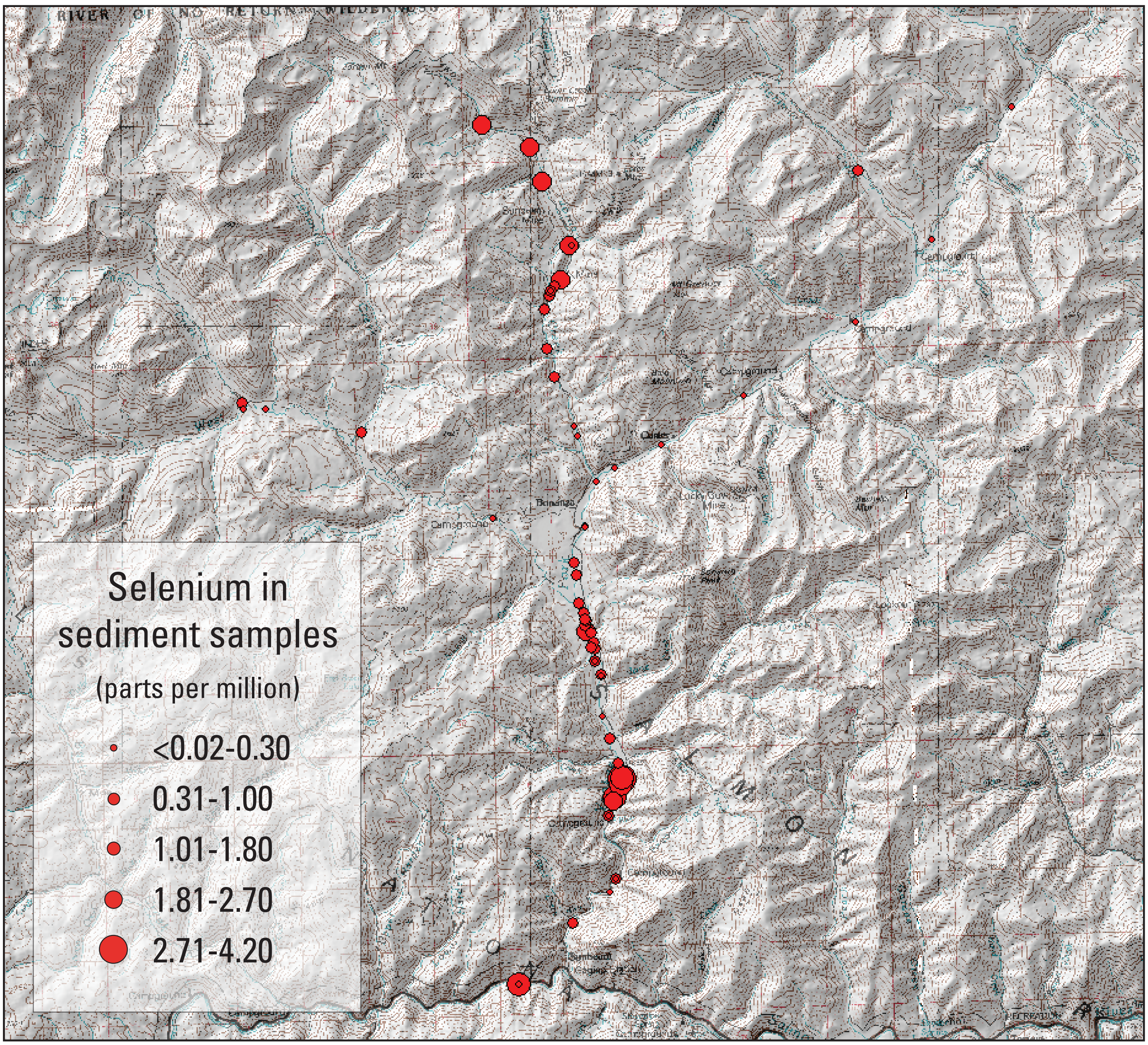

Figure 4. Map showing selenium contents in parts per millions in the fine fraction (<0.063 mm) from samples taken in Yankee Fork drainage, Idaho.

north-south locations can be shown. Only Se, Hg, As, and Cu are discussed here, other elements are summarized in the section on stream reach and sample type.

Selenium in the Fine Fraction

Selenium values in the fine fraction samples ranges from below the detection limit of 0.2 ppm to 4.25 ppm. Samples from Jordan Creek above (crosses) and below (plus sign) Grouse Creek Mine (figs. 8 and 9) decrease downstream from a maximum of 1.75 ppm to near the detection limit of 0.2 ppm. Three samples from above Grouse Creek Mine contain greater than 1 ppm Se; and three samples from below Grouse Creek Mine are at or above 1 ppm Se; but in general, there is a decrease downstream in Se content in the fine fraction in Jordan Creek, irrespective of the mine. The fine fraction of Yankee Fork Main stem sediment samples (orange squares below Custer, green squares above Custer) have values below 0.8 ppm Se. The pond sediment samples range in value from near detection limit to 2.6 ppm Se, with the lower values in

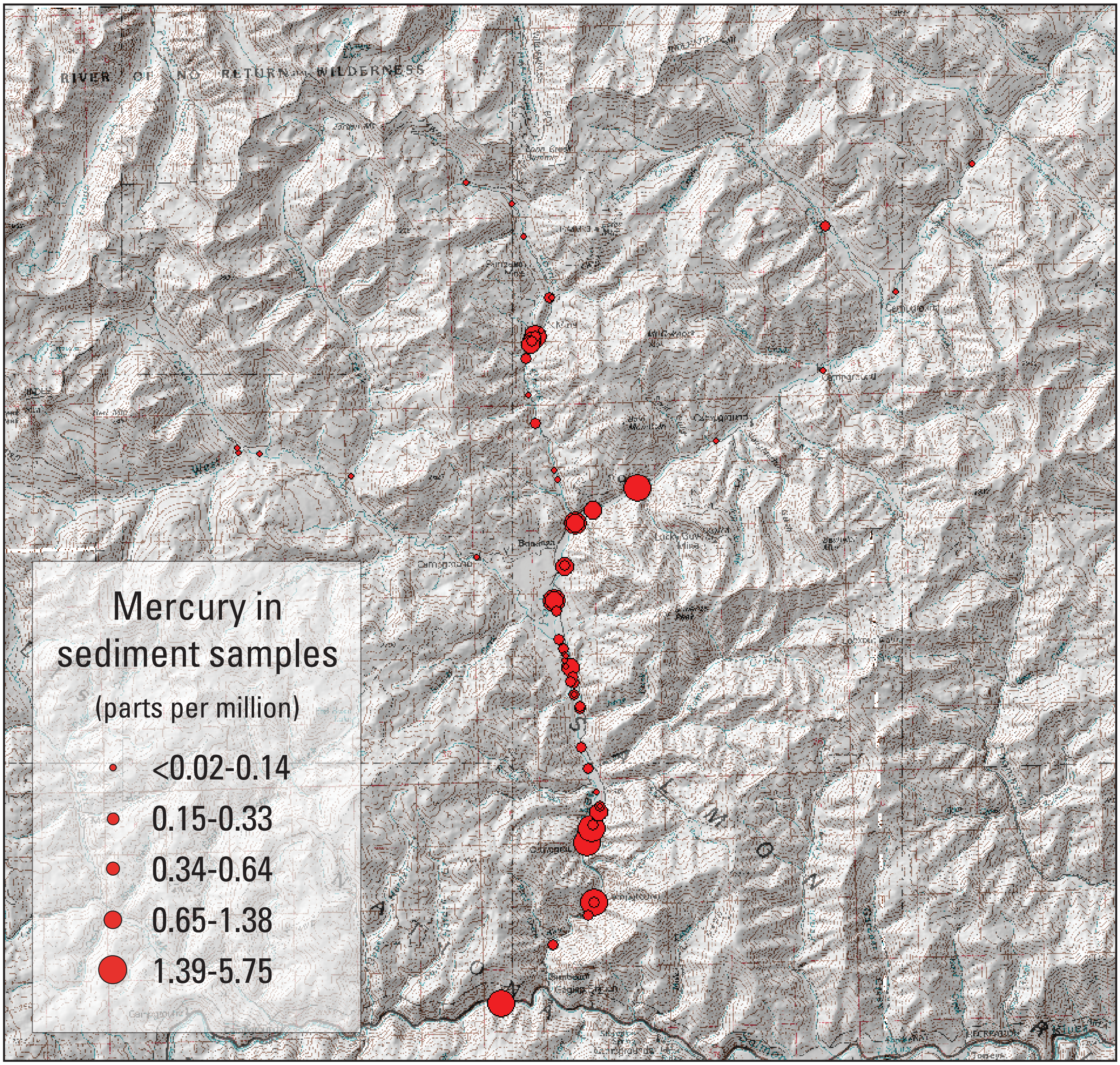

Figure 5. Map showing mercury contents in parts per million in the fine fraction (<0.063 mm) from samples taken in Yankee Fork drainage, Idaho.

upstream ponds relative to those in the downstream pond sediments.

The two samples of undisturbed alluvium obtained from a single location at the north end of a pond bank at the downstream ponds (samples 0YA028 and 1YA070, figs. 2 and A-10) contain the highest values for Se obtained in this study for Se, 2.7 and 4.2 ppm. The samples were taken from the embankment left by the dredge at its farthest excavation at the northeast edge of the pond. The alluvium sampled showed undisturbed sedimentary structures characteristic of normal alluvial stream sediments, and the grasses overlying the samples were also undisturbed. There was evidence of burrowing animals in the embankment, it is possible that Se taken up by the rodents or by animals grazing on the fields above the ponds was excreted and contaminated the sampled sediment, but it is unclear how otherwise undisturbed sediments could contain the highest Se values of all samples in this study. It is beyond the scope of this study to speculate further on the reasons for the high Se contents in these samples. Duplicate samples of pond sediments in this pond were taken and submitted separately for analysis under different sample numbers (0YP027 and 0YP047); these samples contained 0.20 and 2.1 ppm Se, respectively (table 2, figs. 2, 8*A* and A-10).

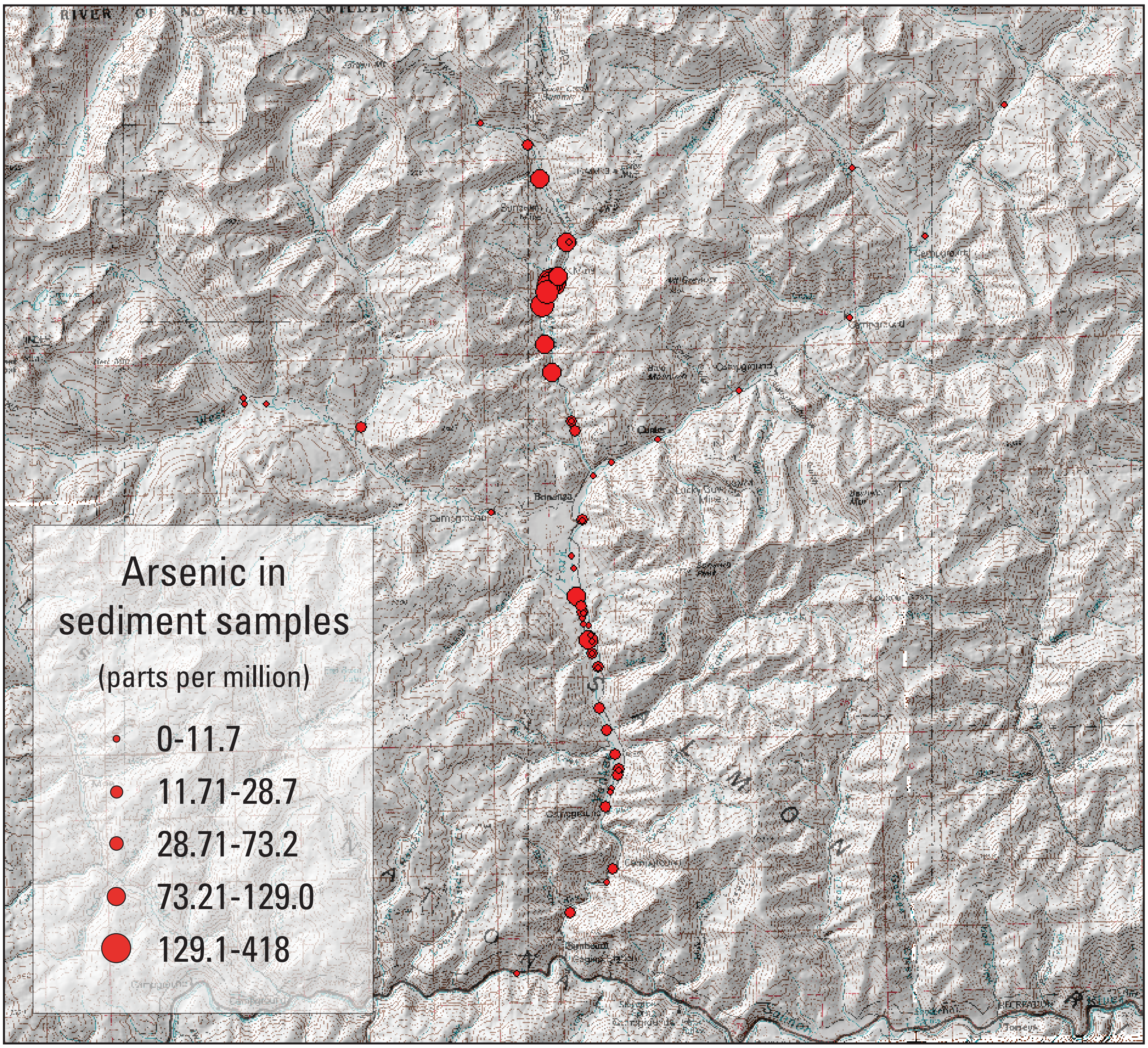

Figure 6. Map showing arsenic contents in parts per million in the fine fraction (<0.063 mm) from samples taken in Yankee Fork drainage, Idaho.

Selenium in the Intermediate Fraction

Selenium content in the intermediate-fraction is generally lower than that of the fine fraction for stream-sediment samples, but more variable for the pond-sediment samples (fig 9*A*). Selenium values in the intermediate fraction range from 0.2 to 2 ppm in samples from the upper ponds and from 0.6 to 3 ppm in samples from the lower ponds. The undisturbed alluvial sediment sample at the north edge of the lower ponds also has elevated Se values between 1.6 and 2 ppm. There is a slight increase in average Se content in the intermediate-fraction bed sediments in Jordan Creek from above (0.88 ppm) to below (1 ppm) Grouse Creek Mine.

Selenium in the Coarse Fraction

Selenium values were not determined for the coarse-fraction sediment samples.

Mercury in the Fine Fraction

Mercury values in the fine fraction are shown in figure 8. The elemental values are shown on a logarithmic axis to

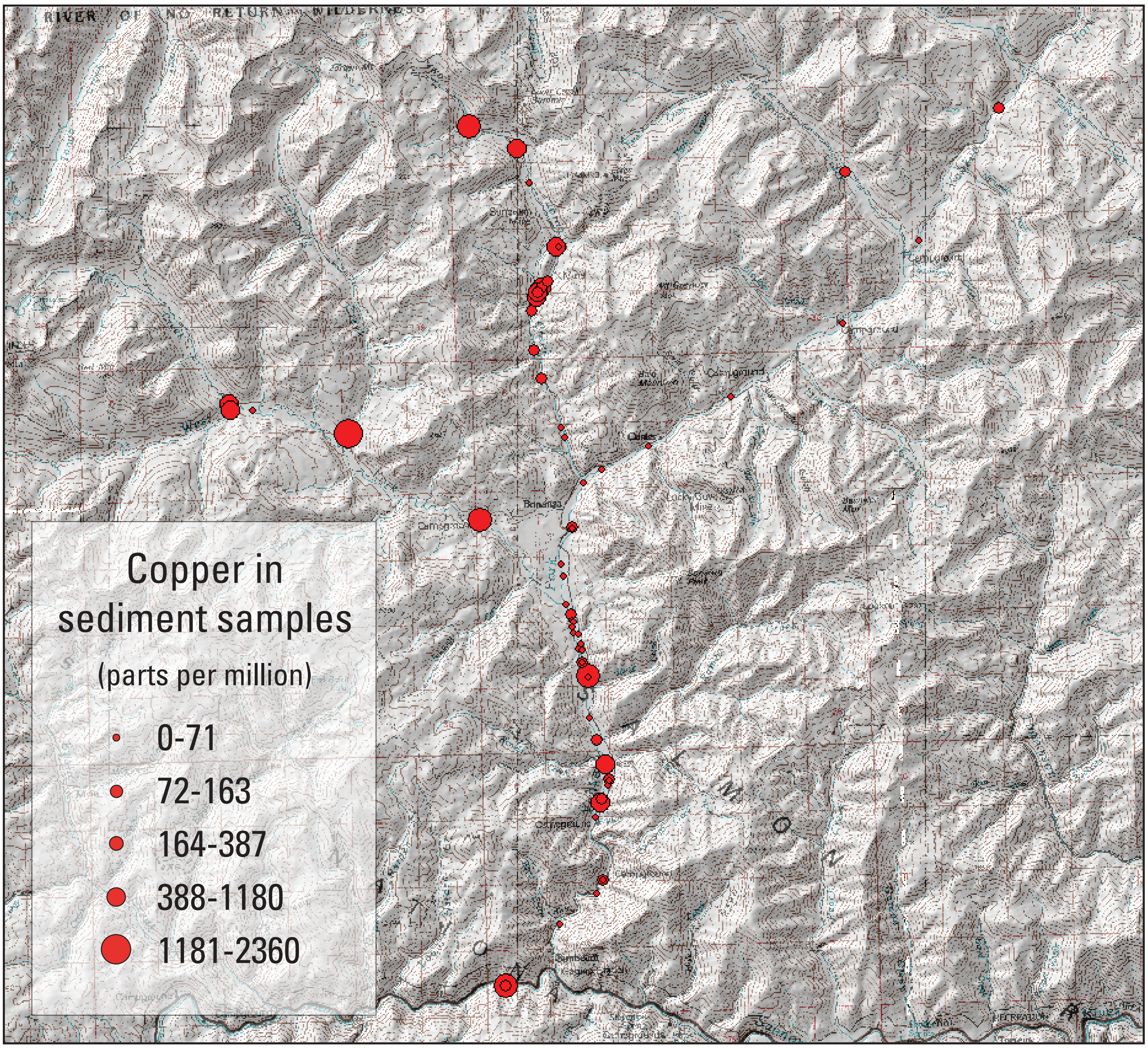

Figure 7. Map showing copper content in parts per million in the fine fraction (<0.063 mm) from samples taken in Yankee Fork drainage, Idaho.

allow visual separation of the generally low values. The West Fork and Main Stem above Custer, and much of Jordan Creek above Grouse Creek contain less than 0.1 ppm Hg in the fine-fraction samples.

Several spikes in Hg values occur in the fine fraction of stream-sediment samples. Beginning from immediately below the present day Grouse Creek Mine site the Hg content in the fine-fraction samples decreases downstream from 1 ppm to around 0.1 ppm. During the early hard-rock vein mining, the Sunbeam Mine was located in the same area as the Grouse Creek Mine, and a mill in Jordan Creek processed ore from the Sunbeam and the Estes Mountain Mines in the early nineteen hundreds (Anderson, 1949). Fine fraction stream-sediment samples at and just below the townsite and millsite at Custer have Hg values as high as 6 ppm. The mill at Custer operated for 8 years and processed as much as 900 tons of ore a month using, at least in part, a mercury amalgamation process (Dee, 1988). The mill operators also dumped their mill tailings into the river (Dee, 1988). High Hg values occur in fine-fraction stream bed sediment samples from two other locations. One location is near the southern end of the ponds adjacent to Polecamp Flat campground, where samples taken each of the two sampling seasons (0YB029 and 1YB053) contained 3.3 and 3.5 ppm Hg, respectively. The second location is along the steep, bouldery reach at Flat Rock Campground where one sample (0YB036) from the first season contained 5.75 ppm Hg. A duplicate sample taken the second year at the same location contained only 0.21 ppm Hg.

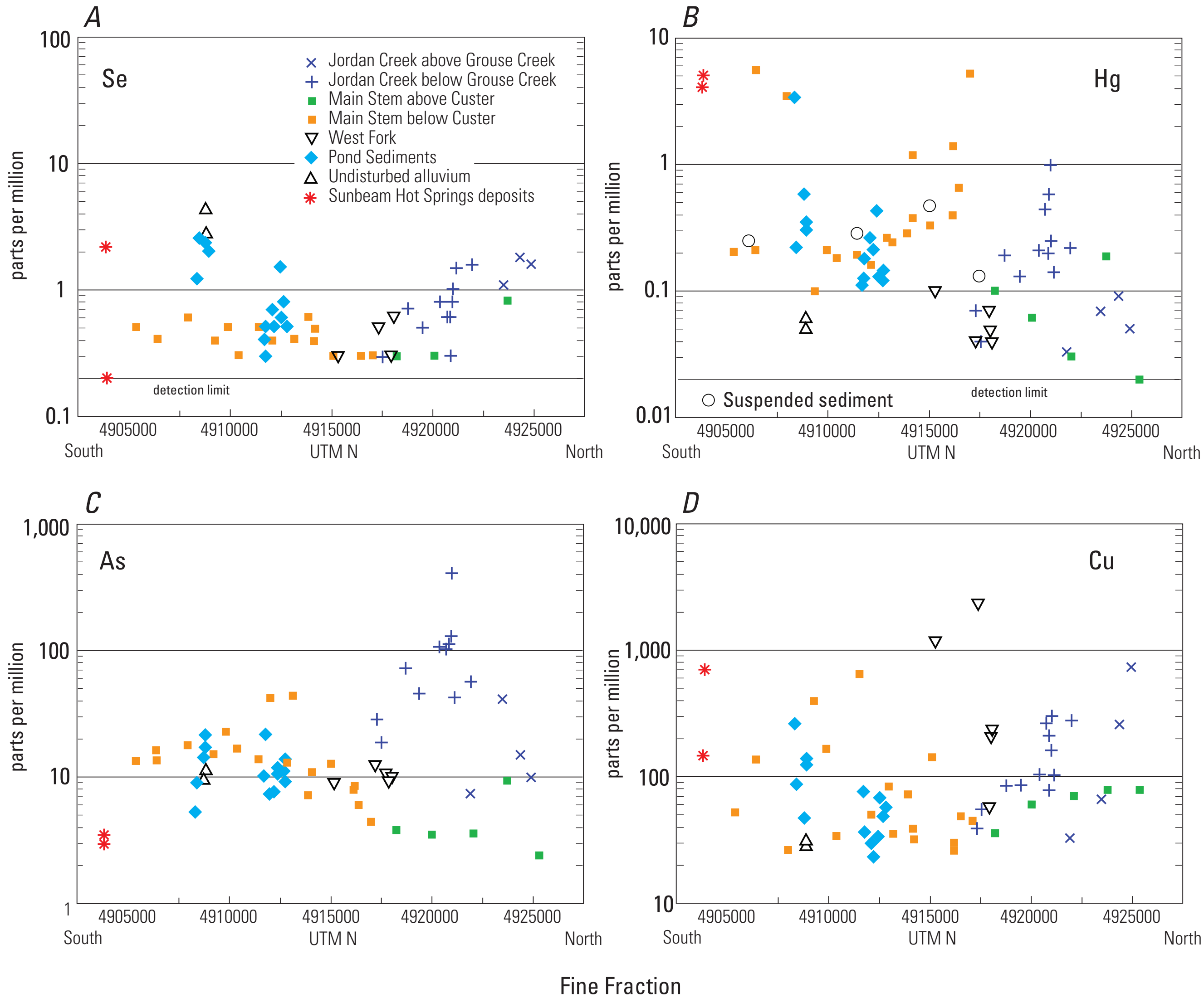

Figure 8. Element contents in parts per million versus UTM-N for fine-fraction (<0.063 mm) sediment samples collected in Yankee Fork drainage, Idaho. *A*, selenium; *B*, mercury; *C*, arsenic; and *D*, copper. The north-south orientation of the Main Stem of Yankee Fork below the West Fork Junction and Jordan Creek enables such a plot to closely reflect the real spatial distribution of the samples along those reaches. Upstream is to the right.

With the exception of sample 0YP033 from the lower rearing pond, which contained 3.3 ppm Hg, all other pond sample fine fractions contained less than 0.6 ppm Hg. The sample with the highest value came from the pond immediately adjacent to the stream-sediment samples near Polecamp Flat campground that also contained elevated Hg.

As noted earlier, the suspended-sediment sampling did not collect much sediment due to the extremely low flow during sampling, however, enough material was obtained for Hg analysis (fig. 8). Suspended-sediment sample 1YS054 from below the Grouse Creek Mine site contained 0.13 ppm Hg. Collected along the Main Stem, just downstream from the Bonanza town site at the bridge crossing, sample 1YS054 contained 0.47 ppm Hg. Sample collected along the Main Stem just upstream from the mouth of Jerry's Creek (sample 1YS050) and downstream from Flat Rock Campground (1YS051) contained 0.29 and 0.25 ppm Hg, respectively.

For comparison, the fine-fraction sediment samples OYH034A and B from the active Sunbeam Hot Springs along the Salmon River upstream from Yankee Fork contained 4 and 5 ppm Hg, respectively. These values reflect the ongoing introduction of Hg into the Salmon River through present-day hydrothermal activity.

Mercury in the Intermediate Fraction

Mercury contents in the intermediate-fraction samples range from below detection limit at 0.02 ppm to 2.8 and 4

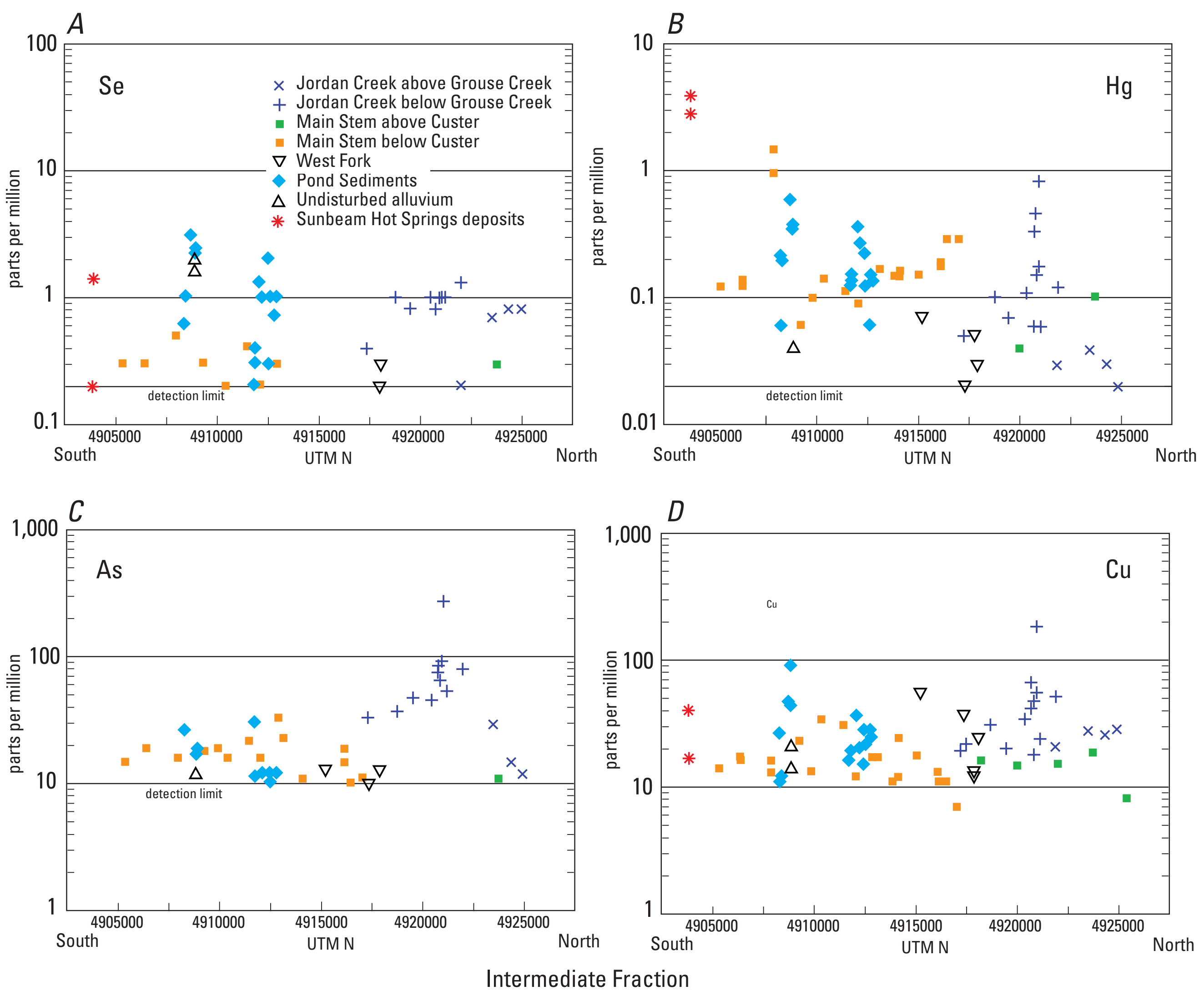

Figure 9. Element content in parts per million versus UTM-N for intermediate-fraction (0.063-0.250 mm) sediments collected in Yankee Fork drainage, Idaho. *A*, selenium; *B*, mercury; *C*, arsenic; and *D*, copper. The north-south orientation of the Main Stem below the West Fork Junction and Jordan Creek enables such a plot to closely reflect the real spatial distribution of the samples along those reaches. Upstream is to the right.

ppm in samples from Sunbeam Hot Spring, outside the study area (fig. 9*B*). Intermediate-fraction bed-sediment samples from the Main Stem above Custer, Jordan Creek above Grouse Creek Mine, and the West Fork all contain less than 0.1 ppm Hg. Below Grouse Creek Mine on Jordan Creek, values jump to as much as 0.82 ppm Hg, decreasing downstream from there to 0.05 ppm at the confluence with the Main stem. Samples from the Main Stem below Custer have values as high as 0.3 ppm just below the townsite, decreasing to an average of 0.13 ppm downstream. Similar to the fine-fraction samples collected at Polecamp Flat (0YB029 and 1YB053) the intermediate-fraction samples contain anomalously high Hg values of 1.46 and 0.83 ppm, respectively.

Mercury content in the intermediate-fraction of the pond-sediment samples ranges from 0.06 to 0.35 ppm in the upper ponds and 0.06 to 0.6 ppm in the lower ponds.

The intermediate-fraction sediment samples from Sunbeam Host Springs, along the Salmon River above Yankee Fork, contain 3 and 4 ppm Hg, more than twice as much as any of the samples from Yankee Fork drainage. As with the fine-fraction splits from these same samples, the values reflect the ongoing introduction of Hg into the Salmon River through present-day hydrothermal activity.

Mercury in the Coarse Fraction

Mercury was not determined in the coarse-fraction splits.

Arsenic in the Fine Fraction

Arsenic in the fine-fraction samples was determined by two methods, this discussion is restricted to the results for the more sensitive method, continuous-flow hydride generation atomic absorption spectrometry (Hageman and others, 2002) which has a detection limit of 0.6 ppm (appendix B). Fine-fraction samples from bed sediments from the relatively undisturbed Main Stem above Custer contain less than 10 ppm As (fig. 8). Samples from Jordan Creek above Grouse Creek Mine contain between 8 and 40 ppm As; below the mine site samples contain between 418 and 20 ppm. Only one sample reported 418 ppm, all others are less than 130 ppm. Samples from the Main stem below Custer site contain between 5 and 40 ppm As, and samples from the West Fork, the ponds, undisturbed alluvium, and Sunbeam Hot Spring all contain less than 25 ppm As.

Arsenic in the Intermediate Fraction

With the exception of fine-fraction samples from just below the Grouse Creek Mine, As values are as high as 276 ppm (fig. 9*C*), As content is below 35 ppm in samples from all reaches, and in many samples As is below the detection limit of 10 ppm for the ICP-AES method used on the intermediate fraction. Note that the detection limit for As on figure 9*C* is ten times the detection limit for the more sensitive method shown in figure 8*C*.

Copper in the Fine Fraction

Fine-fraction samples from the Main Stem above Custer contain less than 80 ppm Cu (fig.8*D*). Copper content in Jordan Creek samples above Grouse Creek decrease from 732 ppm in the sample (0YB001) collected near the headwaters to 30 ppm in the sample from just above the Grouse Creek Mine. Below the mine, Jordan Creek Cu contents are as high as 300 ppm and decrease downstream to 30 ppm. In samples from the West Fork, Cu values are as high as 2,360 ppm. There is a molybdenum-copper prospect at Red Mountain on the West Fork that probably accounts for the high Cu contents. Copper values in sediment samples from the Main Stem below Custer range from 25 to 600 ppm with no discernable trends. Copper content in fine-fraction pond sediment samples is between 30 and 70 ppm in the upper ponds and between 40 and 250 ppm in the lower ponds.

Copper in the Intermediate Fraction

Copper values in the intermediate fraction (fig. 9*D*) mimic those in the fine fraction (fig. 8*D*) except that the abundances are almost an order of magnitude lower, as expected due to the tendency of Cu to be contained in the finer grain-sized heavy minerals. Copper in the West Fork intermediate-fraction samples is not the highest reported, that distinction belongs to samples immediately below the Grouse Creek Mine on Jordan Creek, which contain as much as 200 ppm Cu. Some of the samples from the lower ponds series are also relatively high in Cu content in the intermediate fraction, as well.

Sediment Chemistry by Reach and Sample Type—Enrichment Relative to Premining Concentrations

This section examines the variation in sediment chemistry for the size fractions by average value for reaches and sample types compared to the average composition of samples presumed to represent as close to a “baseline” as possible, those of the relatively pristine Main Stem above Custer (samples 0YB011-014; figs 4-9). This discussion allows for an overview of the average elemental content of each sediment size fraction in each stream reach or in the ponds, compared to that “baseline,” where there has been little placer mining or extensive hard-rock prospecting. Most elements determined in this study have enrichment factors smaller than 3 times the background values and the discussion that follows only highlights those elements with enrichment factors larger than 3 times background.

Metal Enrichment Compared to Background Sediments

The main stem and tributaries of the Yankee Fork upstream from Custer experienced little, if any, placer or hard-rock mining activity, and undisturbed sediments there probably are close to the original background values for most elements in Yankee Fork stream sediments prior to mining. The metal contents for sediments above Custer, therefore, should provide a best estimate for values from the entire Yankee Fork drainage prior to mining. The main stem of Yankee Fork above the Custer townsite and one tributary drainage were sampled in four locations for bed sediments to establish an average "baseline" value for elemental contents in each size fraction of bed sediments. The average of the four samples for any given element for any grain-size fraction from the baseline samples is used as a normalizing value in the metal enrichment section that follows.

To get an estimate of the metals that are significantly enriched in mining-contaminated sediments, plots of the enrichment factors for the average of samples of the three grain-size fractions of sediment for different reaches and environments in the Yankee Fork Basin are plotted in figures 10 through 12. The individual reaches distinguished are: (1) West Fork, Jordan Creek (2) above, and (3) below the Grouse Creek mine, (4) the Main Stem from Custer to the West Fork Junction, (5) the Main Stem from West Fork junction to Ramey Creek, (6) the Main Stem from Ramey Creek to Polecamp Flat, and (7) from Polecamp Flat to Sunbeam. Also plotted for each size fraction, where recovered, are sediments from the rearing ponds, undisturbed alluvial sediment near Ramey Creek, mollusk shells, and, for comparison, sediment from Sunbeam Hot Spring relative to the average values for fine, intermediate, and coarse fractions of the stream sediments relatively undisturbed by mining upstream from Custer. Arsenic was determined by two analytical protocols (see appendix B) for the fine fraction and both reported values are shown on figures 10 through 12.

Fine Fraction

Main Stem and Jordan Creek

The enrichment factors for the average fine-fraction stream-bed sediment sample in the reaches defined abov, relative to the background values, have greater than 5 times the background value for As, Hg, and Sb for some reaches, and lesser enrichment in Cu, Se, and Zn (fig. 10*A*).

Jordan Creek fine-fraction stream-bed sediments below Grouse Creek Mine average 20-28 times the background value for As, depending on which analytical technique is used (fig. 10). The average As content of other Main Stem fine-fraction sediment are between 3 and 6 times background values.

Fine-fraction main-stem sediments from below Custer to the West Fork junction, from Ramey Creek to Polecamp Flat, and from Polecamp Flat to Sunbeam all contain greater than 15 times the background for Hg (fig. 10*B*). Mercury in the fine-fraction sediments from Jordan Creek below Grouse Creek Mine is four times the background, whereas sediments above Grouse Creek Mine show no evidence of Hg enrichment relative to background sediments.

Antimony in the fine-fraction bed-sediment samples shows variable enrichments relative to the background values (fig. 10*A*). The greatest Sb enrichment is in the fine sediments in Jordan Creek below the Grouse Creek Mine, where the enrichment factor is 20 times the background value. Jordan Creek fine-fraction bed-sediments above the mine contain 8 times the background values. Bed-sediment samples from below the West Fork Junction all contain less than 8 times the background values.

Selenium in the fine-fraction bed-sediment samples (fig. 10*A*) for all reaches has less than five times the background value. Jordan Creek above Grouse Creek Mine has the highest Se values, which are 4.1 times the background values.

Zinc is the only other element in the fine-fraction bed-sediment samples below Grouse Creek Mmine that shows enrichment greater than 4 times the background value (fig. 10*A*).

Ponds and Hot Springs

Average enrichment factors in the rearing ponds relative to background values are all less than 3 times the background value except for Hg, which is 5.8 times background, and Se, which is 4 times the background value (fig. 10*B*). The average for the two samples from Sunbeam Hot Springs, which are shown for comparison purposes, is greater than five times the background value for beryllium (Be; 8x), Cu (5.9x), gallium (Ga; 4.5x), Hg (60x), Se (4.5x), and strontium (Sr; 6.6x). The hot springs at Sunbeam represent a geologic setting similar to the hydrothermal systems that gave rise to the deposits in Yankee Fork, so the high values for all these elements are not unusual and provide a context in which to compare the elemental enrichments in Yankee Fork sediments.

Undisturbed Alluvium, West Fork, and Suspended Sediments

Samples from the West Fork contain 10 times the Cu and 6 times the Sb relative to the undisturbed sediments from the Main Stem above Custer (fig. 10*C*). Other enrichment factors from West Fork samples are all less than 3 times the background value, including those for As, Hg, and Se. Extensive mining has not occurred on the West Fork, although there is a major exposure of highly oxidized and mineralized rock underlying Red Mountain.

The high Se content in the undisturbed sediment samples collected from the dredge or rearing pond bank is surprising. In 2000, a sample was collected from the back wall of one of the rearing ponds, at a cut bank that had been created by the dredge during one of its passes through the alluvium (0YA028, tables 2 through 4). The stratigraphy exposed in the bank is as follows, from the top down: grass and roots (5 cm), black organic-rich soil (5 cm), yellowish-tan sandy ash and laminated ashy sand (30 cm), and sandy gravel (10 cm). Below this level the outcrop was covered by loose materials eroded from higher on the face. Sample 0YA028 was obtained from a freshly-scraped surface of the sandy gravel layer. In 2001, a sample of sand was obtained from the same area (sample 1YA070, tables 2 through 4), though we collected material freshly excavated by and deposited near the mouth of a gopher or other rodent's burrow. The fine fraction from sample 0YA028 from 2000 contained 2.7 ppm Se and sample 1YA070 from 2001 contained 4.2 ppm Se, for an average enrichment factor of 12.5 times the background value. The higher result from the rodent-disturbed sample may reflect Se contained in the rodent's urine, though the other sample came from otherwise undisturbed sediment. The biochemistry and possible retention of selenium in rodents and their urine is a topic considerably beyond the scope of the present discussion, and the possibility of Se concentration in urine is offered only as one possible explanation of why the element is anomalously high

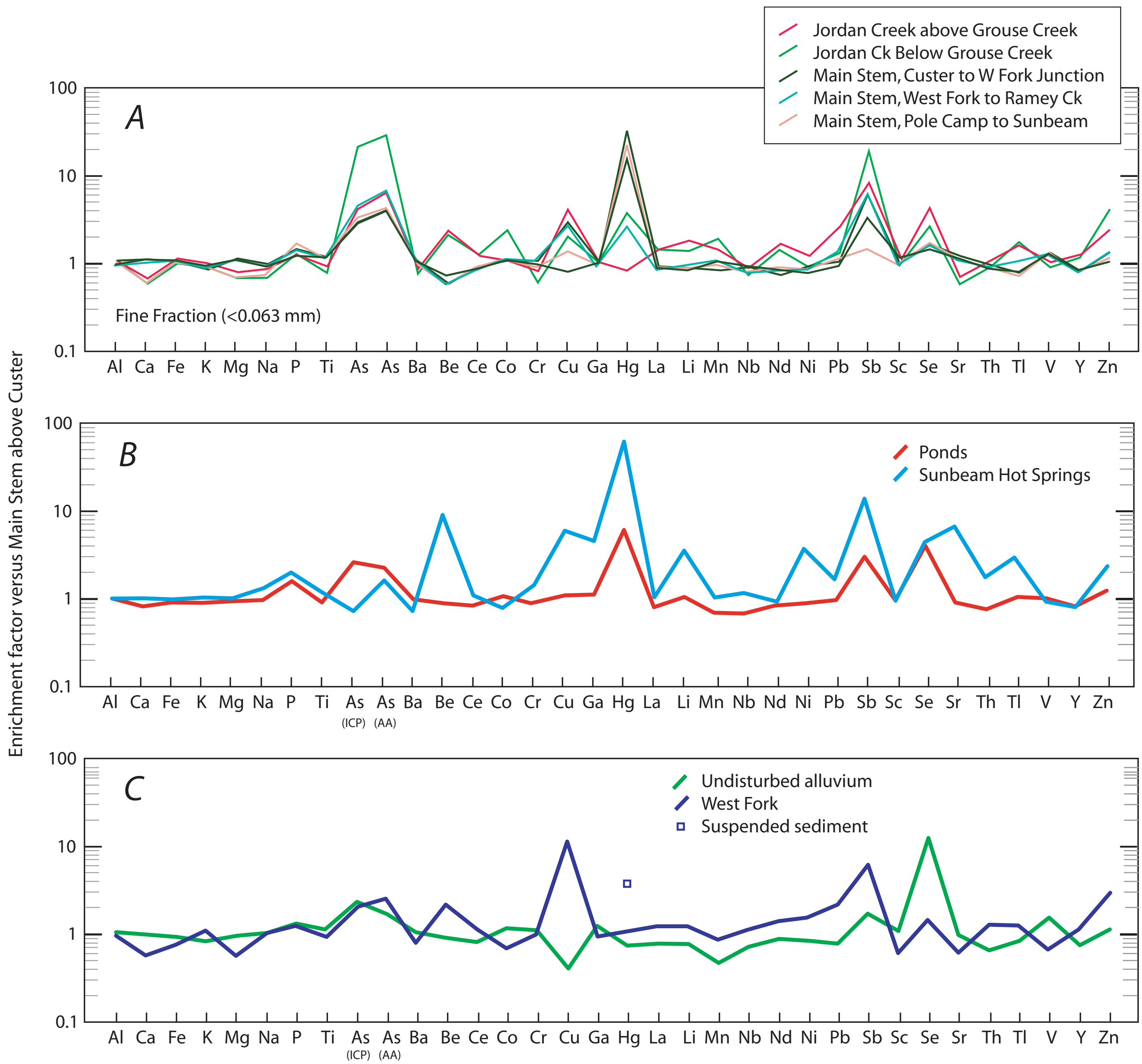

Figure 10. Fine-fraction (<0.063 mm) enrichment factors for the average sample along each reach relative to the average value for each element plotted from samples from the Main Stem above Custer. This method allows comparison of averages of large numbers of samples and elements for each reach. The normalizing factor in each case is the average value for the fine-fraction sediments from the Main Stem above Custer, which represents the best estimate possible for background values that might have been obtained prior to mining disturbance. *A*, Main Stem and Jordan Creek; *B*, ponds and Sunbeam Hot Springs; and *C*, undisturbed alluvium, West Fork, and suspended sediment samples.

in otherwise undisturbed alluvial sediments. Suggestions for additional work to determine the extent of the Se anomaly are contained in the discussion section.

Suspended Sediment

Even though the sampling occurred on the day of the highest daily water flow for the year at the nearby Sunbeam streamflow gage on the Salmon River, the very low amount of suspended sediment in the low-water year of 2001 yielded only enough sample material for analysis of Hg (fig. 10*C*). As mentioned previously, the water at all suspended sediment sampling locations was clear at the time of collection. The suspended material recovered was primarily organic matter, and no effort was made to separate organic from inorganic components. The average Hg enrichment factor of the bulk suspended sediment, relative to the fine fraction of bed sediment from upstream of Custer on the Main Stem, was 3.8 times the background value.

Intermediate Fraction

Enrichment factors for the different stream reaches and sample types for the intermediate fraction (0.25-1.0 mm) samples (fig. 11) are displayed at the same scale and layout as used in figure 10, even though some elements analyzed for in the fine fraction were not analyzed for the intermediate-fraction samples.

Main Stem and Jordan Creek

Average intermediate size fraction samples from some reaches of the main stem of the Yankee Fork below Custer and Jordan Creek are greater than 3 times the background value in As, Hg, and Se relative to the background values for the Main Stem above Custer (fig. 11*A*). Arsenic by ICP-AES is 18 times the background value in stream sediment samples in Jordan Creek below Grouse Creek Mine. Similar to the results for the fine fraction, Hg is 12.9 times the background value between Ramey Creek and Polecamp Flat. The main stem below Custer and Jordan Creek below Grouse Creek mine contain 3.1 times background for mercury, all other reaches are below 3 times background. Selenium in the intermediate fraction is elevated both above and below the Grouse Creek Mine, average values are 12.5 times and 14.5 times the background value, respectively. Selenium in other reaches is between 4 times and 5.3 times background, with the exception of the Main Stem below Custer, which shows no enrichment factor for Se. Zinc in Jordan Creek below Grouse Creek Mine is 3 times the background value, other reaches show no enrichment in Zn.

Ponds and Hot Spring

Average intermediate-fraction pond sediment samples are below 3 times enrichment for all elements except Hg, which is 3.6 times, and Se, which is 23 times background values (fig. 11*B*). Intermediate fraction samples from sediments in the active thermal pools of Sunbeam Hot Springs are elevated in beryllium (Be; 4.8 times), Hg (53 times), and Se (16 times) relative to the background values. Although high, these values are not significant to the present study except as comparisons to what nearby active hydrothermal springs are producing.

West Fork, Undisturbed Alluvium, and Shells and Casings

The intermediate fractions from the West Fork, undisturbed alluvium, and mollusk shells and stonefly casings are unremarkable except for As (6 times) in the bivalve shells and stonefly casings subsampled from sample 033, and for Se in the shells and casings (12 times) and in the undisturbed alluvium sample in which Se is 33 times background values (fig. 11*C*). The elevated Se in the medium-fraction undisturbed alluvium samples (0YA028 and 1YA70) is similar to the results for the fine-fractions of these same samples.

Coarse Fraction

With the exception of As (9.3 times) determined by ICP-AES in Jordan Creek below Grouse Creek Mine, the coarse fraction (1.0-2.0 mm) for all samples is at or below 3 times the background values (fig. 12*A-C*) for all measured elements. The coarse fraction is made up of sand-sized material, which is composed predominantly quartz, feldspars, other ordinary rock-forming silicate minerals, and rock fragments, none of which typically contain anomalous contents of transition or heavy metals.

Discussion

Historical hard-rock mining of gold vein deposits and placer mining of stream and terrace gravels, and the recent bulk-mining operations to exploit low-grade ores in the Yankee Fork District have resulted in enrichments of Hg, Se, As, and to a lesser extent Cu and lead (Pb) in the stream and pond sediments below the mining and milling operations. Some of the high values, for example, Cu on the West Fork, are due to the naturally high values in sediments derived from the copper-molybdenum prospect at the aptly named Red Mountain near the stream's headwaters.

Selenium commonly is present at elevated levels in many epithermal Au and Ag deposits, and numerous descriptions of the early mining in Yankee Fork include mention of the high levels of Se, mostly in Ag and Au selenide minerals associated with the deposits (Nolan, 1933; Anderson, 1949, Davidson, 1960; Davidson and Powers, 1959). Shannon (1926) mentions the occurrence of naumannite (silver selenide) in Yankee Fork District. Allen and Hahn (1994) identified naumannite and aguilarite (a silver-selenium sulfide) as occurring in the Grouse Creek deposit. No modern analyses for Se in the bedrock or ore samples were located during the course of this study. The high Se contents in the Yankee Fork sediments are therefore most probably a result of the high background contents in the volcanic rocks of the area and the high contents of the veins exploited for their Au and Ag. The disturbances due to mining have increased the volume of Se-containing rock exposed to weathering, resulting in high concentrations of readily soluble Se in the Yankee Fork drainages.

Mercury contents in the stream sediments of Yankee Fork show obvious spikes at the sites of Custer, Sunbeam Mill, and in several spotty locations downstream. The early mills used Hg to recover Au, and there were undoubtedly many releases of Hg into the rivers, as well as Hg vapors released during retorting of the Hg to recover the Au. Localized high Hg contents, such as near the mouth of Rankin Creek, are probably also due to localized Hg-based processing to recover Au. Additional local high values may

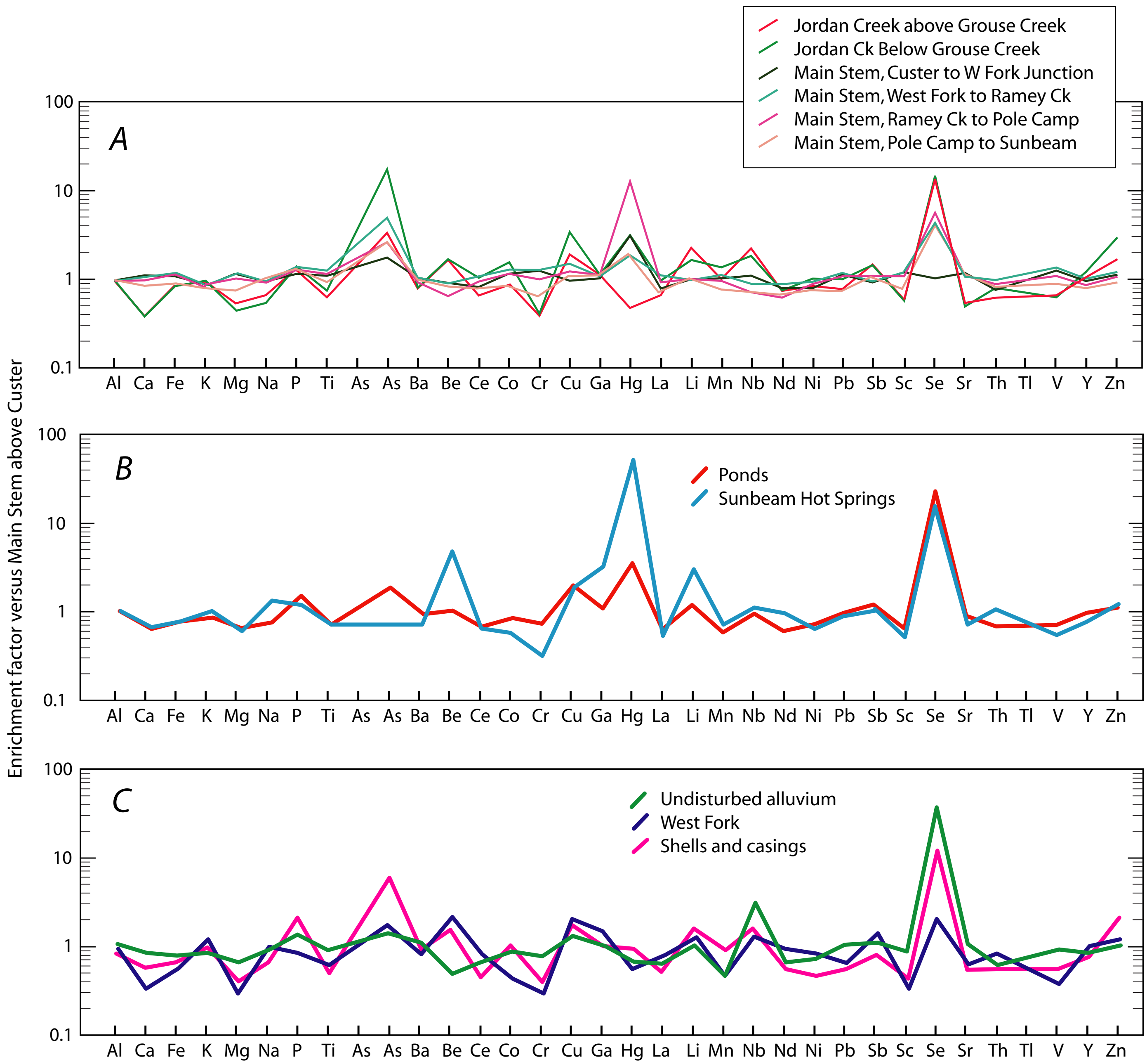

Figure 11 Intermediate-fraction (0.063-0.250 mm) enrichment factors for the average sample along each reach relative to the average value for each element plotted from samples from the Main Stem above Custer. This method allows comparison of the average of large numbers of samples and elements for each reach. The normalizing factor in each case is the average value for the fine-fraction sediments from the Main Stem above Custer, which represents the best estimate possible for background values that might have been obtained prior to mining disturbance. *A*, Main Stem and Jordan Creek; *B*, ponds, mollusk casings and shells and Sunbeam Hot Springs; and *C*, undisturbed alluvium and West Fork.

be present, although the sampling density of this study is not adequate to identify all such high concentrations.

Suggestions for Additional Sampling

To determine if the high Se content in the undisturbed alluvium at sample localities 0YA028 and 1YA070 is representative of the broader alluvial plain sediments there, or is localized to the immediate pond bank, several auger pits in the grassy meadow upstream of the bank could be made and samples taken from the subsoil could be analyzed. No samples were obtained from the coarse, mostly boulder- and cobble-sized material left behind as the surface spoils from the dredge. Analysis of several samples of the fine material interstitial to the boulders and cobbles from some of these piles could determine if there is elevated mercury or selenium in the upper parts of the largely undisturbed piles.

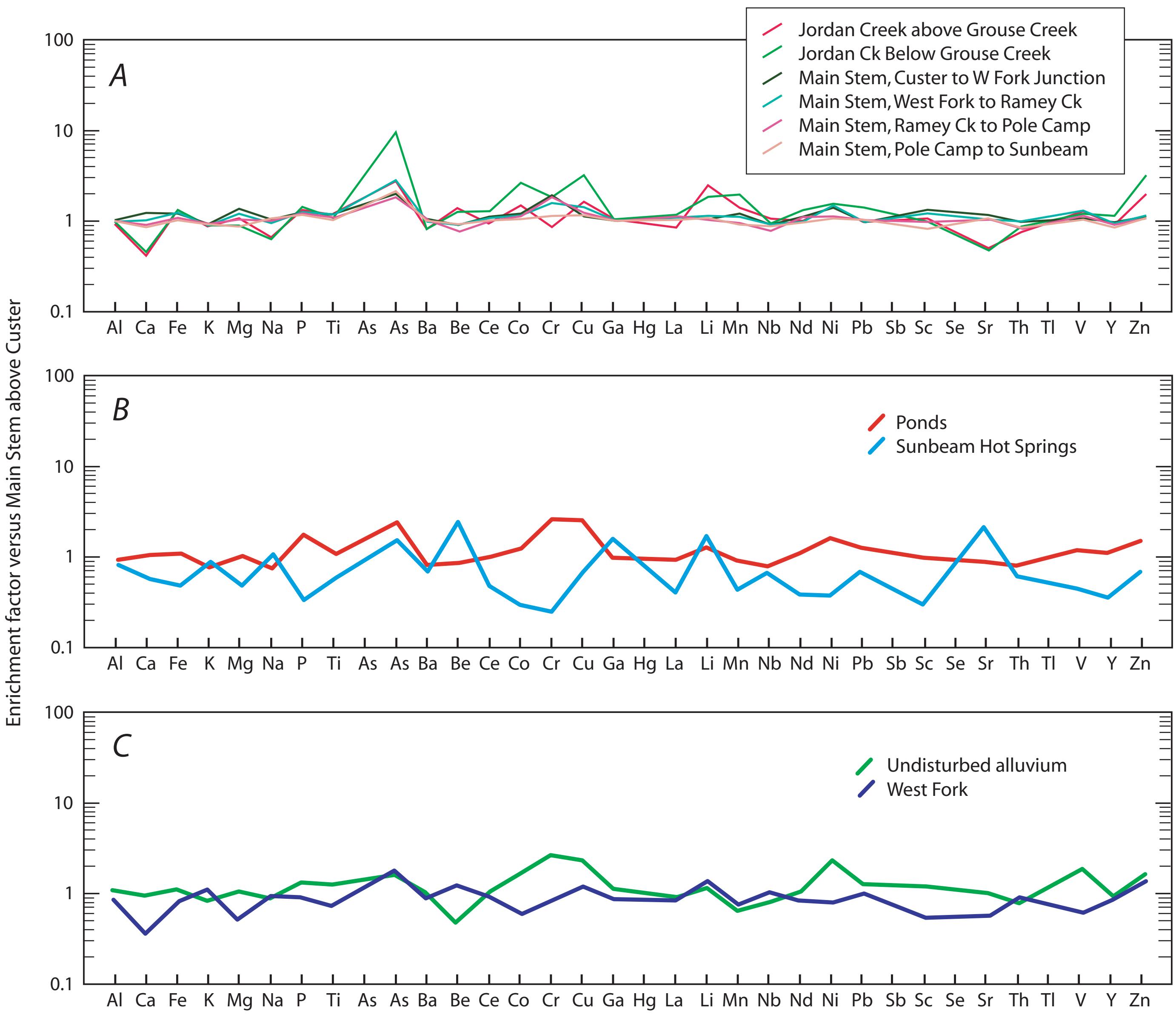

Figure 12. Coarse-fraction (0.250-1.0 mm) enrichment factors for the average sample along each reach relative to the average value for each element plotted from samples from the Main Stem above Custer. This method allows comparison of averages of large numbers of samples and elements for each reach. The normalizing factor in each case is the average value for the fine fraction sediments from the Main Stem above Custer, which represents the best estimate possible for background values that might have been obtained prior to mining disturbance. *A*, Main Stem and Jordan Creek; *B*, Ponds and Sunbeam Hot Springs; *C*, undisturbed alluvium and West Fork.

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Tables 1-4

Table 1. Sample descriptions, UTM zone 11 locations, mass, and grain size distribution.

Sample ID	Sample Type	Fork or Sample Type	Topo Map	UTM E	UTM N	Proportion									
						Grams total	>8mm	4-8 mm	2-4 mm	1-2 mm	0.5-1.0 mm	0.25-0.50 mm	0.125-0.250 mm	0.063-0.125 mm	<0.063 mm
						Not Analyzed				Coarse Fraction		Medium Fraction		Fine Fraction	
0YA028	undisturbed	undisturbed	Sunbeam	682271	4908904	510	0.221	0.106	0.030	0.093	0.074	0.108	0.170	0.126	0.074
0YB001	bed_sed	jordan_ck	Mt. Jordan	678825	4924906	6590	0.639	0.191	0.094	0.054	0.015	0.005	0.002	0.001	0.001
0YB002	bed_sed	jordan_ck	Custer	679994	4924356	5111	0.427	0.277	0.152	0.087	0.035	0.015	0.004	0.001	0.001
0YB003	bed_sed	jordan_ck	Custer	680314	4923510	4135	0.058	0.102	0.116	0.316	0.276	0.102	0.018	0.006	0.005
0YB004	bed_sed	jordan_ck	Custer	681022	4921944	1507	0.091	0.005	0.002	0.019	0.187	0.368	0.211	0.079	0.039
0YB005	bed_sed	jordan_ck	Custer	680966	4921944	3979	0.224	0.212	0.253	0.210	0.065	0.027	0.006	0.002	0.002
0YB006A	bed_sed	jordan_ck	Custer	680494	4920730	4354	0.580	0.175	0.076	0.080	0.047	0.024	0.009	0.005	0.005
0YB006B	bed_sed	jordan_ck	Custer	680494	4920730	44	0.023	0.020	0.009	0.036	0.307	0.477	0.123	0.005	0.000
0YB007	bed_sed	jordan_ck	Custer	680422	4919437	2430	0.158	0.210	0.210	0.202	0.086	0.063	0.042	0.017	0.012
0YB008	bed_sed	jordan_ck	Custer	681180	4917282	2370	0.171	0.102	0.081	0.145	0.167	0.178	0.094	0.036	0.026
0YB009	bed_sed	main stem	Custer	681635	4916180	3483	0.145	0.045	0.028	0.036	0.041	0.287	0.295	0.082	0.040
0YB010	bed_sed	main stem	Eleven mile	689836	4922106	5918	0.059	0.088	0.125	0.285	0.252	0.148	0.032	0.007	0.003
0YB011	bed_sed	main stem	Eleven mile	691790	4925365	3339	0.257	0.088	0.066	0.157	0.233	0.136	0.044	0.013	0.006
0YB012	bed_sed	main stem	Eleven mile	688037	4923793	5936	0.442	0.160	0.129	0.128	0.070	0.042	0.017	0.006	0.005
0YB013	bed_sed	main stem	Custer	687982	4920097	5773	0.400	0.165	0.051	0.090	0.101	0.116	0.052	0.014	0.010
0YB014	bed_sed	main stem	Custer	685222	4918289	6502	0.236	0.238	0.149	0.045	0.096	0.162	0.055	0.013	0.005
0YB015	bed_sed	main stem	Custer	683214	4917067	4388	0.224	0.058	0.042	0.113	0.213	0.234	0.090	0.020	0.006
0YB016	bed_sed	main stem	Custer	682064	4916513	2679	0.334	0.117	0.069	0.074	0.064	0.130	0.146	0.045	0.020
0YB017	bed_sed	main stem	Sunbeam	681355	4915090	1994	0.315	0.146	0.116	0.106	0.098	0.116	0.069	0.023	0.010
0YB018	bed_sed	main stem	Sunbeam	681081	4914173	2933	0.141	0.128	0.131	0.128	0.113	0.156	0.132	0.048	0.023
1YB019	bed_sed	main stem	Sunbeam	681197	4913202	2614	0.113	0.177	0.174	0.183	0.140	0.138	0.052	0.014	0.009
0YB020	bed_sed	main stem	Sunbeam	681315	4912940	3691	0.344	0.158	0.074	0.144	0.103	0.099	0.057	0.013	0.007
0YB024	bed_sed	main stem	Sunbeam	681502	4912101	4145	0.222	0.078	0.048	0.106	0.134	0.223	0.142	0.032	0.015
0YB025	bed_sed	main stem	Sunbeam	681772	4910435	2399	0.188	0.134	0.083	0.060	0.083	0.205	0.151	0.058	0.038
0YB026	bed_sed	main stem	Sunbeam	682178	4909278	3707	0.277	0.134	0.072	0.143	0.233	0.118	0.019	0.003	0.001
0YB029	bed_sed	main stem	Sunbeam	681925	4907983	2575	0.091	0.076	0.037	0.111	0.191	0.254	0.147	0.066	0.027
0YB031	bed_sed	main stem	Sunbeam	681155	4913898	3811	0.336	0.175	0.116	0.110	0.100	0.097	0.045	0.014	0.007

Table 1. Sample descriptions, UTM zone 11 locations, mass, and grain size distribution.—Continued.

Sample ID	Sample Type	Fork or Sample Type	Topo Map	UTM E	UTM N	Proportion									
						Grams total	>8mm	4-8 mm	2-4 mm	1-2 mm	0.5-1.0 mm	0.25-0.50 mm	0.125-0.250 mm	0.063-0.125 mm	<0.063 mm
						Not Analyzed				Coarse Fraction		Medium Fraction		Fine Fraction	
0YB032	bed_sed	main stem	Sunbeam	681738	4911463	3429	0.369	0.195	0.117	0.172	0.096	0.039	0.009	0.002	0.001
0YB033	pond	pond	Sunbeam	682060	4908352	787	0.362	0.093	0.038	0.058	0.049	0.138	0.203	0.053	0.006
0YB035	bed_sed	main stem	Sunbeam	681058	4905377	4572	0.526	0.206	0.074	0.054	0.051	0.053	0.024	0.008	0.004
0YB036	bed_sed	main stem	Sunbeam	682097	4906450	2420	0.226	0.277	0.100	0.092	0.092	0.116	0.069	0.019	0.007
0YB037	bed_sed	main stem	Sunbeam	681950	4909872	3490	0.402	0.204	0.062	0.072	0.095	0.100	0.045	0.013	0.008
0YB040	bed_sed	west fork	Jordan Mtn.	672970	4918103	389	0.065	0.282	0.221	0.290	0.078	0.031	0.020	0.010	0.003
0YB041	bed_sed	west fork	Jordan Mtn.	673520	4917942	664	0.165	0.280	0.173	0.111	0.076	0.098	0.062	0.023	0.012
0YB042	bed_sed	west fork	Jordan Mtn.	672980	4917961	829	0.177	0.110	0.081	0.172	0.202	0.178	0.065	0.011	0.003
0YB043	bed_sed	west fork	Jordan Mtn.	675887	4917388	890	0.084	0.259	0.175	0.237	0.157	0.071	0.013	0.002	0.001
0YB044	bed_sed	west fork	East Basin Ck.	679111	4915283	812	0.121	0.147	0.094	0.308	0.227	0.087	0.013	0.003	0.001
0YH034A	hot_spring	hot spring	Sunbeam	679734	4903867	571	0.011	0.052	0.058	0.278	0.262	0.184	0.090	0.039	0.026
0YH034B	hot_spring	hot spring	Sunbeam	679734	4903867	469	0.362	0.061	0.029	0.096	0.250	0.147	0.030	0.013	0.011
0YP021	pond	pond	Sunbeam	681384	4912777	307	0.000	0.000	0.000	0.003	0.001	0.001	0.085	0.307	0.604
0YP022	pond	pond	Sunbeam	681499	4912459	2782	0.033	0.125	0.097	0.024	0.043	0.189	0.312	0.114	0.062
0YP023	pond	pond	Sunbeam	681586	4912090	220	0.000	0.000	0.000	0.002	0.000	0.000	0.125	0.230	0.642
0YP027	pond	pond	Sunbeam	682256	4908910	193	0.391	0.148	0.009	0.036	0.026	0.042	0.064	0.098	0.186
0YP030A	pond	pond	Sunbeam	681600	4911780	5953	0.224	0.211	0.145	0.173	0.126	0.087	0.025	0.005	0.004
0YP030B	pond	pond	Sunbeam	681600	4911780	458	0.001	0.027	0.016	0.093	0.098	0.101	0.205	0.235	0.224
1YA070	undisturbe	undisturbed	Sunbeam	682270	4908904	875	0.001	0.004	0.037	0.064	0.187	0.273	0.262	0.105	0.066
1YB052	bed_sed	main stem	Sunbeam	682097	4906450	425	0.151	0.091	0.097	0.103	0.133	0.195	0.130	0.061	0.040
IYB053	bed_sed	main stem	Sunbeam	681925	4907983	970	0.380	0.150	0.094	0.054	0.072	0.128	0.082	0.028	0.012
1YB056	bed_sed	jordan_ck	Jordan Mtn.	681092	4917513	514	0.146	0.124	0.094	0.058	0.094	0.209	0.174	0.069	0.032
1YB057	bed_sed	jordan_ck	Jordan Mtn.	680738	4921111	538	0.307	0.215	0.156	0.094	0.094	0.087	0.033	0.009	0.006
1YB058	bed_sed	jordan_ck	Jordan Mtn.	680607	4920967	1807	0.289	0.277	0.188	0.129	0.080	0.023	0.007	0.004	0.004
1YB050	bed_sed	jordan_ck	Jordan Mtn.	680607	4920967	1739	0.307	0.282	0.196	0.113	0.063	0.024	0.008	0.003	0.003
1YB060	bed_sed	jordan_ck	Jordan Mtn.	680522	4920830	1790	0.329	0.211	0.177	0.128	0.074	0.033	0.021	0.015	0.010
1YB061	bed_sed	jordan_ck	Jordan Mtn.	680522	4920830	1913	0.255	0.215	0.193	0.151	0.089	0.047	0.025	0.014	0.011

Table 1. Continued.

Sample ID	Sample Type	Fork or Sample Type	Topo Map	UTM E	UTM N	Proportion									
						Grams total	>8mm	4-8 mm	2-4 mm	1-2 mm	0.5-1.0 mm	0.25-0.50 mm	0.125-0.250 mm	0.063-0.125 mm	<0.063 mm
						Not Analyzed				Coarse Fraction		Medium Fraction		Fine Fraction	
1YB062	bed_sed	jordan_ck	Jordan Mtn.	680374	4920380	1966	0.277	0.204	0.199	0.138	0.087	0.053	0.025	0.009	0.007
1YB063	bed_sed	jordan_ck	Jordan Mtn.	680593	4918721	1229	0.250	0.191	0.177	0.135	0.126	0.075	0.028	0.010	0.007
1YP064	pond	pond	Sunbeam	681349	4912808	249	0.000	0.000	0.000	0.000	0.206	0.107	0.185	0.248	0.253
1YP065	pond	pond	Sunbeam	681358	4912647	941	0.438	0.149	0.098	0.072	0.061	0.064	0.057	0.032	0.030
1YP066	pond	pond	Sunbeam	681376	4912510	164	0.042	0.055	0.239	0.173	0.128	0.136	0.093	0.060	0.074
1YP067	pond	pond	Sunbeam	681559	4912216	450	0.000	0.000	0.028	0.125	0.049	0.050	0.084	0.315	0.349
1YP068	pond	pond	Sunbeam	682088	4908436	1265	0.464	0.115	0.095	0.081	0.088	0.082	0.056	0.015	0.005
1YP069	pond	pond	Sunbeam	682240	4908756	509	0.000	0.000	0.052	0.040	0.137	0.193	0.111	0.087	0.380
1YS050	suspended	suspended	Sunbeam	681732	4911430	1	--	--	--	--	--	--	--	--	1.000
1YS051	suspended	suspended	Sunbeam	681960	4906120	1	--	--	--	--	--	--	--	--	1.000
1YS054	suspended	suspended	Sunbeam	681355	4915062	1	--	--	--	--	--	--	--	--	1.000
1YS055	suspended	suspended	Jordan Mtn.	681092	4917513	1	--	--	--	--	--	--	--	--	1.000

Table 2. Geochemistry of the fine (<0.063 mm) fraction samples.

Table 2 is available online only as a data file

at http://pubs.usgs.gov/sir/2009/5115/data/

Table 3. Geochemistry of the intermediate (0.063-0.25 mm) fraction samples.

Sample Id	type	fork	Topo Map	Hg	Sb	Se	Al	Ca	Fe	K	Mg	Na	P	Ti	As.2
				ppm			percent								ppm
0YA028	undisturbed	undisturbed	Sunbeam	.04	n.d.	1.6	8.47	3.07	3.56	2.32	1.45	1.78	.08	.61	12
0YB001	bed_sed	jordan_ck	Mt. Jordan	.02	n.d.	.8	7.15	.87	3.23	2.40	1.00	1.20	.07	.35	12
0YB002	bed_sed	jordan_ck	Custer	.03	n.d.	.8	7.12	.81	3.20	2.47	.89	1.23	.07	.36	15
0YB003	bed_sed	jordan_ck	Custer	.04	n.d.	.7	7.40	.73	3.09	2.85	.73	1.08	.06	.30	30
0YB004	bed_sed	jordan_ck	Custer	.03	n.d.	.2	8.94	2.93	5.39	2.03	1.54	1.50	.12	.53	<10
0YB005	bed_sed	jordan_ck	Custer	.12	n.d.	1.3	7.22	.68	3.06	2.57	.72	.79	.07	.34	82
0YB006A	bed_sed	jordan_ck	Custer	.34	n.d.	.8	8.08	1.50	4.14	2.31	.92	.98	.09	.37	86
0YB006B	bed_sed	jordan_ck	Custer	.06	n.d.	.9	7.11	1.22	4.14	2.48	.90	.99	.09	.50	78
0YB007	bed_sed	jordan_ck	Custer	.07	n.d.	.8	7.29	1.29	3.56	2.70	.73	1.38	.08	.46	49
0YB008	bed_sed	jordan_ck	Custer	.05	n.d.	.4	8.10	1.90	4.04	2.79	1.15	1.56	.09	.53	34
0YB009	bed_sed	main stem	Custer	.19	n.d.	<.2	8.23	3.88	5.07	2.48	2.23	1.78	.09	.72	15
0YB009dupe	bed_sed	main stem	dupe of 009	.18	n.d.	<.2	7.64	3.60	4.80	2.29	2.03	1.66	.09	.69	19
0YB010	bed_sed	main stem	Eleven mile	<.02	n.d.	<.2	8.32	3.67	4.43	2.85	2.05	2.13	.06	.63	<10
0YB011	bed_sed	main stem	Eleven mile	<.02	n.d.	<.2	8.02	2.83	3.29	2.95	1.42	2.19	.05	.45	<10
0YB012	bed_sed	main stem	Eleven mile	.10	n.d.	.3	7.26	1.92	3.04	2.67	.90	1.63	.05	.43	11
0YB013	bed_sed	main stem	Custer	.04	n.d.	<.2	8.26	3.88	4.39	2.48	2.08	1.90	.07	.56	<10
0YB014	bed_sed	main stem	Custer	.03	n.d.	<.2	7.48	4.72	6.24	2.07	3.02	1.73	.08	.92	<10
0YB015	bed_sed	main stem	Custer	.29	n.d.	<.2	6.59	5.30	8.11	1.75	3.83	1.63	.08	1.32	11
0YB016	bed_sed	main stem	Custer	.29	n.d.	<.2	8.02	3.90	4.70	2.40	2.10	1.89	.07	.68	10
0YB017	bed_sed	main stem	Sunbeam	.15	n.d.	<.2	7.63	3.66	4.37	2.28	1.97	1.78	.07	.57	<10
0YB018	bed_sed	main stem	Sunbeam	.16	n.d.	<.2	7.49	3.79	4.60	2.16	2.18	1.70	.07	.62	11
0YB019	bed_sed	main stem	Sunbeam	.17	n.d.	<.2	8.16	3.43	4.22	2.42	1.83	1.89	.07	.51	23
0YB020	bed_sed	main stem	Sunbeam	.14	n.d.	.3	6.52	4.71	7.54	1.79	3.31	1.58	.09	1.27	33
0YB024	bed_sed	main stem	Sunbeam	.09	n.d.	.2	8.36	3.27	4.15	2.51	1.71	1.94	.08	.58	16
0YB025	bed_sed	main stem	Sunbeam	.14	n.d.	.2	8.06	2.82	3.93	2.47	1.51	1.83	.09	.52	16
0YB026	bed_sed	main stem	Sunbeam	.06	n.d.	.3	7.49	4.28	5.46	1.96	2.60	1.95	.08	.75	18
0YB029	bed_sed	main stem	Sunbeam	1.46	n.d.	.5	8.24	2.86	3.64	2.44	1.42	1.86	.08	.47	16
0YB031	bed_sed	main stem	Sunbeam	.15	n.d.	<.2	8.04	3.54	3.97	2.38	1.81	1.87	.07	.47	<10
0YB032	bed_sed	main stem	Sunbeam	.11	n.d.	.4	7.18	4.04	5.86	2.08	2.74	1.75	.08	.90	22
0YB033	pond	pond	Sunbeam	.21	n.d.	.6	8.11	2.89	3.09	2.46	1.33	1.92	.07	.49	<10
0YB033	shells	shells	Sunbeam	.06	n.d.	.6	6.77	1.98	3.01	2.56	.78	1.28	.13	.32	26
0YB035	bed_sed	main stem	Sunbeam	.12	n.d.	.3	7.82	3.13	4.10	2.24	1.60	1.91	.08	.57	15
0YB036	bed_sed	main stem	Sunbeam	.14	n.d.	.3	7.84	3.23	4.28	2.22	1.72	1.89	.08	.64	19
0YB037	bed_sed	main stem	Sunbeam	.10	n.d.	<.2	7.90	3.52	4.21	2.23	1.91	1.87	.09	.58	19

Ba	Be	Ce	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sr	Th	V	Y	Zn
ppm																				
1140	2	122	16	48	14	19	68	22	374	4	33	52	16	17	18	582	16	130	22	84
689	3	100	12	32	29	21	59	52	562	3	25	52	12	24	11	195	14	81	28	124
754	3	102	11	22	26	21	63	59	501	4	27	50	9	19	10	181	13	75	22	114
699	5	148	15	25	28	20	75	57	1130	7	26	74	8	26	9	160	16	64	28	242
1030	2	85	25	35	21	20	44	22	975	2	25	39	19	13	17	534	18	126	22	90
753	4	160	16	20	52	19	96	51	755	6	25	72	24	30	10	157	19	70	30	302
785	4	170	31	33	67	20	100	38	1460	4	23	76	18	22	13	273	20	87	32	369
845	3	251	23	27	41	18	143	42	783	4	28	84	17	23	12	219	27	107	23	223
818	3	133	15	21	20	18	71	31	773	4	39	54	11	27	10	265	20	77	25	147
916	3	127	16	44	19	21	67	30	746	3	35	48	13	18	13	349	19	100	25	112
1110	2	117	20	84	13	18	67	23	887	3	38	53	16	15	24	550	21	173	25	99
985	2	118	18	75	11	19	65	20	815	<2	34	47	16	13	21	519	19	158	22	94
1050	2	173	17	82	15	20	102	22	883	2	43	75	16	16	21	518	27	121	25	92
997	2	174	12	47	8	18	98	21	622	<2	35	61	13	15	14	438	26	79	23	70
936	2	185	11	43	18	18	105	24	575	2	35	67	11	22	11	391	27	75	25	81
999	2	124	18	47	15	18	66	21	758	2	30	51	16	13	21	556	16	135	23	84
855	2	208	25	153	16	20	124	20	1100	2	31	74	22	10	32	542	28	237	26	106
809	1	245	33	231	7	20	150	18	1540	2	33	88	25	12	42	473	27	334	29	149
1100	2	133	19	75	11	17	74	20	799	2	31	53	17	14	22	594	18	155	22	85
1050	2	132	18	67	17	20	74	19	783	2	27	57	19	14	21	573	19	140	21	84
997	2	114	19	84	24	19	65	19	837	<2	27	44	16	14	23	548	17	153	22	93
1150	2	109	16	71	17	20	59	22	754	3	24	39	19	18	19	578	16	122	28	88
789	1	288	31	180	17	20	177	19	1310	2	35	97	25	14	36	460	36	293	27	130
1100	2	108	18	56	12	19	62	23	707	2	30	47	16	15	18	573	16	128	21	89
1050	2	109	15	54	33	20	61	24	647	2	23	41	16	15	15	523	13	114	19	89
861	2	181	22	99	23	19	109	21	933	2	28	70	20	15	28	540	25	185	22	97
1090	2	90	14	41	13	20	51	24	524	2	27	37	13	16	14	580	15	103	19	85
1130	2	92	16	55	11	18	52	20	715	2	28	43	12	14	18	597	17	111	21	84
921	2	232	24	118	31	19	138	21	1030	2	33	71	18	13	29	496	33	210	24	104
1060	2	93	12	62	11	19	53	22	360	2	24	39	11	13	14	571	16	93	17	76
933	3	78	17	30	26	19	48	35	742	3	21	30	9	12	9	261	13	74	18	185
977	2	114	15	57	14	20	66	22	630	2	27	44	12	15	16	567	20	122	19	81
996	2	134	17	51	16	19	77	22	690	2	30	49	12	15	18	558	20	132	19	88
1010	2	118	17	68	13	23	70	22	740	<2	29	43	13	17	21	549	17	142	22	90

Table 3. Geochemistry of the intermediate (0.063-0.25 mm) fraction samples—Continued.

Sample Id	type	fork	Topo Map	Hg	Sb	Se	Al	Ca	Fe	K	Mg	Na	P	Ti	As.2
				ppm			percent								ppm
0YB040	bed_sed	west fork	Jordan Mtn.	<.02	n.d.	.3	6.86	.67	2.07	3.15	.52	1.76	.05	.20	<10
0YB041	bed_sed	west fork	Jordan Mtn.	.05	n.d.	.2	7.33	1.05	2.15	3.26	.32	1.65	.05	.30	13
0YB042	bed_sed	west fork	Jordan Mtn.	.03	n.d.	<.2	7.03	.89	1.83	3.24	.37	1.82	.05	.30	<10
0YB043	bed_sed	west fork	Jordan Mtn.	.02	n.d.	<.2	7.05	1.13	2.63	2.55	.80	1.82	.06	.34	10
0YB044	bed_sed	west fork	East Basin Ck.	.07	n.d.	<.2	7.31	2.10	3.30	2.50	1.01	1.92	.08	.66	13
0YF018dupe	bed_sed	main stem	dupe of 018	.15	n.d.	<.2	7.59	3.89	4.63	2.20	2.23	1.75	.08	.63	<10
0YH034A	hot_spring	hot spring	Sunbeam	2.85	n.d.	1.4	8.37	3.06	4.58	2.59	1.84	2.36	.11	.64	<10
0YH034B	hot_spring	hot spring	Sunbeam	3.85	n.d.	.2	7.49	1.70	2.06	2.57	.52	2.58	.05	.24	<10
0YP021	pond	pond	Sunbeam	.15	n.d.	.7	7.74	1.71	3.43	2.25	1.08	1.36	.09	.37	<10
0YP022	pond	pond	Sunbeam	.22	n.d.	.3	8.06	2.90	3.79	2.37	1.54	1.70	.08	.47	12
0YP023	pond	pond	Sunbeam	.36	n.d.	1.3	8.15	2.33	3.89	2.29	1.32	1.32	.10	.42	12
0YP027	pond	pond	Sunbeam	.35	n.d.	2.4	7.64	1.96	3.40	2.08	1.22	1.18	.11	.37	18
0YP027dupe	pond	pond	dupe of 027	.36	n.d.	2.2	7.48	1.92	3.33	2.02	1.21	1.15	.11	.37	17
0YP030A	pond	pond	Sunbeam	.14	n.d.	.2	7.06	3.77	5.58	2.04	2.54	1.70	.09	.82	31
0YP030Adupe	pond	pond	dupe of 030	.12	n.d.	.3	7.77	2.44	3.55	2.13	1.28	1.62	.09	.44	<10
0YP030B	pond	pond	Sunbeam	.15	n.d.	.4	8.04	2.51	3.73	2.21	1.32	1.69	.10	.45	11
1YA070	undisturbe	undisturbed	Sunbeam	.04	.6	2.2	8.55	2.70	3.13	2.03	1.21	1.66	.09	.49	<10
1YB052	bed_sed	main stem	Sunbeam	.12	.9	.3	8.35	2.51	3.38	2.02	1.19	1.99	.09	.52	<10
1YB053	bed_sed	main stem	Sunbeam	.93	.9	.4	7.22	3.12	5.61	1.95	1.91	1.55	.08	.85	<10
1YB056	bed_sed	jordan_ck	Jordan Mtn.	.02	<.6	<.2	8.32	2.52	4.78	1.29	2.05	1.00	.10	.49	<10
1YB057	bed_sed	jordan_ck	Jordan Mtn.	.06	3.1	1.4	7.43	.88	3.65	2.40	.70	.66	.10	.48	55
1YB058	bed_sed	jordan_ck	Jordan Mtn.	.18	2.6	.8	8.15	1.51	3.91	2.22	.95	.94	.11	.44	92
1YB059	bed_sed	jordan_ck	Jordan Mtn.	.82	5.7	.7	8.47	.67	3.23	2.38	.49	.67	.08	.27	276
1YB060	bed_sed	jordan_ck	Jordan Mtn.	.46	8.8	.3	7.19	.77	2.10	2.64	.33	.78	.04	.25	87
1YB061	bed_sed	jordan_ck	Jordan Mtn.	.15	2.9	.6	8.14	1.27	3.63	2.38	.83	.92	.10	.39	67
1YB062	bed_sed	jordan_ck	Jordan Mtn.	.11	2.2	.7	7.39	1.07	3.62	2.55	.49	1.29	.09	.62	47
1YB063	bed_sed	jordan_ck	Jordan Mtn.	.10	2.3	.7	7.27	1.53	3.87	2.21	.94	1.12	.09	.67	37
1YP064	pond	pond	Sunbeam	.13	.8	.6	7.62	1.63	3.21	2.25	.99	1.35	.10	.37	12
1YP065	pond	pond	Sunbeam	.06	.7	.6	7.43	1.63	2.93	2.33	.91	1.45	.09	.48	<10
1YP066	pond	pond	Sunbeam	.12	.8	1.7	7.45	1.68	2.56	2.05	.99	1.32	.11	.51	10
1YP067	pond	pond	Sunbeam	.26	.6	.7	7.46	2.12	3.22	2.09	1.18	1.21	.09	.38	<10
1YP068	pond	pond	Sunbeam	.19	<.6	.9	8.08	2.72	2.74	2.17	1.24	1.82	.08	.46	<10
1YP069	pond	pond	Sunbeam	.59	3.1	2.6	7.92	1.73	3.80	2.86	1.19	.92	.11	.33	<10

Ba	Be	Ce	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sr	Th	V	Y	Zn
									ppm											
711	4	87	6	12	24	20	52	38	365	3	23	44	7	38	5	202	17	35	23	178
773	3	143	5	17	12	21	76	26	353	3	41	57	5	18	5	301	24	32	26	85
765	3	146	5	12	13	19	84	28	255	2	39	51	5	17	5	260	23	34	23	91
1050	2	132	9	29	37	17	75	27	399	2	27	48	22	12	8	326	17	64	17	72
908	2	152	12	40	55	18	89	23	520	3	38	55	11	13	12	399	19	108	20	85
1040	2	127	20	87	12	17	73	20	866	3	27	48	19	14	24	563	18	160	23	92
641	6	87	16	31	17	49	44	89	822	4	36	36	14	12	17	745	14	116	21	145
794	13	131	4	15	40	69	69	50	345	<2	31	47	15	20	4	<2	38	36	17	61
837	3	107	13	47	28	21	62	30	434	3	26	55	15	19	11	365	13	77	29	108
1020	2	96	16	39	15	19	51	23	497	2	26	38	15	15	15	532	16	105	21	91
1140	3	115	16	48	36	20	62	31	501	3	20	57	19	24	14	470	18	93	32	115
903	2	96	14	49	88	19	49	29	371	3	22	48	19	23	12	391	16	97	24	139
890	2	99	13	47	42	22	51	28	364	3	22	39	19	23	13	382	16	94	24	121
894	2	208	22	90	17	20	124	22	958	2	36	70	17	15	27	471	29	194	24	105
865	2	95	13	39	16	20	54	29	621	<2	25	40	11	15	12	529	19	86	21	91
912	2	103	14	64	19	20	59	32	655	3	28	45	17	18	13	543	20	91	23	104
991	<1	95	14	71	21	20	50	21	346	7	12	39	16	17	15	507	12	129	20	96
911	1	129	13	43	17	24	65	23	557	<2	15	52	12	20	13	569	21	109	20	73
856	<1	183	23	90	16	23	106	21	907	<2	11	67	17	19	23	464	23	157	22	96
621	1	90	23	49	22	22	48	21	753	<2	13	41	14	14	20	334	12	133	24	121
767	2	180	16	39	24	22	100	38	535	4	19	66	12	23	13	168	17	108	22	158
786	4	168	43	34	56	23	99	37	2010	3	17	72	22	21	14	266	15	101	35	393
655	5	241	83	21	184	20	124	48	2770	4	23	95	29	21	9	142	26	55	40	496
613	4	123	5	12	18	21	59	22	382	2	32	49	4	25	5	217	27	36	29	253
768	4	158	28	26	49	24	89	38	1190	3	20	64	15	23	13	239	18	92	32	312
769	3	158	19	33	34	22	83	31	977	3	29	62	11	18	10	224	17	74	27	258
739	2	166	23	38	31	21	90	30	931	3	25	62	13	17	14	261	17	120	27	220
840	2	98	13	58	24	21	51	27	408	<2	16	45	13	17	11	357	14	81	24	102
911	2	109	11	65	21	21	59	25	423	<2	16	47	13	16	11	354	15	90	21	89
885	2	128	12	62	28	21	69	34	366	3	18	52	13	19	12	370	15	94	24	90
894	2	92	14	28	20	20	48	24	435	<2	14	42	11	18	13	439	13	86	25	83
969	1	91	13	73	12	19	50	21	378	<2	13	37	10	15	13	553	12	93	17	71
987	2	112	16	42	46	23	53	37	504	2	16	47	22	29	12	327	19	114	27	120

Table 4. Geochemistry of the coarse (0.25-1.0 mm) fraction samples.

Sample Id	type	fork	Topo Map	Al	Ca	Fe	K	Mg	Na	P	Ti	As.2	Ba	Be
				percent								ppm		
0YA028	undisturbed	undisturbed	Sunbeam	7.76	2.27	2.39	2.51	.83	1.68	.06	.38	<10	1210	2
0YB001	bed_sed	jordan_ck	Mt. Jordan	7.32	.68	3.64	2.56	1.13	1.35	.08	.36	<10	804	3
0YB002	bed_sed	jordan_ck	Custer	6.86	.56	3.16	2.54	.90	1.21	.07	.33	17	903	3
0YB003	bed_sed	jordan_ck	Custer	6.86	.45	2.82	2.86	.71	1.10	.05	.29	21	833	4
0YB004	bed_sed	jordan_ck	Custer	8.19	2.30	4.40	2.33	1.17	1.45	.12	.52	12	1120	2
0YB005	bed_sed	jordan_ck	Custer	6.76	.48	3.00	2.69	.65	.81	.06	.28	44	823	4
0YB006A	bed_sed	jordan_ck	Custer	7.07	.99	3.32	2.53	.74	.94	.09	.34	45	854	3
0YB006B	bed_sed	jordan_ck	Custer	6.68	.99	3.51	2.42	.74	.99	.08	.33	50	905	3
0YB007	bed_sed	jordan_ck	Custer	6.76	1.02	3.07	2.84	.65	1.32	.06	.31	42	869	3
0YB008	bed_sed	jordan_ck	Custer	7.39	1.53	3.06	2.89	.87	1.52	.07	.35	22	1010	3
0YB009	bed_sed	main stem	Custer	7.60	2.76	3.25	2.57	1.26	1.71	.08	.42	17	1090	2
0YB009dupe	bed_sed	main stem	dupe of 009	7.69	2.80	3.27	2.61	1.30	1.73	.08	.39	14	1130	2
0YB010	bed_sed	main stem	Eleven mile	7.46	2.05	1.81	3.13	.55	1.97	.04	.22	<10	1110	2
0YB011	bed_sed	main stem	Eleven mile	6.89	1.57	1.67	3.20	.44	2.04	.04	.22	<10	940	2
0YB012	bed_sed	main stem	Eleven mile	7.29	1.64	2.19	2.96	.54	1.92	.05	.24	<10	1060	3
0YB013	bed_sed	main stem	Custer	8.10	2.72	2.69	2.90	.92	1.95	.06	.33	<10	1230	2
0YB014	bed_sed	main stem	Custer	7.91	3.02	3.20	2.65	1.28	1.85	.08	.38	<10	1200	2
0YB015	bed_sed	main stem	Custer	7.74	3.51	3.52	2.60	1.67	2.05	.07	.39	<10	1240	2
0YB016	bed_sed	main stem	Custer	8.01	3.02	3.14	2.81	1.20	1.99	.07	.39	<10	1260	2
0YB017	bed_sed	main stem	Sunbeam	7.69	2.95	3.22	2.70	1.20	1.91	.07	.38	10	1170	2
0YB018	bed_sed	main stem	Sunbeam	8.33	3.23	3.41	2.86	1.38	2.05	.08	.41	<10	1290	2
0YB019	bed_sed	main stem	Sunbeam	7.90	2.50	3.10	2.73	1.06	1.89	.08	.36	20	1250	2
0YB020	bed_sed	main stem	Sunbeam	7.43	2.81	3.32	2.60	1.25	1.85	.08	.38	19	1100	2
0YB024	bed_sed	main stem	Sunbeam	7.55	2.56	3.27	2.66	1.17	1.80	.08	.42	13	1140	2
0YB025	bed_sed	main stem	Sunbeam	7.57	2.15	2.94	2.72	.96	1.76	.08	.37	12	1190	2
0YB026	bed_sed	main stem	Sunbeam	7.67	2.32	2.74	2.67	.90	2.02	.07	.34	<10	1180	2
0YB029	bed_sed	main stem	Sunbeam	7.74	2.24	2.71	2.76	.83	1.94	.07	.33	11	1180	2
0YB031	bed_sed	main stem	Sunbeam	7.85	2.60	2.79	2.90	.91	1.91	.08	.34	<10	1280	2
0YB032	bed_sed	main stem	Sunbeam	7.40	2.58	3.34	2.65	1.19	1.92	.08	.39	14	1160	2
0YB033	pond	pond	Sunbeam	7.68	2.11	2.35	2.82	.77	1.83	.07	.32	<10	1210	2
0YB035	bed_sed	main stem	Sunbeam	7.49	1.95	2.49	2.83	.72	2.03	.07	.31	10	1170	2
0YB036	bed_sed	main stem	Sunbeam	7.61	2.27	2.85	2.71	.87	1.95	.08	.34	12	1170	2
0YB037	bed_sed	main stem	Sunbeam	7.45	2.27	2.84	2.76	.91	1.90	.08	.35	<10	1190	2
0YB040	bed_sed	west fork	Jordan Mtn.	5.88	.48	1.70	3.04	.39	1.63	.04	.15	<10	750	3

Ce	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sr	Th	V	Y	Zn
ppm																		
90	9	26	15	18	54	20	211	3	22	33	16	17	12	484	15	90	18	62
81	12	12	15	21	44	53	584	4	26	35	11	18	11	190	11	91	17	120
82	9	18	11	20	48	64	516	4	27	32	7	15	10	164	11	78	17	97
99	13	7	17	19	47	56	826	5	24	37	7	20	8	143	15	62	18	181
83	17	13	11	19	48	21	768	2	21	31	8	12	15	456	14	112	21	79
115	13	18	23	17	62	49	750	5	19	42	8	25	8	141	16	64	19	239
122	25	22	31	18	71	39	1060	4	23	45	16	21	11	204	15	79	23	237
119	19	27	30	19	70	41	923	4	20	39	13	26	10	207	17	79	18	194
95	12	17	13	19	55	30	687	3	27	36	9	22	8	216	17	63	22	121
87	11	12	11	19	53	27	531	3	27	31	8	16	10	312	15	73	22	92
101	12	19	10	18	64	21	553	2	25	39	10	14	14	491	15	91	20	72
91	11	32	8	17	56	21	573	2	24	38	10	15	14	501	17	91	20	72
72	5	6	5	17	43	18	330	<2	21	27	6	15	6	447	19	37	17	45
80	5	4	5	20	46	19	321	<2	25	27	6	16	5	315	16	34	18	45
115	7	7	12	19	68	20	454	2	20	37	7	19	7	408	18	48	21	59
84	8	8	8	19	50	19	450	<2	22	31	7	13	10	551	17	69	19	58
80	11	22	8	19	52	19	574	2	20	28	9	15	14	575	14	87	20	64
106	12	41	8	19	66	17	681	2	20	38	13	14	19	541	16	101	20	66
127	10	27	13	18	77	19	553	<2	23	42	16	13	14	570	18	85	20	64
102	11	29	8	20	63	18	564	<2	19	35	10	14	13	540	18	85	18	64
97	12	27	10	19	58	21	609	2	22	34	12	15	15	582	16	97	21	76
87	10	20	9	19	52	22	525	2	20	31	9	18	11	516	18	79	18	70
96	12	22	9	19	60	19	558	2	21	34	11	18	14	479	17	90	19	72
105	11	26	9	20	66	21	565	2	22	36	10	15	13	475	16	93	19	69
93	10	13	13	17	54	23	501	2	22	32	14	15	10	478	15	78	19	72
86	8	12	10	18	55	21	434	<2	18	33	9	16	10	483	13	73	17	64
77	9	17	8	19	47	21	422	3	20	35	8	15	9	514	15	68	17	67
85	9	17	8	18	51	19	488	2	20	34	8	18	10	549	13	69	19	67
112	9	32	15	19	72	21	551	2	21	35	15	15	14	445	22	92	20	69
69	8	17	9	18	42	21	215	2	22	25	8	15	8	507	12	60	15	64
95	7	10	8	19	56	23	378	3	21	31	8	16	8	506	17	63	16	60
86	9	17	9	17	52	21	448	2	20	32	9	16	9	502	14	71	17	68
82	9	19	12	18	49	29	465	2	21	24	9	13	10	471	13	75	18	66
71	4	17	10	15	40	29	341	3	15	22	5	18	4	172	12	28	15	120

Table 4. Geochemistry of the coarse (0.25-1.0 mm) fraction samples—Continued.

Sample Id	type	fork	Topo Map	Al	Ca	Fe	K	Mg	Na	P	Ti	As.2	Ba	Be
				percent								ppm		
0YB041	bed_sed	west fork	Jordan Mtn.	6.49	.80	1.87	3.34	.24	1.62	.04	.21	11	868	3
0YB042	bed_sed	west fork	Jordan Mtn.	6.27	.63	1.61	3.18	.28	1.70	.04	.18	<10	815	3
0YB043	bed_sed	west fork	Jordan Mtn.	6.88	.88	2.37	2.76	.68	1.81	.06	.26	<10	1220	2
0YB044	bed_sed	west fork	East Basin Ck.	7.02	1.48	2.54	2.81	.71	1.92	.08	.33	<10	1140	2
0YF018dupe	bed_sed	main stem	dupe of 018	7.73	2.99	3.09	2.67	1.26	1.94	.08	.37	<10	1190	2
0YH034A	hot_spring	hot spring	Sunbeam	6.52	1.96	1.98	2.19	.75	1.93	.03	.32	<10	790	4
0YH034B	hot_spring	hot spring	Sunbeam	5.73	.80	.50	2.91	.13	1.96	.01	.05	<10	744	7
0YP021	pond	pond	Sunbeam	5.73	2.97	2.20	2.09	.54	1.46	.15	.27	18	827	2
0YP022	pond	pond	Sunbeam	7.56	2.34	3.08	2.56	.99	1.63	.08	.36	11	1140	2
0YP023	pond	pond	Sunbeam	4.00	8.37	1.83	1.39	.54	.86	.19	.18	13	498	1
0YP027	pond	pond	Sunbeam	7.10	1.81	3.07	1.95	1.15	1.05	.11	.35	15	902	2
0YP027dupe	pond	pond	dupe of 027	7.36	1.88	3.17	2.00	1.18	1.11	.11	.35	19	926	2
0YP030A	pond	pond	Sunbeam	7.57	2.49	3.12	2.69	1.15	1.90	.08	.37	15	1190	2
0YP030Adupe	pond	pond	dupe of 030	7.44	2.27	3.12	2.06	1.04	1.74	.09	.40	12	833	2
0YP030B	pond	pond	Sunbeam	7.15	2.16	2.92	1.99	.93	1.63	.09	.39	<10	768	2
1YA070	undisturbed	undisturbed	Sunbeam	8.58	2.21	3.18	2.10	.91	1.55	.09	.40	<10	1030	<1
1YB052	bed_sed	main stem	Sunbeam	7.87	1.87	2.41	2.51	.77	2.12	.07	.32	<10	991	2
1YB053	bed_sed	main stem	Sunbeam	7.70	2.13	3.00	2.56	1.03	1.86	.08	.38	<10	1080	1
1YB056	bed_sed	jordan_ck	Jordan Mtn.	8.13	2.20	4.36	1.75	1.82	1.21	.09	.47	<10	747	1
1YB057	bed_sed	jordan_ck	Jordan Mtn.	7.45	.80	3.56	2.42	.71	.75	.10	.36	38	822	2
1YB058	bed_sed	jordan_ck	Jordan Mtn.	7.99	1.24	3.35	2.81	.85	1.24	.10	.36	41	1040	2
1YB058 dupe	bed_sed	jordan_ck	Jordan Mtn.	7.79	.98	3.56	2.43	.96	1.16	.13	.40	32	927	2
1YB059	bed_sed	jordan_ck	Jordan Mtn.	7.48	.63	2.97	2.77	.63	.88	.08	.31	130	952	3
1YB060	bed_sed	jordan_ck	Jordan Mtn.	6.96	.90	2.49	2.80	.48	1.15	.05	.24	52	805	3
1YB061	bed_sed	jordan_ck	Jordan Mtn.	7.32	.87	3.15	2.57	.69	.94	.09	.32	39	824	3
1YB062	bed_sed	jordan_ck	Jordan Mtn.	7.29	.78	2.91	3.33	.37	1.79	.07	.32	15	896	3
1YB063	bed_sed	jordan_ck	Jordan Mtn.	7.36	1.36	3.38	2.68	.83	1.42	.08	.39	27	897	2
1YP064	pond	pond	Sunbeam	7.49	1.60	3.40	2.14	.96	1.24	.12	.38	<10	797	2
1YP065	pond	pond	Sunbeam	7.51	1.56	2.89	2.51	.85	1.59	.10	.39	<10	1010	2
1YP066	pond	pond	Sunbeam	7.58	1.63	2.29	2.25	.82	1.52	.10	.40	<10	964	2
1YP067	pond	pond	Sunbeam	7.05	2.05	3.26	1.87	1.10	1.12	.10	.40	<10	789	2
1YP068	pond	pond	Sunbeam	7.79	2.00	2.13	2.56	.76	1.90	.08	.32	<10	1120	1
1YP069	pond	pond	Sunbeam	7.86	1.69	3.69	2.71	1.17	.98	.11	.35	<10	977	2

Ce	Co	Cr	Cu	Ga	La	Li	Mn	Mo	Nb	Nd	Ni	Pb	Sc	Sr	Th	V	Y	Zn
ppm																		
103	4	4	5	17	53	24	323	2	31	32	4	16	4	248	19	25	21	67
75	4	4	6	16	41	25	266	2	21	27	4	16	4	211	15	25	16	74
73	6	22	15	15	43	27	363	3	19	23	9	10	7	303	12	54	14	62
82	7	13	11	15	44	25	436	2	25	29	9	13	8	344	14	63	17	69
110	11	31	8	16	70	20	562	3	20	43	12	13	14	543	18	87	19	67
47	5	7	3	29	22	52	328	3	19	13	6	10	6	527	13	50	9	65
39	<2	<2	8	30	22	16	81	<2	11	12	<3	11	<2	1430	8	8	5	17
76	8	37	41	14	47	17	347	4	17	28	16	19	6	365	12	51	18	82
80	10	25	12	18	49	22	410	<2	20	31	10	16	10	508	14	78	20	77
57	7	32	32	<4	31	15	326	4	5	18	13	36	5	304	7	43	14	107
89	10	40	26	19	51	28	372	3	18	35	16	19	13	342	18	93	23	112
91	10	40	27	19	53	30	381	3	20	35	15	21	13	361	14	95	24	113
93	12	22	10	18	58	22	528	2	20	38	10	16	13	462	17	85	19	73
106	9	43	13	20	66	37	662	3	23	43	11	15	10	552	18	77	22	87
88	9	34	12	19	50	30	610	3	25	38	10	13	9	517	15	69	20	82
82	17	46	22	22	44	23	366	7	13	32	18	21	12	458	10	151	19	123
94	10	21	11	21	57	21	471	<2	17	32	8	16	8	527	12	69	16	57
110	12	50	12	18	61	21	502	<2	15	41	10	17	11	470	13	88	20	64
83	21	39	19	21	49	22	722	<2	17	35	13	15	17	331	10	124	22	122
105	15	37	17	19	61	38	501	3	14	43	12	21	11	174	12	98	17	136
117	31	23	28	20	65	36	1240	2	19	44	17	21	10	288	12	87	22	227
90	27	24	19	11	53	46	861	2	18	36	15	30	11	214	13	97	19	207
159	58	22	84	21	84	42	1960	2	21	57	22	20	8	157	18	63	27	291
113	8	13	13	20	59	25	512	<2	27	41	5	24	6	222	19	45	26	202
116	23	31	27	19	68	37	953	3	19	43	13	19	10	194	13	81	22	207
120	15	24	17	22	65	25	742	2	25	46	7	19	7	170	15	45	22	138
114	18	37	18	20	62	27	827	2	22	42	10	18	10	258	12	85	22	143
107	13	51	21	21	62	28	533	<2	9	49	13	23	11	339	13	85	28	111
96	11	31	16	20	55	24	386	<2	16	40	11	17	10	368	12	81	22	80
83	12	53	16	18	47	29	288	2	16	35	11	19	10	392	12	74	20	77
103	15	54	22	21	57	24	534	<2	18	47	12	19	12	396	13	92	30	88
78	10	40	9	19	43	20	244	<2	15	29	8	14	8	504	12	65	15	61
110	16	52	40	24	56	35	469	2	22	45	21	31	12	334	15	115	27	118

Appendixes A and B

A. Maps showing detailed sample locations

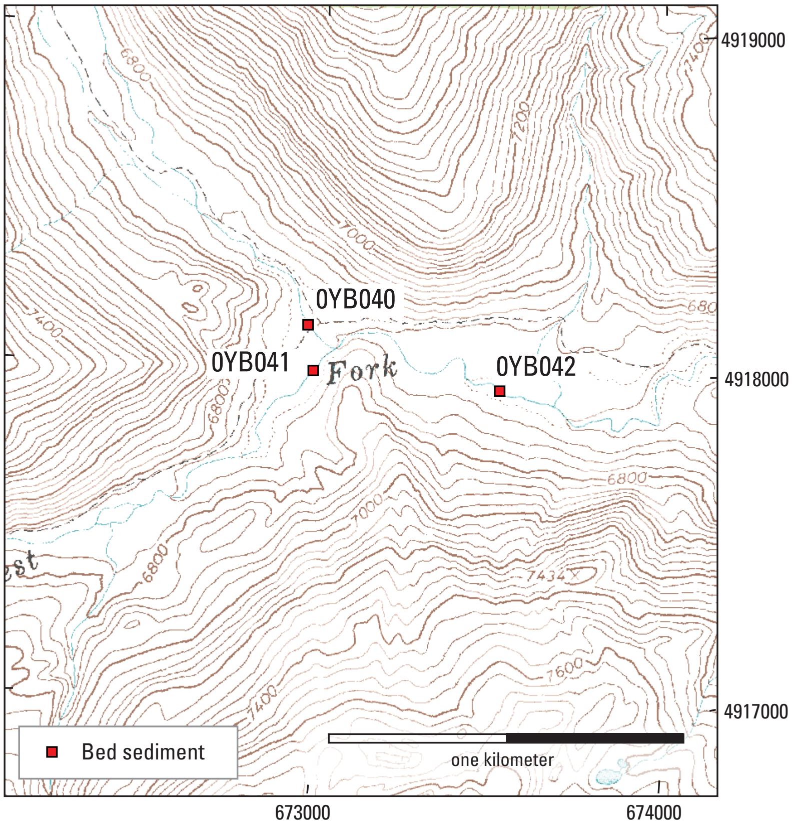

Figure A1. Detailed sample location map for Area A. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Mt. Jordan quadrangle.

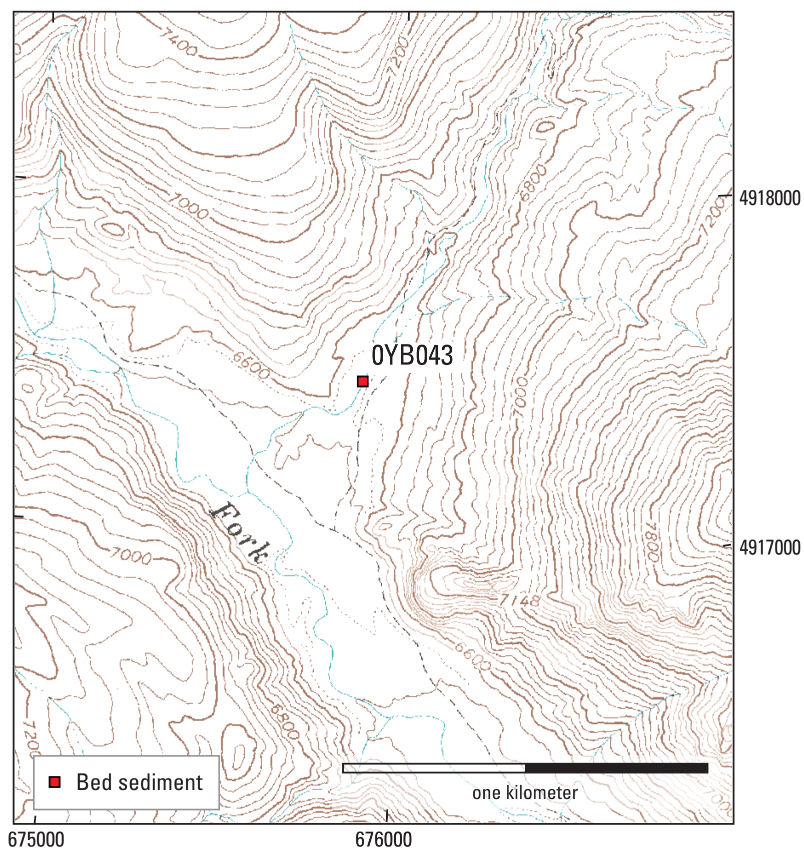

Figure A2. Detailed sample location map for Area B. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Mt. Jordan quadrangle.

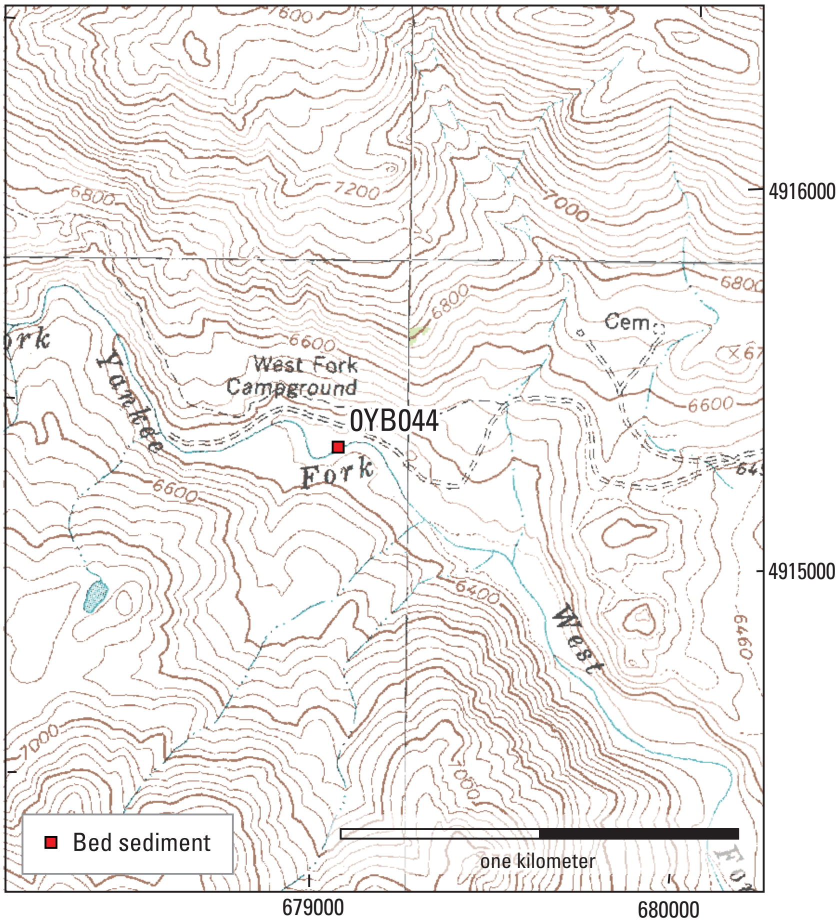

Figure A3. Detailed sample location map for Area C. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Mt. Jordan, Custer, Sunbeam, and East Basin Creek quadrangles.

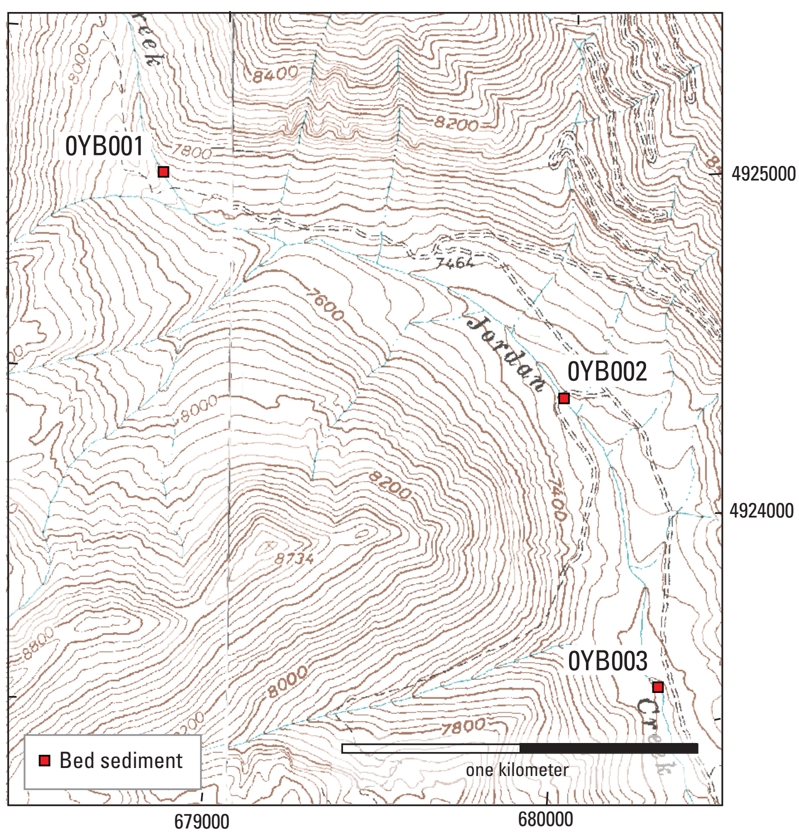

Figure A4. Detailed sample location map for Area D. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Mt. Jordan and Custer quadrangles.

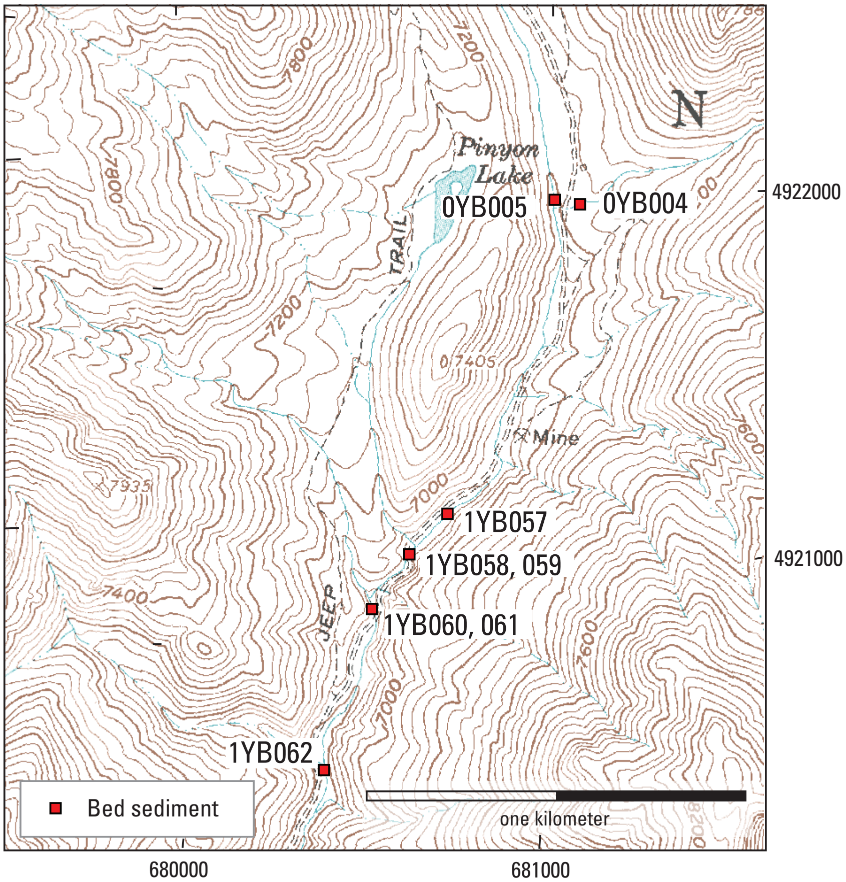

Figure A5. Detailed sample location map for Area E. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

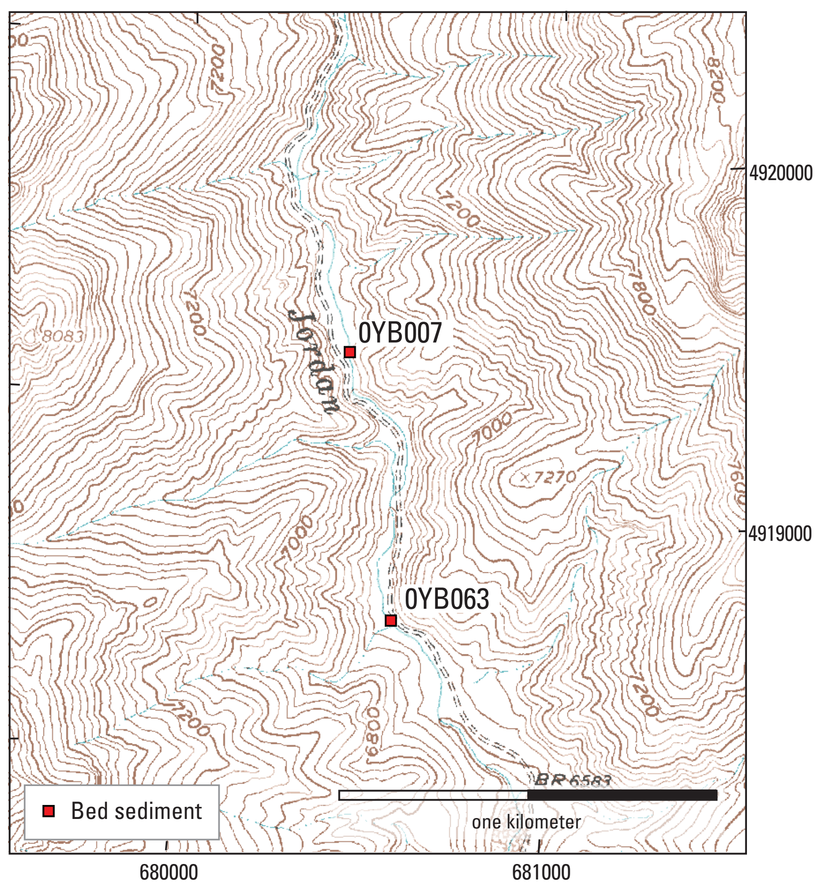

Figure A6. Detailed sample location map for Area F. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

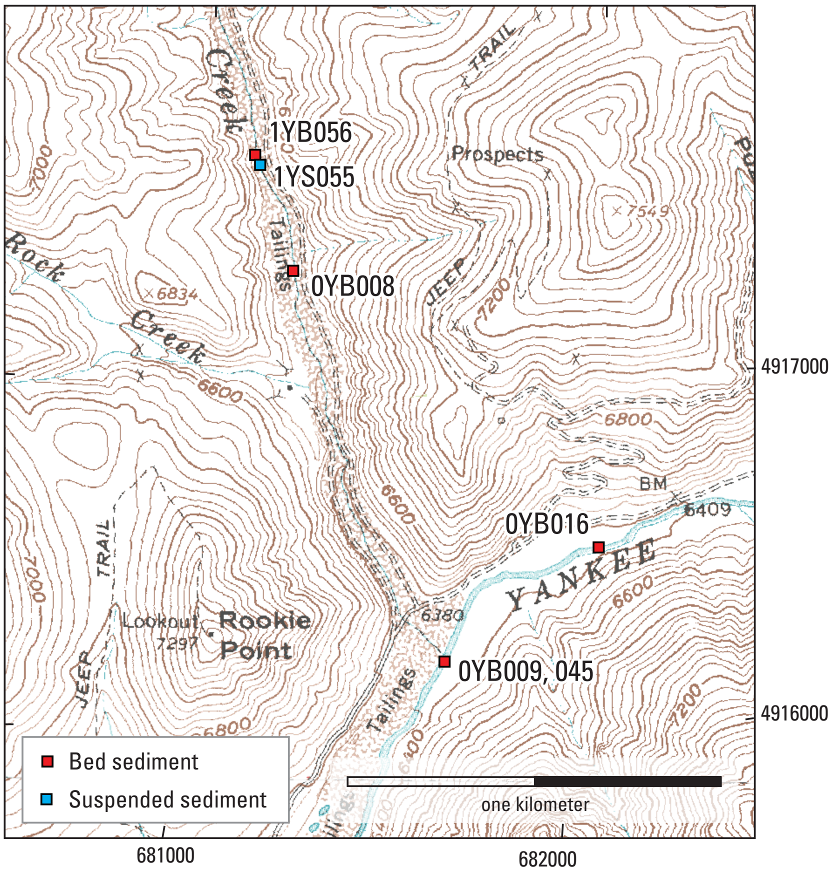

Figure A7. Detailed sample location map for Area G. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer and Sunbeam quadrangles.

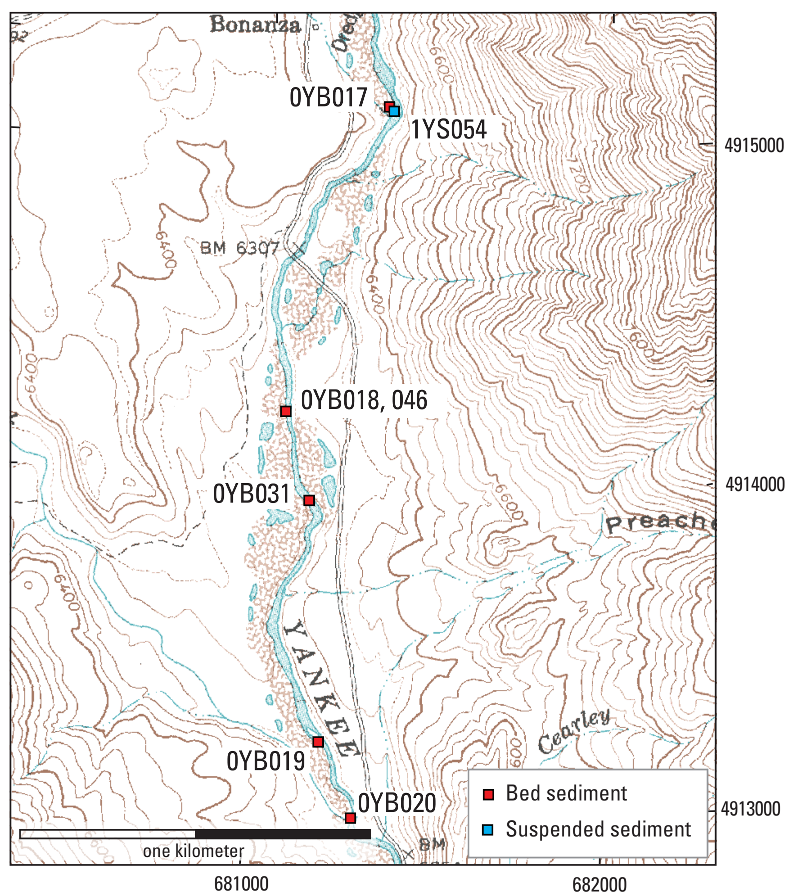

Figure A8. Detailed sample location map for Area H. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Sunbeam quadrangle.

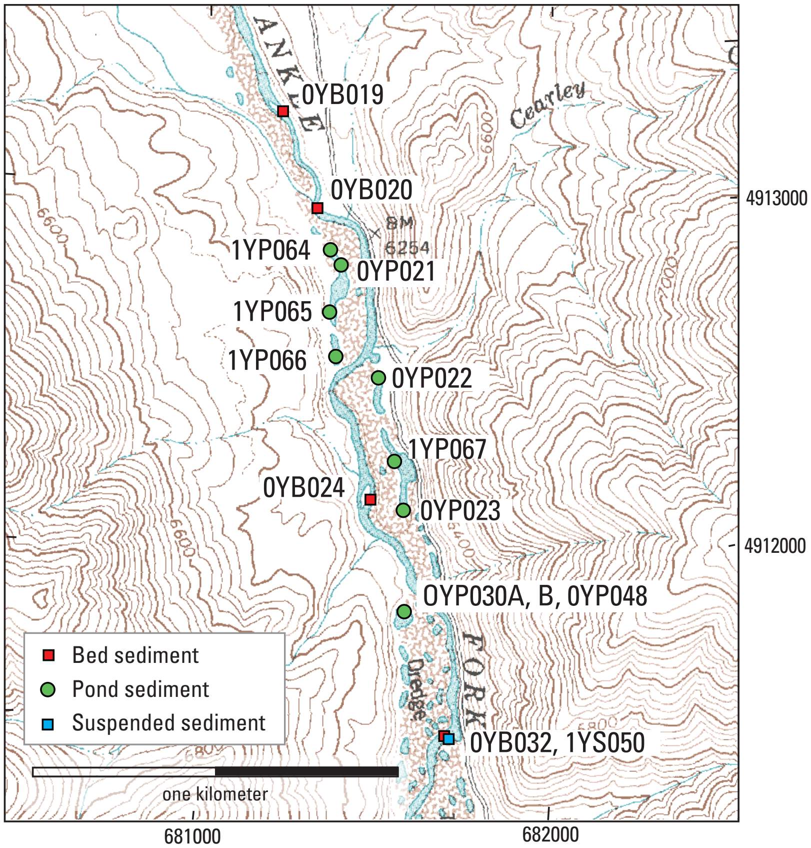

Figure A9. Detailed sample location map for Area I. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Sunbeam quadrangle.

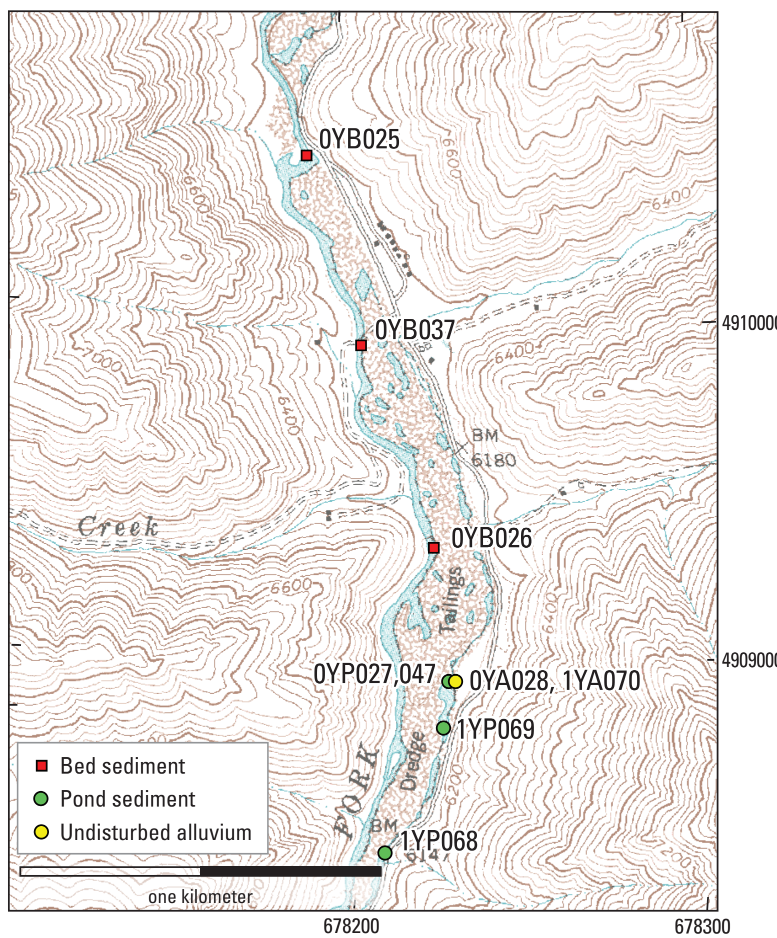

Figure A10. Detailed sample location map for Area J. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Sunbeam quadrangle.

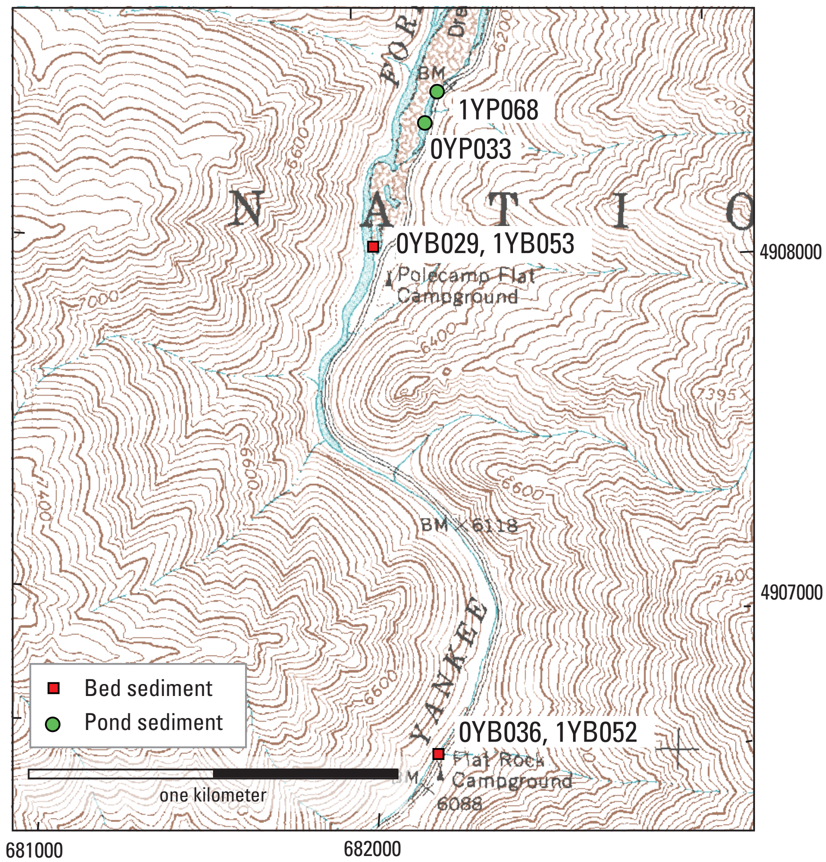

Figure A11. Detailed sample location map for Area K. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Sunbeam quadrangle.

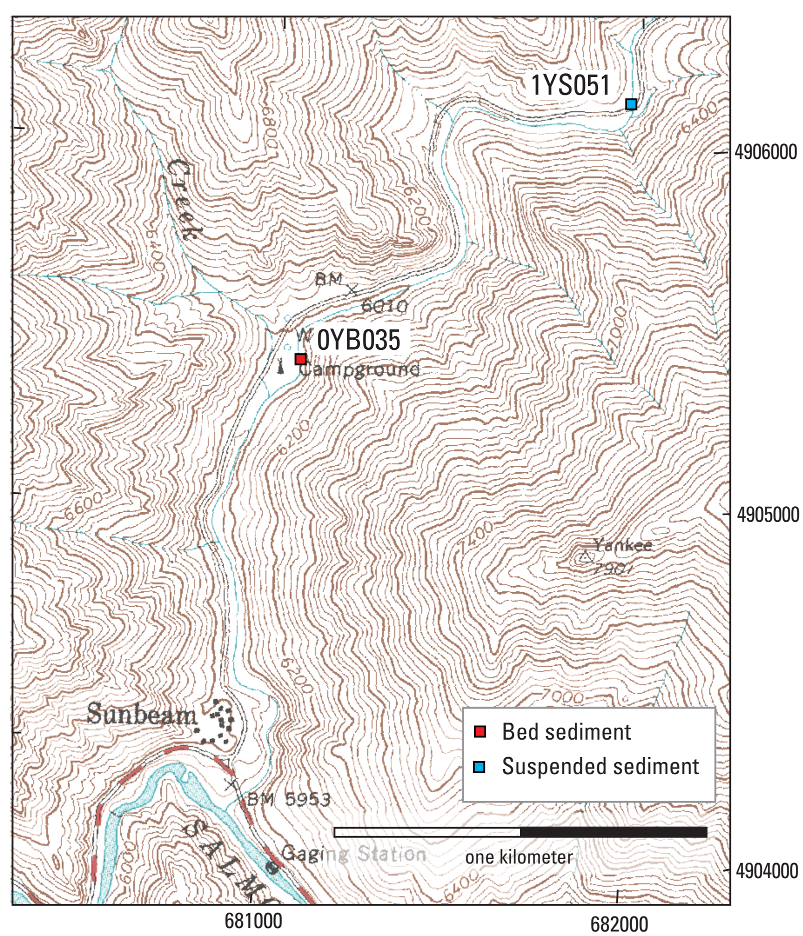

Figure A12. Detailed sample location map for Area L. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Sunbeam quadrangle.

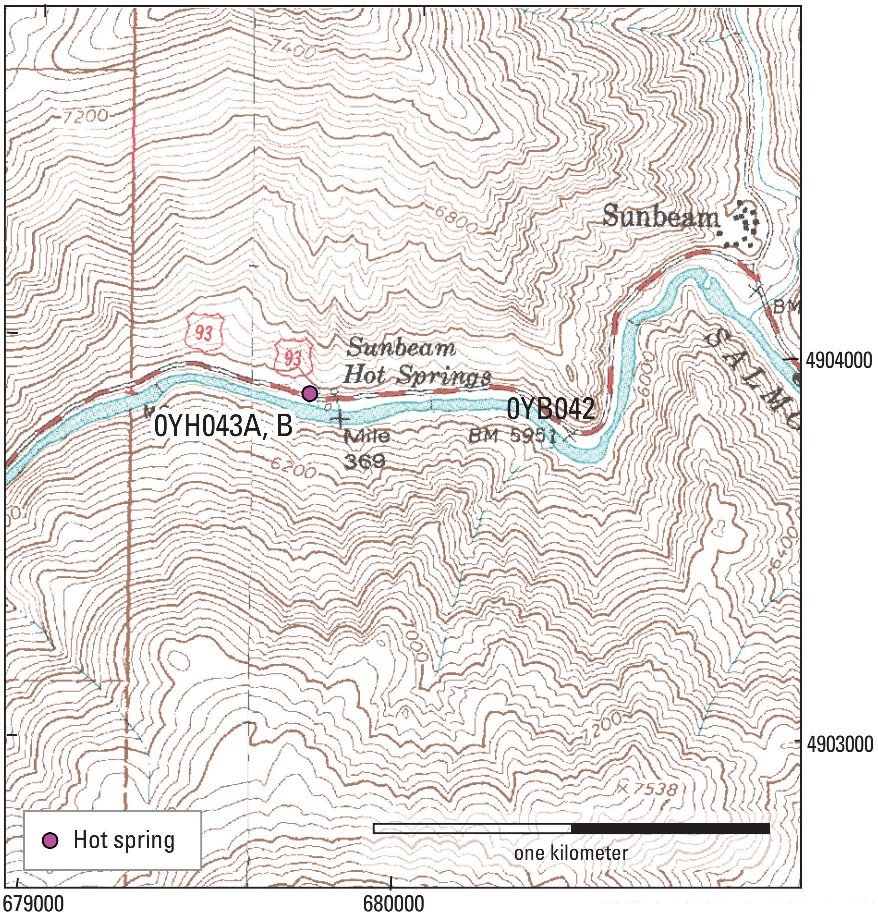

Figure A13. Detailed sample location map for Area M. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale East Basin Creek and Sunbeam quadrangles.

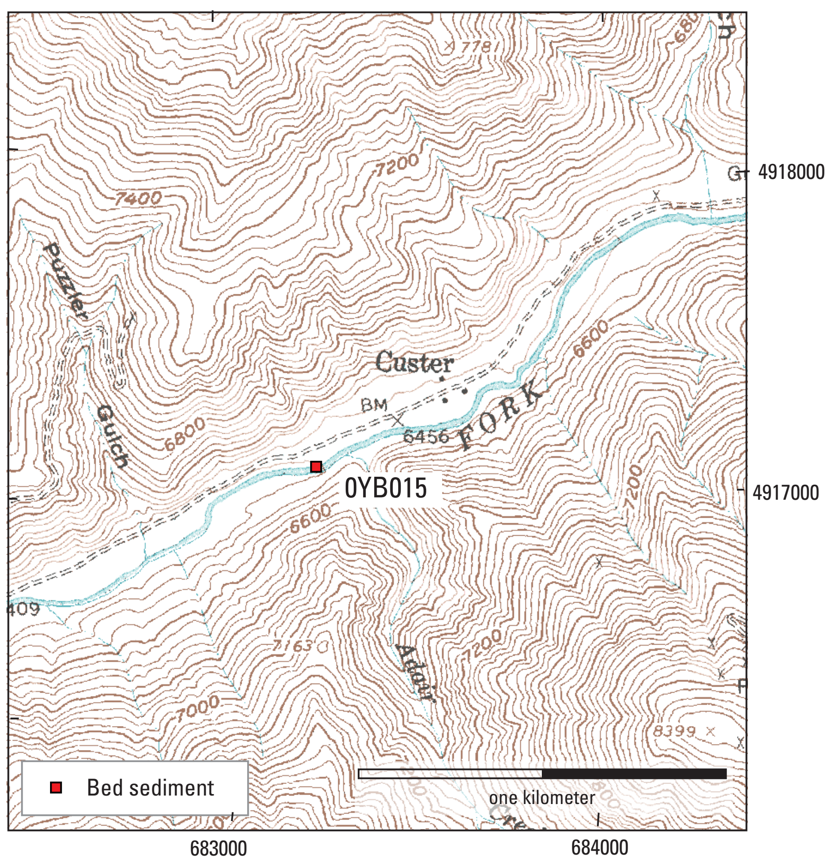

Figure A14. Detailed sample location map for Area N. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

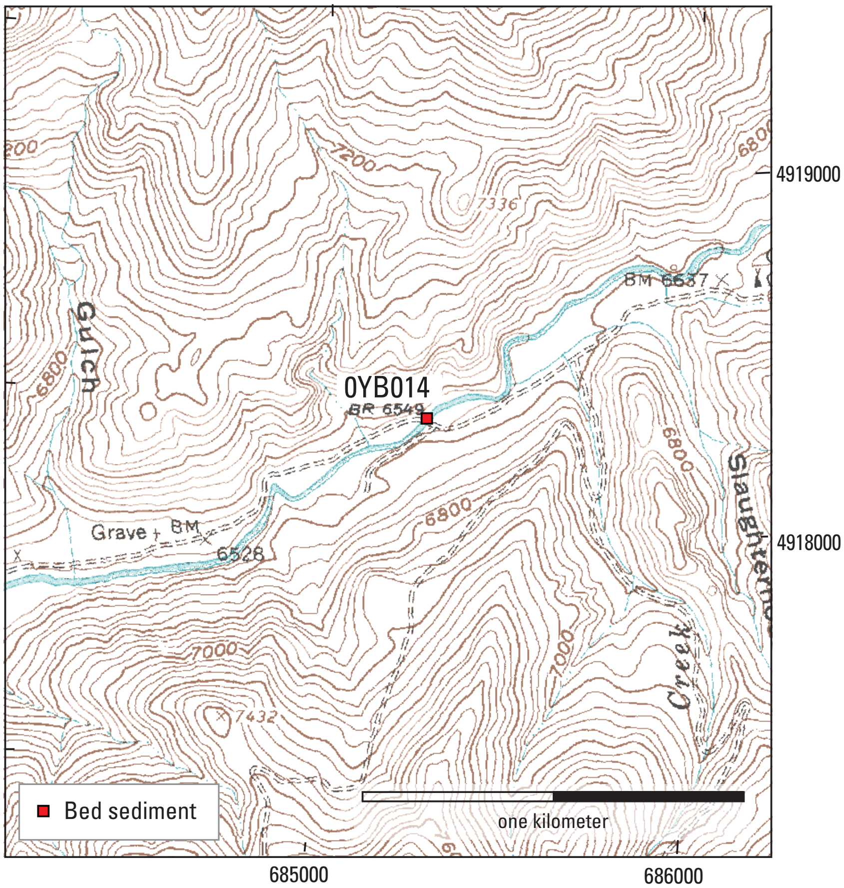

Figure A15. Detailed sample location map for Area O. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

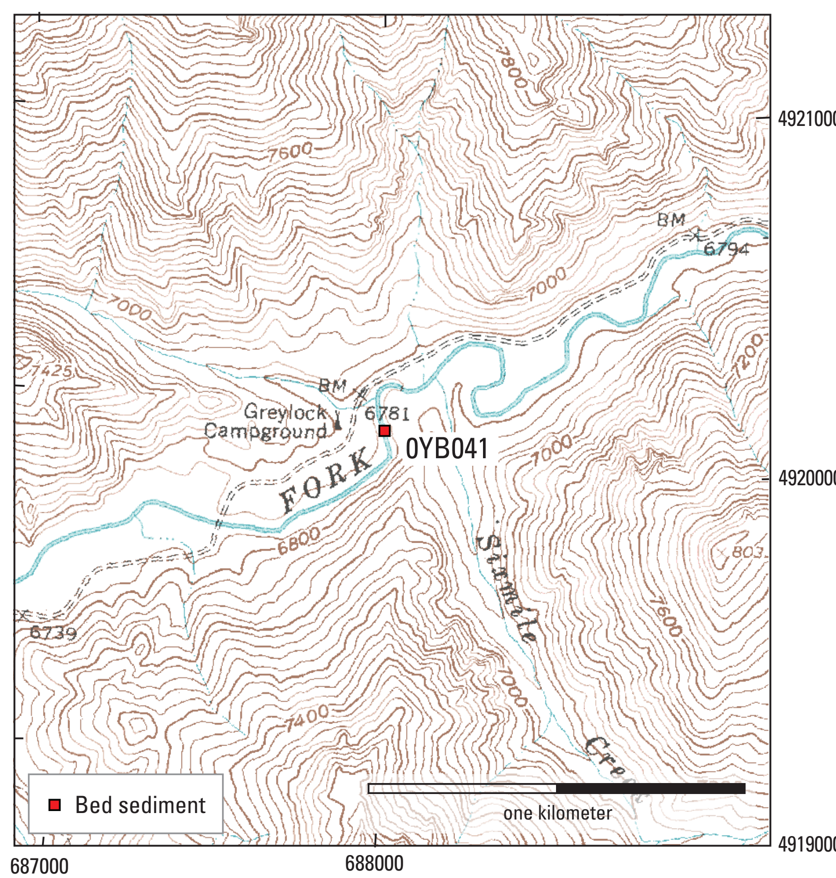

Figure A16. Detailed sample location map for Area P. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

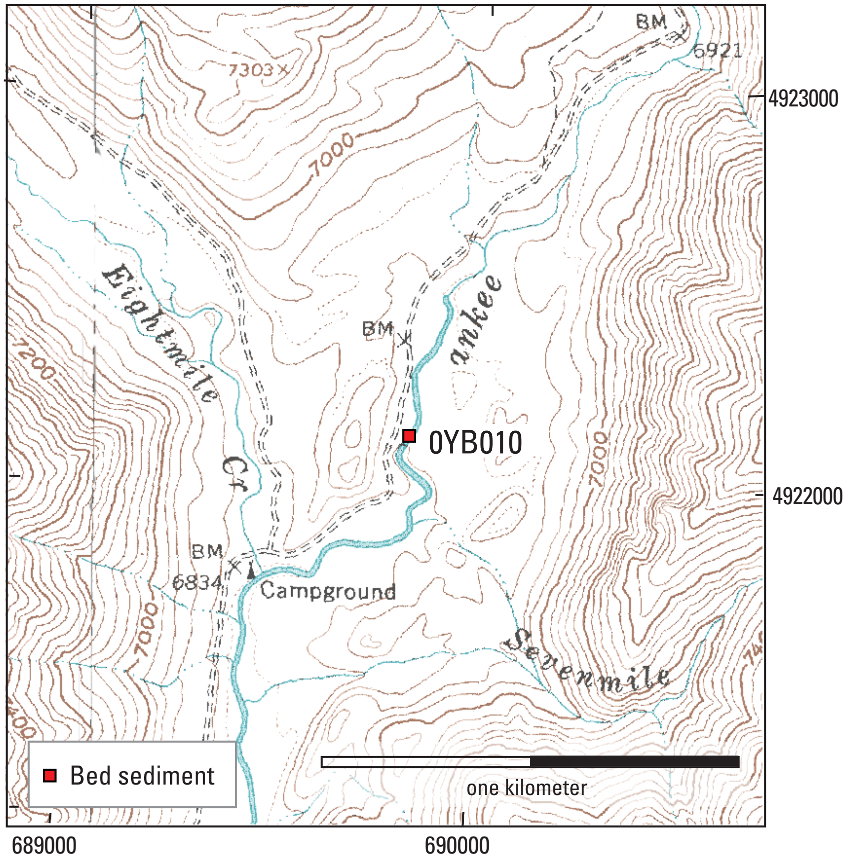

Figure A17. Detailed sample location map for Area Q. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer and Elevenmile Creek quadrangles.

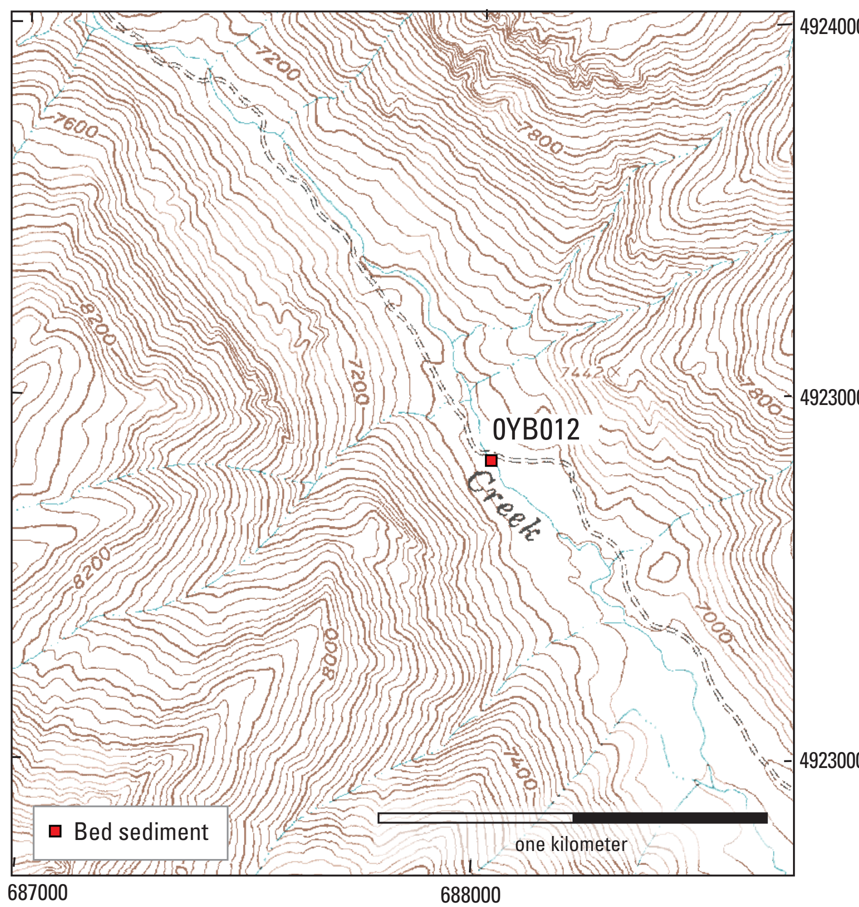

Figure A18. Detailed sample location map for Area R. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Custer quadrangle.

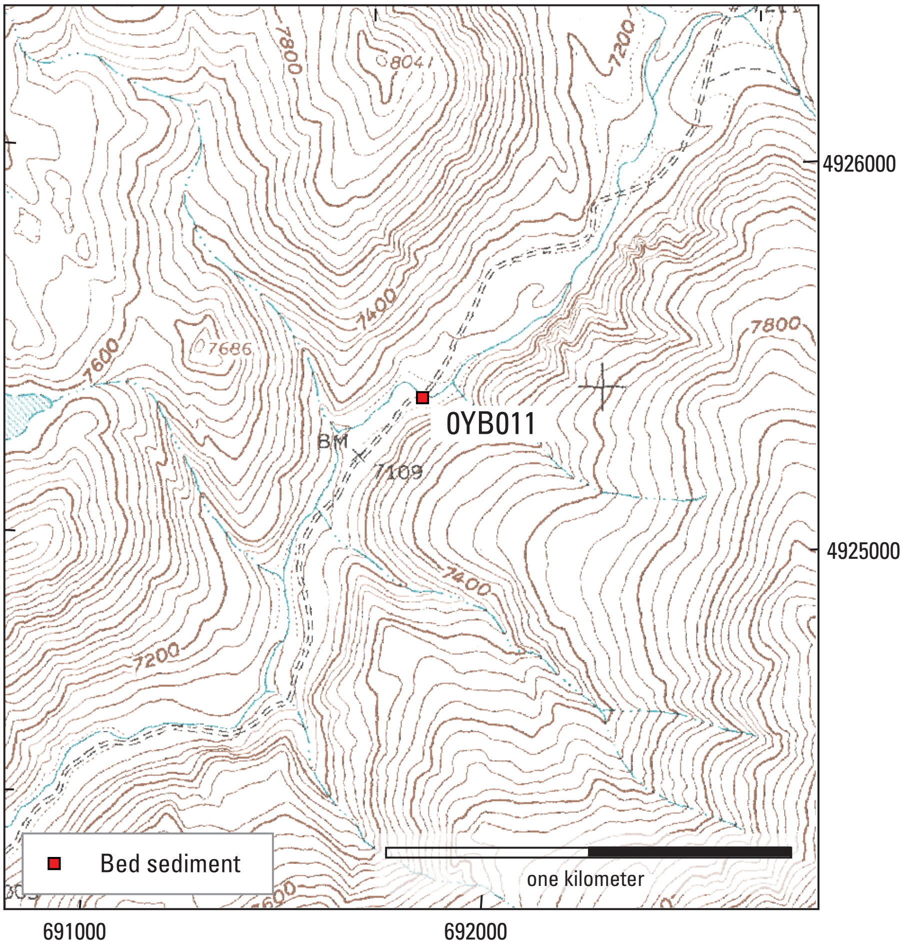

Figure A19. Detailed sample location map for Area S. See figure 2 for location. UTM Zone 11 ticks shown. Topographic base from USGS 1:24,000 scale Elevenmile Creek quadrangle.

B. Summary of analytical methods used in this study

The following information is from the U.S. Geological Survey Web site that describes the analytical procedures and detection limits for commonly run analyses. The complete descriptions of these and other techniques is at: http://minerals.cr.usgs.gov/intranet/chem/labmethods.html.

Summary of the Analytical Method for Analysis of 40 Elements by ICP-AES

Forty major, minor, and trace elements are determined in geological materials by inductively coupled plasma-atomic emission spectrometry (ICP-AES). A mixture of hydrochloric, nitric, perchloric, and hydrofluoric acids at low temperature is used to digest 0.2 g. of sample material. The digested sample is aspirated into the ICP-AES discharge where the elemental emission signal is measured simultaneously for the forty elements. Calibration is performed by standardizing with digested rock reference materials and a series of multielement solution standards. Detection limits and range of reported concentrations are listed below:

Element, Symbol	Detection Limit, in percent	Element, Symbol	Detection Limit, in percent
Aluminum, Al	0.005	Magnesium, Mg	0.005
Calcium, Ca	0.005	Sodium, Na	0.005
Iron, Fe	0.02	Phosphorous, P	0.005
Potassium, K	0.01	Titanium, Ti	0.005

Element, Symbol	Detection Range, in parts per million	Element, Symbol	Detection Range, in parts per million
Silver, Ag	2-10,000	Manganese, Mn	4-50,000
Arsenic, As	10-50,000	Molybdenum, Mo	2-50,000
Gold, Au	8-50,000	Niobium, Nb	4-50,000
Barium, Ba	1-35,000	Neodymium, Nd	9-50,000
Beryllium, Be	1-5,000	Nickel, Ni	3-50,000
Bismuth, Bi	50-50,000	Lead, Pb	4-50,000
Cadmium, Cd	2-25,000	Scandium, Sc	2-50,000
Cerium, Ce	5-50,000	Tin, Sn	50-50,000
Cobalt, Co	2-25,000	Strontium, Sr	2-15,000
Chromium, Cr	2-25,000	Tantalum, Ta	40-50,000
Copper, Cu	2-15,000	Thorium, Th	6-50,000
Europium, Eu	2-5,000	Uranium, U	100-100,000
Gallium, Ga	4-50,000	Vanadium, V	2-30,000
Holmium, Ho	4-5,000	Yttrium, Y	2-25,000
Lanthanum, La	2-50,000	Ytterbium, Yb	1-5,000
Lithium, Li	2-50,000	Zinc, Zn	2-15,000

Note: Data is deemed acceptable if recovery for all 40 elements is ±15 percent at five times the Lower Limit of Determination (LOD) and the calculated Relative Standard Deviation (RSD) of duplicate samples is no greater than 15 percent.

Summary of the Analytical method for Mercury

Mercury content is determined by digesting 0.1g of sample using a mixture of nitric and hydrochloric acids. Potassium permanganate, sulphuric acid, and potassium persulphate are added to the solution, followed by a NaCl-hydroxylamine solution and then the solution is diluted to 25mL. The solution is mixed thoroughly, allowed to settle and then transferred to the auto sampler rack of the Perkin-Elmer Flow Injection Mercury System, FIMS-100.

The FIMS-100 is a cold-vapor atomic absorption mercury analyzer, which determines the mercury concentration in a solution after it has been liberated as vapor using a stannous chloride reducing agent. The absorption of the sample is measured using a mercury lamp at 253.7nm.

The lower reporting limit is 0.02 ppm mercury in solid-phase samples. Data is deemed acceptable if recovery of mercury is ±20 percent at five times the LOD and the calculated percent RSD of duplicate samples is no greater than 20 percent.

Summary of the Analytical Method for Arsenic and Antimony

Arsenic and antimony are determined by weighing 0.1 g of sample into a zirconium crucible. Approximately 0.75 g of sodium peroxide is added and mixed. The mixture is heated in a muffle furnace at 750°C for 4 minutes. The sample is cooled then 15 ml of water and 5 ml of concentrated HCl is added. The mixture is shaken, 0.25 ml of an ascorbic acid-KI solution is added, diluted with 20 per cent HCl and left to stand overnight. Arsenic and antimony are then measured using hydride generation atomic absorption spectrometry.

The optimum concentration ranges without sample dilution for these elements in various solid-phase sample media are: As-0.6 ppm to 20 ppm and Sb-0.6 ppm to 20 ppm. Data will be deemed acceptable if recovery of As and Sb is ±20 percent at five times the LOD and the calculated percent RSD of duplicate samples is no greater than 20 percent.

Summary of the Analytical Method for Selenium

Selenium is determined by weighing 0.25 g of sample into a test tube, adding a mixture of nitric, hydrofluoric, and perchloric acids, and heating. After the solution is cooled hydrochloric and nitric acids are added, and the solution is heated again and cooled. The sample is then diluted and analyzed using hydride generation atomic absorption spectrometry.

The expected analytical range for selenium is 0.2 to 4 ppm. Data for selenium is deemed acceptable if recovery of that element is ±20 per ent at five times the LOD and the calculated percent RSD of duplicate samples is no greater than 20 percent.

Summary of the Analytical Method for Thallium:

Thallium is determined by weighing 0.1g of sample into a zirconium crucible. Approximately 0.75 g of sodium peroxide is added and mixed. The mixture is heated in a muffle furnace set at 750°C for 4 minutes. The crucible is cooled and transferred to a vial containig 15 ml of DI water. After the cake disintegrates, 5 ml of concentrated HC1 is added and mixed. A 5 ml aliquot is transferred to a 20 ml test tube, followed by the addition of 1.5 ml of concentrated HNO_3. The solution is diluted to 10 ml with DI water and mixed. A volume of 0.5 ml DIBK is added, then capped and shaken for 3 minutes. The organic layer is transferred to an auto sampler, and the Tl concentration is measured by a graphite furnace-atomic absorption spectrophotometer (GFAAS) equipped with a Zeeman background correction.

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