Sapphire Deposits along the Missouri River near Helena, Montana

Richard B. Berg and Martin T. Landry

Bulletin 136
2018

Montana Bureau of Mines and Geology

Cover Photo: Assortment of natural (no heat treatment) sapphires from the Eldorado Bar, Missouri River District. Largest sapphire is 17.5 mm and weights 23.16 carats. Sapphires provided by Robert E. Kane and American Sapphire Company.

Bulletin 136

Sapphire Deposits along the Missouri River near Helena, Montana

Richard B. Berg[1] and Martin T. Landry[2]

[1]Montana Bureau of Mines and Geology, Butte, Montana
[2]Montana State Library, Helena, Montana

MBMG
Montana Bureau of Mines and Geology

CONTENTS

FIGURES

TABLES

Plates 1 and 2 are included in the back pocket.

ABSTRACT

Sapphires were first discovered in Montana in 1865 by placer miners searching for gold at Eldorado Bar, along the Missouri River near Helena, Montana. Early attempts to develop the sapphire deposit on Eldorado Bar were generally unsuccessful. With the completion of Hauser Dam in 1911, this section of the Missouri River became Hauser Lake. During World War II, the Perry Schroeder Mining Company was allowed to operate a dredge on Eldorado Bar for the recovery of gold and sapphires; sapphires were required for instrument bearings for the war effort, and most of the commercial production of artificial sapphires was then in Europe. Eldorado Bar is the largest of the six bars along Hauser Lake and is estimated to have produced 10–15 million carats (2–3 tonnes) of sapphires. Present sapphire production is still mainly from Eldorado Bar, but is now for the gemstone market. The color of many of the sapphires is enhanced by heat treatment.

Sapphires are mined from gravel on strath terraces, many of which are 200–300 ft (60–90 m) above the level of Hauser Lake. The highest concentration of sapphires is in the lowest meter or two of these gravels. We speculate that these terraces were developed on metasedimentary rocks of the Belt Supergroup during the Pleistocene, when there was a large flow of water from melting glaciers in the mountains of southwestern Montana. Most sapphires in these deposits are pale green, with occasional pale blue and even rarer dark blue specimens. Distinctive surface morphology of these sapphires aids in differentiating them from alluvial sapphires from other deposits in southwestern Montana (Rock Creek and Dry Cottonwood Creek). Sparse sapphires occur in a small sill on the west shore of Hauser Lake just below Canyon Ferry Dam, but this occurrence is clearly too small to account for the sapphire deposits along Hauser Lake. Diorite intrusive rocks in the Big Belt Mountains on the northeast side of Hauser Lake are the most likely bedrock source.

INTRODUCTION

In addition to the well-known bedrock Yogo deposit in central Montana, there are three major alluvial sapphire deposits in western Montana (fig. 1). This report is the third of a series on these alluvial sapphire deposits published by the Montana Bureau of Mines and Geology. The first (Berg, 2007) described the sapphire deposits in the Butte–Deer Lodge area, including the placer deposits on the South Fork of Dry Cottonwood Creek. The second was devoted to the geology and sapphires of the southwestern part of the Rock Creek sapphire district (Berg, 2014). This report is the last in this series. A compilation of reported sapphire occurrences in Montana (Berg, 2015) is available from the Montana Bureau of Mines and Geology.

A major source of information on the Missouri River sapphire deposits is Clabaugh's (1952) comprehensive report on corundum deposits in Montana. Geology of the Canyon Ferry Quadrangle, Montana (Mertie and others, 1951) also has useful information on the sapphire deposits in this area. The geology of this area is discussed in Reynolds and Brandt (2005), Vuke (2011), and Stickney (1987).

The emphasis of this report is on the descriptions of the sapphire-bearing gravels on the strath terraces, generally known as bars, mainly along Hauser Lake. Fieldwork for this project was conducted from the summer of 2012 on a limited basis into the summer of 2016.

Metric conversion follows elevations reported in feet. Appendix 1 provides conversion factors for conversion to metric units, and Appendix 2 is a glossary of technical terms. Unless photo credit is given in the captions, photos are by Richard B. Berg.

Saphhires from this research, as well as those from other deposits in southwestern Montana, are available for research. They are catalogued with the Montana Tech Mineral Museum collection.

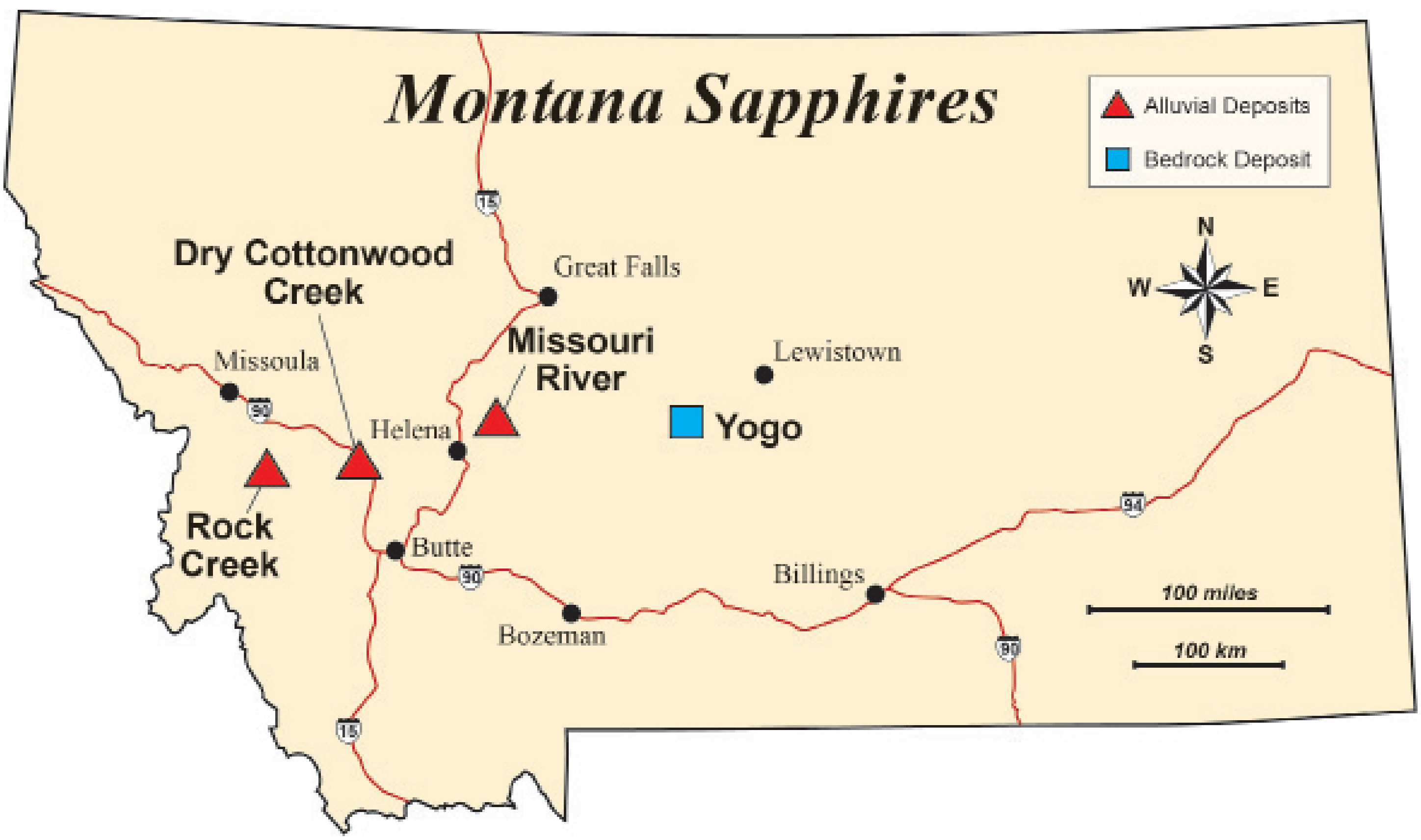

Figure 1. Montana sapphire deposits.

HISTORY

by Martin T. Landry

Eldorado Bar and Early Development

Sapphires were first discovered in Montana in 1865 by miners prospecting for gold along the Missouri River, northeast of Helena. The sapphires were found in gravel deposits lying on the bedrock terraces that flank this stretch of river. The ancient Missouri River created these terraces as it cut down to its current elevation. The miners found that the stranded river benches, called "bars," contained alluvial gold deposits. Although the gold is fine grained, the quantities were significant enough to make mining profitable. They also discovered that the deposits contained small, pale-colored stones of exceptional clarity and hardness. The stones were first misidentified as quartz, emeralds, and even diamonds, but they were in fact sapphires.

Along the Missouri River, the sapphire-bearing gravel bars are concentrated between Emerald Bar upriver and Eldorado Bar downriver (plate 1). The main deposits are Emerald Bar, Ruby Bar, French Bar, Gruell's Bar, Spokane Bar, Metropolitan Bar, McCune Bar, Dana's Bar, and Eldorado Bar. Sapphires have also been found on the east side of Canyon Ferry Lake in the alluvial deposits along Magpie Creek. Additional deposits have also been worked for gold and possibly sapphires farther downriver at American Bar and Ming's Bar.

Eldorado Bar is the best known of all the sapphire deposits; a mining town by the same name was established along the river following the discovery of gold. The bar is located on the east bank of the Missouri River 1 mi (1.6 km) upstream from Prickly Pear Creek. It was on mining claim No. 4 Below Discovery (the fourth claim northwest of the claim where gold was first discovered) that the translucent stones first came to the attention of Edward R. Collins. With the help of Helena jeweler N.B. Hale, Collins tested the stones and also sent them back east, to Tiffany & Co. of New York among others, and overseas to be identified. By the summer of 1867, the stones had been positively identified as sapphires. "We were shown today, by Mr. E.R. Collins, nine fine sapphires (cut and set), the production of Montana. The same gentleman also showed us letters from the best lapidaries in the East, who pronounced the stones to be genuine saphires (sic), beyond a doubt" (Tri-Weekly Post, August 27, 1867). The reports elicited some local interest, but aside from a short mention by J. Ross Browne noting the discovery of "fine, though small" sapphires in Montana, the discovery had little national impact (Browne, 1868, p. 50).

Because of the extensive overburden, miners relied on drift mining during the first years. By digging horizontal tunnels through the gravel, while remaining in contact with bedrock, they could access the richest gravel without having to move as much barren material. They would then further separate these concentrates by rocker and other methods. The miners were aware that ground sluicing and high-pressure hydraulic mining had been successfully introduced at Virginia City and at Diamond City, Montana. Although this was an efficient means to move large amounts of material, it also required a substantial amount of water. Early on, a small ditch was built to bring water to the lower claims (Rocky Mountain Gazette, June 22, 1867). However, getting water to the upper claims proved more difficult. The upper bar at Eldorado Bar rises over 180 ft (55 m) above the river level and is set back as much as 0.5 mi (0.8 km) from the water's edge. Compounding the issue, the gulches that empty onto the bar contain only dry or ephemeral streams. Lacking available means to lift the water from the Missouri River, the miners looked to the perennial streams located upriver. Purportedly, the first attempt ended when a flume at Soup Creek collapsed during a severe storm shortly following its completion (Anaconda Standard, February 5, 1891). In 1867, the Eldorado Ditch Company was formed to bring water from Trout Creek (plate 2). The ditch started at a point on the south side of Trout Creek, just 1 mi (1.6 km) below the town of York (founded as New York). The ditch was over 5 mi (8 km) long and carried 1,000 miner's inches of water (25 ft^3/s or 708,000 mL/s). The completion of the ditch in July 1868 marked the advent of full-scale hydraulic mining at Eldorado Bar. The increased production led to the consolidation of claim ownership as smaller operators sold out to larger operations. In 1872, when claim owners were required to re-file their claims under the newly passed General Mining Law, E.R. Collins was among eight partners that filed a claim encompassing 1,583 acres (639 ha) that takes up the greater portion of the upper terrace at Eldorado Bar (Lewis and Clark County Placers, Book J, p. 55).

Missouri River sapphires next came to national attention following an address given by J. Lawrence Smith at the August 1872 meeting of the American Association for the Advancement of Science, held in Dubuque, Iowa. At the meeting, he revealed that he had received samples of gemstones from Montana, which upon examination he found to be sapphires of the green color often called “oriental emeralds” (World, August 30, 1872). He would later report, “They were either colorless or green, varying in shade from a light to dark green; some were bluish-green, but none red.” There were also some “red pebbles” included in the package, which Smith identified as spinel, but were most likely garnets (Smith, 1873, p. 185–186).

By the 1880s, the water carried by the ditches was of more value for agricultural operations and no longer supplied the mines. However, mining still continued sporadically. In 1883, G.F. Kunz’s report on precious stones found in the United States noted, “the finest of the sapphires for the gem trade really all come from near Helena, Montana, collected there by the miners in the sluice boxes of the placer mines. These are rolled crystals, rarely over one-quarter to one-half inch long, and the colors are pale but brilliant.” (Kunz, 1884, p. 736). He would later recall that in 1883, Tiffany & Co. had created, “A very beautiful piece of jewelry, in the form of a crescent, at one end the stones were red, shaded to bluish-red in the center, and blue at the other end; by artificial light the color of all turned red” (Kunz, 1890, p. 49).

It was during this relative downturn that Frank D. Spratt and his brother Thomas H. Spratt came to Montana and quietly began purchasing mining properties and staking mining claims on Eldorado Bar. Among the mining claims filed by the Spratts during their visit in 1886 were claims covering the acreage formerly claimed by E.R. Collins and his partners 14 years earlier (Lewis and Clark Placers Book J, p. 111–122). In 1887 the Spratts relocated to Montana permanently. Frank was the mine manager and Thomas the bookkeeper (fig. 2). Their brother Augustus N. Spratt provided the capital for their venture into mining. Augustus was the president of the Minor Lumber Company, which held extensive timber holdings and a large lumber mill in Alpena, Michigan. In 1887, the Spratts incorporated the Trout Creek Mining Company for the purpose of mining gold on claims located on New York Gulch, southeast of York. During this time, the Spratts became convinced that there was an opportunity to successfully market the gold and sapphires found on their Missouri River claims. As they continued to acquire property, they also had the properties examined by several nationally known experts.

Figure 2. Mining crew of the Sapphire and Ruby Company at Eldorado Bar. Photo by Arthur Canning, Helena, MT, 1893. Tom Spratt in front of right window and Supt. Alex Macaulay just to right of door. Photo from Photograph Archives, Montana Historical Society, Helena, MT.

As news of the rediscovery of sapphires along the Missouri River began to circulate, local and international interest rose. Among the precious and ornamental stones displayed in Tiffany & Co.'s prize-winning exhibit at the Paris Exposition of 1889 were six cut Montana sapphires totaling 12.7 ct, along with seven small uncut sapphires from Eldorado Bar (Tiffany & Company, 1889, p. 9–10). G.F. Kunz noted, "A preliminary examination made at the sapphire locality in Montana reveals the fact that sapphires exist in large quantities in the gold glacial gravels that lie immediately on the bed rock, a green slate." However, he did include the caveat that "No true red rubies nor any true blue sapphires have been found" (Kunz, 1891, p. 445). Late in 1889, the Spratts also obtained an option to purchase the Ruby Bar (plate 1). The property, located on the eastern end of French Bar, was being worked at the time by Frank Langdon and his brother Edgar (Lewis and Clark Ranches and Ditches Book F, p. 555–556). That fall A.B. Wood, a mining engineer from Michigan, spent several weeks examining the property, including a drift the Langdons had dug along the bedrock. In the drift they encountered "a true fissure vein of mica schist and trachite (sic)" (Daily Independent, February 6, 1891) that contained sapphires This same location has also been referred to as Ruby Bar dike, the French Bar dike, and the French Bar sill.

Around this time, an English syndicate was formed with the intention of marketing the sapphires. In March 1890, the syndicate entered into contracts to purchase the Ruby Bar from the Langdons, and in September secured a contract to purchase the remainder of the Spratt's property at French Bar and the properties at Eldorado Bar. Finalization was contingent upon at least two of the directors inspecting the properties. Directors E.W. Streeter and H. Mallaby-Deely visited the properties in February 1891. Based on his visit, E.W. Streeter estimated that 25 percent of the stones would be of gem quality, the remaining 75 percent being suitable for "mechanical uses and watch works" (Daily Independent, December 20, 1891). The syndicate was incorporated under the title The Sapphire and Ruby Company of Montana, Limited. In order to secure capital, a public stock offering was made in which 400,000 shares were offered at £1 each (St. James Gazette, October 29, 1891).

In order to begin to generate profits, drift mining commenced very early in the operation. "The workmen dig down through the soil and sand, which they throw away until they are within a few inches of the rock. That rock is practically smooth and is like a shelf, upon which the gold and gems are found. The gravel or dirt close to the rock is passed through a coarse sieve, and then through a fine one. What the coarse sieve holds is thrown away. The second sieve lets the dirt through it, and the stones rattle down the screen into a box. The contents of the box are put into a sack and carried to the river, where the stones are washed and sorted" (Ralph, 1892, p. 13). G.F. Kunz estimated only $5,000 in sales during 1892. That same year the Spokane Sapphire Company was organized by the Spratt brothers to mine Spokane Bar, purportedly as a subsidiary of the Sapphire and Ruby Company Limited.

The excitement generated by the revival of mining along the Missouri River brought a rush to secure gem properties. In 1891, Henry Matheson installed a steam pump to raise water the 250 ft (76 m) required to reach the placers on Emerald Bar (plate 1). The water was used primarily for sluicing (Daily Independent, July 7, 1891). Among the other companies formed was The Montana Gold and Gem Company, made up of Helena investors, including Henry Crittenden. The company acquired the Matheson placers near Emerald Bar plus an additional 2 mi (3.2 km) of properties along both sides of Prickly Pear Creek near its mouth. The Emerald Bar property was worked by drifting (Pratt, 1906, p. 108). Somewhat unique to this location, one of the drifts empties through a tunnel cut through the granite bedrock of the terrace. Pratt (1906) reported that the Montana Gold and Gem Company transported the concentrates to the river for processing.

Kunz reported that in 1893 more Montana sapphires were sold than in previous years due partly to the interest they generated when featured at the Chicago World's Fair. Unfortunately for the Sapphire and Ruby Company and proponents of Montana sapphires, 1893 marked the beginning of an economic downturn known as "The Panic of 1893," which set back purchasing and investment worldwide well into 1897. When shareholders of the company met at the end of the year, it was revealed that the company was operating under a deficit of £6,000 and that the sales of gems had been meager. It was also disclosed that instead of the £450,000 in stock sales that had been anticipated, in actuality only £45,000 had been raised. The discovery in 1895 of spectacular blue sapphires at Yogo, near Utica, Montana, also lowered the market's interest in the fancy Missouri River sapphires. Following the liquidation of the Sapphire and Ruby Company in 1897, the properties reverted to the ownership of A.N. Spratt. The company was renamed the Eldorado Gold and Gem Company, but mining reportedly did not resume. The properties were eventually offered for sale in 1913 with equal focus on their value as farmland rather than their value as mining property (Helena Independent, 1913, June 9, p. 16). For a considerable time the failure of the Sapphire and Ruby Company marked the final chapter of Missouri River sapphires. The words written by George F. Kunz in 1890 became the watchwords for many generations to come: "Extensive workings will be carried on for these fancy stones, which are not true ruby red nor true sapphire blue. The success of the enterprise depends very much upon how many of these peculiar colored gems the markets of the world will absorb" (Kunz, 1890).

For many years, small operations continued to sporadically work the deposits. The advent of the Great Depression in 1929 brought about a renewed interest in mining throughout the West as displaced workers sought any means available to make a living. Completion of the Hauser Dam in 1911 resulted in the lowest of the terraces at Eldorado Bar and Spokane Bar being submerged. This brought with it new opportunities. In 1930, the Eldorado Mining Company installed a 4,000 gallon (15, 100 L) per minute centrifugal pump to lift water from Hauser Lake for hydraulic mining. Upon reaching the terrace, the water was run through a secondary pump that brought it to the proper pressure for hydraulic mining.

In October 1938, the Perry-Schroeder Mining Company was formed. With financing from the Reconstruction Finance Corporation, they secured leases for mining ground at Eldorado Bar and purchased a Yuba bucket-line dredge (fig. 3). The dredge was manufactured in California and then transported to Helena for final assembly, and assembled on the west shore of Hauser Lake near present-day Black Sandy Campground. Construction was completed in a record 45 days. "Concentrates were classified from 2 mesh to 8 mesh and the sapphires separated from these fractions. Few, if any, crystals larger than three quarters of an inch were found. No attempt was made to save material smaller than 8 mesh" (Mertie and others, 1951, p. 92). Upon completion in December, the dredge was towed across Hauser Lake to Eldorado Bar. After the dredge had completed excavation of the lower bar, which was leased from the Montana Power Company, the dredge was moved southwest across the flats. This was accomplished by using the bucket line to excavate a channel in front of the dredge, while at the same time the stacker was used to backfill the channel behind the dredge. In this manner, the Company was able to move the dredge forward while remaining afloat. When the dredge reached the upper terrace, the Company used the same method to work the upper bar. The property that the Perry-Schroeder Company leased on the upper bar was the same property previously worked by the Sapphire and Ruby Company of Montana Limited. This time, however, world events worked in favor of mining sapphires.

Figure 3. The Perry Schroeder Mining Company's dredge mining sapphires and gold on Eldorado Bar. The buckets are on the digging ladder to the left and the stacker is in the white covering on the right. Photo from the Photograph Archives, Montana Historical Society, Helena, MT.

The Verneuil process for producing synthetic corundum was introduced in 1902. Through refinement, the process became cost effective, so that by the 1930s synthetic sapphires were commonly used as jewel bearings. The production of synthetic sapphires and rubies took place in France, Germany, and Switzerland. The advent of World War II in Europe caused the supply of synthetic sapphires produced in Europe to decrease rapidly. As a result, sapphire production was designated as essential to the war effort. When other gold mining operations were forced to shut down under War Production Board Order L-208, the Perry-Schroeder Mining Co. was permitted to continue to operate throughout the war. A very small amount of platinum metals was also recovered while mining. However, platinum and osmium were not in short supply and were not designated as minerals of critical importance to the war effort (U.S. War Production Board Record, WPB-1475). For estimated total production from Eldorado Bar, including Sam Speerstra's more recent mining, see the Descriptions of Bars section on Eldorado Bar.

The sapphires were rough sorted at the Perry-Schroeder Mining Company's offices at Eldorado Bar and the final sorting was done in Helena. Sorting was done using a sizer made from two parallel, inclined rolls, one on an eccentric cam, which rotates upward. "The gems roll down over the sizer and the thin, tabular sapphires (which will not pass through a screen sizer) drop through between the rolls" (Clabaugh, 1952, p. 44). The average price received for industrial sapphires was estimated at $1.00 to $2.00 per carat (U.S. War Production Board Record). Even as the production of natural sapphires was increasing, the search for a replacement was underway. At the beginning of the War, a development contract was awarded to Linde Air Products Company, Indiana, to manufacture synthetic sapphires. By 1943, synthetic sapphires became more readily available, resulting in the price dropping. The dredge ceased operations in 1945. In 1947, the dredge was towed upriver where they began dredging in Hauser Lake below French Bar. A short time into this operation, the company obtained a subcontract to excavate the riverbed in preparation for placement of the footings for the new Canyon Ferry Dam. The dredge also excavated a gravel deposit located between this site and the old dam to provide aggregate for use in constructing the new dam. Records have not been located to indicate whether the company was permitted to recover gold or sapphires as part of this operation.

French Bar

French Bar was an important gold mine with total production of gold for the years 1867–1869 estimated to be $600,000 (Raymond, 1870). Gold was recovered using ground sluicing and hydraulicking (fig. 4), with water supplied by the French Bar ditch and the Taylor and Thompson ditch (plate 2). The French Bar ditch carried 260 miner's inches of water and the Taylor and Thompson ditch carried 1,000 miner's inches of water from Beaver Creek. Although sapphires have been recovered from French Bar in recent years, they were not reported in the early production.

Magpie Creek

Gold deposits on Magpie Creek were discovered about the same time as the Missouri River deposits. Sapphires were also found in the alluvial gravel along Magpie Creek but were reportedly only recovered in small quantities. Sapphires have not been found farther upstream than the tributary Never Sweat Gulch (see chapter on Possible Bedrock Sources). During the 1870s, miners worked the lower 3 mi (4.8 km) of Magpie Creek, primarily drift mining. However, hydraulic mining was employed when feasible. Bedrock drains were also constructed to facilitate drainage of the workings. During the late 1880s, Courtney Sheriff Sr. of Canyon Ferry worked the upper end of Magpie Creek below the mouth of Bar Gulch. To reduce flooding, a tunnel was driven along bedrock to act as a drain. The operation was then able to proceed by sinking shafts and drifting along the bedrock. In 1892, the operation was incorporated as the Magpie Mine and Drain Company.

Following the completion of the first Canyon Ferry Dam in 1898, the lower end of Magpie Creek became submerged by the water of Lake Sewell. The Magpie Development Corporation acquired a lease on 400 acres (161 ha) where Magpie Creek entered Lake Sewell. The company operated a connected bucket line dredge between 1911 and 1913. The dredge, which was built by the Union Iron Works of San Francisco, was assembled on site in 1910. All the parts for the dredge were shipped in by rail from out of state, including 250,000 board feet of Oregon fir used to construct the hull and super structure.

In 1931, The Big Belt Gold Mining Co., managed by J.W. Kager, obtained a lease on an unworked portion of the Sheriff claim on upper Magpie Creek. Like the previous operation, the deposits were worked by driving a bedrock drain and sinking shafts to permit drifting along the bedrock.

Figure 4. Photo of hydraulic mining at French Bar showing a monitor to the left and, barely visible, the hose bringing water down from the ditch above. Alluvium that forms the cliffs was stripped from the area in the foreground by ground sluicing. Photo from Photograph Archives, Montana Historical Society, Helena, MT.

Mining between Magpie Creek and Eldorado Bar

In 1865, when Eldorado Bar was discovered, similar discoveries took place on other bars along the river (plate 1). Although these deposits also contained sapphires, the focus remained on gold recovery. Like Eldorado Bar, initial efforts relied on hand work and drifting, and like Eldorado Bar, they progressed to hydraulic mining when possible. Extensive ditch building was required to bring the necessary water to run the operations.

The McCune ditch, which in 1870 cost $15,000 to build, carried 600 miner's inches of water from Trout Creek, 3.5 mi (5.6 km) upriver of McCune and Metropolitan Bars (plate 2). Metropolitan Bar was worked during the summer of 1899. The gravels were from 6 to 20 ft (2 to 6 m) thick, and were washed in a hand rocker. Several of the claims were owned by Robbin Bird, Charles Johnson, and John Durrant, of Helena, Montana (Pratt, 1906, p. 108).

Hydraulic operations started at Spokane Bar when the Banner ditch was completed in 1869 (plate 2).One year later, a branch ditch was completed to bring water from the Banner ditch to Dana's Bar (fig. 5).The Banner ditch cost an estimated $60,000 to construct. The ditch originated in McClellan Creek, 3 mi (5 km) southeast of present-day East Helena, and extended over 27 mi (43 km) along the southern edge of the Helena Valley. The Spokane Bar deposits were also worked by the Spokane Sapphire Company during the early 1890s.

Hydraulic mining at Gruell's Bar commenced in 1875 when Marshall and Sutton extended the ditch from their claims along Clark Gulch. The Marshall and Sutton ditch started on Trout Creek, several miles above York. Starting in 1935, the Lorraine Placer Company of Great Falls operated a dry land dredge on Gruell's Bar for several years. Another company

Figure 5. Photo by E.H. Train, Helena, MT, circa 1870s, of mining at Dana's Bar. This is the upper part of Dana's Bar with Prickly Pear Creek to the left, which is now flooded by Hauser Lake. Photo from Photograph Archives, Montana Historical Society, Helena, MT.

also ran a dry land dredge during 1939 (Lyden, 2005, p. 49).

Recent Mining

In the 1960s, recreational sapphire mining in the bars along Hauser Lake became an important activity, which still continues. Typically, individuals pay a fee to sieve gravel for sapphires. These operations included Lovestone's and Guffey's on Gruell's Bar, Castles on Spokane Bar, and an operation above French Bar. See the description of Eldorado Bar in the chapter on Descriptions of Bars for information on the commercial mining there.

GEOLOGY AND SAPPHIRE DEPOSITS

by Richard B. Berg

Geology of Area

The construction of Canyon Ferry Dam, which formed Canyon Ferry Lake, and Hauser Dam downriver, which formed Hauser Lake, significantly altered this stretch of the Missouri River from Townsend to Hauser Dam (fig. 6). Canyon Ferry and Hauser Lakes are bounded on the northeast by the Big Belt Mountains, and the Spokane Hills southwest of Canyon Ferry Lake. The broad Townsend Valley is a graben bounded by faults (fig. 7), unlike the valley northwest of Canyon Ferry Dam, which is a more typical "river-carved valley." Metasedimentary rocks of the Belt Supergroup dominate the higher elevations of the Big Belt Mountains, and sedimentary formations of Paleozoic age predominate at lower elevations closer to Canyon Ferry Lake. Diorite sills and dikes intruded rocks of the Belt Supergroup and also along the contact between these rocks and the Cambrian Flathead Formation. Radiometric ages on these intrusive rocks range from 741.3 ± 32.2 to 826 ± 41 Ma (Marvin and Dobson, 1979). Some of these intrusives in the Big Belt Mountains are interpreted to be Tertiary or Late Cretaceous in age, because they post-date Cretaceous folds (Lonn and McDonald, 2003). Additionally, the diorite sill on French Bar Mountain (plate 1) between the Empire Formation and the Flathead Formation metamorphosed the Cambrian Flathead Formation, indicating a post Flathead Formation age. Mertie and others (1951) indicate that this sill is a lamprophyre, but field examination shows it to resemble the diorite intrusives. Although these intrusions appear similar in the field, they may actually be of two generations. Two thin sections of the diorite show intensely altered plagioclase feldspar to be the dominant mineral. Other minerals, listed in order of decreasing abundance, are quartz, orthoclase, magnetite, apatite, pyroxene, and biotite.

The Six Mile Creek Formation of Tertiary age is exposed along the east shore of Canyon Ferry Lake (Vuke, 2011), and the Canyon Ferry stock of quartz monzonite, granite, and related rocks is exposed along the southwest shore (Mertie and others, 1951). Uphill from this intrusive in the Spokane Hills, Paleozoic sedimentary rocks predominate. Hauser Lake differs from Canyon Ferry Lake because metasedimentary rocks of the Belt Supergroup are exposed along both shores of this lake.

Strath Terraces

Essentially all of the sapphire deposits along this stretch of the Missouri River are in gravel deposited on strath terraces (plate 1). A strath terrace is an erosional remnant of an elevated broad river valley. These terraces are Pleistocene age, formed by erosion of metasedimentary rocks of the Belt Supergroup. Sapphire-bearing gravel, also thought to be Pleistocene, was deposited on these terraces. More recent erosion subsequently dissected these terraces, leaving only remnants. Younger alluvial deposits that lack sapphires overlie the Pleistocene gravel. Terraces along the Missouri River are generally referred to as bars; this term is used through the rest of this report. Field observations and Google Earth images were used to map these terraces, as shown on plate 1. Notes on these images:

1. White lines on Google Earth images typically show the limit of mining, because the alluvium overlying the sapphire-bearing gravel is light colored.
2. Where mining is more than 50 years old, small trees typically cover the gravel piles.
3. Windrows of cobbles can be recognized on Google Earth images in some areas.

Elevations of bars as shown in table 1 are only approximate and probably accurate within 20 ft (6 m), because the contour interval on the topographic maps is 40 ft (12 m). The elevation of bedrock within an individual mined area is also variable. For the larger bars, such as Gruell's Bar, there is a significant range in elevation, from 3,765 ft (1,148 m) to 3,925 ft (1,197 m), a difference of 160 ft, or 49 m. An attempt was made to plot bar elevations above the bed of the Missouri River to determine if these bars could be related to specific erosional events. Plotting bar elevations taking into account a gradient of 4 ft/mi (0.75 m/km) for the Missouri River did not reveal an obvious pattern. Many of the bars are between 100 and 200 ft (30 and 60 m) above the surface of Hauser Lake, which is at an elevation of 3,650 ft (1,113 m).

The gravel was deposited on the bars by the Missouri River flowing in the present direction, generally northerly as indicated by the occurrence of quartzofeldspathic gneiss pebbles. Most of the pebbles and cobbles are of local source, mainly metasedimentary rocks of the Belt Supergroup. However, even as far downriver as Eldorado Bar, there are rounded pebbles of quartzofeldspathic gneiss in the sapphire-bearing

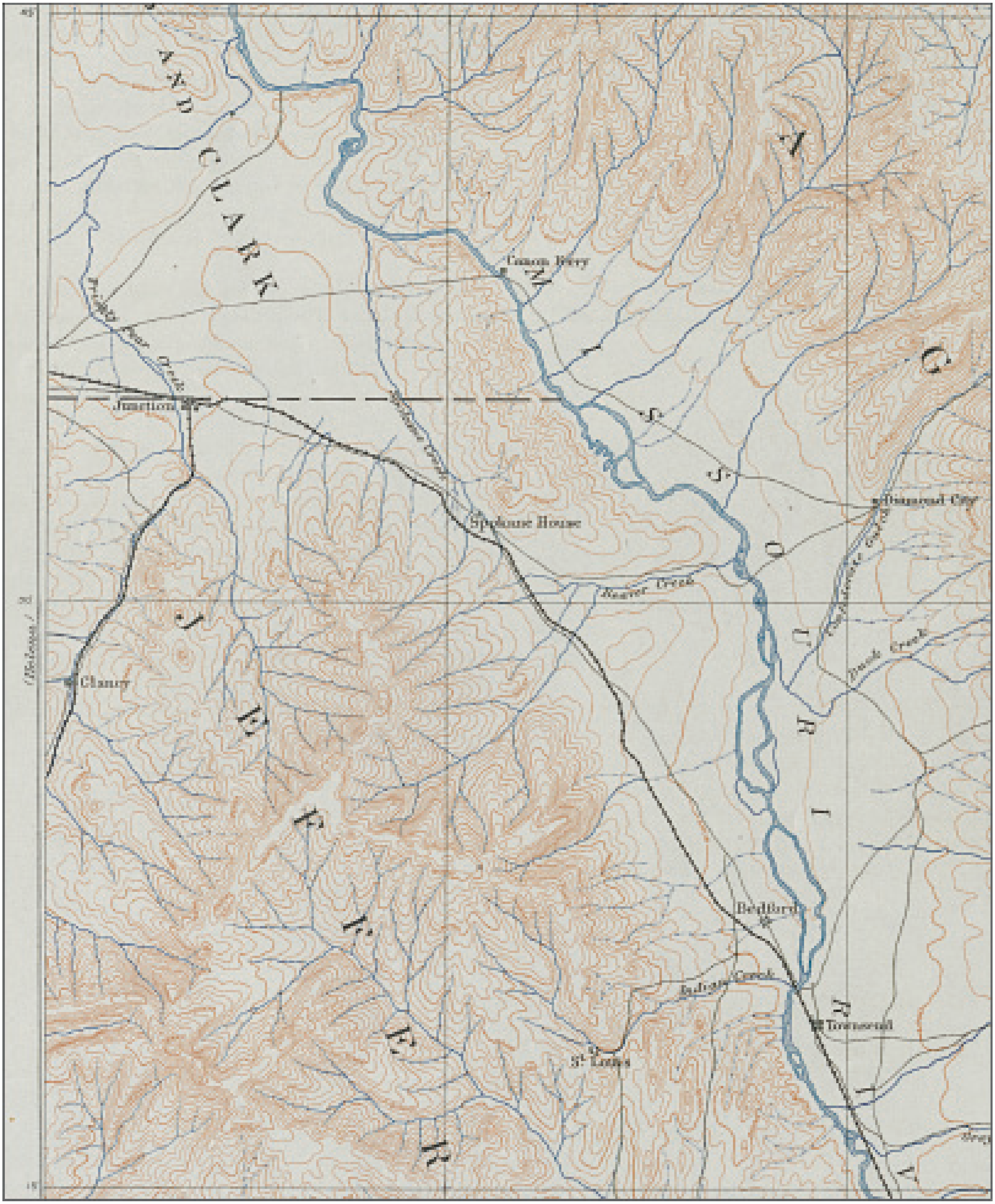

Figure 6. Part of the USGS Fort Logan reconnaissance map of 1889, scale 1:250,000.

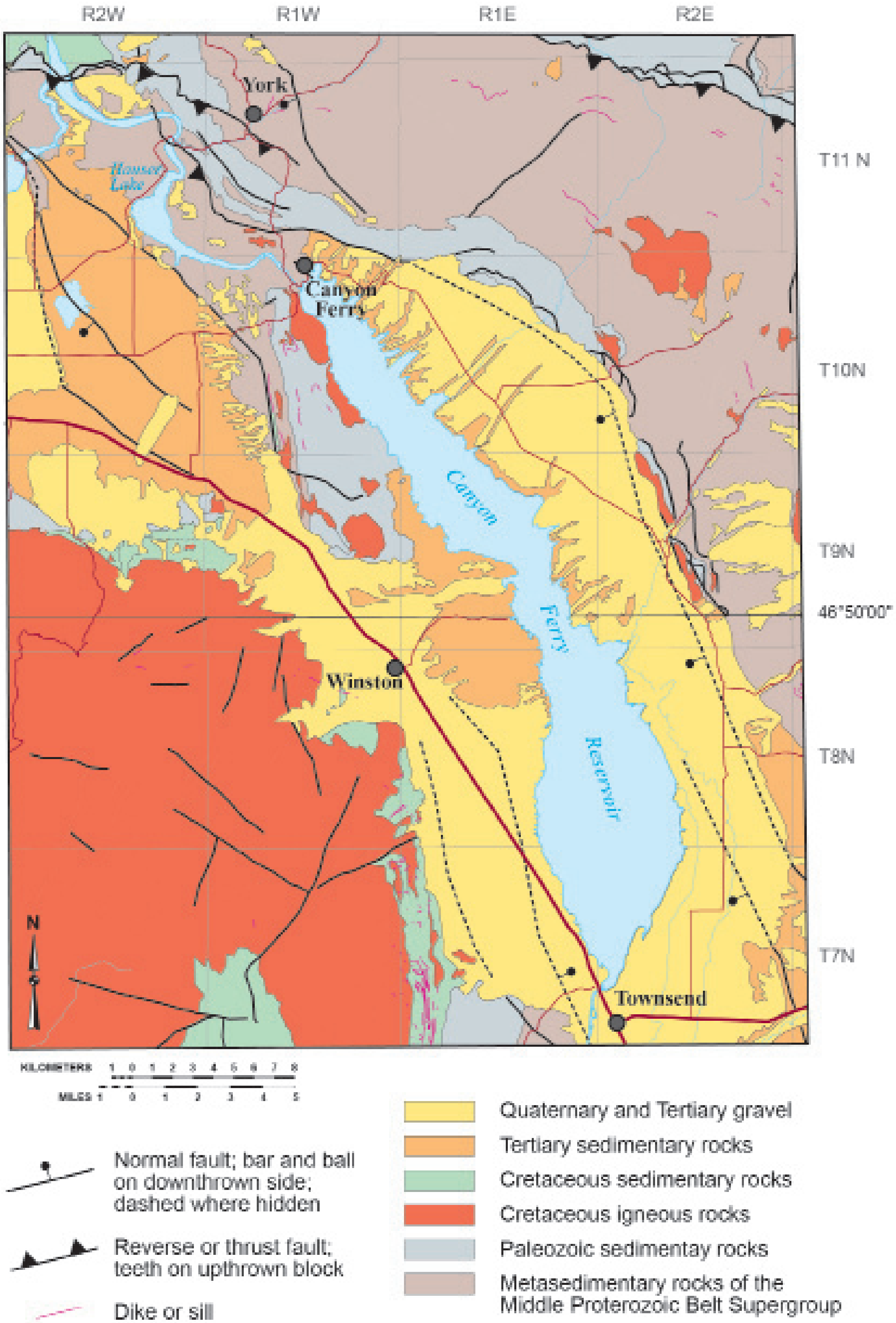

Figure 7. Simplified geologic map of the Canyon Ferry and Hauser Lake area from Vuke and others, 2007. See plate 1 for deposits of sapphire-bearing gravel.

Table 1. Approximate elevations of bars and gravel remnants of terraces.

Emerald Bar	3,960 ft	1,208 m
Pilgrim Bar	3,675 ft	1,121 m
Virginia Bar	3,680 ft	1,122 m
Center Bar	3,750 ft	1,144 m
French Bar	3,830 ft	1,168 m
McMaster Ranch gravel	3,920 ft	1,196 m
Gruell's Bar	3,765 ft	1,148 m
	3,790 ft	1,156 m
	3,820 ft	1,165 m
	3,850 ft	1,174 m
	3,875 ft	1,182 m
	3,925 ft	1,197 m
Spokane Bar	3,700 ft	1,128 m
	3,750 ft	1,144 m
Hill above Spokane Bar	3,880 ft	1,183 m
Metropolitan Bar		
North	3,725 ft	1,136 m
South	3,740 ft	1,141 m
McCune Bar	3,760 ft	1,147 m
Lakeside gravel	3,670 ft	1,119 m
Two Camps Vista gravel	3,840 ft	1,171 m
S. of Trout Creek	3,840–3,880 ft	1,171–1,183 m
N. of Trout Creek	3,820 ft	1,165 m
Eldorado Bar	3,615 ft	1,103 m
	3,780 ft	1,153 m
	3,800 ft	1,159 m
Dana's Bar	3,780 ft	1,153 m

gravel. These pebbles are particularly abundant at French Bar. The closest bedrock sources of quartzofeldspathic gneiss are in the sequences of Archean metamorphic rocks exposed upriver past Three Forks, 52 mi (83 km) almost due south of Canyon Ferry Dam, where the Jefferson, Madison, and Gallatin Rivers join to form the Missouri River. Quartzofeldspathic gneiss is exposed in the mountain ranges of southwestern Montana, specifically the Highland Mountains, Ruby Range, Gravelly Range, Tobacco Root Mountains, Madison Range, and Gallatin Range. However, most of the sapphires were not derived from these Archean metamorphic rocks, but probably from closer sources. See the section on possible bedrock sources of sapphires for further discussion. The abundance of red and pink garnets in the gravels is also suggestive of an upriver source. The garnet was probably derived by weathering of the abundant garnetiferous gneisses in Archean metamorphic rocks.

I speculate that the strath terraces (bars) developed during the Pleistocene, when there was large flow on the Missouri River during glacial melting. The restriction of bars to the Hauser Lake area was governed by the topography of the Missouri River Valley before construction of the dams. Above the site of Canyon Ferry Dam, this was a broad valley that is now largely flooded by Canyon Ferry Lake (fig.6). Below the dam, the valley was much more restricted. Thus, the velocity of the former Missouri River increased, as did its erosive ability, enabling the river to cut the strath terraces in the hard metasedimentary rocks of the Belt Supergroup along the present Hauser Lake. Following the erosion of the terraces and deposition of overlying gravel, this area was covered by Glacial Lake Great Falls, which had a maximum elevation of about 4,000 ft (1,220 m) (M. Stickney, oral commun., 2012). Glacial Lake Great Falls sediments are well exposed at several localities on the west shore of Hauser Lake, including an area near Lakeside (Stickney, 1987). Windblown silt deposits (loess), presumably related to the emptying and drying up of Glacial Lake Great Falls, overlie many of the gravel deposits on the strath terraces. It is likely that all of the Pleistocene gravel characterized by quartzofeldspathic gneiss pebbles and abundant garnet contains sapphires.

DESCRIPTIONS OF BARS AND SAPPHIRE-BEARING GRAVEL ALONG CANYON FERRY AND HAUSER LAKES

Emerald Bar

Description

Remnants of this bar are situated several hundred feet northwest of the entrance to the Overlook Picnic Area near the southwest shore of Canyon Ferry Lake (southeast corner of plate 1). The name Emerald Bar likely comes from the pale green sapphires found along the Missouri River, which were known as oriental emeralds. There is no record of true emeralds being found in any of the Missouri River bars.

Gravel at an elevation of about 3,960 ft (1,208 m), above 160 ft (49 m) above Canyon Ferry Lake, lies on partly decomposed quartz monzonite. A partly caved tunnel at bearing N. 27º W., 87 ft long (26 m), is at the contact of the gravel with bedrock (fig. 8). Mertie and others (1951, p. 91) stated that the gravel was reportedly hauled to the Missouri River where it was washed to recover sapphires.

Ownership

Administered by the Bureau of Reclamation.

Gravel

Subrounded cobbles of black basalt, with prominent plagioclase phenocrysts, are the most abundant rock type in the gravel, followed by subangular to subrounded quartzite cobbles and less abundant subrounded crumbly diorite cobbles. Distinctive rounded, very light gray biotite granite pebbles and rounded quartzofeldspathic gneiss pebbles are minor constituents of this gravel.

Figure 8. Entrance to tunnel along the contact between quartz monzonite bedrock and overlying gold and sapphire-bearing gravel at Emerald Bar.

Sapphires and other heavy minerals

A very pale green sapphire with prominent basal pinacoids (1.48 ct.) was recovered from this gravel. Goldschmidt (1918, fig. 2.2) showed a sketch of a tabular sapphire and a somewhat thicker sapphire with a triangular twin on the basal pinacoid, both from Emerald Bar. Sand collected from the cut adjacent to the portal of the tunnel yielded a trace of gold and abundant garnet in addition to magnetite and an unidentified black mineral. Most garnets are about 1 mm, with fractured surfaces, and are pale pink with less abundant root-beer-colored specimens.

French Bar

Description

French Bar, and its associated bars, are on the south side of Hauser Lake below Canyon Ferry Dam (plate 1 and fig. 9). There are four named bars here: Pilgrim, Virginia, Center, and French, which is the largest and highest (fig. 10; Raymond, 1870, p. 285–286). Ruby Bar appears to be a continuation of French Bar to the southeast (plate 1). Figure 10 also shows what is probably Pilgrim Bar, now occupied by the road along the southwest shore of Hauser Lake. The rock exposed in cliffs above Hauser Lake is the Spokane Formation of the Belt Supergroup. The grassy area above Pilgrim Bar is Virginia Bar, with scattered bedrock outcrops. There is no evidence of mining on Virginia Bar, other than scattered shallow prospect trenches and pits. Center Bar was mined for gold and is approximately 70 ft (21 m) above Virginia Bar. French Bar is up a steep slope from Center Bar and covers a large mined area. Raymond (1870, p. 285–286) made no mention of sapphires having been recovered, but production figures showed that French Bar was a rich gold placer. In recent years, individuals have recovered sapphires from French Bar. During the gold mining, channels were excavated into the

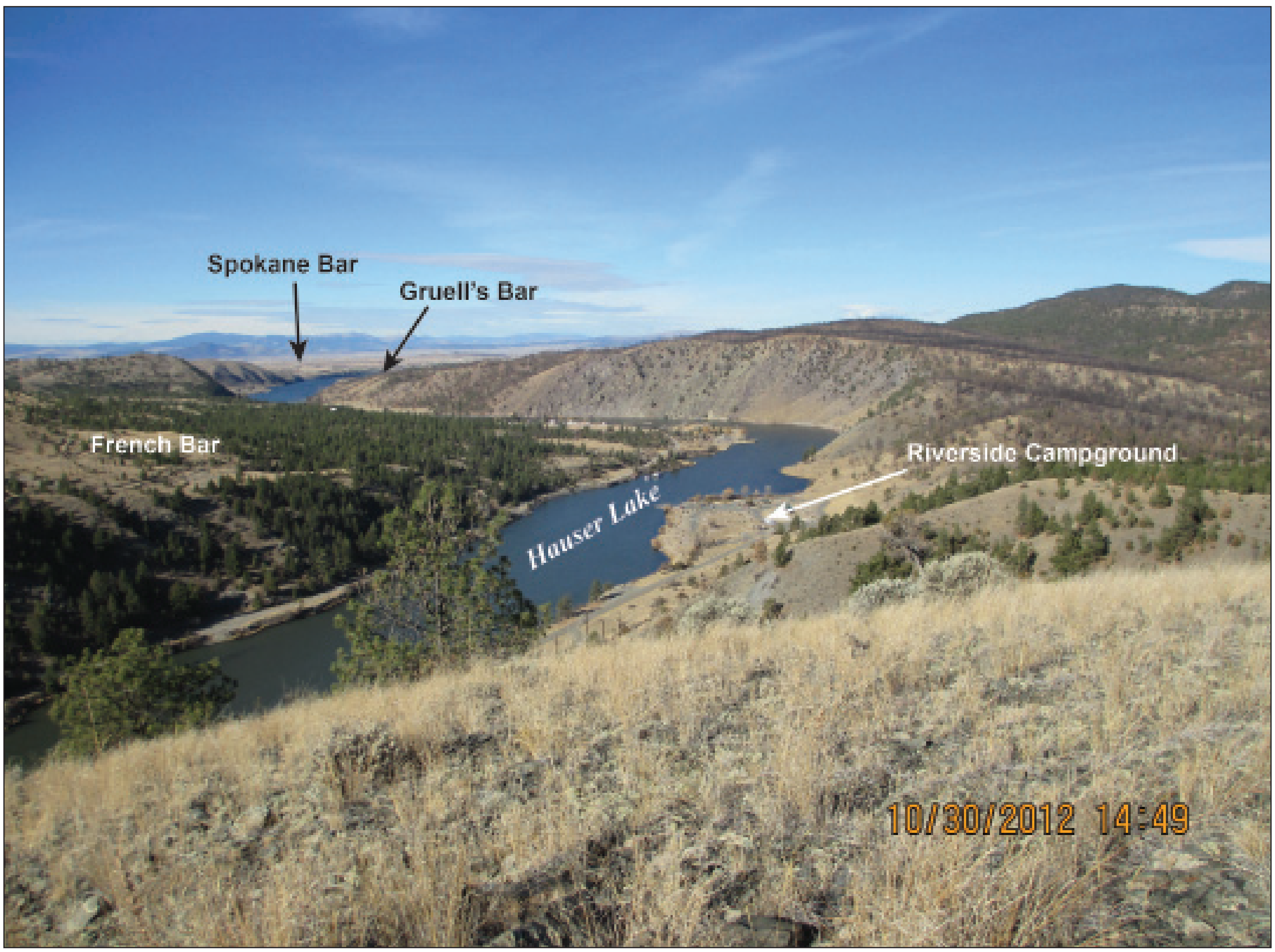

Figure 9. View northwest from Goon Hill situated above the northeast abutment of Canyon Ferry Dam, showing French Bar area and Gruell's Bar just barely visible farther down Hauser Lake.

Figure 10. View southwest across Hauser Lake from Riverside Campground showing road on Pilgrim Bar just above the cliffs on the shore of Hauser Lake. Virginia Bar is the grass-covered area above road.

underlying Spokane Formation and the tailings, which consisted largely of pebble-size gravel and probably sapphires, were washed downhill to the Missouri River (fig. 11). The larger cobbles and boulders were piled adjacent to the sluice boxes. In both Center and French Bars, irregular pillars of fine-grained alluvium were left unmined. A possible explanation is that at these locations the alluvium overlying the auriferous gravel was thicker and simply not worth the effort and water to remove. Deposits of gravelly alluvium overlain by loess are exposed uphill from French Bar, and similar deposits were partly stripped from French Bar. The continuation of French Bar to the southeast, probably Ruby Bar, was prominent in early efforts to develop these sapphire deposits. A reclaimed area at the eastern end of French Bar, also probably Ruby Bar, was reportedly recently mined for gold. Approximate elevations are: Pilgrim Bar, 3,675 ft (1,121 m); Virginia Bar, 3,680 ft (1,122 m); Center Bar, 3,750 ft (1,144 m); and French Bar, 3,830 ft (1,168 m) (table 1).

West of the main area of mining at French and Center Bars on the former McMaster Ranch (recently acquired by the Bureau of Land Management), the difference in elevation between the apparent continuations of Center and French Bars is only 20 ft (6 m), less than to the east. Also in this area, there are three shallow prospect pits in similar gravel at higher elevations, the highest one at 3,920 ft (1,196 m). It is not known whether sapphires were recovered from these pits.

Ownership

Part private ownership and part administered by the Bureau of Land Management.

Gravel

Most of the gravel on French Bar is in the cobble and boulder size range, left after the smaller tailings material was washed downhill during mining. Gravel

Figure 11. Channel excavated in bedrock at French Bar where gold-bearing gravel was washed into sluices to recover gold. The tailings were washed down to the Missouri River and the larger cobbles and boulders were piled above the sluices.

on French Bar consists of mainly subangular to subrounded tan to gray quartzite from the Belt Supergroup and cobbles of Paleozoic formations, including the Flathead, Meagher, and Jefferson Formations. These Paleozoic formations are exposed above French Bar on French Bar Mountain. Diorite is a minor constituent of the gravel on French Bar. The material washed down the gulch toward Hauser Lake during mining also consists mainly of rounded quartzite and rarer quartzofeldspathic gneiss pebbles. Rare very large boulders are dropstones carried by the ice on Glacial Lake Great Falls and deposited when the ice melted. One such boulder of siltite of the Belt Supergroup is over 6 ft (2 m) across (fig. 12).

Sapphires

Sapphires were not available for study.

Dredging Hauser Lake

Mac Mader Jr. provided the following information (Mac Mader, written commun., 2017). Using an 8-in (20-cm) suction dredge in September 1973, Mac Mader recovered a deep blue sapphire, named the Big Sky sapphire (fig. 13), near French Bar a short distance below Canyon Ferry Dam. In 1983–1986, Mac Mader constructed a large suction dredge to recover gold and sapphires from Hauser Lake (fig. 14). This 16-in (41-cm) suction dredge has a closed-circuit television camera that enables the operator to see the area being dredged. During the summer of 2012 in the French Bar area, testing was done for gold and sapphires using a hand-held 8-in (20-cm) suction dredge and washing plant on a 16 x 30 ft (5 x 9 m) barge with a small cabin (fig. 15) (Zeitner, 1978).

Figure 12. Boulder of siltite from the Belt Supergroup (over 2 m across) that was left at French Bar when an iceberg on Glacial Lake Great Falls melted and deposited this dropstone.

Figure 13. Big Sky Sapphire (12.54 ct cut) dredged by Mac Mader from Hauser Lake. Photo by Harold and Erica Van Pelt, courtesy of Mac Mader.

Gruell's Bar

Description

Gruell's Bar is one of the largest bars and extends for about 1 mi (1.6 km) along the north shore of Hauser Lake (plate 1). It is not situated across Hauser Lake from French Bar as shown on the printed version of the Canyon Ferry 7.5' quadrangle. This bar is divided into three major remnants, separated by Browns Gulch and a less prominent gulch to the east (fig. 16). As of this writing, Tim Beard mines gold and sapphires from the area east of Browns Gulch and west of the smaller gulch. The easternmost segment of Gruell's Bar was developed by Jerry Lorbeck, who had a fee digging operation for the public there. This area is often referred to by the name of that operation, Lovestones.

Terrace elevations estimated from the topographic map range from 3,765 to 3,930 ft (1,148 to 1,198 m), an interval of 165 ft (50 m). There does not seem to be any dominant elevation of these terraces. Specifi-

Figure 14. Large suction dredge and smaller barge-mounted washing plant, both constructed by Mac Mader and moored on the west shore of Hauser Lake near French Bar in 2012.

Figure 15. Mac Mader and crew washing gravel dredged from Hauser Lake for gold and sapphires on barge-mounted washing plant, September 2012.

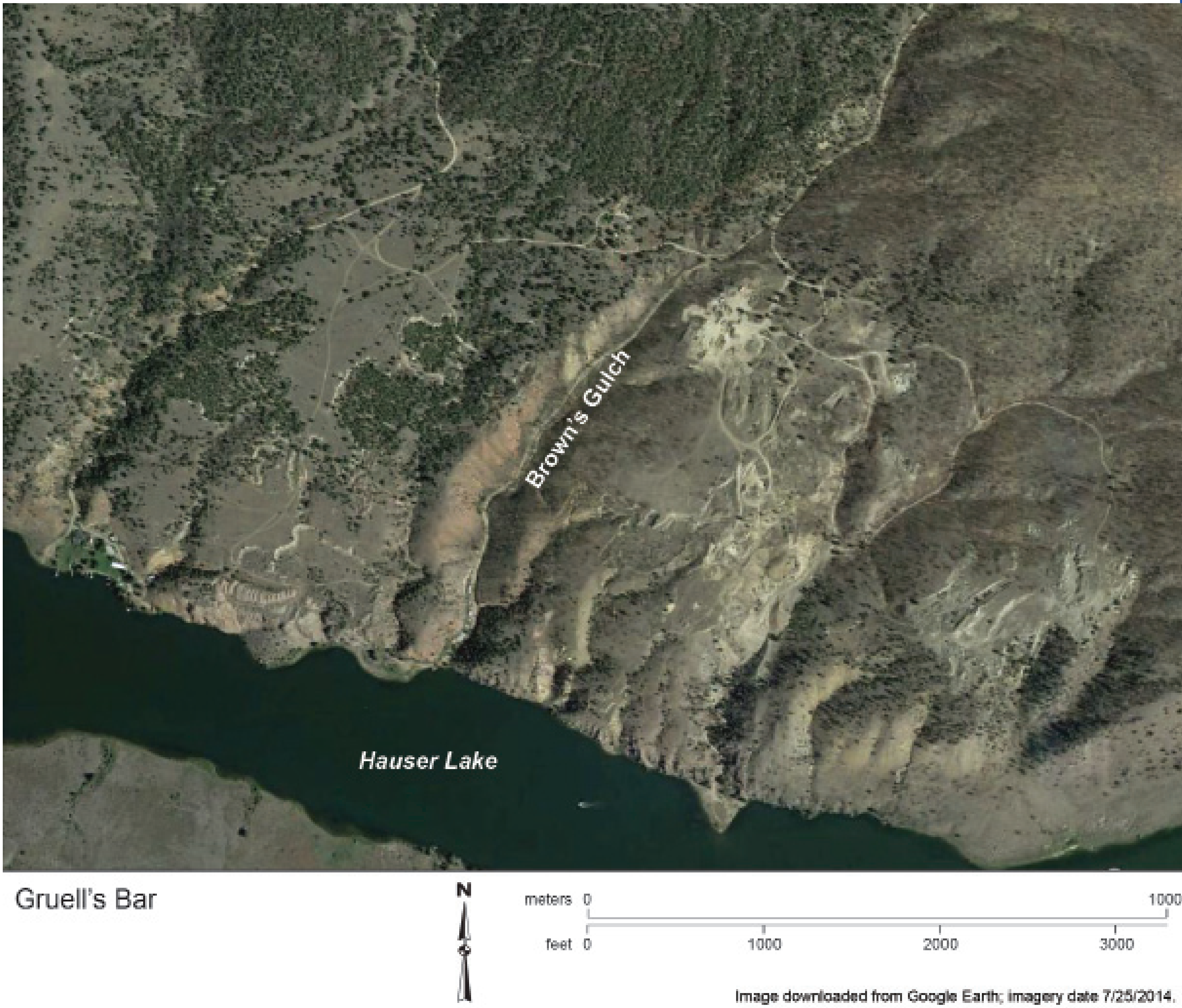

Figure 16. Google Earth Image of Gruell's Bar. Overlying white alluvial deposits at the edges of the mined areas show their extent. See also plate 1.

cally, the terraces are separated by about 25 ft (8 m), and elevations are 3,765 ft (1,148 m); 3,790 ft (1,156 m); 3,820 ft (1,165 m); 3,850 ft (1,174 m); 3,875 ft (1,182 m); 3,890 ft (1,186 m); and 3,925 ft (1,197 m) (table 1).

Most of the early mining of Gruell's Bar was for gold and not for sapphires. The lower part of the middle segment of Gruell's Bar was mined for gold in the 1930s, and the tailings from this mining remain along the prominent gulch to the east of Browns Gulch. More recently, some of these tailings have been processed for sapphires, with the waste from this operation forming the small delta in Hauser Lake at the mouth of this gulch.

Ownership

There are several individual private landowners for mined areas in sec. 31, T. 11 N., R. 1 W., and located mining claims in sec. 32, T. 11 N., R. 1 W.

Gravel

Gravel from 10 to 15 ft (3 to 4.6 m) thick lies on the Spokane Formation of the Belt Supergroup. Pebbles and cobbles of quartzite, siltite, and argillite derived from the Belt Supergroup dominate the gravel, which also includes diorite, quartzofeldspathic gneiss, and basalt with prominent plagioclase phenocrysts, hornfels, and leucogranite. Bedding is indistinct and there does not seem to be any systematic variation in pebble size, but pebbles greatly predominate over cobbles. Pebbles and cobbles are in a fine-grained matrix of clay and sand. A 1–2 ft (0.3–0.6 m) bed of light tan sediment overlies the gravel here and consists mainly of loess (fig. 17). This bed is easily recognizable on the Google Earth images and generally outlines the extent of mining of an individual terrace (fig. 16).

Gravel in the highest terrace (elevation 3,925 ft; 1,197 m) at Gruell's Bar is exposed in a small excavation east of the extensively mined area and is strongly caliche cemented (fig. 18).

Sapphires and gold

As is typical of these terrace gravels, the greatest concentration of sapphires at Gruell's Bar is within several feet of bedrock (fig. 19). Unusually rich "pockets" of gravel occur in small depressions on the surface of the bedrock here.

Sapphires recovered by Tim Beard at Gruell's Bar are typically very pale green with a few light blue specimens. Relict hexagonal prisms are prominent, but most sapphires are equidimensional. In addition to minor gold, garnet and magnetite are abundant heavy minerals.

Spokane Bar

Description

Spokane Bar is situated on the southwest shore of Hauser Lake 3.7 mi (6 km) west of French Bar (plate 1), where the Greyson Formation of the Belt Supergroup is exposed below the bar along the shore of Hauser Lake. The elevation of Spokane Bar is about 3,700 ft (1,128 m). This bar was mined for gold and sapphires, but evidence of mining has been obscured by landscaping and houses built along the shore of Hauser Lake. The bar was reported to be about 3,000 ft (915 m) long and 50 to 500 ft (15 to 152 m) wide, but consisted of only a few feet of gravel (Mertie and

Figure 17. Bed of silt with rare pebbles overlying Pleistocene gravel on Gruell's Bar. Much of the silt is wind-blown loess.

Figure 18. Caliche-cemented gravel exposed in small pit at the upper part of Gruell's Bar east of Browns Gulch.

Figure 19. Tim Beard standing on bedrock and pointing to an unusually rich bed of sapphire-bearing gravel in his pit on Gruell's Bar.

others, 1951, p. 79). Current sapphire mining is at two pits situated east of the Spokane Bar. The Independence pit may be at about the same elevation as Spokane Bar, and the Brinks pit is at 3,750 ft (1,144 m). Recently the Spokane Bar Sapphire Mine and Gold Fever Rock Shop has mined sapphires from these pits for their business, where they concentrate the sapphires in the gravel and sell this concentrate to individuals for screening. Currently the main source of gravel for their operation is Eldorado Bar.

Ownership

Private.

Gravel

Gravel from the Independence pit consists mainly of subangular to subrounded tan to light gray quartzite, black basalt with prominent plagioclase phenocrysts, hornblende granite, biotite granite, gray porphyry, quartozfeldspathic gneiss, and diorite.

Sapphires

Sapphires from the Independence pit are almost colorless to very pale green with a few pale blue specimens. Approximately one-third of these sapphires have a hexagonal outline inherited from the hexagonal prismatic form of corundum. Most of these are relatively thin tablets, but a few have the hexagonal prismatic shape of corundum.

Gravel on Terrace at Top of Hill above Spokane Bar

Description

Like Spokane Bar, this terrace is situated on bedrock of the Greyson Formation. It is on the top of a hill, at an elevation of about 3,880 ft (1,183 m), situated in SE¼ SE¼ 35, T. 11 N., R. 2 W. at the southern boundary of this section. For a fee, individuals can dig sapphires from this gravel, which is 3 to 6 ft (1 to 2 m) thick (fig. 20).

Ownership

Private.

Gravel

This gravel is essentially the same as the gravel described at the Independence pit.

Sapphires

Sapphires from this gravel were not available for study.

Remnants of Gravel along Hauser Lake near Lakeside

Description

Remnants of gravel from terraces near Lakeside are exposed for a distance of about 2.7 mi (4.2 km) along the west side of Hauser Lake between the Spokane Bar area and Two Camps Vista (plate 1). These areas were not mined for sapphires and thus not recognized as bars, although the gravel is similar to that in the bars. A general elevation for these gravels is 3,720 ft (1,134 m). Gravel exposed in a road cut along the York Road about 500 ft (150 m) north of the convenience store at Lakeside is at the lower elevation of 3,670 ft (1,119 m).

Gravel

In addition to the typical pebbles of siltite and quartzite derived from the Belt Supergroup, this gravel contains sparse plagioclase basalt, leucogranite, diorite, and quartzofeldspathic gneiss pebbles.

Two Camps Vista on the Lewis and Clark Trail provides an excellent view of McCune Bar and the McCune Bar ditch cut into the steep slope on the east shore of Hauser Lake (plate 2). A small remnant of sapphire-bearing gravel at an elevation of about 3,830 ft (1,168 m) is situated at this overlook between York Road and cliffs of the Greyson Formation along the shore of Hauser Lake (plate 1). Sapphires have been recovered from this gravel. A terrace just west of the highway on private land is at about the same elevation of 3,840 ft (1,171 m) and is poorly exposed in the road cut on the west side of the highway. It is reported that sapphires have also been found in this gravel on the terrace west of the highway.

Ownership

The area east of the highway to York is administered by the Bureau of Land Management; west of the highway, it is private ownership.

Sapphires

Sapphires were not available for study.

Figure 20. Exposure of sapphire-bearing gravel overlain by alluvium on terrace above Spokane Bar. Shovel with orange handle is resting on bedrock.

Metropolitan Bar

Description

Remnants of gravel above the cliffs of the Greyson Formation along the east shore of Hauser Lake across from Lakeside are situated just below McCune ditch (plates 1 and 2). The northern terrace is at an elevation of 3,725 ft (1,136 m) and the southern terrace is slightly higher at 3,740 ft (1,140 m). Sapphires have been found here.

Ownership

Administered by the Bureau of Land Management.

Gravel

Mainly quartzite cobbles, pebbles, and rare quartzofeldspathic gneiss pebbles.

Sapphires

Sapphires were not available for study.

McCune Bar

Description

McCune Bar is on the east shore across Hauser Lake and south of Devil's Elbow (plate 1). Elevation is estimated to be about 3,760 ft (1,146 m); the cut excavated by the Helena Mineral Society on this bar is about 75 ft (23 m) northwest of the McCune ditch (fig. 21). This strath terrace was cut into argillaceous siltite of the Greyson Formation of the Belt Supergroup. Windblown silt is exposed from the shore of Hauser Lake uphill to the bar, and shallow exploratory trenches to the northeast, close to Hauser Lake, expose Glacial Lake Great Falls sediments. Remnants of gravel and shallow excavations to bedrock southwest of the Helena Mineral Society's cut indicate that previous mining continued past a small gully in a timbered area. Remnants of this strath terrace may have been mined to a limited extent to the northeast of the cut shown in figure 21. The Pleistocene sapphire-bearing gravel is generally about 3 to 6 ft (1 to 2 m) thick, with

Figure 21. Google Earth image of McCune Bar showing Helena Mineral Society's cut and McCune ditch to the southeast.

the greatest concentration of sapphires on bedrock or within a few centimeters of bedrock (fig. 22).

Ownership

The Helena Mineral Society has claims on 120 acres (48 hectares) where members of this society can dig for sapphires.

Sapphire-bearing gravel

Gravel is typical Pleistocene gravel deposited on strath terraces along Hauser Lake. Subrounded cobbles and pebbles of tan and white to gray quartzite derived from the Belt Supergroup predominate, with trace concentrations of plagioclase basalt, dense black basalt, leucogranite, quartzofeldspathic gneiss, diorite, and rounded to subrounded feldspar porphyry pebbles. Rare large, subangular quartzite boulders, much larger than the typical quartzite cobbles, may be ice-rafted dropstones deposited when ice on Glacial Lake Great Falls melted.

Sapphires

Sapphires are mainly pale green to bluish green with rare sky blue sapphires.

Gravel along Hauser Lake South of Trout Creek

Description

Gravel on a strath terrace that ranges in elevation from about 3,840 ft to 3,880 ft (1,171 to 1,183 m) is situated on the east side of Hauser Lake just south of Trout Creek (plate 1). Shallow excavations where gravel was mined for sapphires are above the McCune ditch and 300 ft (92 m) east of it. The gravel is about 8 ft (2 m) thick and lies on the Greyson Formation of the Belt Supergroup. A gravel pit unrelated to this deposit is at a much lower elevation, close to Hauser Lake and visible from the opposite shore.

Ownership

Located claim.

Figure 22. Bill Russell digging for sapphires on bedrock at the Helena Mineral Society's Miss Beverly claim on McCune Bar. The greatest concentration of sapphires is on and just above bedrock.

Gravel

Gravel consists mainly of subrounded tan and gray quartzite derived from the Belt Supergroup. In addition, listed in order of decreasing abundance, the gravel contains: quartzofeldspathic gneiss, plagioclase basalt, gray limestone, leucogranite, diorite, and black basalt. A caliche coating is prominent on much of the gravel.

Sapphires

Sapphires were not available for study.

Gravel along Hauser Lake North of Trout Creek

Description

Sapphires were recovered from gravel on the east side of Hauser Lake north of Trout Creek at an elevation of about 3,820 ft (1,165 m) (plate 1). Bedrock is the Spokane Formation of the Belt Supergroup. A pit 6 ft (2 m) deep was evidently dug in search for sapphires in the ditch that at one time carried water from Trout Creek to Eldorado Bar.

Ownership

Administered by the Bureau of Land Management.

Gravel

Rounded, tan quartzite cobbles and pebbles constitute most of the gravel, with sparse diorite, gray limestone, porphyry, plagioclase basalt, leucogranite, and angular boulders of the Flathead Quartzite derived from exposures of this formation on the ridge just to the north. No quartzofeldspathic pebbles were found here. However, it seems probable that this is a small remnant of sapphire-bearing gravel like that found on the terraces above Hauser Lake.

Sapphires

Sapphires were not available for study.

Dana's Bar

Description

Dana's Bar occupies the peninsula between Prickly Pear Creek and Hauser Lake opposite Eldorado Bar (plate 1 and fig. 23). There are also remnants of this terrace on both sides of Prickly Pear Creek. The Greyson Formation of the Belt Supergroup underlies the Missouri River gravel on this peninsula, and Tertiary sedimentary rocks underlie most of the gravel deposits to the south (Reynolds and Brandt, 2005; Stickney, 1987). Dana's Bar is the only described deposit that is in part on Tertiary sedimentary rocks. Gravel exposures near the west shore of Prickly Pear Creek are remnants of a terrace now largely covered by an alluvial fan. Elevation of the bedrock contact with the gravel at Dana's Bar is about 3,780 ft (1,153 m), similar to one of the lower exposed terraces across Hauser Lake at Eldorado Bar.

Early mining at Dana's Bar was in the southernmost gravels on the east side of Prickly Pear Creek, whereas more recent activity in 1993 consisted of some mining and sampling that was largely confined to gravel on the peninsula. An individual who mined that area reported that the most productive material for recovery of sapphires was the uppermost bedrock, excavated using a ripper, and the gravel right above this bedrock.

Ownership

Private except for a small area near the tip of the peninsula between Prickly Pear Creek and Hauser Lake that is administered by the Bureau of Land Management.

Gravel

Pebbles and cobbles of quartzite derived from the Belt Supergroup predominate, with rare quartzofeldspathic gneiss pebbles and even rarer diorite pebbles.

Sapphires

Sapphires were not available for study.

Eldorado Bar

Description

Eldorado Bar is the largest of the bars in this area along Hauser Lake and has produced more sapphires than any of the other bars. Bedrock is the Greyson Formation of the Belt Supergroup overlain by sapphire-bearing gravel. Locally light-colored silt (loess) overlies the gravel, probably wind-blown material left when the former Glacial Lake Great Falls emptied. Alluvium that overlies the sapphire-bearing gravel appears to increase in thickness going uphill away from Hauser Lake. Glacial Lake Great Falls sediment is exposed along the Hauser Lake shore below Eldorado Bar.

There are at least three terraces at approximate elevations of 3,615 ft (1,102 m), 3,780 ft (1,153 m), and 3,800 ft (1,159 m). Mertie and others (1951, p. 79) mentioned two terraces, one 160 ft (49 m) above Hauser Lake and the other 35 ft (11 m) below the level of Hauser Lake. Hauser Lake is at an elevation of 3,650 ft (1,113 m), so the elevation of the higher terrace at 3,810 ft (1,162 m), within the error of these approximations, is the 3,800 ft (1,159 m) terrace, and the lower terrace is at an elevation of 3,615 ft (1,103 m).

Production and Grade

Eldorado Bar was and is the major source of sapphires in this area. Because records on the early production from this bar are not available, historic figures are only approximate. From 1940 to 1944 the Perry-Schroeder Mining Company mined both gold and sapphires by dredging on Eldorado Bar and recovered a reported 50,000 ounces of sapphires (Clabaugh, 1952, p. 43). If these are troy ounces, this is about 7.7 million ct of sapphires. Mertie and others (1951, p. 93) stated that dredging by the Perry-Schroeder Mining Co. between 1938 and 1944 produced 58,000 troy ounces (9 million ct) of sapphires sold for jewel bearings. They also concluded that an equal or greater quantity of sapphires was sold for other uses. If this is correct, total production of sapphires was a much larger 18 million ct. Whatever figure is closest to the actual production by the Perry-Schroeder Mining Company; this was obviously a very significant period in the production of sapphires from Eldorado Bar or any of the deposits in this area. Between 1988 and 1993, Sam Speerstra recovered 6 million ct of sapphires from Eldorado Bar using large earth-moving equipment (S. Speerstra, oral commun., 2015). The largest recorded sapphire from Eldorado Bar was a perfectly clean, elongate, light blue crystal of 64.7 carats recovered by Sam Speerstra (S. Speerstra, written commun., 2017). S. Speerstra also reported that during the first 2 years of mining this deposit, sapphires weighing more than 50 ct were not uncommon. Total production of sapphires for Eldorado Bar may be in the range of 2 to 3 tonnes, of which only a small fraction would have been of gem quality.

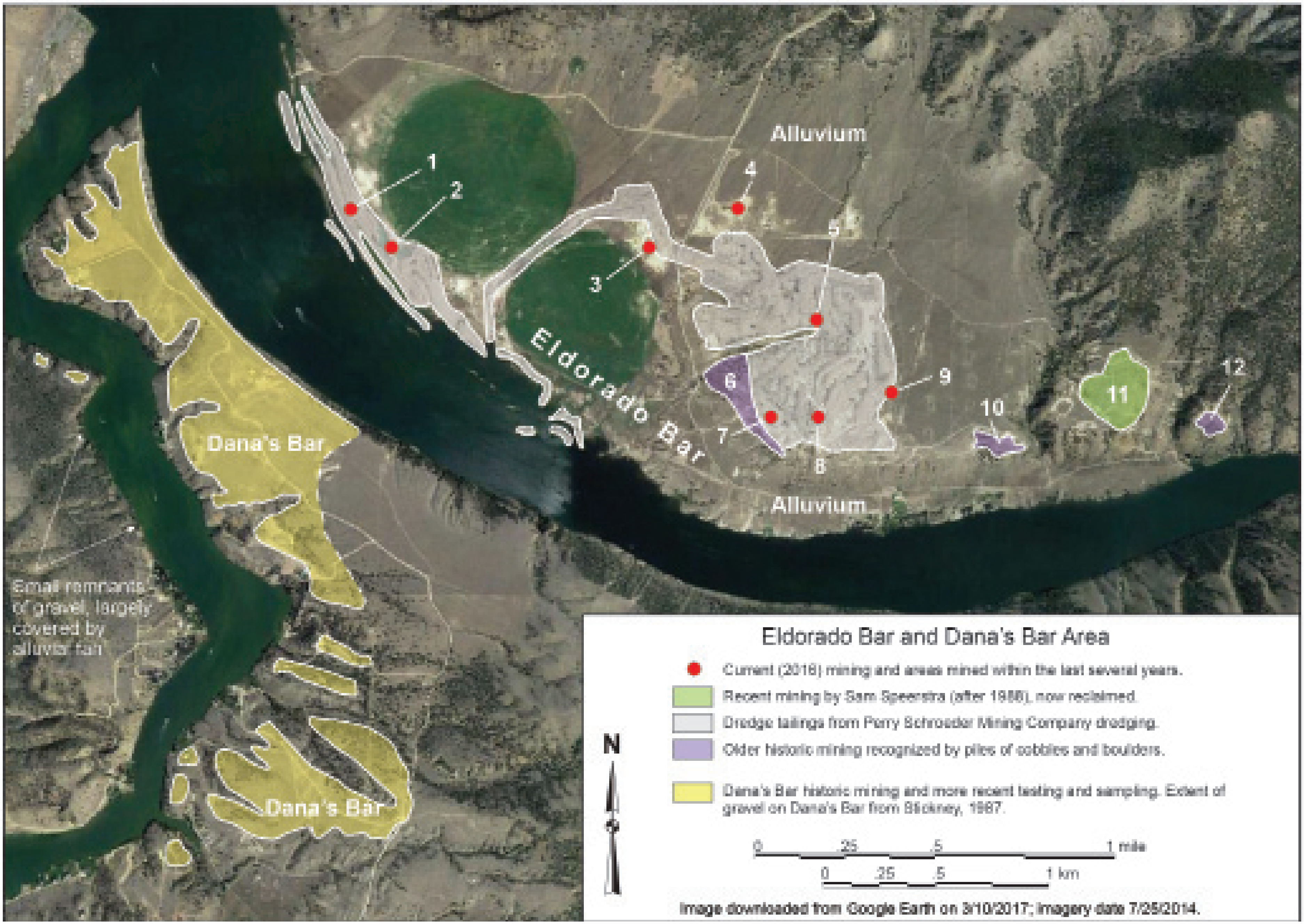

Figure 23. Google Earth image of Dana's and Eldorado Bars showing current (2016) and historic mining. See text for explanation of numbers.

The Perry-Schroeder Mining Company reported that the gravel they were dredging (1938–1947) carried a grade of 1 troy oz of sapphire/100 yd^3 (Clabaugh, 1952, p. 44). Although reported as the grade of the gravel, the report likely referred to recovery of sapphires per yard processed on the dredge. Production figures for 1943 from the War Production Board showed 1.3 ct/yd^3 (1.7 ct/m^3) recovery for sapphires and 0.005 troy oz/yd^3 (0.005 oz/m^3) gold by the Perry-Schroeder Mining Co.

Most of the sapphire production at the six mines operating in 2016 was from the dredge tailings, where the recovery of sapphires is reported to show significant range: reportedly from 2 to 16 ct/yd^3 (3 to 22 ct/m^3), but probably generally around 5 ct/yd^3 (6 ct/m^3). Evidently, the sapphire miners who now concentrate on sapphires are more efficient in their recovery than the Perry-Schroeder Mining Co. dredge, which was also recovering gold. One figure available on the recovery of sapphires in mining virgin gravel is 16 ct/yd^3, but probably an average grade is considerably less.

Ownership

Private.

Gravel

Gravel consists mainly of quartzite clasts with rare diorite and quartzofeldspathic gneiss pebbles. Round and irregular concretionary hematite nodules are common at Eldorado Bar.

The following descriptions refer to the numbers in figure 23, which shows areas of current (2016) and past mining on Eldorado Bar.

1. Mining dredge tailings by Shawn Toney, President, H & L Drilling, Inc. These dredge tailings are presumably from mining the lowest bar at an elevation of 3,615 ft (1,102 m), 35 ft (11 m) below the level of Hauser Lake.
2. Eldorado Placers LLC mines sapphires from the dredge tailings at this site.
3. The Spokane Bar Sapphire Mine and Gold Fever Rock Shop mines gravel and dredge tailings for their operation at Spokane Bar, where they sell bags of sapphire-bearing concentrate. The elevation of bedrock is approximately 3,760 ft (1,147 m).
4. The mine of Lewis and Clark Sapphires is 300 ft (92 m) north of the dredge tailings. Their pit is approximately 20 ft (6 m) deep, with most of the sapphires in the lower 6 to 8 ft (2 to 3 m) of the virgin gravel (fig. 24). The bedrock is estimated to be at an elevation of about 3,800 ft (1,159 m). Neal Hurni owns and operates this mine.
5. Blaze-N-Gems (Blaze Wharton) mines sapphires from this small area of virgin gravel.
6. Gravel on this terrace at an elevation of about 3,770 ft (1,150 m) was mined, as indicated by boulder windrows. More recently, a small area of this terrace was mined down to bedrock of the Greyson Formation.
7. Washing plant operated by Blaze-N-Gems for processing adjacent dredge tailings. Blaze Wharton is the owner and operator.
8. Washing plant operated by Blue Jewel for processing dredge tailings mined here. Bruce Scharf is the owner and operator.
9. Blaze-N-Gems has mined sapphires from a cut situated just east of the dredge tailings where exposed bedrock is at an approximate elevation of 3,800 ft (1,159 m) and is overlain by 3 ft (1 m) of loess. Sapphires are mainly limited to the lower 3 ft (1 m) of gravel (fig. 25).
10. East of the dredge tailings, gravel remnants from early mining for either gold or sapphires, or both, are at an elevation of about 3,840 ft (1,171 m).
11. Between 1988 and 1993, Sam Speerstra mined a large area using earth-moving equipment, including a ripper to break up the top few centimeters of bedrock. There was a reported 30 ft (9 m) of overburden and total production of 6 million ct of sapphires. This mined area has been reclaimed.
12. This small area, also at about 3,800 ft (1,159 m) elevation, was also mined.

Sapphire Occurrences Downriver from Hauser Lake

Hauser Dam

Sapphires have been reported, but not verified, in gravel on a bench close to Hauser Dam (Berg, 2015, p. 38).

American Bar

American Bar is on the southeast side of Upper Holter Lake, 5 mi (8 km) downriver from Hauser Dam. Google Earth imagery shows windrows of cobbles from placer mining in a small area close to Holter

Figure 24. Neal Hurni standing on bedrock in the bottom of his cut in coarse sapphire-bearing gravel overlain by barren alluvium (location 4, fig. 23).

Lake. This mining was probably for gold, but it is likely that sapphires were also found.

Ming Bar

Ming Bar covers a large area on the east side of the Missouri River 6 mi (10 km) downriver from American Bar and just downriver from the Gates of the Mountains. No evidence of mining was seen on Google Earth images, although Ming Bar is known for the Ming Bar diatreme that contains unusual xenoliths (Meen and others, 1986).

Craig

Dan Satterthwaite panned eight sapphires from gravel across the Missouri River from the confluence of the Dearborn River, about 4.5 mi (7 km) north of Craig along the frontage road (Berg, 2015, p. 23). This locality is 54 mi (86 km) downriver from the Canyon Ferry Dam. Two of these sapphires show evidence of intense abrasion, but the other six are only slightly abraded. This observation raises the interesting possibility that the highly abraded sapphires were carried downriver from a Hauser Lake locality, but the other sapphires are from a local source.

Figure 25. Blaze Wharton standing on bedrock in his cut and pointing to the upper limit of richest sapphire-bearing gravel (location 9, fig. 23).

SAPPHIRES

Color

The predominant color for the Missouri River sapphires is very pale green to pale bluish green. Some are pale blue, a few purple, and a few yellow. Rare sapphires are deep blue, such as the Big Sky Sapphire (fig. 13). Early development efforts mention rubies in this area along the Missouri River. Because of the lack of analytical techniques now routinely used, and perhaps a little wishful thinking, it is quite possible that many of these “rubies” were actually the relatively common red garnets found with these sapphires.

Heat treatment

A much lower percentage of the Missouri River sapphires are amenable to color enhancement by heat treatment as compared to the Rock Creek sapphires. An extremely comprehensive study has shown that the color of 65 to 70 percent of the Rock Creek sapphires can be enhanced by heat treatment (Emmett and Douthit, 1993). Reports vary as to the percentage of Missouri River sapphires whose color can be enhanced by this method. It is reported that 30 percent of the sapphires mined from virgin ground at Eldorado Bar heat treated nicely (S. Speerstra, oral commun., 2015). Others have suggested that the figure should be considerably lower. This may depend in part on how carefully the rough sapphires are sorted before being heated.

Size

Some noteworthy large sapphires have been recovered from Hauser Lake and Eldorado Bar. Perhaps the largest sapphire from this area is one reported to be 64.7 ct, recovered by Sam Speerstra’s group at Eldorado Bar. A large blue sapphire recovered by Mac M. Mader, Jr. using a suction dredge on Hauser Lake near French Bar, in September 1973, weighed 24 ct. This sapphire, named the Big Sky Sapphire, is 12.54 ct cut (fig. 13). During the summer of 2012, Bruce Scharf recovered a green sapphire from Eldorado Bar (fig. 26) that weighed 32 ct and heat treated to a nice blue stone. More recently, in 2016, Blaze Wharton recovered a tabular sapphire from Eldorado Bar that weighed 37.78 ct (fig. 27).

Figure 26. Green sapphire from Eldorado Bar mined in 2012 by Bruce Scharf. When heat treated, this 32-ct sapphire was reported to be a beautiful blue.

Figure 27. Pale bluish green 37.78-ct sapphire mined by Blaze Wharton from Eldorado Bar in 2016.

The smallest sapphire that I have been able to recover from this area is from the undersize screenings at the deposit south of Trout Creek and is 270 μm across.

Associated Heavy Minerals

Magnetite, garnet, zircon, barite, and gold are associated with these sapphires.

Morphology

The following generalizations are based on microscopic examination of more than 300 sapphires from the Missouri River deposits, and are intended to provide information that will help in identifying sapphire rough from these deposits. On the basis of these observations, inferences can be made on bedrock sources and geologic history.

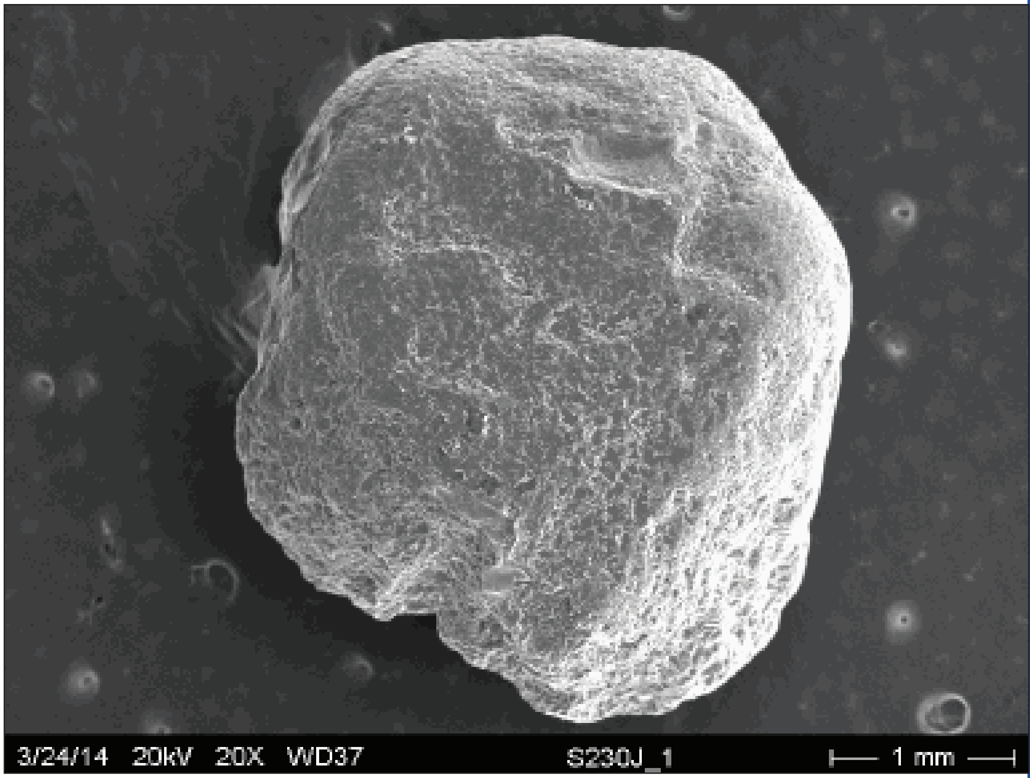

Figure 28. SEM photo of sapphire dredged from Hauser Lake by Mac Mader showing typical pitted surface. Photo by Nancy Equall.

Typical Overall Shape

Observations

Many of these sapphires are roughly equidimensional, but some have the hexagonal crystal form of corundum and some are hexagonal tablets. Sapphire surfaces are typically covered with many irregular pits less than several tens of microns deep (figs. 28–30).

Interpretation

Resorption of the sapphire by the transporting magma formed this feature.

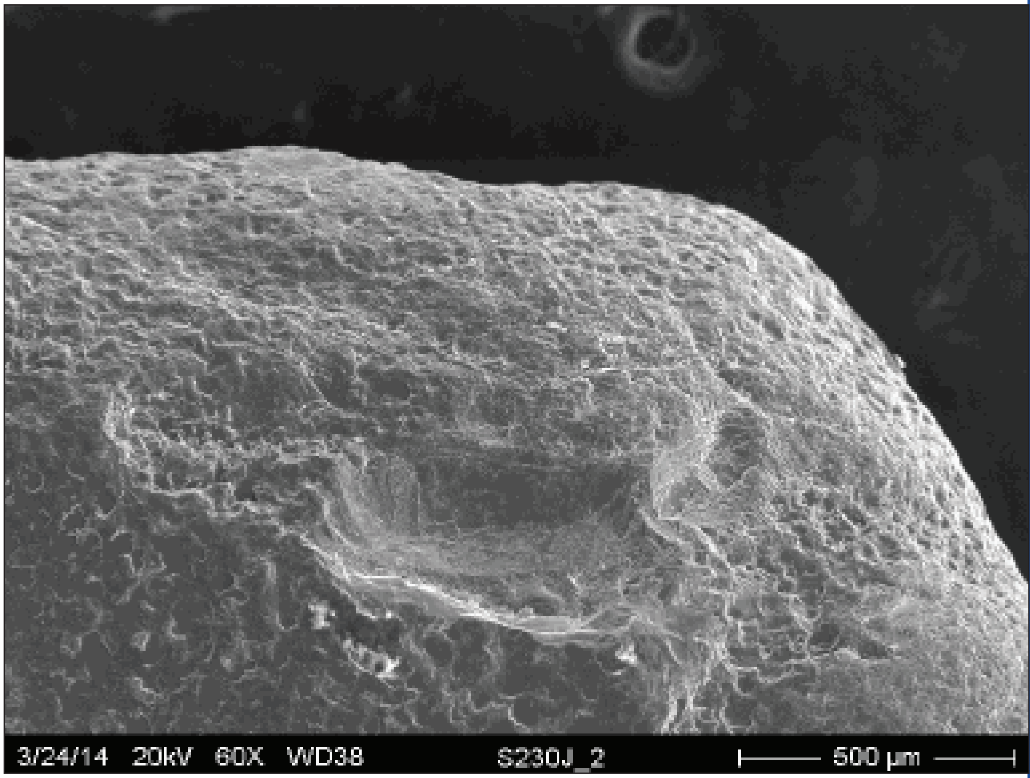

Figure 29. Enlargement of area shown in previous SEM photo. Photo by Nancy Equall.

Grooves

Observations

Deep irregular grooves, generally along the poorly preserved prism faces, are situated at the intersections of the basal parting with these surfaces (fig. 31). See description of adhering spinel for discussion of spinel commonly found in these grooves and other depressions on the sapphire surface.

Interpretation

Grooves on Missouri River sapphires are irregular, in contrast to those on sapphires from the South Fork of Dry Cottonwood Creek, which are smooth and planar (Berg, 2007, p. 5).

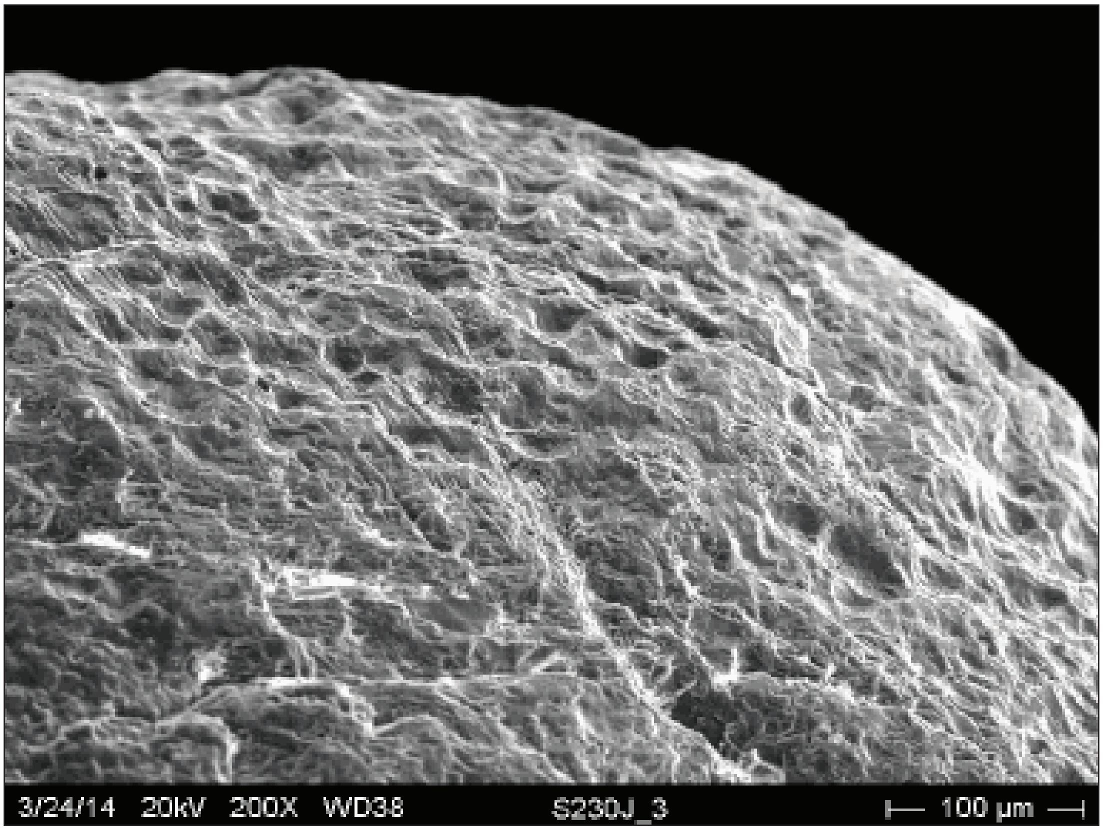

Figure 30. Further enlargement of area shown in previous SEM photo. Photo by Nancy Equall.

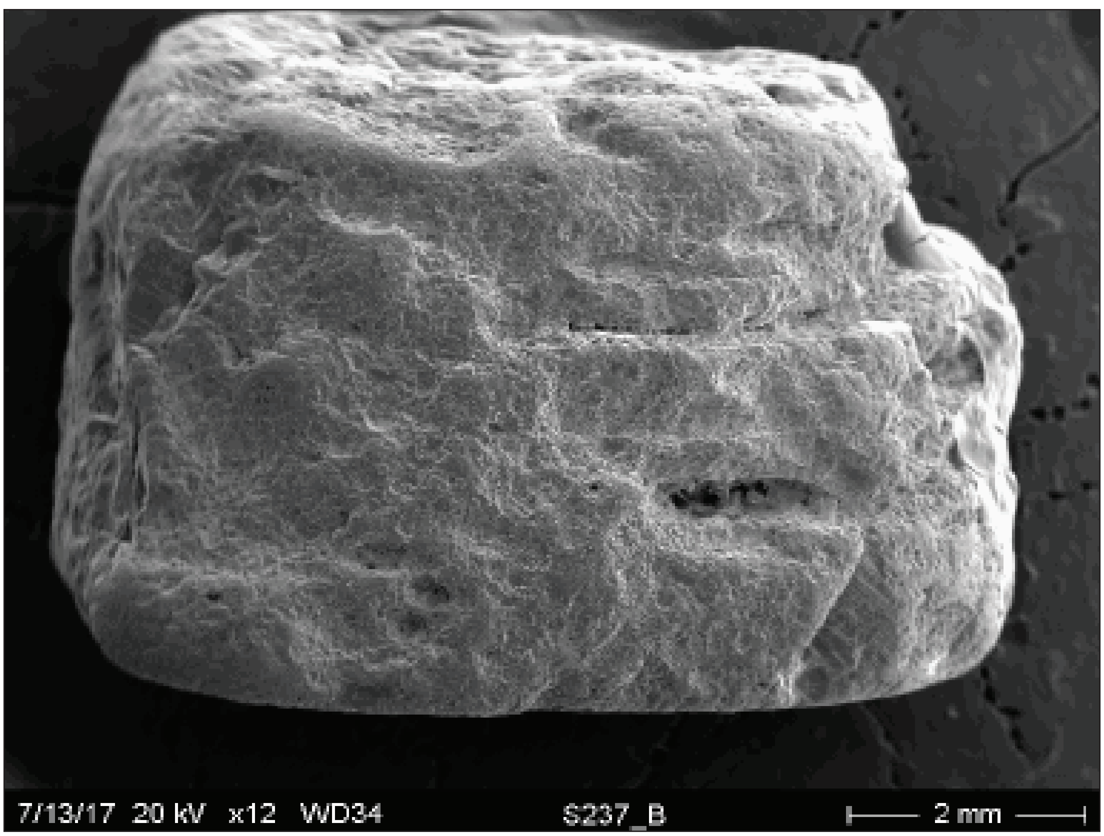

Figure 31. SEM photo of irregular cavities on partly resorbed prism face, some containing relict spinel (black). Sapphire mined from Eldorado Bar by Neal Hurni and SEM photo by Laura Kellerman.

Closely Spaced Steps on Basal Pinacoids

Observations

Parallel steps on the basal pinacoid, some as small at 10 µm, are prevalent on some sapphires (fig. 32).

Interpretation

These are probably caused by fracturing along the basal parting.

Flat Areas on the Basal Pinacoid

Observations

Glassy, flat areas from less than 100 µm to almost 1 mm across are surrounded by irregular surfaces (figs. 33, 34). Some of these flat areas are coplanar and all parallel the basal pinacoid. Rarely, small spinel crystals surround but do not coat the flat areas (fig. 35).

Interpretation

A possible interpretation is that these smooth, glassy surfaces formed by parting along the basal pinacoid. This is substantiated by the small steps along the edges of the flat surfaces that resemble those shown by the stepping of fracture planes in a diamond (Tappert and Tappert, 2011, p. 29). The smooth, flat surface shown in figure 35, which is surrounded by spinel crystals, defies simple interpretation. If the spinel formed by reaction of the sapphire with the enclosing magma, spinel crystals should have formed on this flat surface.

Evidence of Abrasion of Missouri River Sapphires

Glassy conchoidal fractures

Glassy conchoidal fractures are found on sapphires from all of the alluvial deposits in western Montana (fig. 36). Although some may have formed by breakage in the trommel during recovery, most probably developed during fluvial transport.

Microscopic chips on ridges and along edges

Microscopic chips are also a common feature on sapphires from all deposits, as shown in the enlargement of figure 36 (fig. 37). The areas between the ridges and edges show little evidence of abrasion.

Rounding of edges

The edges at the intersections of prism faces with the basal pinacoid on some sapphires from the Hauser Lake bars are rounded and smoothed. The abundance of sapphires with rounded edges may be an indication of distance of fluvial transport. See section on possible upriver sources for an example of this feature.

Summary of abundance of edge rounding on Missouri River sapphires

Sapphires dredged from Hauser Lake below French Bar	0% rounded
Gruell's Bar	0% rounded
Spokane Bar–Independence Pit	4% rounded
Eldorado Bar	28% rounded
Craig	55% rounded

On the basis of these somewhat sketchy subjective data, it appears that that the percentage of rounded sapphires increases downriver from the vicinity of Canyon Ferry Dam. This suggests that rounding occurred during river transport in this stretch of the Missouri River and not as a result of transport of sapphires from a distant upriver source. If it were the result of transport from a distance source, rounded sapphires should be in approximate equal concentrations at all bars.

Spinel

Small spinel crystals adhere to the surface of an estimated 25 to 50 percent of the Missouri River sapphires (fig. 38). Spinel can be recognized with a hand lens on many of these sapphires, but on some, the remnants are so small that they must be examined with a binocular microscope. Typically, the spinel is preserved in small depressions such as the irregular grooves along remnant prism faces. Most of the spinel appears black, but when examined with a microscope under intense illumination, some is dark green. Semi-quantitative analyses by EDX show a range in atomic Fe-Mg ratios from 0.4 to 0.9, with an average of 10 analyses of 0.6.

Because spinel is confined to the surfaces of sapphires, it is reasonable to assume that it formed by a reaction of the sapphire (Al_2O_3) with Fe and Mg in the transporting magma. The lack of spinel on the surface of sapphires from Rock Creek, South Fork of Dry Cottonwood Creek, and Lowland Creek may be attributed to the relatively low concentration of Fe and Mg in the inferred source volcanic rocks for these deposits, which are of rhyolitic to dacitic composition.

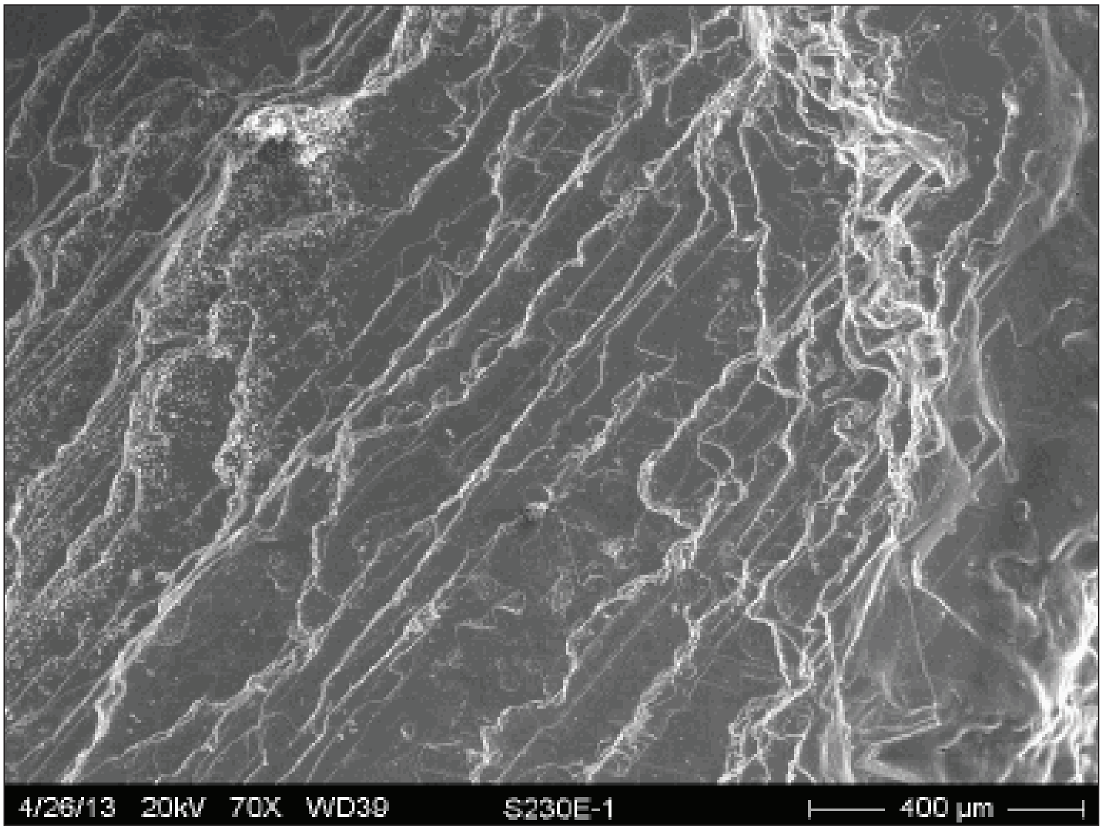

Figure 32. SEM photo of closely spaced steps on basal pinacoid of sapphire dredged from Hauser Lake by Mac Mader. Photo by Nancy Equall.

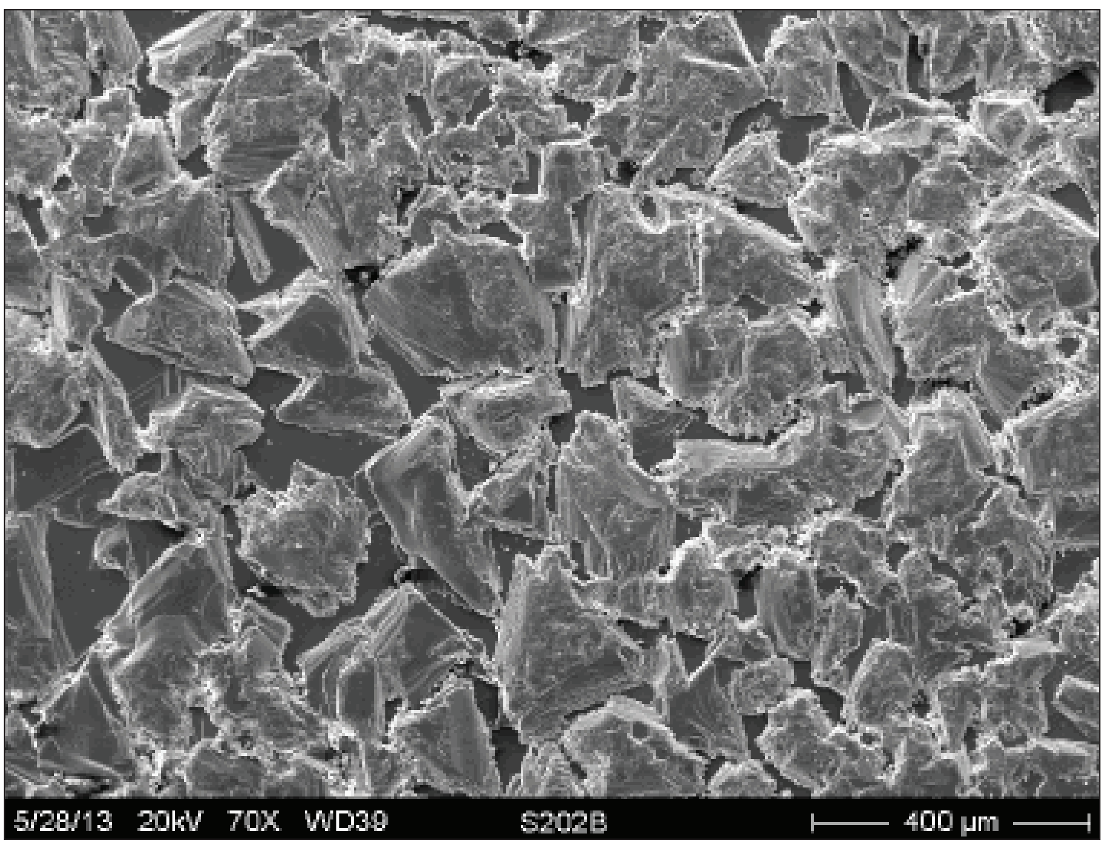

Figure 33. SEM photo of sapphire from Eldorado Bar provided by Blaze Wharton showing glassy flat areas on basal pinacoid. Photo by Nancy Equall.

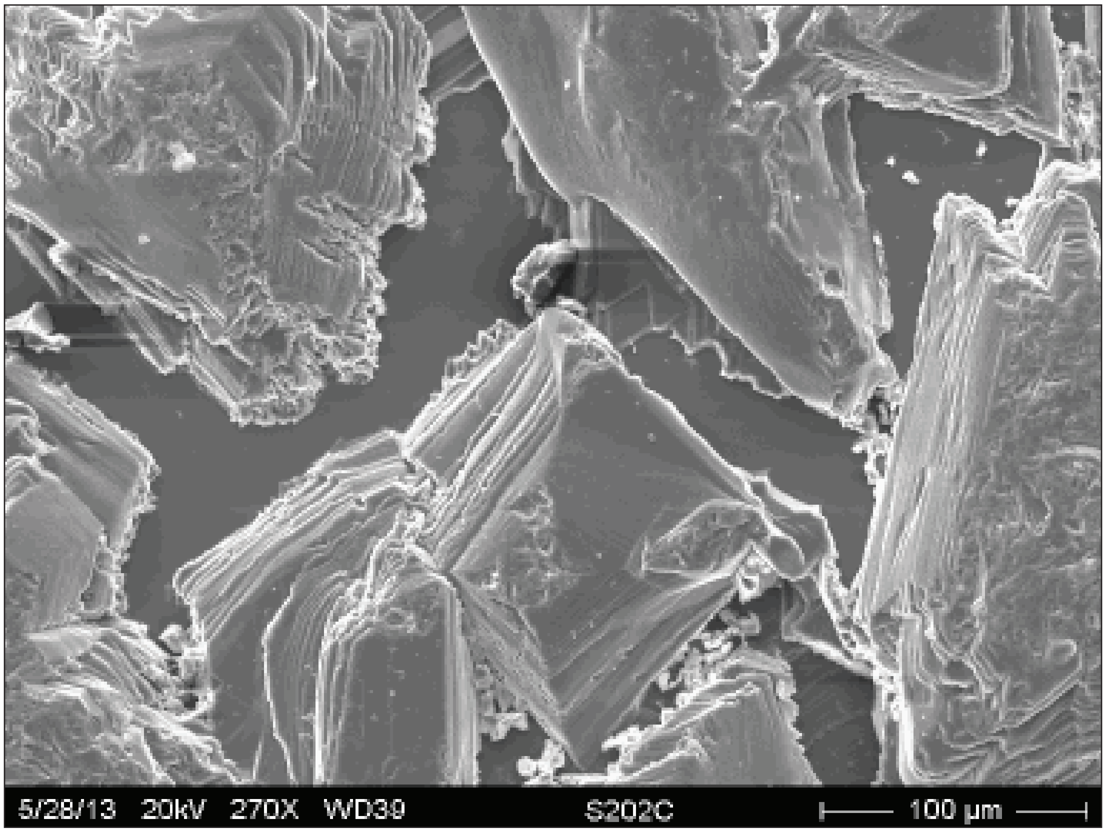

Figure 34. Enlargement of area shown in previous SEM photo. Photo by Nancy Equall.

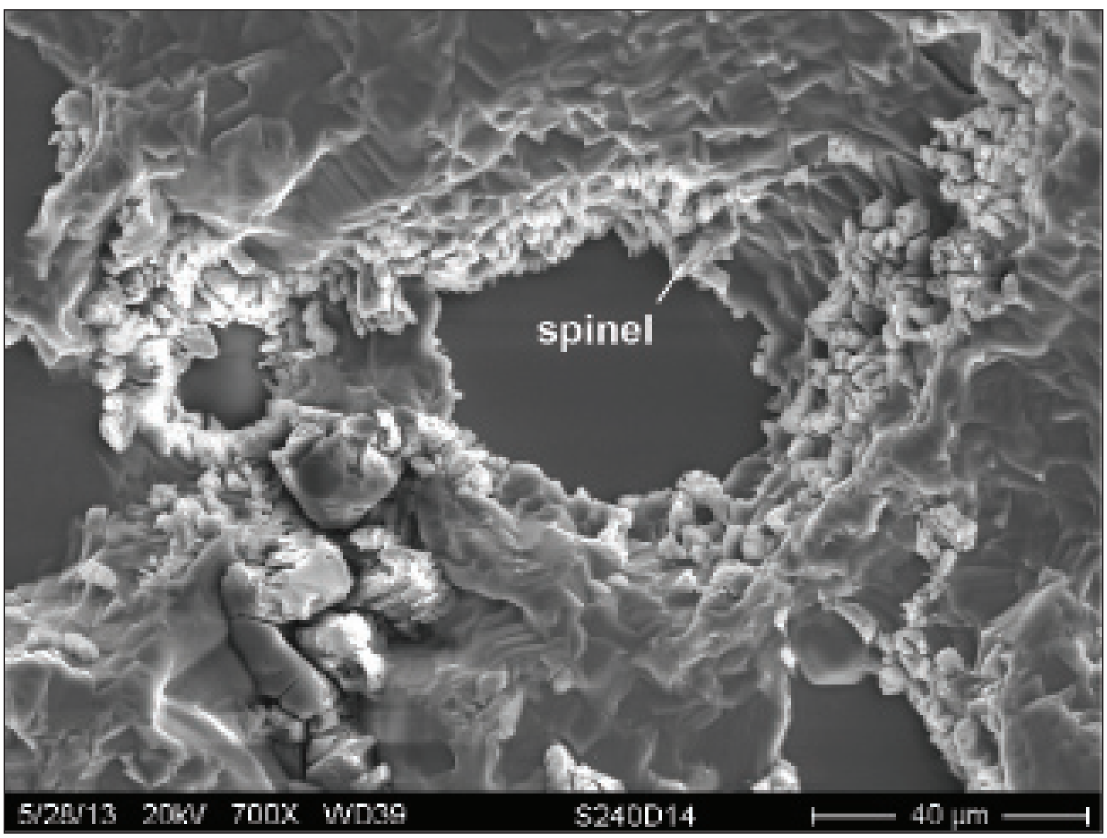

Figure 35. SEM photo of sapphire from Eldorado Bar provided by Neal Hurni showing flat area surrounded by small spinel crystals. Photo by Nancy Equall.

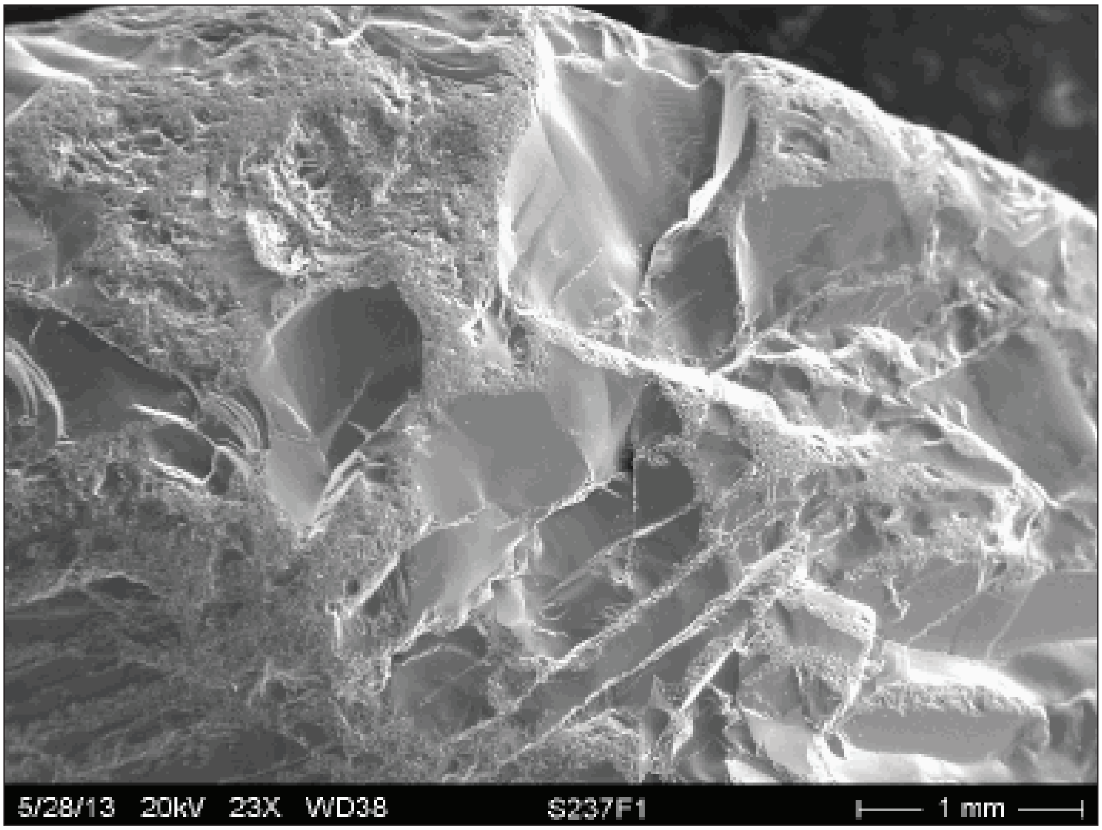

Figure 36. SEM photo showing evidence of abrasion (small chips on ridges and large conchoidal fractures). Sapphire from Eldorado Bar provided by Neal Hurni. Photo by Nancy Equall.

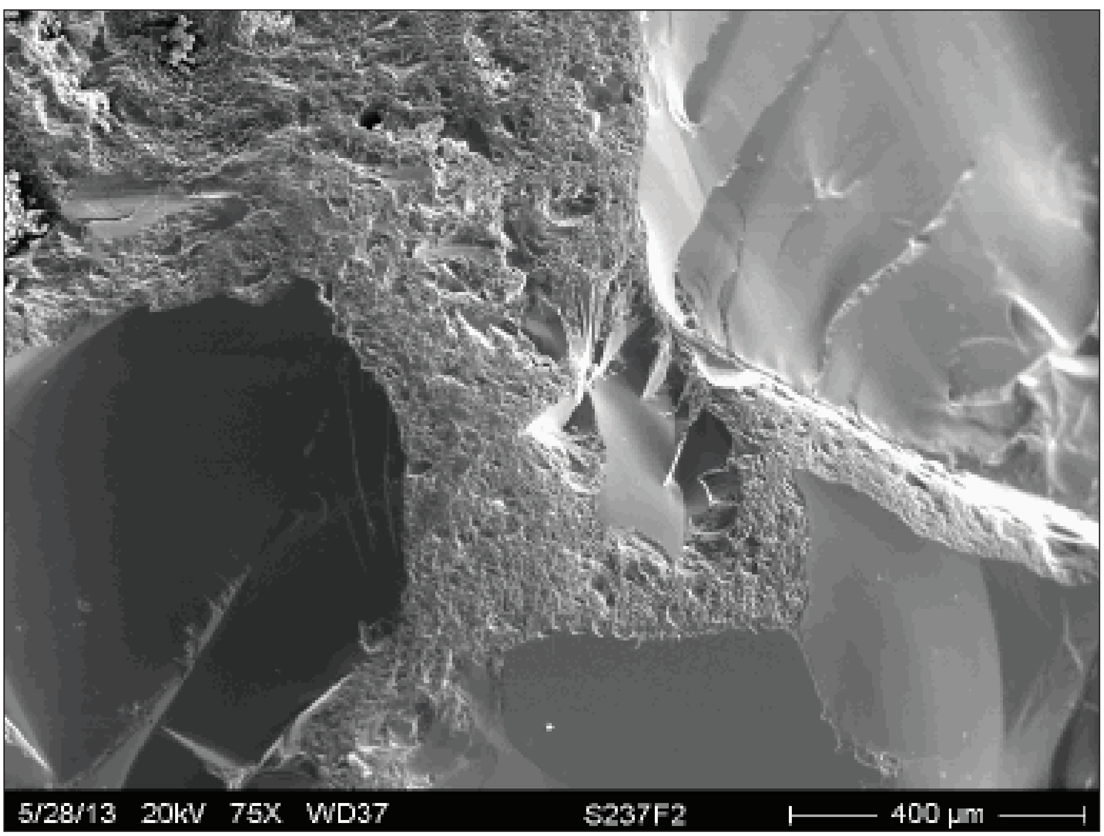

Figure 37. Enlargement of part of figure 36. Sapphire from Eldorado Bar provided by Neal Hurni showing small chips on ridges and conchoidal fractures. Photo by Nancy Equall.

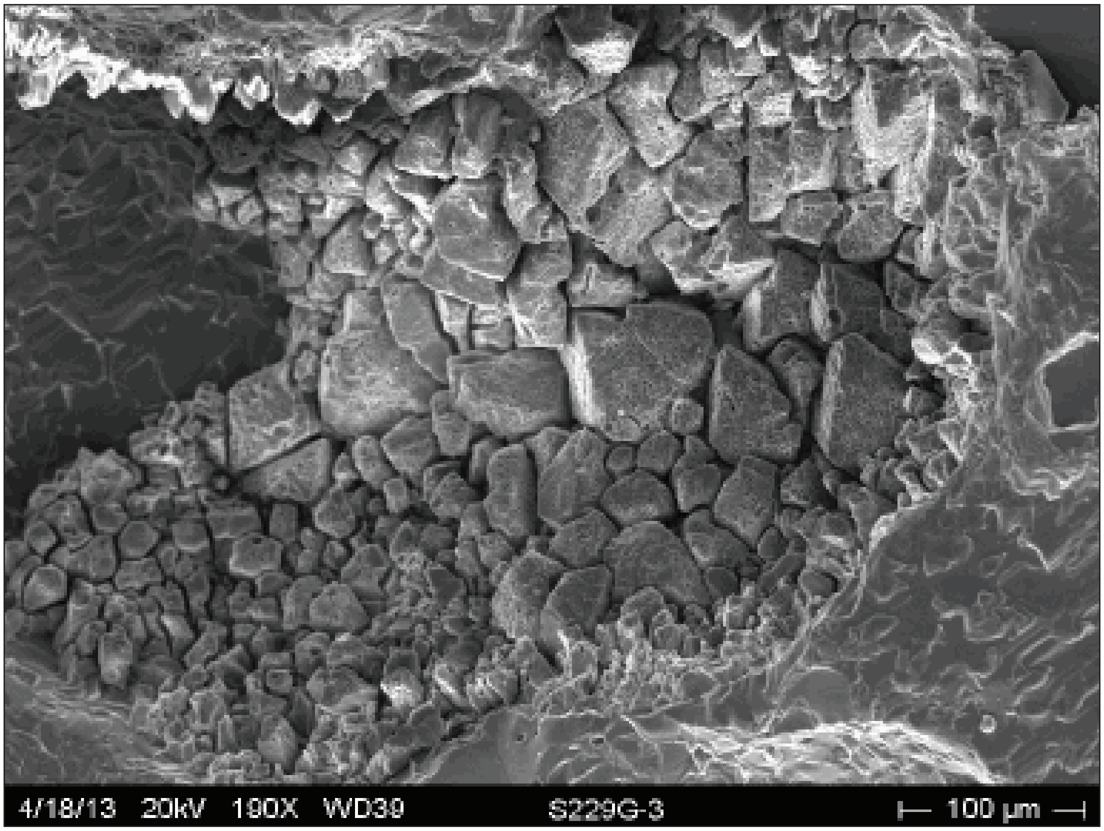

Figure 38. SEM photo of spinel crystals on sapphire dredged from Hauser Lake by Mac Mader. Photo by Nancy Equall.

Sapphires in the French Bar sill are coated with a very thin reaction rim of biotite, but no spinel. On the basis of two whole-rock analyses, the French Bar sill contains 4.5 wt. percent Fe_2O_3 and 1.8 wt. percent MgO (Berg and Dahy, 2002, p. 201). Some sapphires in the Yogo dike rock, described as an ultramafic lamprophyre, are rimmed with spinel (Claubaugh, 1952, p. 18). On the basis of these comparisons, it seems likely that the presence of spinel on sapphires is controlled by the Fe and Mg content of the transporting magma, suggesting that the Missouri River sapphires with adhering spinel weathered from a rock that contains significant Fe and Mg.

Distinguishing Features

The below features may aid in distinguishing Missouri River sapphires from those from the other major alluvial deposits in western Montana. See Berg (2007, 2014) for images of sapphires from the Butte–Deer Lodge area and the Rock Creek district.

1. Spinel is found in depressions on 25 to 50 percent of the Missouri River sapphires, but not on sapphires from the other alluvial deposits.

2. Missouri River sapphires lack the deep, smooth grooves along the intersections of basal parting planes and the remnants of the prism surfaces that are characteristic of sapphires from the South Fork of Dry Cottonwood Creek and Lowland Creek.

3. Missouri River sapphires lack the prominent raised flat surfaces that resemble plateaus on the basal surfaces of many Rock Creek sapphires.

4. Coplanar, shiny flat areas surrounded by an irregular topography are restricted to Missouri River sapphires.

5. Exsolved rutile is much more abundant in sapphires from the Rock Creek district than any of the other alluvial deposits.

6. Missouri River sapphires are more angular than either Rock Creek or Dry Cottonwood Creek sapphires (D. Siegford, written commun., 2017).

ADDITIONAL SAPPHIRE OCCURRENCES

The following sapphire occurrences are all situated on the east side of Canyon Ferry and Hauser Lakes, and most are at least 200 ft (61 m) above the level of the highest bars (fig. 39). These sapphire occurrences do not contain gravel typical of the bars at lower elevations, which, as previously described, include quartzofeldspathic gneiss pebbles, but are alluvial deposits of local sources. These occurrences are significant in speculation about possible bedrock sources of these sapphires.

Confederate Gulch

Confederate Gulch, in the Big Belt Mountains, enters Canyon Ferry Lake approximately 23 mi (37 km) southeast of Canyon Ferry Dam. Exceedingly rich placer deposits along this gulch were mined extensively for gold in the 1860s and to a limited extent more recently. It has been reported that three sapphires were recovered during recent placer mining on this gulch (location 1, fig. 39; G. Hodge, oral commun., 2016).

Debris Flow East of Magpie Creek

Magpie Creek is a major drainage about 3 mi (5 km) southeast from Canyon Ferry Dam. Sapphires, garnets, and minor gold have been recovered from a small cut in a debris flow on the south side of Magpie Creek at an elevation of about 4,090 ft (1,247 m), on private property (location 2, fig. 39). Poorly sorted gravel is mainly composed of angular and subrounded cobbles and pebbles of quartzite derived from beds in the Belt Supergroup, and also diorite cobbles and pebbles.

Never Sweat Gulch

Never Sweat Gulch joins Magpie Creek from the northwest about 5 mi (8 km) from its mouth at an elevation of approximately 4,600 ft (1,403 m) (location 3, figs. 39, 40). Sapphires have not been reported in Magpie Creek upstream from Never Sweat Gulch, but an individual has reportedly recovered a “jar full” of sapphires from Never Sweat Gulch. (Incidentally, there are many unconfirmed reports of individuals who have jars full of sapphires from Montana localities, but I have yet to see any of these jars full of sapphires.) Although now grown over, there is evidence of past digging near the mouth of Never Sweat Gulch. Gravel at this locality consists mainly of angular to slightly rounded pebbles of siltite and argillite from the Belt Supergroup and also contains rare angular diorite cobbles and several subrounded diorite boulders in addition to rare porphyry pebbles. Bill Dansie panned several sapphires, garnets, and minor gold from this gravel. Remnants of very dark green spinel adhere to one of these sapphires. I collected a 166-lb (75-kg) sample of alluvium along Never Sweat Gulch and separated many small sapphire fragments.

A porphyry sill with altered plagioclase phenocrysts in a fine-grained ground mass 3 ft (1 m) thick is poorly exposed along the trail on the west side of Magpie Gulch just south of Never Sweat Gulch (MR 84, fig. 40). About a mile up Never Sweat Gulch, a 6-ft-thick (2-m) sill is exposed on the west side (MR 193, fig. 40). It is unlikely that this sill was a source of sapphires because it is a hard durable rock that would not weather easily to liberate sapphires. Farther up Never Sweat Gulch, two more sills are exposed, a diorite sill that is a continuation of the sill exposed along Magpie Gulch (fig. 39) and a thinner biotite–quartz–monzonite sill, 0.8 mi (1.3 km) farther up the gulch, that is also apparently the continuation of a sill exposed in a road cut along Magpie Gulch (Reynolds and Brandt, 2005).

Systematic sampling of alluvium along Never Sweat Gulch employing large samples collected on bedrock might identify the source of these sapphires.

Lower Magpie Creek

Sapphires are reported to have been recovered from the alluvium near the mouth of Magpie Creek where gold was mined (location 4, fig. 39; Mertie and others, 1951, p. 91). Gravel from placer mining along the northwest side of the Magpie Gulch consists largely of cobbles of quartzite derived from the Belt Supergroup, diorite cobbles, and much less abundant dolomite, limestone, hornfels, and basalt. All of these rock types are exposed within the Magpie Gulch drainage (Lonn and McDonald, 2003).

Other Occurrences in this Area

Mertie and others (1951, p. 91) reported that sapphires occur in the auriferous gravels mined on the spur between Cave Gulch and Cooper Gulch (location 5, fig. 39), and on a small terrace along Oregon Gulch close to the Missouri River (location 6, fig. 39). The Riverside Campground, located approximately 0.75 mi below Canyon Ferry Dam (plate 1), has been developed on an alluvial fan next to Hauser Lake, obscuring any terrace in this area. Farther to the northwest, well above the level of Hauser Lake, there are two reported sapphire occurrences; however, permis-

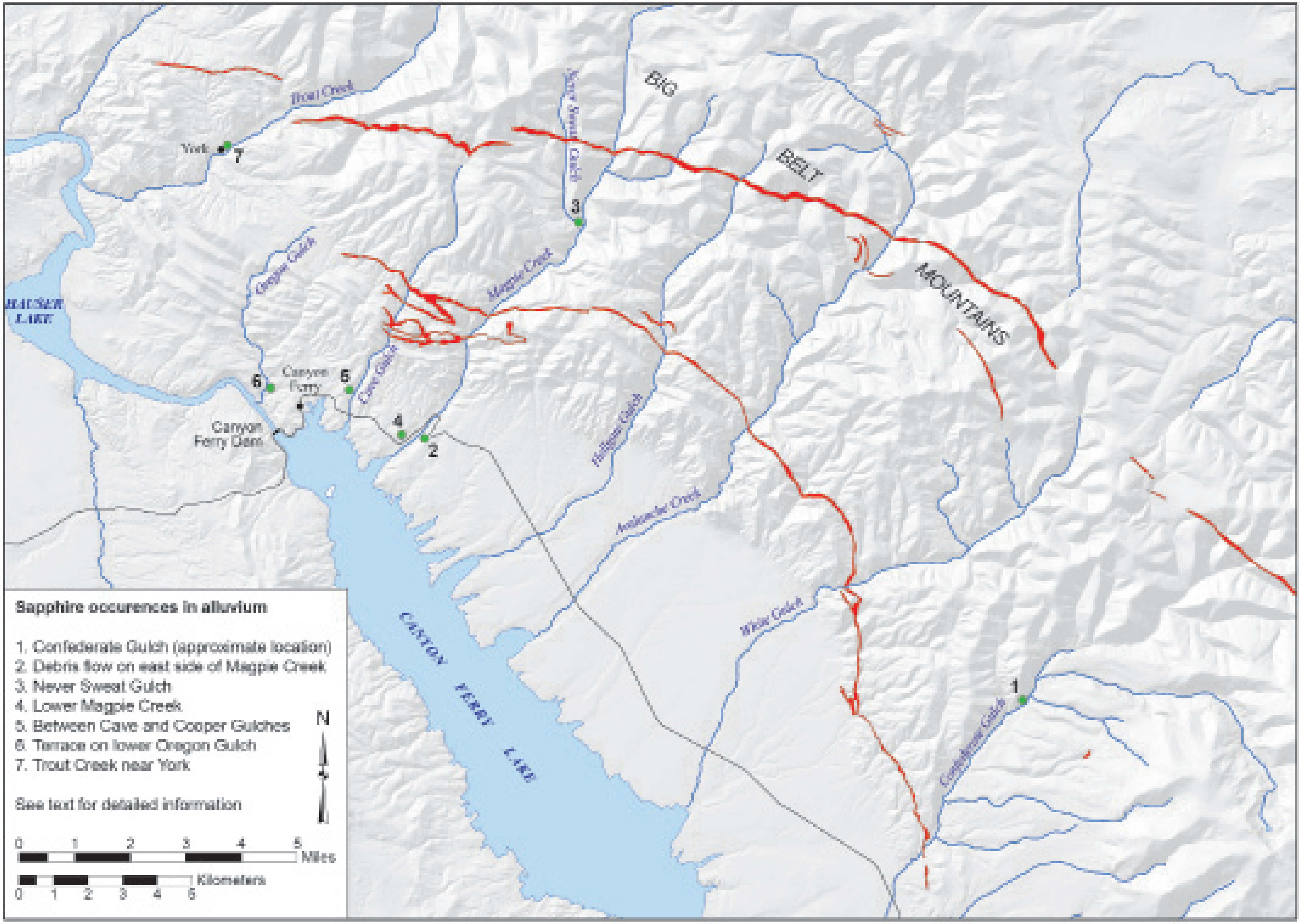

Figure 39. Diorite intrusives, mainly sills (red), in Big Belt Mountains from Reynolds and Brandt, 2005. Sapphire occurrences in alluvium. 1) Confederate Gulch (approximate location); 2) Debris flow on east side of Magpie Creek; 3) Never Sweat Gulch; 4) Lower Magpie Creek; 5) Between Cave and Cooper Gulches; 6) Terrace at lower Oregon Gulch; 7) Trout Creek near York. See text for detailed information.

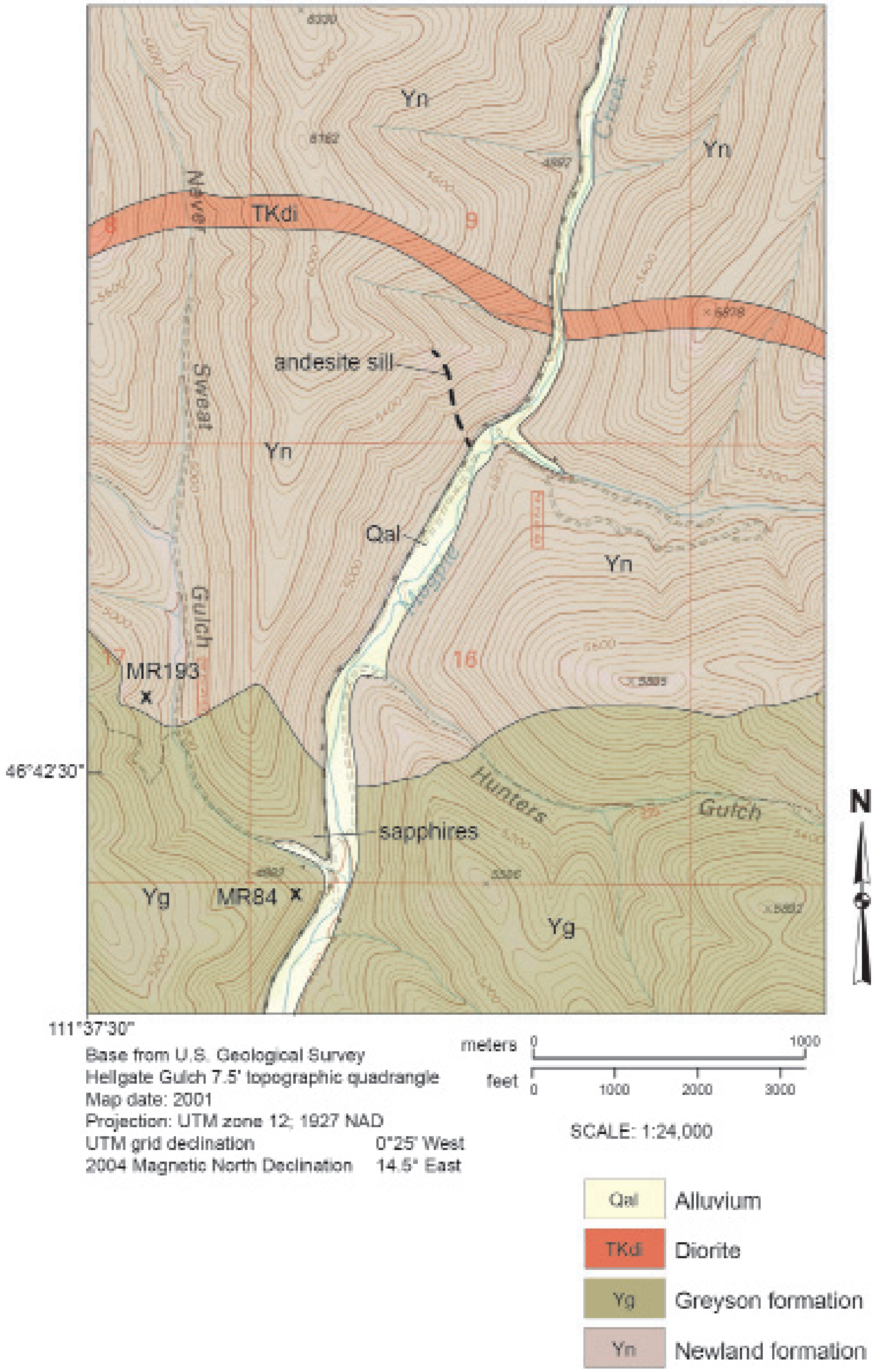

Figure 40. Map of Never Sweat Gulch and part of Magpie Creek showing sapphire occurrences, igneous rocks described in text, and geology from Lonn and McDonald, 2003. Numbers refer to igneous rocks described in text. Qal, alluvium; Yg, Greyson Formation (Belt Supergroup); Yn, Newland Formation (Belt Supergroup).

sion to publish information on these occurrences was withheld. Diorite intrusive rocks are exposed close to both of these localities. There are also reports of sapphires in alluvium along Trout Creek close to York (location 7, fig. 39).

I was told that sapphires occur on a small bench about 0.25 mi (0.4 km) northwest of the Riverside Campground at an elevation of 3,850 ft (1,174 m), but I did not find sapphires or gravel typical of the sapphire-bearing Pleistocene gravel at this locality.

POSSIBLE BEDROCK SOURCES FOR SAPPHIRES IN THE MISSOURI RIVER DEPOSITS NEAR HELENA

Sapphires have been verified in only one bedrock occurrence in this area along Hauser Lake. This is a small sill at French Bar that only contains sparse sapphires and is clearly not the source for most of the sapphires in the deposits along Hauser Lake. In the earlier literature, some confusion was caused by a dike or sill described at Ruby Bar and also at French Bar, which led to the conclusion that there were two sapphire-bearing intrusives. However, historical research has shown that Ruby Bar is a continuation of French Bar and not another locality. Because the sapphire-bearing French Bar sill may offer insight into other bedrock sources of sapphires in this area, a brief description is included here. This sill is poorly exposed between French Bar and Hauser Lake for less than 320 ft (98 m) and is 3–6 ft (1–2 m) thick. This tan, altered, fine-grained rock is classified on the basis of chemical analyses to be a basaltic trachyandesite. It contains biotite and augite phenocrysts and garnet grains interpreted to be xenocrysts (Berg and Palke, 2017). Sapphire xenocrysts are very pale green, generally small, and enclosed by a thin layer of biotite mica that looks like a pencil line around the sapphire (fig. 41). Corundum-bearing metamorphic xenoliths from the French Bar sill contain calcic plagioclase, augite, garnet, margarite, and spinel (Berg and Dahy, 2002, p. 202–203). Research on this sill and included sapphires and xenoliths is continuing.

The most decisive method of determining the bedrock source for an alluvial sapphire deposit is to identify sapphires in bedrock. Because of the durability and density of sapphire, this mineral can be concentrated in alluvium where there is no apparent bedrock source. As an example, a simple calculation made for the probable bedrock source of the alluvial sapphires

Figure 41. Sapphire in French Bar sill showing thin, black biotite coating.

in the South Fork of Dry Cottonwood Creek shows the challenge with this method (Berg, 2007, p. 27). The historic production of sapphires in this deposit was multiplied 100 times to account for recent mining and unmined sapphires. The volume of bedrock that was eroded at the head of this drainage was calculated; from this calculation, the average grade in the bedrock source was calculated. The average grade was only 1 ct/48 yd^3 (36 m^3) of rock (Berg, 2007, p. 27).

The following considerations aid in limiting the possible bedrock sources of sapphires mined along the Missouri River in this area.

1. Most of the sapphires mined along Hauser Lake do not show significant evidence of abrasion, which suggests relatively short river transport.
2. Sapphire occurrences at significantly higher elevations than the bars are restricted to the east side of Hauser and Canyon Ferry Lakes.
3. Early in this study, I considered that the sapphires might have formed where intrusive igneous rocks had metamorphosed aluminous sedimentary rocks in the Spokane Hills. However, lack of sapphire occurrences in the Spokane Hills on the east side of Canyon Ferry Lake makes this hypothesis unlikely.
4. Spinel was found adhering to the surface of 25 to 50 percent of the sapphires from the Hauser Lake deposits. This observation implies significant Mg and Fe in the magma that transported the sapphires and reacted with them to form spinel.
5. Rocks of the Belt Supergroup are exposed in the Big Belt Mountains and also along the west side of Hauser Lake. The Belt Supergroup is an unlikely source of these sapphires because aluminous beds such as kaolinitic clays have not been reported in this sequence and corundum has not been reported in these rocks.

Diorite intrusive bodies, mainly sills, are the most abundant igneous bodies in the Big Belt Mountains between Magpie Creek and Trout Creek. Most of the sapphire occurrences at significantly higher elevations than the Missouri River bars are in the area of these diorite intrusives (fig. 39). Although there are intrusives of Eocene and late Cretaceous age, they are of small areal extent when compared to the diorite intrusives (Reynolds and Brandt, 2005). With the exception of one occurrence at French Bar Mountain

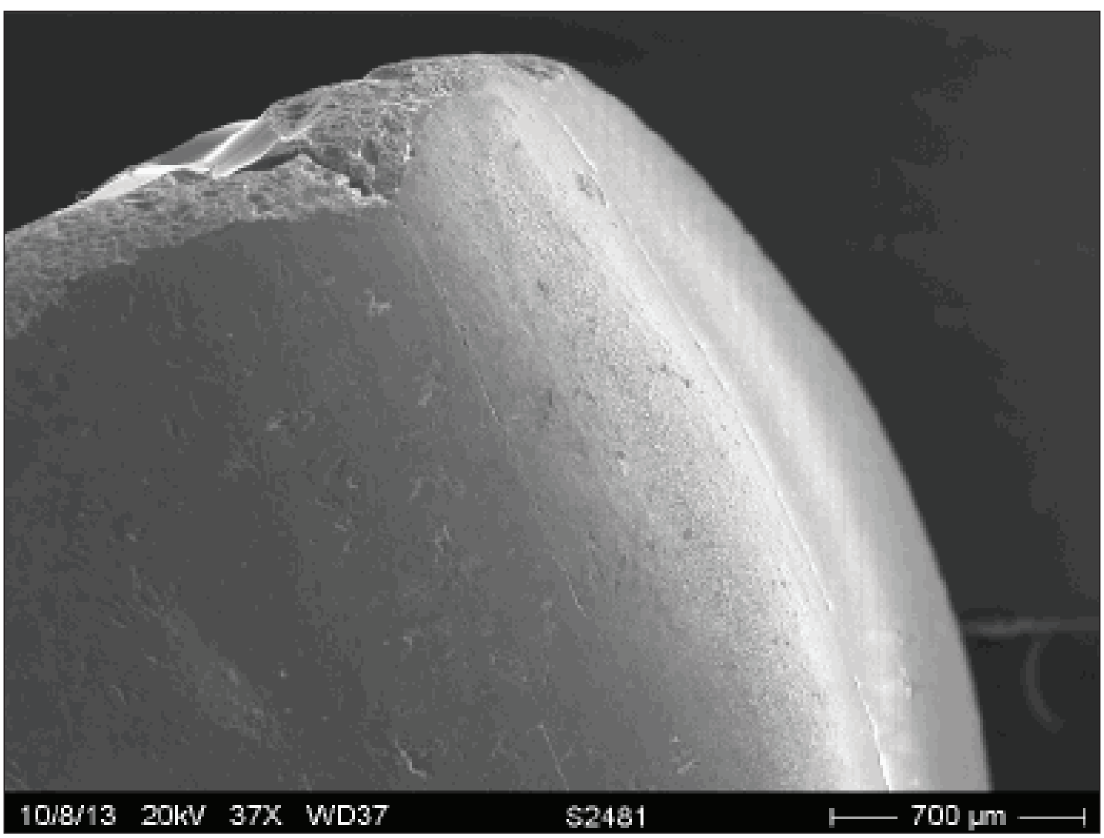

Figure 42. SEM photo of sapphire from Eldorado Bar provided by Bruce Scharf showing unusually smooth surface. Photo by Nancy Equall.

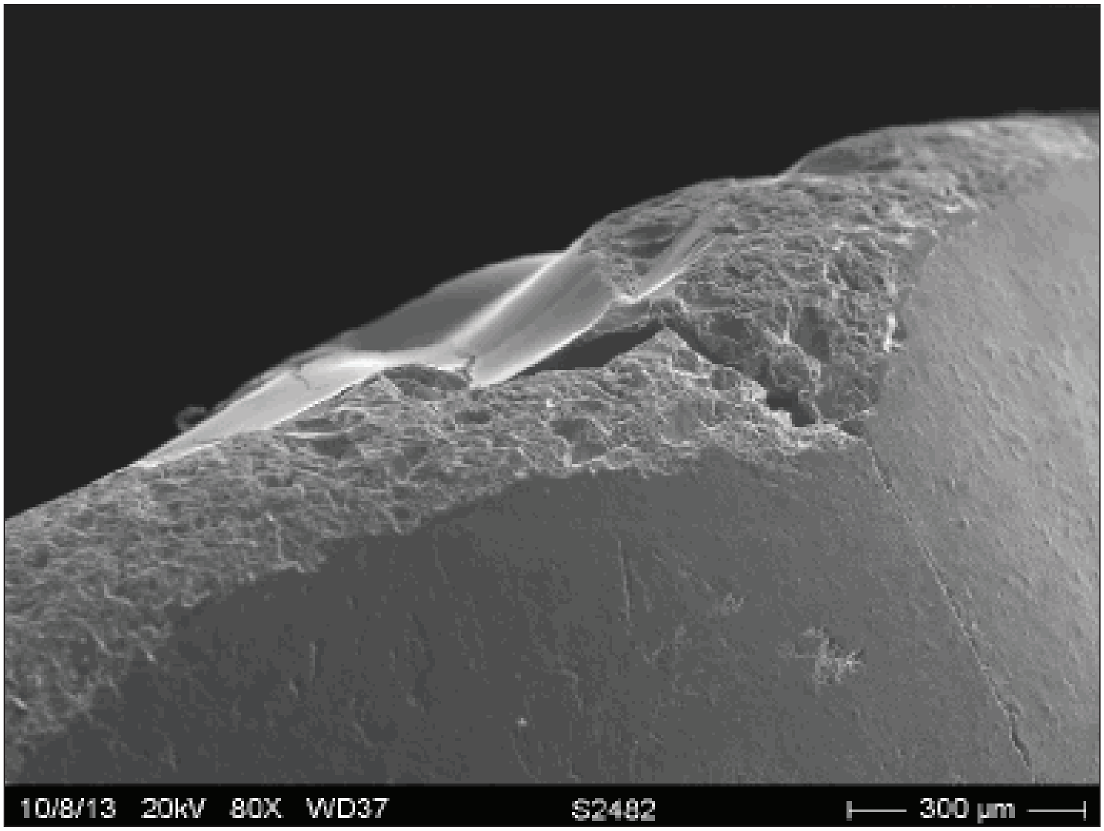

Figure 43. Enlargement of figure 42 photo showing evidence of abrasion on this unusually smooth sapphire. Photo by Nancy Equall.

above French Bar, diorite intrusives are limited to the Big Belt Mountains. The diorite weathers readily to granular material, and contains significant Fe and Mg, both features that are favorable for a sapphire source rock. In addition, the sapphire-bearing gravel on all of the bars contains pebbles and cobbles of diorite. Diorite intrusives in the Big Belt Mountains seem the most likely bedrock source for these sapphires.

It is possible that some sapphires in the Missouri River bars came from distant upriver sources. Rare sapphires have rounded and smooth surfaces (figs. 42, 43), in striking contrast to the irregular surfaces of most of the sapphires from these bars. These surfaces may be an indication of abrasion during lengthy river transport. There are two verified occurrences of sapphires in the Missouri River basin upriver from the sapphire deposits. One of these is along Pole Creek, a tributary of Cherry Creek that joins the Madison River west of Bozeman (Pratt, 1906, p. 116). I have examined and verified a colorless sapphire from Cherry Creek that contains exsolved rutile (Berg, 2015, p. 56). Another potential source of these rare sapphires found along the Missouri River is Alder Gulch, famous for gold production in the Virginia City district of Montana. Alder Gulch joins the Ruby River, which is a major tributary of the Jefferson River. Both the Madison and Jefferson Rivers as well as the Gallatin River join at Three Forks, Montana to form the Missouri River. I have examined and verified two sapphires from Alder Gulch. In addition, gravel from an undisclosed locality in the Alder Gulch area contains abundant sapphires (Berg, 2015, p. 29–30).

CONCLUSIONS

These conclusions are summarized from more detailed information in the text.

1. Strath terraces and sapphire-bearing gravel along Hauser Lake are Pleistocene age, formed during post or interglacial melting in southwestern Montana when large volumes of water flowed along the Missouri River.

2. Twenty five to 50 percent of the sapphires have remnants of spinel remaining in surface depressions. The only other reported Montana sapphire deposit where some of the sapphires have adhering spinel is the Yogo deposit.

3. Microscopic examination of these sapphires, both by optical methods and by scanning electron imaging, show rare surface morphology not found on other Montana sapphires.

4. Limited evidence of abrasion on most sapphires indicates relatively short fluvial transport.

5. Sapphires occur sparsely in a basaltic trachyandesite sill exposed along the west shore of Hauser Lake below French Bar. Aside from the Yogo dike in central Montana, this is the only verified occurrence of sapphires in bedrock in Montana.

6. On the basis of distribution of sapphires in this area, a bedrock source in the Big Belt Mountains is indicated, quite likely diorite intrusives in these mountains.

ACKNOWLEDGMENTS

Many individuals have contributed to this study by sharing information with me, providing access to their properties, and providing sapphires from their mines. These sapphires are archived in the Montana Tech Mineral Museum where they are available for further research. The assistance of all of these individuals was necessary to complete this study and is appreciated. Without their help, this research would not have been possible: Tim Beard, Dan Corbett, Bill Dansie, Earl Griffith, Gene Hodge, Neal Hurni, Robert Kane, Dave Jordan, Mac Mader, Dan Satterthwaite, Bruce Scharf, Dale Siegford, Sam Speerstra, Chuck Sprague, Cass Thompson, Russ Thompson, Chris van Laer, Blaze Wharton, and Darcy Zahacy.

In addition, this report was significantly improved by critical reviews by the following individuals: John Childs, Gene Hodge, Catherine McDonald, Mike Stickney, and Dale Siegford. Editing and layout by Susan Barth; cartography and figures by Susan Smith, both MBMG.

REFERENCES CITED

Anaconda Standard, 1891, February 5, Montana's sapphires, p. 9, c. 1–3.

Berg, R.B., 2007, Sapphires in the Butte–Deer Lodge area, Montana: Montana Bureau of Mines and Geology Bulletin 134, 57 p.

Berg, R.B., 2014, Sapphires in the southwestern part of the Rock Creek sapphire district, Granite County, Montana: Montana Bureau of Mines and Geology Bulletin 135, 86 p.

Berg, R.B., 2015, Compilation of reported sapphire occurrences in Montana: Montana Bureau of Mines and Geology Report of Investigation 23, 77 p., map scale 1:100,000.

Berg, R.B., and Dahy, J.P., 2002, Montana sapphires and speculation on their origin, in Scott, P.W., and Bristow, C.M., eds., Industrial Minerals and Extractive Industry, Geological Society London, p. 199–204.

Berg, R.B., and Palke, A.C., 2017, Sapphires from an Eocene sill near Helena, Montana [abs.]: Geological Society of America Abstracts with Programs, v. 48, no. 7, paper no. 254-3.

Browne, J.R., 1868, Mineral resources of the states and territories west of the Rocky Mountains, U.S. Treasury Dept., 1867, p. 502.

Clabaugh, S.E., 1952, Corundum deposits of Montana: U.S. Geological Survey Bulletin 983, 100 p.

Daily Independent (Helena), 1891, February 6, Rich in precious stones, p. 8, c. 4.

Daily Independent (Helena), 1891, July 7, The sapphire fields, p. 5, c. 2.

Daily Independent (Helena), 1891, December 20, A sapphires deal, p. 8, c. 1–3.

Emmett, J.L., and Douthit, T.R., 1993, Heat treating the sapphires of Rock Creek, Montana: Gems and Gemology, winter 1993, p. 250–272.

Goldschmidt, V., 1918, Atlas Der Krystallformen, reprinted by the Rochester Mineralogical Society (referenced in Hughes, R.W., 1990, Corundum: London, Butterworth-Heinemann, Butterworth Gem Books, 314 p.).

Helena Independent, 1913, June 9, p. 16.

Kunz, G.F., 1884, Mineral resources of the United States, 1883: U.S. Geological Survey, p. 736.

Kunz, G.F., 1890, Gems and precious stones of North America: New York, Scientific Publishing Co., p. 48–49.

Kunz, G.F., 1891, Precious stones, mineral resources of the United States 1889: U.S. Geological Survey, p. 445.

Lonn, J.D., and McDonald, C., 2003, Preliminary geologic map of the Hellgate 7½' quadrangle, western Montana: Montana Bureau of Mines and Geology Open-File Report 482, map scale 1:24,000.

Lyden, C.J., 2005, Gold placers of Montana: Montana Bureau of Mines and Geology, Reprint 6, p. 46–51.

Marvin, R.F., and Dobson, S.W., 1979, Radiometric ages—Compilation B., U.S. Geological Survey: Isochron/West, no. 26, p. 3-–32.

Meen, J.K., Eggler, D.H., and McCallum, M.E., 1986, Proterozoic granulite xenoliths from Ming Bar diatreme, Montana [abs.]: Geological Society of America Abstracts with Programs, v. 18, no. 6.

Mertie, J.B., Jr., Fischer, R.P., and Hobbs, W., 1951, Geology of the Canyon Ferry quadrangle, Montana: U.S. Geological Survey Bulletin 972, 97 p., map scale 1:48,000.

Pratt, J.H., 1906, Corundum and its occurrences in the United States: U.S. Geological Survey Bulletin 269.

Ralph, J., 1892, Montana's sapphire beds: Harpers Weekly, v. 37, no. 1881, p. 12–13.

Raymond, R.W., 1870, Statistics of mines and mining in the states and territories west of the Rocky Mountains: Washington, D.C., Government Printing Office, Prepared for 41st Congress, 2nd Session, House of Representatives, ex. doc. no. 207, 805 p.

Reynolds, M.W., and Brandt, T.R., 2005, Geologic map of the Canyon Ferry Dam 30' X 60' quadrangle, west-central Montana: U.S. Geological Survey Scientific Investigations Map 2860, 32 p., map scale 1:100,000.

Rocky Mountain Gazette (Helena, MT), 1867, June 22, The El Dorado (sic) Water Ditch Company, p. 2, c. 2.

Smith, J.L., 1873, Notes on the corundum of North Carolina, Georgia, and Montana, with a description of the gem variety of the corundum in these localities: American Journal of Science, ser. 3, v. 6, p. 185–186.

St. James Gazette, 1891, October 29, Sapphire and Ruby Company prospectus, London, p. 16.

Stickney, M.C., 1987, Quaternary geologic map of the Helena valley: Montana Bureau of Mines and Geology: Geologic Map 46, map scale 1:50,000.

Tappert, R., and Tappert, M.C., 2011, Diamonds in nature: Heidelberg, Springer, 142 p.

Tiffany & Company, 1889, Catalogue of a collection of precious and ornamental stones of North America exhibited at the Paris Exposition, 1889, De Vinne Press, p. 9–10.

Tri-Weekly Post (Virginia City, Montana), 1867, August 27, Eldorado Bar sapphires (sic), p. 3, c. 2.

Vuke, S.M., 2011, Geologic map of the Canyon Ferry area, west central Montana: Montana Bureau of Mines and Geology Open-File Report 607, 16 p., map scale 1:50,000.

Vuke, S.M., Porter, K.W., Lonn, J.D., and Lopez, D.A., 2007, Geologic map of Montana: Montana Bureau of Mines and Geology Geologic Map 62, scale 1:500,000.

World (New York), 1872, August 30, The American Association for the Advancement of Science, p. 1, c. 6, p. 8, c.1.

Zeitner, J.C., 1978, The Big Sky sapphire: Lapidary Journal, v. 32, no. 6, p. 1244–1254.

UNPUBLISHED SOURCES

Montana, Lewis and Clark County Placers, Book J, p. 55, p. 111–122, Lewis and Clark County Clerk and Recorder, Helena, MT.

Montana, Lewis and Clark County Ranches and Ditches (placers), Book F, p. 555–556, Lewis and Clark County Clerk and Recorder, Helena, MT.

U.S. War Production Board Record, Helena District Office Records, MC 239, box 7/25, Material Scarcity Report WPB-1475, Montana Historical Society Archives, Helena.

APPENDIX 1

Conversion Factors

Cubic feet—One cubic foot (ft^3) = 0.028 cubic meters (m^3)

Cubic yards—One cubic yard (yd^3) = 0.76 cubic meter (m^3)

Feet—One foot (ft) = 0.30 meter (m)

Gallon—One gallon = 3.78 liters (L)

Miles—One mile (mi) = 1.61 kilometers (km)

Miner's inch—One miner's inch in Montana = 11.2 gallons/minute. A miner's inch is not the same in all states.

Troy ounces—One troy ounce (troy oz) = 31.1 grams (g)

Tonne—A metric ton weighs 2204.6 lbs. One short ton = 0.91 metric tonne. Five million carats of sapphires, or any other gemstone, equals 1 tonne.

APPENDIX 2

Glossary

Augite—A common mineral in many igneous rocks that is a member of the pyroxene group of minerals.

Basaltic trachyandesite—This designation, usually only of interest to petrologists, is based on chemical analyses of the French Bar sill and employs a classification of igneous rocks in common use. The chemical composition of this rock is roughly intermediate between a basalt and a rhyolite.

Biotite—A common black mica.

Carat— One carat = 0.2 g abbreviated ct. One gram is about the weight of a paper clip 1¾ inches long.

Diorite—An igneous rock composed of plagioclase feldspar, amphibole, and pyroxene.

Exsolved rutile—Rutile (TiO_2) is a relatively common inclusion in sapphires. Some sapphires have thin bands of microscopic rutile needles that parallel the hexagonal prism form of corundum. It is generally thought that these very small rutile crystals crystallized from Ti and O scattered throughout the sapphire when the sapphire cooled.

Graben—A structure formed when the rock between two bounding faults has moved downward along these faults, often forming a valley.

Loess—The loess in the Hauser Lake area is very fine material (silt) that was probably deposited by the wind and derived from sediment remaining when Glacial Lake Great Falls emptied.

Margarite—A relatively rare Ca mica that is more aluminous than most micas and frequently occurs with corundum.

Micron—Also known as micrometer. One micron = 1/1000 of a millimeter and is abbreviated µm. The diameter of a human hair is about 60 µm.

Orthoclase—A common feldspar, contains K in addition to Si, Al, and O.

Pebble—A rock fragment between 1/6 and 2.5 inches (4–64 mm).

Phenocryst—A relatively large crystal in an igneous rock that crystallized from the magma that solidified to form the surrounding rock.

Pinacoid—A term used in crystallography to describe two parallel faces of a crystal. A well- formed corundum crystal has two parallel faces at both ends of the prism, referred to as the basal pinacoids.

Plagioclase—A common feldspar that consists of Na and Ca in addition to Si, Al, and O.

Quartzofeldpathic gneiss—A metamorphic rock composed mainly of quartz and feldspar.

Quartz monzonite—An igneous rock that contains quartz and feldspars, specifically potassium feldspar and plagioclase feldspar.

Resorption—The process by which a crystal is partly dissolved when transported in molten rock (magma).

Sapphire—The gem variety of the mineral corundum that comes in all colors but red. Red corundum is ruby. Sapphire may also be colorless.

SEM—Scanning electron microscopy. Electron microscopy can provide much greater enlargement than optical microscopy.

Sill—A roughly tabular body of igneous rock whose contacts are parallel for the most part to the layering in the enclosing rock. Generally, this is the bedding of the enclosing sedimentary rock.

Strath terrace—A terrace eroded by a river that was above the present river. Further erosion usually leaves only remnants of old terraces, as along Hauser Lake.

Spinel—A group of minerals that contain Fe, Mg, Al, and O. The relative concentration of Fe as compared to Mg varies.

Xenocryst—An inclusion of a foreign mineral grain in an igneous rock. These mineral grains did not crystallize from the molten rock (magma) that solidified to form the surrounding rock.

Xenolith—An inclusion of a foreign rock in an igneous rock.

Geologic Time Designations Mentioned in the Text

Pleistocene—The last Ice Age that extended from 2.6 million years ago (Ma) to approximately 10,000 years ago.

Tertiary—From 2.6 million years ago to 65 million years ago.

Paleozoic—The Paleozoic Era extended from approximately 540 million years ago to approximately 250 million years ago.

Cambrian Period—The oldest period of the Paleozoic Era.

Proterozoic—The younger division of the Precambrian from 2.5 billion years (Ga) to the beginning of the Paleozoic approximately 540 million years (Ma) ago.

Archean—The oldest rocks on Earth from the oldest known rocks about 4 billion years (Ga) old to rocks 2.5 billion years (Ga) old.