WYOMING STATE GEOLOGICAL SURVEY
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GEOLOGY OF THE CEDAR RIM OPAL DEPOSIT, GRANITE MOUNTAINS, CENTRAL WYOMING

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Open File Report 05-1
Laramie, Wyoming
2005

Introduction

During 2003, the senior author initiated investigations of the Cedar Rim opal deposit in central Wyoming, and both authors conducted additional reconnaissance of the deposit in 2004. Our initial investigations suggest that this deposit could potentially be one of the larger opal deposits in North America.

Based on size and extent along with proper marketing strategies, this deposit could potentially become a significant source for semi-precious and common opal for many decades to come. However, like any low-value colored gemstone deposit, the success will require marketing skills and an understanding of geological concepts along with support from the government for a gemstone operation to be successful. Thus the Cedar Rim deposit, even though it appears to host a very large amount of low-quality gems, could suffer a fate of non-production due to a number of domestic factors. If this deposit were found in a county such as Sri Lanka, it would undoubtedly be considered a major discovery and would be mined for decades. In Wyoming, it may be considered as a marginal deposit.

The variety of opal found in this deposit includes common and fire opal, with traces of precious opal. The possibility of significant undiscovered seams of precious opal must be considered and further exploration is recommended since much of the deposit remains hidden. Considering the enormous size and extent of this deposit, only a very small part has been examined, to date. Several specimens collected by the WSGS exhibit weak color play along with transparency and translucency, thus a possibility of finding significant seams of precious opal must be considered in future exploration.

Other Wyoming gemstones

During the past several years, the WSGS has been the most successful State Geological Survey in the U.S. for finding precious stones. For example, the two authors have been responsible for identifying, and/or mapping more than a dozen gemstone and precious metal deposits in Wyoming. These include two large iolite (water sapphire) deposits, along with some ruby, sapphire, kyanite, peridot, agate, jasper, pyrope garnet (Cape rubies), chromian diopside, chromian enstatite, diamond, gold and palladium deposits (Hausel, 1989, 1997, 1998; Hausel and Sutherland, 2000). Further investigations of gemstones in Wyoming are guaranteed to produce more discoveries based on the State's favorable geology.

Opal

Opal ($SiO_2 \cdot nH_2O$) is considered to be a precious to semi-precious stone that has been sought throughout much of history for personal adornment, decoration, and statuary.

Opal is amorphous and considered to be a mineraloid: it may contain as much as 6 to 10% water. It is formed of closely packed spheres of amorphous silica and has a hardness of 5.5 to 6.5. Thus it may produce relatively durable gems or semi-precious gemstones depending on its water content. In general, the higher the water content, the less stable the opal.

Common white opal exhibits a random packing of silica spheres that are visible only with a scanning electron microscope. In contrast, precious opal exhibits distinct orderly three-dimensional array of silica spheres that is favorable for light diffraction, which produces an attractive play of colors.

There are two general categories of precious opal. Black opal is considered to be the most valuable because the internal color play is enhanced against its dark matrix. Precious white opal is considered to be less valuable, as it is thought that the internal color play is less attractive against a white opaline matrix. Even so, the value is in the eye of the marketer, as precious white opal has extraordinary inherent beauty and color play. Fire opal, which may or may not have a play of colors, may be translucent to transparent and is red, orange-red, orange and/or yellow. Common opal, which typically is translucent, is primarily milky white. Hyalite, a lower quality opal, is a colorless, transparent opal that occurs as globules that resemble drops of water and will not usually show a color play. All varieties of opal have been observed at the Cedar Rim deposit.

Geology and genesis opal deposits

Most primary deposits of opal are hosted by sedimentary rock or by felsic volcanic rock. Opal has also been reported in some basalts and in some other rock types, but these are all less common. The majority of the world's precious opal is mined from Australia where opal is hosted by Cretaceous marine sedimentary rock of the Great Artesian Basin in New South Wales, Queensland, and in South Australia (Keller, 1990). It is also found in joints in deeply weathered Proterozoic gneiss of the Musgrave-Mann Metamorphics in the Granite Downs of northwestern part of South Australia (Barnes and others, 1992). The occurrence in gneiss in this latter area appears to be the result of the same processes responsible for sedimentary-hosted opal.

Because of low specific gravity, conchoidal fracture, and tendency to craze (loose water and fracture) when subjected to dry conditions or heat, opal is not favorably concentrated in placers and preservation is unfavorable where surface weathering has occurred over lengthy periods of time. Thus placers are essentially unheard of and eluvial and alluvial deposits are uncommon and restricted. Where found, eluvial and alluvial deposits typically occur on top or adjacent to an in situ deposit. Exposure to dry environments and heat causes opal to loose water resulting in opaque, chalky-white fractured crusts and masses replacing the opal. Opal cannot survive deep burial, nor can it survive structural adjustments that would result in increased temperatures and pressures. Because of these durability limitations, all opal, whether sedimentary- or volcanic-hosted, is believed to be geologically young (Darragh and others, 1976).

Barnes and others (1992) cite various studies in Australia indicating that much of the opal in that part of the world is Early Cretaceous due to digenetic changes related to deposition of the Bulldog Shale. Australian opal is generally thought to be a product of complex weathering and silicification processes. Darragh and others (1966) estimated possible opal deposition rates in Australia to vary between 0.3 inch of thickness in 5 million years to a maximum of 0.3 inch in 200,000 years. However, Eckert (1997) reports that deposition may be much more rapid and cites partial opal replacement of wooden fence posts and some animal bones.

Sedimentary-hosted opal

Sedimentary-hosted opal is attributed to the movement of silica-rich water through sedimentary rocks. The water flow can be downward (from surface waters), upward, or laterally with silica-laden groundwater. Sinkankas (1959) notes that some basalt flows in Washington appear to have served as the confining layers for circulation of silica-rich water in underlying opal-bearing sediments. To form such deposits, there needs to be a nearby source of readily soluble silica as well as a transporting fluid to dissolve the silica and transport it to a site of precipitation. Known silica sources include volcanic ash beds, siliceous micro-fossils, digenetic changes associated with bentonites, or in situ kaolinization of detrital feldspars. Deep chemical weathering of rocks such as pyroxenite and serpentinite, are also thought to have provided some silica for formation of some opal in parts of the world (Eckert, 1997).

Sedimentary-hosted opal is found in Australia down to depths of about 130 feet. Host rocks include conglomerates, sandstones, claystones, and bentonites. The sites for opal deposition include pore spaces, joints, fractures, shrinkage cracks, partings, bedding planes, and cavities (Barnes, Townsend, Robertson, and Scott, 1992). In many places, the site of deposition also coincides with the bottom of deep weathering profiles, which is accompanied by intense bleaching (Kievlenko, 2003).

Darragh and others (1966) demonstrate that neutral to slightly acidic groundwater at temperatures of 20° to 25°C, similar to that currently found in Australia's opal fields, could dissolve as much as 100 ppm silica. Their field evidence, combined with the orderly structure required for precious opal, suggests that the opal formed in rock openings by relatively slow evaporation rates of localized pockets of groundwater. It is thought that the water needed to remain undisturbed for long periods of time to allow for the formation of colloidal silica spheres followed by slow settling into regular arrays. As evaporation proceeded, a steady-state balance was maintained and accompanied by hydrostatic inflow of more silica-laden water resulting in a continual accumulation of opal. Soluble salts which could disrupt regular silica deposition are thought to have exited the system by upward diffusion – this is expressed by the presence of discontinuous gypsum veins that are seen above the opal deposits. Secondary opal filling fractures in primary opal along with thin clay layers between some opal layers provide evidence for depositional disruptions.

Deeply weathered rocks, combined with the arid climate in Australia's opal fields appear to be essential components for the formation of precious opal, and for the development of siliceous cap rocks in that region (Barnes and others, 1992).

Darragh and others (1966) suggested that opal had to have formed under near-surface conditions (depths from 15 to 130 feet below the surface) to account for the necessary steady-state conditions. The arid climate in Australia's opal fields confined shallow groundwater for millions of years to areas defined by impermeable barriers such as bentonite beds that restrict flow from overlying porous rock. Opal most often fills voids, rock matrix pore spaces, or joints at or near such boundaries, but not all cavities are filled with opal; its distribution is usually patchy. Large interconnected cavities are generally filled with common opal. The best quality precious opal is most often found in small isolated cavities. The rarity of steady state conditions necessary to form precious opal explains its rarity compared to common opal.

Volcanic-hosted opal

Volcanic-hosted opal appears to be either related to post-volcanic hydrothermal activity, or to silica-rich waters derived from surface weathering processes similar to sedimentary-hosted deposits. The difference between these two processes may be obscured by deep surface weathering and a lack of detailed site investigations. Opal hosted by volcanic rock generally contains more water than opal formed in shallow sedimentary environments. Consequently, volcanic-hosted opal (with exceptions, i.e. Mexican fire opal) is generally less stable than opal recovered from sedimentary rocks and often exhibits a greater propensity for crazing (Barnes and others, 1992).

Opal deposition often occurs within rounded voids in volcanic rocks known as vesicles. This type of opal is deposited from siliceous solutions at temperatures higher than normal groundwater temperatures. Opal deposition under these conditions resulted in tiny silica spheres with close-packed arrays that exhibit almost no interstitial voids. These opals tend to be transparent, exhibit no noticeable grain pattern, and show a play of color only in diffuse bands as the stone is rotated in light. Conversely, opals hosted in volcanic rocks that show well-defined grain patterns are interpreted to have formed under normal sedimentary conditions (Darragh and others, 1976). Kievlenko (2003) cites opal formation temperatures of 50° to 150° C for post-volcanic hydrothermal environments. Opal associated with siliceous sinter or geyserite is often attributed to post-volcanic hydrothermal activity.

Cedar Rim opal deposit

A variety of opals have been found in the Cedar Rim deposit and further investigations and exploration are highly recommended to determine the potential for gem material. Essentially, every variety of opal has been identified in this deposit. The deposit consists primarily of vast amounts of white to very light-blue translucent to opaque common opal, with significant amounts of translucent to opaque yellow, yellow-orange to orange fire opal, along with significant amounts of clear, transparent hayalite opal. Only trace precious opal (both white and black) have been identified in the samples collected by the WSGS. Based on the fact that all varieties of opal have been identified, and that much of the field remains unexplored, the potential for discovery of significant seams of precious opal must be considered. During this study by the WSGS, opal was identified within 12 sections of land (**Figure 1**). In places the opal beds are anywhere between a few feet to more than 50 feet thick and primarily found as ridge caps in the field, but also material was exposed along a pipeline cutting through the field (**Figure 2**).

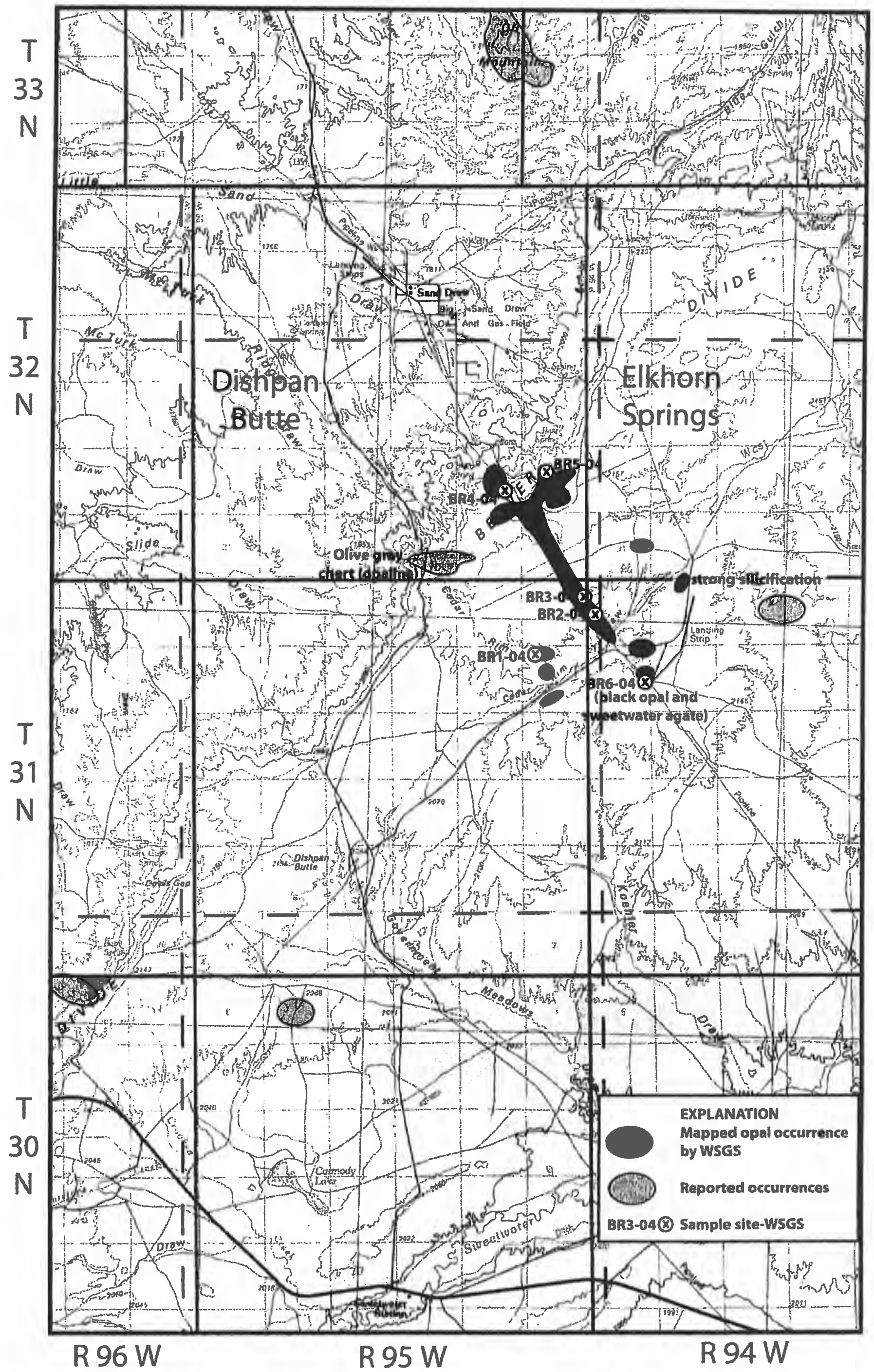

Figure 1. Location map of the Cedar Rim opal deposit, central Wyoming.

Location

The Cedar Rim opal deposit is found in the Cedar Rim area along Cedar Rim Draw near the northwestern margin of Beaver Rim. Beaver Rim is located in the western portion of the Granite Mountains uplift in central Wyoming. The nearest towns are Riverton to the northwest, Lander to the west, and Jeffrey City to the southeast. Much of the deposit is located on the US Geological Survey Lander 1:100,000 sheet, with some reported opal further east on the Rattlesnake Hills 1:100,000 sheet.

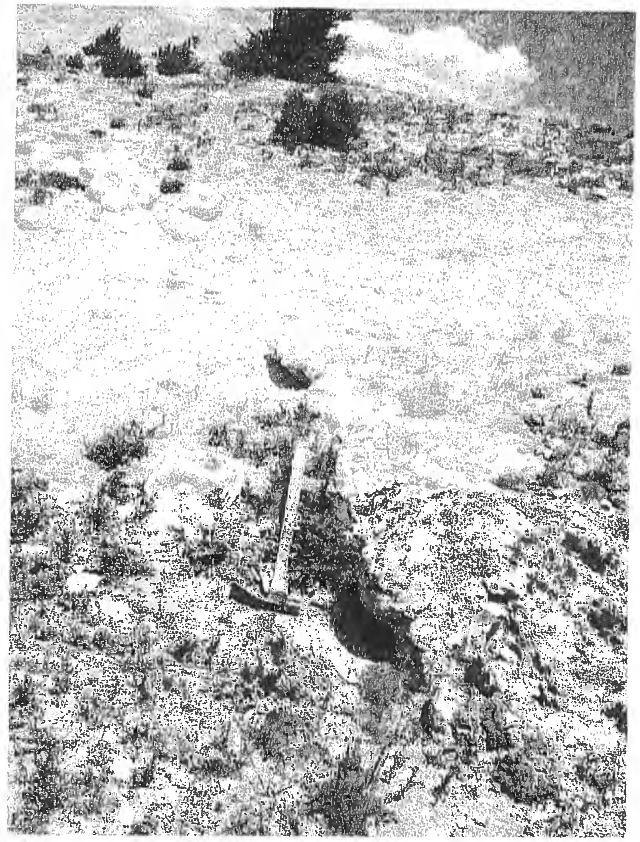

Figure 2. Large boulder of opal exposed on the side of a hill in the Cedar Rim deposit.

History

The first report of opal in this area was probably by Sinclair and Granger (1911). In their report on the Eocene and Oligocene sediments, they depicted opal in a cross-section near Wagon Bed Spring (SW sec.34, T32N, R95W). They also noted that opal and chalcedony were repeatedly observed as replacements of soft tuffaceous limestone at the top of the Oligocene sediments that capped Beaver Rim as well as on several buttes to the south. In places, the limestone formed a layer with masses of white chalcedony and opal nodules that are enclosed in calcareous crusts. The presence of cylindrical pipes of silica, cutting through some of the limy layers was also noted.

The source for both the limestone and silica was interpreted by Sinclair and Granger (1911) to be from underlying ash beds. The silica was thought to have mobilized in percolating water which surfaced in springs. Some chalcedony and opaline cement was also described in silicified arkose lower in the section, possibly in what is today known as the Wagon Bed Formation.

Opal in the Beaver Rim area was later noted by Van Houton (1964). Van Houton described opal with chert and chalcedony in the Wagon Bed Formation, the volcanic facies of the Beaver Divide conglomerate member of the White River Formation (now the Wiggins Formation), the White River Formation, and the Split Rock Formation. Numerous chert nodules and silicified zones are found in both the White River and Split Rock Formations. Locally opal and yellowish-brown to light olive gray chert, in masses up to 3 feet in diameter, are found in mudstone in the Wagon Bed Formation in the vicinity of Wagon Bed Spring and northeastward as far as the Rogers Mountain Anticline. Irregular chert masses up to 15 feet long are also found in the Kirby

Draw syncline (which extends northwest from NE sec. 31, T33N, R94W to sec.14, T33N, R95W).

At Green Cove (sec.35, T31N, R96W) Van Houton (1964) noted that the uppermost 20 feet of the lower part of the Wagon Bed Formation hosted altered yellowish- to light-gray, distinctly bedded tuff containing abundant siliceous nodules up to few inches in diameter. These were accompanied by 6- to 12-inch thick chert beds and rock formed of quartz, dolomite and opal.

The Wiggins Formation, which in this area forms a wide channel fill within the basal White River Formation, is characterized by debris derived from the Yellowstone-Absaroka volcanic field. This ranges from sand-sized material to boulders 8 feet long. Within this unit, sandy limestone lenses up to 5 feet thick have been partly replaced by irregular fibrous chalcedonic chert and massive gray opaline silica containing irregular tubes and pores: many of which are filled with calcareous montmorillonitic clay.

South of the Conant Creek anticline (secs. 3 & 4, T31N, R94W) Van Houton (1964) described a prominent 160-foot high south facing escarpment. In the lower 50 feet of the upper part of the White River Formation, he described local layers of light blue to greenish-gray, limonite-stained, brittle opaline chert containing rounded pellets up to 3 mm in diameter. Farther to the east in sec 14, T32N, R93W, the lower greenish-gray tuffaceous mudstone of the White River Formation contains several 2- to 4-inch thick layers of slightly calcareous opaline chert. It was also noted that these mixed chalcedony and opal layers contained 1- to 2-mm diameter ellipsoidal to subspherical pellets. Both the opal/chalcedony pellets and the rock matrix contain abundant ooliths and round, structureless, thick-rimmed particles.

Within the Split Rock Formation, Van Houton (1964) found irregular domal structures several feet in diameter that were formed of sand adhering to an opaline skeletal structure that resembled tuffa or algal mats. These occur in well-sorted calcareous sandstone southeast of Devils Gap in sec. 5, T30N, R95W. He also noted commonly occurring thin beds of chert, irregular concretions of opaline silica, and fibrous siliceous aggregates along Beaver Rim in the uppermost part of the Split Rock Formation. These are hosted within 2- to 6-inch thick light-gray limestone interbedded with equally thin calcareous tuffaceous sandstone.

The senior author initiated reconnaissance of the Cedar Rim Draw opal deposit in 2003. This was which was followed by later investigations by both authors. The reconnaissance investigations were designed to examine the extent and the varieties of opal in the Cedar Rim Draw deposit to determine if there is any economic potential. Based on our reconnaissance investigations, the Cedar Rim opal deposit may be one of the larger opal deposits in North America, and it is worthy of additional research and mapping. If such a giant opal deposit can remain relatively hidden and unknown in central Wyoming for such a long time, developing geological and exploration models for similar opal deposits should lead to additional discoveries. Reports of opal in the state suggest that similar deposits may occur elsewhere (Hausel and Sutherland, 2000; Ronald Surdam, personal communication, 2005), as well as deposits of precious opal in the Absaroka Mountains in northwestern Wyoming (J.D. Love, personal communication to Wayne Sutherland, 1989).

This current reconnaissance survey resulted in the identification of an enormous opal deposit extending over portions of at least 12 sections. More detailed sampling and mapping in this region would undoubtedly lead to additional discoveries based on the favorable geology in the district.

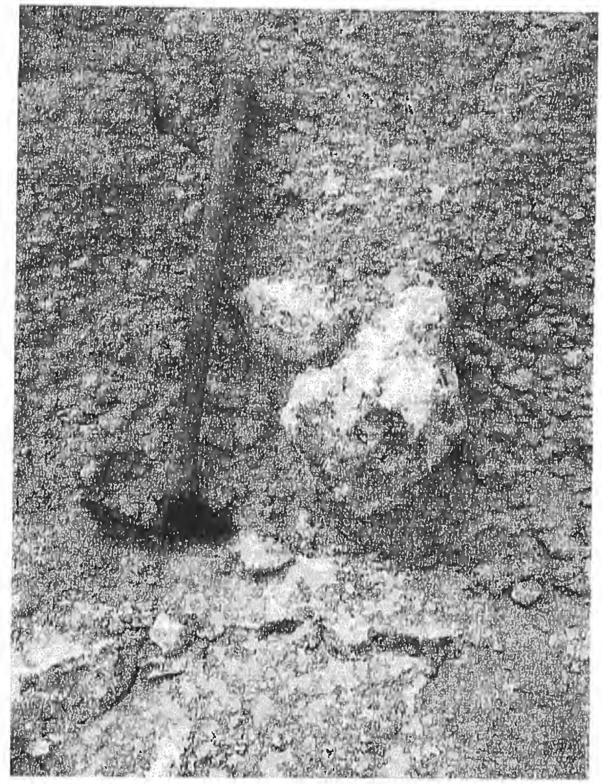

Figure 3. Nodule of opal exposed in the White River Formation.

Cedar Rim Draw opal

Early mapping by Van Houton (1954) suggested that the opal samples recovered by the Wyoming State Geological Survey (WSGS) were found in rock mapped as Miocene(?) marlstone, claystone, siltstone, sandstone and conglomerate, and from rock units of the White River Formation (Oligocene) known as the Beaver Divide conglomerate and boulder facies, and the Sand Draw Sandstone. Later mapping by Van Houton (1964) indicated these units to be the White River Formation (Oligiocene) and the Split Rock Formation (Miocene) (**Figure 3**).

During field reconnaissance by the WSGS, opal was found within the following sections: secs. 25, 26, 35 & 36, T32N, R95W, secs. 31 & 32, T32N, R94W, secs. 5, 6, 7 & 8, T31N, R94W, and secs. 1 & 12, T31N, R 95W. Numerous samples were collected during this reconnaissance study including three giant opals that weighed 25,850 carats (11.4 lbs), 57,100 carats (25.18 lbs) and 77,100 carats (34 lbs) (**Figure 4**)!

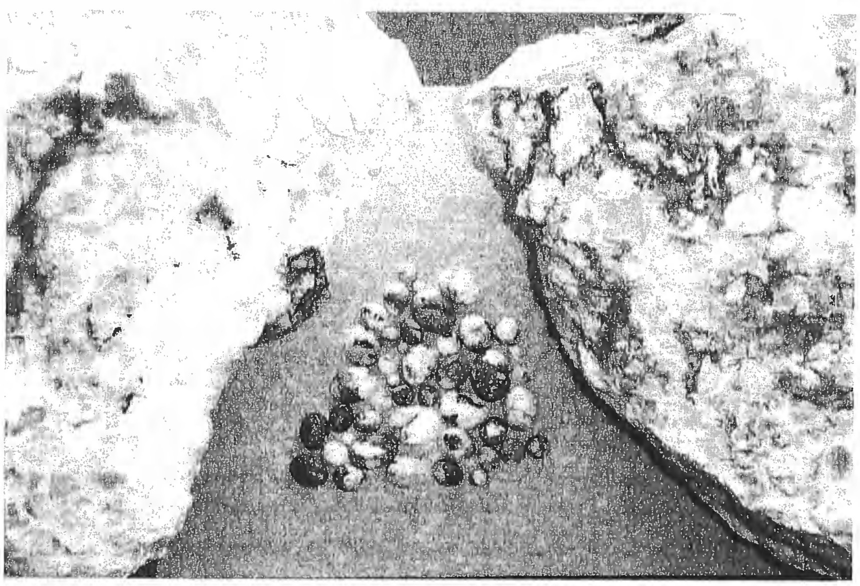

Figure 4. The first opal cabs cut from material from the Cedar Rim deposit sit adjacent to two large opals collected by the WSGS.

It is estimated that a vast field of opal exists in the Cedar Rim area potentially totaling tens of thousands of tons of opal. The opals range from small cobble size nodules to large boulders encased in caliche. The caliche appears to represent a replacement of the opal as it weathers and devitrifies. Several varieties of opal were recovered by the authors and a description of the rock samples collected from the deposit includes:

(1) Opaque milky white to translucent common opal with localized layers or fracture fillings of transparent clear opal. Some of this material includes very light blue opal with minor black dendrite-like inclusions. Some opal is perfectly transparent and much exhibits a very subtle color play with localized zones of stronger color play. Many of these opals are fractured but include some large consolidated unfractured pieces weighing several carats.

(2) Translucent light-blue opal enclosed by milky opaque opal which in turn is enclosed by a narrow perfectly transparent and banded opal crust that exhibits a pleasant spectrum of color play (bands of blue-yellow-violet red) when natural light is reflected from the specimen. These are enclosed in a thin rim of tan to pink quartz.

(3) Opal breccia consisting of milky quartz breccia clasts with some light gray to light blue translucent to transparent opal clasts and veins in a black opal to black chalcedony matrix (**Figure 5**). Some of the translucent to transparent opal and rarely the black opal exhibits some color play.

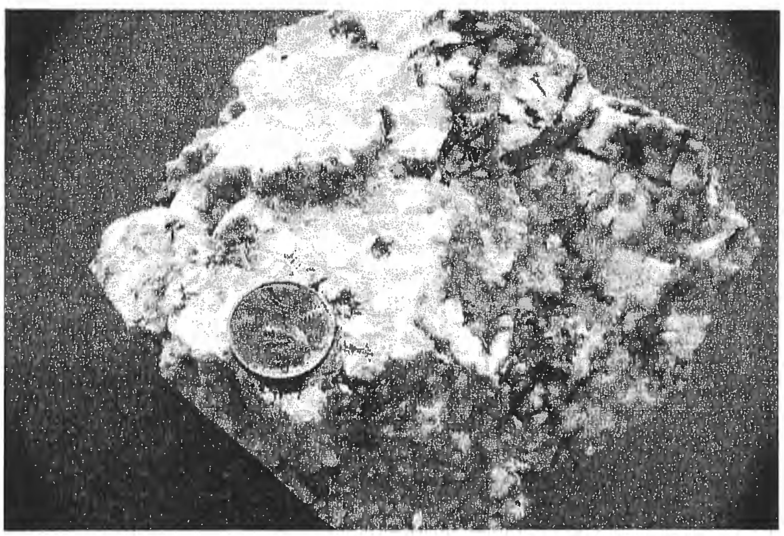

Figure 5. Opal breccia collected from the Split Rock Formation.

(4) Gray black to black translucent opal and quartz. Some of these samples have a distinct appearance similar to the Sweetwater agates mentioned by Love (1970), and this is likely the original source bed of some of the Sweetwater agates. Some of this material was collected in place in sec. 7, T31N, R94W. Very minor play of colors was observed in a couple of the specimens. Much of the color in these appeared as a surface sheen with uncommon, tiny distinct rainbow bands within the opal that may occur along fractures. It is highly recommended that several of these be cut to produce cabochons to see if any play of color continues into the opal,

(5) At one location in the opal field, varicolored opal is common. This opal includes translucent fire opal as replacements and fracture fillings in silicified arkose. The opal

includes milky white translucent to opaque opal, considerable opaque to translucent yellow opal, and lesser opaque to translucent orange opal comparable to the Mexican fire opal. This opal is common capping a hill in sec. 25, T32N, R94W.

Conclusions

The Cedar Rim opal deposit still remains relatively unexplored. The extent of the deposit is only poorly known and additional field work and trenching is highly recommended to determine the aerial extent and thickness of the opal deposit, as well as to search for seams of precious and fire opal. The source of the opal was undoubtedly silica leached from volcanic ash scattered throughout the area.

References cited

Barnes, L.C., Townsend, I.J., Robertson, R.S., and Scott, D.C., 1992, Opal - South Australia's Gemstone: Department of Mines and Energy, Geological Survey of South Australia Handbook No.5, 176 p.

Darragh, P.J., Gaskin, A.J., Terrell, B.C., and Sanders, J.V., 1966, Origin of precious opal: Nature, January 1, 1966, v. 209, no.5018, p.13-16.

Darragh, P.J., Gaskin, A.J., and Sanders, J.V., 1976, Opals: Scientific American, v.234, no.4, p.84-95.

Eckert, Allan W., 1997, The World of opals: John Wiley & Sons, Inc., New York, 448 p.

Hausel, W.D., 1989, The geology of Wyoming's precious metal lode and placer deposits: Geological Survey of Wyoming Bulletin 68, 248 p.

Hausel, W.D., 1997, The geology of Wyoming's copper, lead, zinc, molybdenum, and associated metal deposits in Wyoming: Geological Survey of Wyoming Bulletin 70, 224 p.

Hausel, W.D., 1998, Diamonds and mantle source rocks in the Wyoming Craton, with a discussion of other US occurrences: Wyoming State Geological Survey Report of Investigations 53, 93 p.

Hausel, W.D., and Sutherland, W.M., 2000, Gemstones and other unique minerals and rocks of Wyoming - a field guide for collectors: Wyoming State Geological Survey Bulletin 71, 268 p.

Keller, Peter C., 1990, Gemstones and their origins: Van Nostrand Reinhold, New York, 144 p.

Kievlenko, Eugenii Ya, 2003, Geology of gems: Ocean Pictures Ltd, 432 p.

Love, J.D., 1970, Cenozoic geology of the Granite Mountains, central Wyoming: US Geological Survey Professional Paper 495-C, 154 p.

Sinclair, W.J., and Granger, W., 1911, Eocene and Oligocene of the Wind River and Bighorn basins: Bulletin of the American Museum of Natural History, v. 30, part 7, p. 83-118.

Sinkankas, John, 1959, Gemstones of North America: Van Nostrand Company, Inc., New York, 675 p.

Van Houton, F.B., 1954, Geology of the Long Creek - Beaver Divide area, Fremont County, Wyoming: USGS Geological Survey Map OM 140 map scale 1:62,500.

Van Houton, F.B., 1964, Tertiary geology of the Beaver Rim area, Fremont and Natrona Counties, Wyoming: USGS Bulletin 1164, 99 p., map scale 1:62,500.