Geology and Geochemistry of Jasperoid Near Mackay, Idaho

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ABSTRACT

Extensive areas of jasperoid occur in Paleozoic sedimentary rocks near Mackay, Idaho. Outcrops range from massive, gray-pink colored, hard and dense jasperoid with original sedimentary textures preserved to highly brecciated, quartz-healed, gossan-stained jasperoid showing no sign of its protolith. The Mackay jasperoids are significant because they have geological and geochemical similarities to jasperoids associated with known sediment-hosted precious-metal deposits in the western United States. The jasperoids of the Mackay area are mainly replacements of limestone, commonly along high-angle fault systems, and many outcrops show evidence of more than one period of brecciation and silicification. Quartz and calcite veins cut some of the jasperoids, and they locally contain barite, fluorite, and antimony minerals. Iron-stained outcrops of jasperoid are common and many contain jarosite.

One hundred ten rock chip samples collected from jasperoid outcrops in five geographic areas of the Mackay region were analyzed for eighteen elements: Ag, As, Au, Cu, Hg, Mo, Pb, Sb, Tl, Zn, Bi, Cd, Ga, Pd, Pt, Se, Sn, and Te. Most samples from all five areas contained Ag, As, Au, Cu, Hg, Mo, Pb, Sb, and Zn; Tl was present in most samples from four of the five areas. Element associations determined by correlation analysis centered on As-Sb-Tl-Hg and Cu-Zn. Copper, Mo, Pb, Ag, and Zn may have been locally derived from metalliferous sedimentary rocks and could have been deposited under almost any conditions of jasperoid formation. However, the elements As, Sb, and Hg with Tl and Au suggest jasperoid formation by replacement from hydrothermal solutions, since these elements are characteristically deposited in the upper parts of geothermal systems. Hydrothermal solutions that formed the jasperoids may also have formed large low-grade precious metal deposits within the jasperoid bodies or within altered country rocks associated with the jasperoids.

INTRODUCTION

This report describes the physical and chemical properties of jasperoid rocks near Mackay and is based on reconnaissance sampling during July and August 1987. This investigation is part of a U. S. Geological Survey CUSMAP project to evaluate the mineral resources of the Hailey 1 x 2 degree quadrangle and part of the Idaho Falls 1 x 2 degree quadrangle. An Idaho State University project studying gold and silver mineralization in central Idaho is cooperating with the Hailey project and providing the geochemical analyses of samples. The potential
for large low-grade precious metal deposits in the volcanic rocks is discussed by Moye and others (1988, this volume).

The study area is near the town of Mackay in the northwest corner of the Idaho Falls 1 x 2 degree quadrangle, west of U. S. Highway 93 and north of the Pioneer Mountains (Fig. 1). One hundred ten rock chip samples from jasperoid outcrops were analyzed to determine the presence and distribution of gold and other trace elements, such as As, Sb, Hg, and Tl. For descriptive purposes, samples were grouped according to location and local geologic features into five areas: Bartlett Point, Lehman Butte, Sheep Canyon, Grouse, and Timbered Dome (Fig. 1).

Jasperoid, as used in this paper, refers to "an epigenetic siliceous replacement of a previously lithified host rock" (Lovering, 1972, p. 3). Jasperoid bodies near Mackay are geologically and geochemically similar to those associated with large low-grade, sediment-hosted, precious metal deposits elsewhere in the western United States; as such, they should be of considerable interest to the mineral exploration industry. These deposits are sometimes termed "invisible gold" or Carlin-type deposits.

GEOLOGIC SETTING

The geology of the Mackay region was previously mapped by Nelson and Ross (1968; 1969). Part of the area is currently being mapped by Betty Skipp of the U.S. Geological Survey, and her unpublished mapping was used to locate jasperoid bodies near Grouse and Timbered Dome. Figure 2 is a generalized geologic map of the area.

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Geologic units of the Mackay area are mainly Paleozoic carbonate rocks, intruded by Tertiary granitic stocks and hypabyssal bodies and overlain by the Eocene Challis Volcanics. The area is cut by high-angle faults that trend north-northwest and northeast.

Paleozoic sedimentary rocks that crop out in the area are Early Mississippian to Early Permian in age and consist of the White Knob Limestone and the Copper Basin, McGowan Creek, Middle Canyon, Scott Peak, South Creek, Surratt Canyon, Bluebird Mountain, and Snaky Canyon Formations. The Copper Basin Formation (Mississippian) is interpreted to be a foreland-basin flysch, made up of a thick sequence of clastic rocks, ranging from shale and argillaceous siltstone to conglomerate (Paul and others, 1972; Nilsen, 1977; Skipp and others, 1979). The McGowan Creek Formation (Lower Mississippian) was deposited in the shallow, eastern part of the foreland basin and consists of distal thin-bedded turbidites, calcareous siltstone, and minor silty limestone. The Mississippian White Knob Limestone consists of limestone with interbedded conglomerate and sandstone in its upper part; it gradationally overlies the McGowan Creek Formation and represents deposition in a subtidal to intertidal turbulent marine environment (Skipp and others, 1979). The Lower and Upper Mississippian Middle Canyon Formation and the Upper Mississippian Scott Peak, South Creek, and Surratt Canyon Formations are carbonate bank and forebank deposits across which a flood of fine-grained sand, the Bluebird Mountain Formation, transgressed in latest Mississippian time (Skipp and others, 1979). The Snaky Canyon Formation (Upper Mississippian to Lower Permian), mainly limestone and sandstone, is a shallow-water carbonate bank. For more discussion of these strata and their structural relations see Link and others (1988, this volume).

Extrusive rock units are part of the Eocene Challis Volcanics and include andesitic to rhyolitic flows, breccias, and tuffs. Possible vent areas for the volcanics are near Porphyry Peak and Sheep Mountain where aeromagnetic data suggest buried intrusive bodies. For
Figure 2. Generalized geologic map of the Mackay region, Idaho (adapted from unpublished map of Worl and others). Blackened areas indicate jasperoid. Qa, alluvium; Qb, basalt; Ti, intrusive rocks; Te, extrusive rocks, predominantly Challis Volcanics; PDC, undifferentiated carbonate rocks, including Snaky Canyon, Bluebird Mountain, Surratt Canyon, South Creek, Scott Peak and Middle Canyon Formations, White Knob Limestone and local, unnamed Permian and Devonian carbonate rocks; Mf, flysch deposits including Copper Basin and McGowan Creek Formations, undifferentiated.
more discussion of Challis Volcanics see Moye and others (1988, this volume).

Intrusive rock units are Tertiary plutons and comagmatic hypabyssal bodies. Plutonic bodies, exposed in the White Knob Mountains and along the southeastern and western margins of Copper Basin (Fig. 2), are multi-phase granitic intrusions composed mainly of porphyritic granite, granodiorite, quartz diorite, leucogranite porphyry (Nelson and Ross, 1968 and 1969a and b) and quartz monzonite (Dovcr, 1981). Comagmatic hypabyssal bodies and zones of alteration are common in some areas, aligned in part along northeast- and northwest-trending fracture systems. Numerous dikes of quartz latite, rhyolite, and porphyritic rhyolite cut all rock types and are commonly found in swarms parallel to northwest- and northeast-trending fracture systems (Nelson and Ross, 1969a and b).

MINERAL DEPOSITS

There are three major mining districts, Alder Creek, Copper Basin and Lava Creek, and numerous other prospects in the Mackay area (Fig. 2). Most of the deposits were discovered during the 1880s when rich silver-lead ores were mined throughout central Idaho. Most production of the late 1800s and early 1900s was from oxidized silver-lead ore. The Empire Mine in the Alder Creek district, active intermittently from 1901 into the 1960s, was a major copper producer. Many other properties in the area have been active intermittently since their discovery, but did not produce substantial amounts of ore.

Three types of mineral deposits have been exploited in the Mackay area: skarn deposits, polymetallic veins in Paleozoic sedimentary rocks, and polymetallic veins in volcanic rocks. The skarn deposits are mainly in the White Knob Mountains where Tertiary leucogranite intrudes Paleozoic limestone. Copper was the main commodity mined, but the deposits also contained lead, zinc, silver, gold, tungsten, and molybdenum (Nelson and Ross, 1969a and b). The deposits consist of chalcopyrite, pyrite, pyrrhotite, calcite, quartz, magnetite, fluorite, scheelite, molybdenite, sphalerite, and specularite in addition to skarn silicate minerals (Umpleby, 1917).

Polymetallic vein deposits in Paleozoic rocks, mainly carbonates, include fissure fillings and replacements along fracture systems and some replacement along bedding. Deposits of this type occur in all three districts where they occupy fracture systems that trend northeast and northwest. Ore minerals are mostly argentiferous galena with some sphalerite and chalcopyrite; tungsten minerals have been reported in the Lava Creek district (Umpleby, 1917, p. 85). Gangue is scarce and includes quartz, calcite, and pyrite. Sericite is an alteration product in some vein systems. Tertiary felsic dikes commonly occupy the same fracture systems as the veins.

Polymetallic fissure veins in volcanic rocks are found mainly in the Champagne Creek area of the Lava Creek District. These are epithermal deposits characterized by complex mineralogy and significant amounts of lead, silver, zinc, copper, iron, gold, tungsten, tin, antimony, arsenic, and bismuth (Anderson, 1947). The orebodies are within highly silicified and pyritized zones in a broad area of altered volcanic rock. The veins occupy northeast- and northwest-trending fracture systems.

Mineral deposits in the Mackay area, thought to be Tertiary in age, are the result of either contact metamorphism and metasomatism or deposition from hydrothermal solutions. Metals in these deposits may have been in part remobilized out of Paleozoic sedimentary country rocks. During Paleozoic time, there may have been metal-enriched deposition in deep restricted marine basins resulting in metal-enriched sedimentary rocks that would now be part of the Copper Basin and McGowan Creek Formations. The chemistry of these units is not known, but recent biogeochemical and geochemical studies by Erdman and others (1988) suggest that the McGowan Creek Formation is locally metal-enriched. Magma and hydrothermal activity during Tertiary time could have remobilized these metals into the present deposits. However, some metals were probably transported in magma along with volatile elements such as fluorine. Hydrothermal systems operating during the late stages of volcanism and intrusion probably formed the polymetallic vein deposits that are common in the area. These hydrothermal systems were widespread, affecting all rock types throughout the region. They may also have formed some of the jasperoid bodies in the area, especially those that are aligned along high-angle fault systems.

JASPEROID LITHOLOGY

Jasperoids of the Mackay region are mainly in Paleozoic limestones near either high-angle faults or volcanic rocks, but a few occur in sandstone, mudstone, conglomerate, and the Challis Volcanics. Major fault systems through the host rocks probably acted as conduits for silica-bearing solutions that replaced the host rocks with silica. These solutions may also have been metal-bearing in which case there could be large low-grade precious-metal deposits within or near the jasperoids. For this reason the physical and chemical properties of both the jasperoids and the original host rocks are important.

Jasperoids and jasperoid breccias at five areas are described (Figs. 1 and 2): (1) Bartlett Point, (2) Lehman Butte, (3) Sheep Canyon, (4) Grunse, and (5) Timbered Dome. Geologic settings and physical properties of the jasperoids are slightly different at each of the five areas. Bartlett Point is about 20 miles northwest of Mackay at the mouth of Rock Creek. In this area, Paleozoic sedimentary rocks are gently folded along northwest-
trending axes and are overlain by andesitic flows and breccias of the Challis Volcanics. Faults cutting all rock types trend north-northwest and northeast. Detailed maps are not yet available for this area, but general descriptions of the rocks are found in Nelson and Ross (1968, 1969a and b). The White Knob Limestone consists of gray to black, medium-bedded, silty limestone containing chert nodules and lenses. The upper part of the limestone contains interbedded quartzitic clastic rocks. The sedimentary rocks are overlain by The Eocene Challis Volcanics, which are mainly brownish red andesite lava flows. Massive, multi-colored jasperoid bodies are widespread at Bartlett Point where they form outcrops of dense, flinty, massive silica and silicified breccias that show slickensides and more than one period of brecciation. Jasperoid bodies in Rock Creek appear to be aligned along northeast-trending fracture zones.

Lehman Butte, approximately 5 miles southeast of Bartlett Point, is a large outcrop of White Knob Limestone and possibly Snaky Canyon Formation, surrounded by the Eocene Challis Volcanics. The White Knob Limestone is massive and light to medium gray in color, and it contains dark gray chert nodules and many calcite veins. The limestone is very fractured and jointed, and holes formed from weathering are common. Silicified brecciated limestone crops out near the summit. Thin-bedded gray to pink limestone with siltsone interbeds occurs at the summit and most of this rock is silicified. Challis Volcanics near Lehman Butte consist of medium gray to reddish brown, porphyritic, andesitic lava flows and breccias. A northwest-trending fault cuts the volcanic rocks on the west side of Lehman Butte.

Sheep Canyon is approximately 25 miles southeast of Lehman Butte. Here, Challis Volcanics were extruded over Mississippian limestones of the carbonate bank sequence. Gray to black jasperoid bodies are locally brecciated or iron stained, and many outcrops contain silicified crinoid fragments. Some outcrops are only partly replaced by jasperoid. There is no record of production from the mine workings (one shaft and an adit) at the mouth of the canyon.

Samples of jasperoid were collected along ridges to the north of the small community of Grouse, approximately 6 miles northwest of Timbered Dome. Rocks in this area belong to the McGowan Creek, Middle Canyon, Scott Peak, South Creek, Bartlett Point, and Snaky Canyon Formations. The McGowan Creek Formation is grayish black argillite and siltite with minor thin- to medium-bedded, dark gray limestone. The Middle Canyon Formation is dark- to medium-gray, thin-bedded silty limestone. Cliffs and ledges are light gray calcareous and fine-grained, dark gray, fossiliferous cherty limestone of the Scott Peak Formation. The Scott Peak is overlain by thin-bedded, dark gray limestone containing incipient chert nodules alternating with clayey, fissile limestone of the South Creek Formation. The South Creek Formation consists of dark- to medium-gray, fine-grained, thick-bedded fossiliferous limestone. It is overlain by 15 to 20 feet of very thin-bedded, fine-grained, calcareous sandstone of the Bluebird Mountain Formation. The Snaky Canyon Formation at the top of the sequence consists of thick-bedded, sandy limestone overlain by argillaceous silty limestone, argillaceous limestone, siltstone and sandstone.

These formations are cut by high-angle, north- and east-trending faults, and the rocks are locally silicified to jasperoid both along and away from faults. The jasperoid bodies locally retain original depositional features of the carbonate-bank host formations. Beds vary from massive, siliceous limestone with crinoid stems to pure quartzitic sandstone. Most of the outcrops of jasperoid are very fractured and iron stained; some are brecciated locally. Jasperoids that are not fractured are not iron stained and are gray to grayish pink in color.

At Timbered Dome several high-angle, mainly north- and northeast-trending faults cut outcrops of the McGowan Creek, Middle Canyon, and Scott Peak Formations. Challis Volcanics also crop out in the vicinity. At the summit of Timbered Dome, the McGowan Creek and Middle Canyon Formations have been silicified to maroon- to pink-colored jasperoid and jasperoid breccia.

GEOCHEMISTRY

Analytical Methods

One hundred ten rock-chip samples of jasperoid were collected in the Mackay area from outcrops and mine dumps. Ninety-seven samples were analyzed for eighteen elements using inductively coupled plasma emission spectrography and graphite furnace atomic absorption methods by Geochemical Services, Inc., of Sparks, Nevada. Thirteen samples were analyzed for atomic absorption for Ag, As, Au, Hg and Sb by Skyline Labs, Inc., of Denver, Colorado. (Use of brand names in this report is only for descriptive purposes and does not constitute endorsement by the U. S. Geological Survey.)

All of the data were analyzed by correlation analysis using the USGS STATPAC statistical computer package to determine element associations. Because the data are quantitative and more than 50 percent of the values are unqualified, original units were used and no substitutions were made for qualified data. As the data are insufficient, it was not intended that this method produce statistically rigorous correlations. The data are too sparse and incomplete to allow valid groupings based on factor analysis. Rather, the main purpose was to determine element associations specific to each of the five geographical regions.

Results

A summary of analytical results from the entire data
set is given in Table 1. Data for individual geographic areas are given in Table 2. Ag, As, Au, Cu, Hg, Mo, Pb, Sb, and Zn were detected in more than 84 percent and Tl in more than 50 percent of the samples. Only a few samples had detectable amounts of Bi, Cd, Pt, Se, Sn, and Te (Table 2); those that did were anomalously high in at least one of the other metals. Element associations shown by correlation coefficients are As-Sb-Tl, and Cu-Zn (Table 3).

Discussion

The suite of elements As, Au, Hg, Sb and Tl is present in a majority of the samples. These elements are characteristic of the upper parts of geothermal systems, hot-spring-type precious-metal deposits, and sediment-hosted, disseminated precious-metal deposits. (Barium, another element of this suite, was not determined.) It should also be noted that the ranges in values of Ag, As, Cu, Hg, Pb, Sb, Tl and Zn found in this study are similar to those of some known mineralized (>0.30 ppm gold) areas reported by Bagby and Berger (1985, p. 189).

Detailed geochemical results from each of the five sample areas are discussed below.

Bartlett Point

Thirty-four rock samples were collected in the Bartlett Point area. The samples vary widely from nearly unaltered, gray, massive limestone to oxidized, silicified tectonic breccia.

Correlation analysis of sample chemistry from the Bartlett Point area shows a very strong As-Sb-Hg-Tl association; Mo has a lower correlation coefficient and may also be included. Zinc and copper also show an association (Table 3). The highest values for arsenic come from the more oxidized breccias. In general, concentrations of As, Cu, Mo, Sb, Tl, Zn, Cd, Se, Sn, and Te are higher at Bartlett Point proper than in samples immediately to the south in Rock Creek. Samples from Bartlett Point proper gave the highest recorded values for As, Cu, and Sb of all five areas. Samples from Rock Creek tend to have greater amounts of Ag, Au and Pb, and gave the highest recorded values for Ag and Au of all the areas. In Rock Creek the samples were from silicified limestone and conglomerate of the White Knob Limestone. Most samples were not iron stained or brecciated, but jarosite, barite and fluorite were identified in one oxidized and brecciated zone.

Lehman Butte

Fourteen rock samples taken from Lehman Butte are silicified jasperoid breccia from the White Knob Limestone on the east side of a northwest-trending fault. Samples taken on a ridge east of Lehman Creek are from oxidized jasperoid outcrops in highly altered limestone, near a northwest-trending fault. Where this fault cuts the overlying Challis Volcanics, the rocks are brecciated and highly silicified, and the zone has been locally prospected for precious metals. Correlation analysis of the data suggests three general groupings: As-Hg-Sb-Zn, Ag-Au-Cu-Hg, and Cu-Mo-Pb, all with high correlation coefficients (Table 3). The low number of samples (14) dictates a low confidence level for these groupings. However, at Lehman Butte a large number of samples contain the element suite Ag-As-Au-Hg-Sb-Tl in significant amounts (Table 2).

Sheep Canyon

Twenty samples were analyzed from Sheep Canyon. Most samples were massive jasperoid in carbonate rocks with some healed jasperoid breccia with cross-cutting quartz veins. Gold-silver is the only strong geochemical association (Table 3). The data also show associations of...
Table 2. Minimum and maximum range in ppm of elements for each of five areas near Mackay, Idaho: Min = minimum value detected; Max = maximum value detected; N = number of samples with detectable values.

<table>
<thead>
<tr>
<th>Element</th>
<th>Bartlett (34)</th>
<th>Poi-t</th>
<th>Lehman Butte (14)</th>
<th>Sheep Canyon (20)</th>
<th>Grouse (32)*</th>
<th>Timbered Dome (10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ag</td>
<td>&lt;0.02 - 16.50</td>
<td>32</td>
<td>0.01 - 6.17</td>
<td>0.036 - 1.92</td>
<td>0.067 - 2.15</td>
<td>0.07 - 0.85</td>
</tr>
<tr>
<td>As</td>
<td>2.17 - 1306.00</td>
<td>34</td>
<td>2.06 - 398.0</td>
<td>14.80 - 269.0</td>
<td>5.00 - 630.0</td>
<td>1.10 - 263.0</td>
</tr>
<tr>
<td>Au</td>
<td>0.001 - 0.16</td>
<td>32</td>
<td>0.002 - 0.03</td>
<td>0.005 - 0.04</td>
<td>0.002 - 0.03</td>
<td>0.003 - 0.009</td>
</tr>
<tr>
<td>Cu</td>
<td>2.79 - 127.00</td>
<td>34</td>
<td>1.24 - 62.0</td>
<td>4.82 - 19.30</td>
<td>3.05 - 8.82</td>
<td>4.96 - 77.10</td>
</tr>
<tr>
<td>Hg</td>
<td>0.097 - 6.72</td>
<td>27</td>
<td>&lt;0.09 - 4.59</td>
<td>0.09 - 3.28</td>
<td>0.04 - 54.00</td>
<td>0.249 - 4.11</td>
</tr>
<tr>
<td>Mo</td>
<td>0.88 - 80.30</td>
<td>34</td>
<td>0.34 - 20.7</td>
<td>0.77 - 21.7</td>
<td>0.80 - 32.1</td>
<td>0.37 - 10.8</td>
</tr>
<tr>
<td>Pb</td>
<td>0.62 - 2.06</td>
<td>34</td>
<td>0.77 - 22.0</td>
<td>1.74 - 25.0</td>
<td>2.85 - 45.0</td>
<td>1.81 - 10.2</td>
</tr>
<tr>
<td>Sb</td>
<td>&lt;0.25 - 135.00</td>
<td>33</td>
<td>0.32 - 62.0</td>
<td>1.20 - 42.7</td>
<td>&lt;0.51 - 75.7</td>
<td>0.37 - 9.10</td>
</tr>
<tr>
<td>Ti</td>
<td>&lt;0.47 - 5.37</td>
<td>17</td>
<td>&lt;0.44 - 7.0</td>
<td>&lt;0.44 - 4.20</td>
<td>0.48 - 17.7</td>
<td>0.46 - 0.71</td>
</tr>
<tr>
<td>Zn</td>
<td>0.95 - 107.00</td>
<td>33</td>
<td>0.89 - 65.3</td>
<td>0.95 - 18.0</td>
<td>&lt;0.95 - 21.8</td>
<td>1.91 - 58.0</td>
</tr>
<tr>
<td>Bi</td>
<td>0.23 - 1.02</td>
<td>4</td>
<td>&lt;0.22 - 3.6</td>
<td>&lt;0.22 - 2.1</td>
<td>&lt;0.22 - 1.3</td>
<td>&lt;0.23 - 0.24</td>
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<tr>
<td>Cd</td>
<td>&lt;0.22 - 1.38</td>
<td>7</td>
<td>&lt;0.22 - 0.83</td>
<td>&lt;0.22 - 1.99</td>
<td>&lt;0.22 - 0.25</td>
<td>&lt;0.23 - 0.29</td>
</tr>
<tr>
<td>Ga</td>
<td>0.46 - 3.52</td>
<td>22</td>
<td>&lt;0.44 - 1.41</td>
<td>&lt;0.45 - 2.52</td>
<td>&lt;0.44 - 0.79</td>
<td>&lt;0.44 - 0.84</td>
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<tr>
<td>Pb</td>
<td>&lt;0.09 - &lt;0.25</td>
<td>1</td>
<td>&lt;0.09 - 0.10</td>
<td>&lt;0.09 - 0.10</td>
<td>&lt;0.09 - &lt;0.10</td>
<td>&lt;0.09 - &lt;0.10</td>
</tr>
<tr>
<td>Pt</td>
<td>&lt;0.22 - 0.50</td>
<td>1</td>
<td>&lt;0.22 - 0.24</td>
<td>&lt;0.22 - 0.37</td>
<td>0.23 - 0.38</td>
<td>&lt;0.23 - &lt;0.24</td>
</tr>
<tr>
<td>Se</td>
<td>&lt;0.90 - 6.76</td>
<td>14</td>
<td>&lt;0.89 - 15.90</td>
<td>&lt;0.90 - 4.15</td>
<td>0.87 - 1.44</td>
<td>0.91 - 1.86</td>
</tr>
<tr>
<td>Sn</td>
<td>&lt;0.44 - 3.17</td>
<td>12</td>
<td>&lt;0.44 - 4.14</td>
<td>&lt;0.46 - 2.66</td>
<td>&lt;0.49 - 0.46</td>
<td>&lt;0.46 - 0.48</td>
</tr>
<tr>
<td>Te</td>
<td>&lt;0.44 - 1.00</td>
<td>2</td>
<td>&lt;0.44 - 7.70</td>
<td>&lt;0.44 - 0.50</td>
<td>&lt;0.49 - 0.46</td>
<td>&lt;0.46 - 1.22</td>
</tr>
</tbody>
</table>

*13 of these samples were analyzed for Ag, As, Au, Hg, and Sb only.

As-Mo Zn and Hg Mo Tl, but the importance of the data is the presence of the suite Ag-As-Au-Hg-Sb-Tl in a majority of the samples (Table 2). A small prospect at the eastern end of the canyon contains antimony minerals including stibiconite. A sample collected in the western part of the area had the highest concentration of molybdenum (121 ppm) of any sample in the study.

Grouse

Data from thirty-two samples collected near the town of Grouse show a very strong Ag-Pb association, a strong Au-Hg association, a strong As-Sb-Tl association and a Cu-Mo-Zn association. The last two associations are linked by a moderate correlation between Cu and Tl. The data are not adequate to confidently define these associations because there appear to be three distinct groups of samples based on geography and local geology. Samples with the highest values for Ag-Pb (0.40-2.15 ppm Ag, 100-452 ppm Pb) are generally located at the southern end of a large jasperoid body. These samples also have 0.30-1.35 ppm Bi. Jaspersoid outcrops in this area are silicified McGowan Creek, Middle Canyon, and Scott Peak Formations. Samples vary from dense, gray, nearly cryptocrystalline jasperoid to coarser-grained, maroon, iron-oxide stained jasperoid to brecciated jasperoid. Samples from the northern end of the same jasperoid body had the highest values of Cu and Mo in the Grouse area, and Ga was detected in every sample. Mineralization of the northern group was probably controlled by a north- to northwest-trending fault, and the jasperoid appears to have replaced rocks of the Snaky Canyon or Surrctt Canyon Formations. Most of the samples were collected from gray, silicified limestone or conglomerate with maroon iron-oxide staining. One sample, from an outcrop of jasperoid breccia, is the least mineralized for this area. The third group of samples for this area was collected near Waddoups Canyon. These samples are mostly gray, brecciated jasperoid that replaced rocks of the Snaky Canyon Formation. Samples collected near Waddoups Canyon yielded the highest gold concentrations (0.01 to 0.03 ppm) for the Grouse area, and one sample yielded the highest value for mercury (54 ppm) in the Mackay area.

Timbered Dome

Correlation analysis of the ten samples collected from jasperoid outcrops near Timbered Dome shows a strong element grouping that includes Ag, As, Au, Cu, Hg, Pb, Sb, and Zn (Table 3). The small number of samples dictates that a low level of confidence be assigned to this association. The importance of the data is that the element suite Ag-As-Au-Hg-Sb is present in most samples. Only one sample contained detectable Tl.

The jasperoid bodies at Timbered Dome are within the McGowan Creek and Middle Canyon Formations and apparently aligned along north- to northeast-trending
Table 3. Correlation coefficients for pairs of significant elements, listed according to the five geographic areas that were sampled near Mackay, Idaho.

<table>
<thead>
<tr>
<th></th>
<th>All 110 Samples</th>
<th>Bartlett Point 34 samples</th>
<th>Lehman Butte 14 samples</th>
<th>Sheep Creek 20 samples</th>
<th>Grouse area (32 samples)</th>
<th>Timbered Dome (10 samples)</th>
</tr>
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<tbody>
<tr>
<td>Ag</td>
<td>1.00</td>
<td></td>
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SUMMARY AND CONCLUSIONS

Many jasperoid bodies in the Mackay area are similar to jasperoids in the sediment-hosted precious-metal deposits of Nevada. Mackay jasperoids are replacements of limestone, shale, sandstone, carbonaceous limestone, and calcareous carbonaceous shales. The degree of silicification varies from patchy, silicified areas to dense, massive jasperoid. Many jasperoid bodies show at least two generations of brecciation and silicification. Quartz and calcite veins are common, and minor barite, fluorite, jasperite, and stibiconite are present.

Jasperoid bodies are commonly aligned along high-angle regional faults and were probably formed from solutions moving along and outward from these faults. The volcanic rocks are brecciated and silicified along faults, and commonly have quartz and carbonate veins. Intermediate to silicic plutonic and hypabyssal intrusive rocks are locally present in the area along high-angle fault systems.

Geochemistry of jasperoids in the Mackay area is characterized by the presence of Ag, As, Au, Cu, Hg, Mo, Pb, Sb and Zn in most samples from all five geographic areas. Thallium is present in most samples from four of the five areas.

The trace-element association As-Au-Sb-Hg-Tl occurs in nearly all sediment-hosted, disseminated precious-metal deposits (Bagby and Berger, 1985, p. 194), and these elements also tend to concentrate in the upper parts of geothermal systems (Silberman and Berger, 1985, p. 206). Hot springs type mineral deposits probably all contain the same suite of elements, plus Mo (Berger and Silberman, 1985, p. 246).

Correlation analysis (Table 3) for all samples defines two strong associations: As Sb Ti and Cu Zn. Associations within each of the five geographic areas are not well-defined, because of inadequate sampling. Most of the within-area associations include As, Sb, Hg and Tl, and commonly Au, Ag, Mo, Cu, or Zn. There is a suggestion that base-metals, especially Cu and Zn, form their own associations, and rarely occur with Ag and Mo. Element associations among the areas are probably due to several factors including lithology and chemistry of the host rocks, source and timing of the mineralizing faults. The jasperoid ranges from nearly unaltered, massive, gray, and cryptocrystalline to very altered, iron-oxide stained and brecciated. The lowest concentrations of elements are from the least altered samples. A small prospect pit near the southwest edge of this group of jasperoid bodies yielded the highest concentrations of Ag, Au, Cu, Hg, Mo, Pb, Zn, Se, and Te of all the samples from Timbered Dome.
solutions, distance from the source, pressure-temperature
evolution of the fluids, and structural setting.

The genesis of jasperoid bodies in the Mackay area is
not yet well understood. Nelson and Ross (1968, p. A22)
suggest that some jasperoids formed from fluids
migrating downward from the Challis Volcanics into
underlying limestones. Betty Skipp suggests that some
jasperoid may have been formed by meteoric water in
karst zones as well as in fault zones. Detailed studies of
the geochemistry, alteration, lithology, structure, and
isotopic composition of the country rocks near jasperoids
and high-angle faults are needed to determine the origin
of each jasperoid body.

The suite of elements Ag, Au, As, Hg, Sb and Tl are
consistently present, commonly in anomalous concentra-
tions. This suggests that some, if not most, jasperoids
of the Mackay area formed through the replacement of
sedimentary rocks by silica and associated elements that
were carried in hydrothermal solutions.

Trace metals in jasperoid, together with known vein-
type metal deposits along high-angle faults indicate that
some of the solutions were metal-bearing. These
solutions may also have formed precious-metal deposits
in altered but nonsilicified country rock near the
jasperoids, in silicified country rock, or in veined and
brecciated jasperoid.

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