GEOMORPHIC EVOLUTION AND HISTORY OF POLLUTION IN THE VICINITY OF THE SUMMITVILLE DISTRICT, SAN JUAN MOUNTAINS, COLORADO

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The history of natural pollution in the Summitville vicinity in the eastern San Juan volcanic field, Colorado, is closely tied to the igneous and hydrothermal activity, and to the subsequent geomorphic evolution of the area. This area has had a complex geologic history that progressed from intense volcanic, intrusive igneous, and related hydrothermal activity in late Oligocene and earliest Miocene time, to long-continued erosion and episodic tectonism throughout the remainder of Cenozoic time. Rocks associated with some of the Oligocene-early Miocene igneous centers were highly altered and locally mineralized during igneous activity, and these areas were variously exposed and subjected to weathering and erosion as the topography subsequently evolved. Inasmuch as hydrothermally altered rocks are potential sources for substances deleterious to human activities (pollutants), the history of "pollution" from this general area has varied in response to changing geologic and climatologic environments. The present surge of mine-related pollution from the Summitville district reflects only the latest episode in a long-term sequence of events, and is built on a base of natural pollution that has waxed and waned for nearly 30 million years. Unfortunately the present man-caused surge exacerbates a naturally-occurring surge that has resulted from accelerated deep erosion and enhanced weathering during the last 5-4 million years.

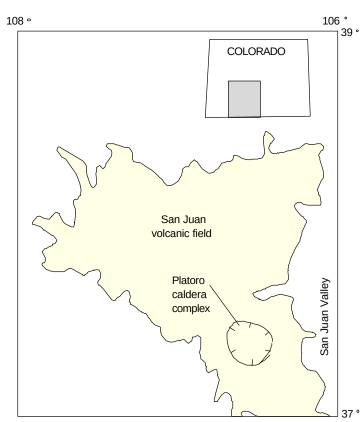

Figure 1. Index map showing San Juan volcanic field.

The Summitville district and its surroundings are within or adjacent to the Platoro caldera complex in the eastern San Juan volcanic field (figs. 1 and 2) (Lipman, 1974; 1975). This complex developed within a cluster of early to middle Oligocene andesitic volcanoes, and in response to a sequence of violent pyroclastic eruptions that emplaced the several ash-flow tuff members of the Treasure Mountain Tuff (30-29 Ma). The final caldera collapse formed the small Summitville caldera (north of modern Alamosa River, fig. 2) in the northern part of the complex, and this feature was in turn filled with a sequence of dense andesitic lava flows. Granodioritic magmas invaded the caldera complex toward the end of its development, and formed shallow intrusions along different caldera structures. Several of these intrusions localized convecting hydrothermal cells which altered, and in places mineralized, large bodies of volcanic and intrusive rock. Locally preserved siliceous sinter and other manifestations of thermal activity (Bove et al., 1995) indicate that some hydrothermal activity vented to the surface to form solfataras that were strongly acidic and probably metal-bearing.

Several million years later, at 23-21 Ma (Mehnert et al., 1973), volcanic activity was renewed along the western margin of the Summitville caldera where viscous silicic dacite to rhyolite lava was extruded to form volcanic domes and thick lava flows. The main extrusion formed the South Mountain dome ((5) on fig. 2) in the northern part of the complex, and emplacement of this dome was followed by intense hydrothermal activity in its core to form the altered and mineralized rocks that have been mined in the Summitville district (Gray and Coolbaugh, 1994). Hydrothermal activity took place within the then-new volcanic edifice, and inescapably vented to the surface as a solfatara. The intense acid-sulfate character of alteration, and the deposition of arsenic, copper, and other metals within a few hundred meters of the surface (Gray and Coolbaugh, 1994) strongly suggest that this solfatara also was the source of toxic effluents. Gray and Coolbaugh (1994) cite specific evidence for local deposition in a hot spring environment.

The main areas of altered rock of interest to the present report, as shown on fig. 2, are: (1) Jasper area; (2) Klondike Mountain (KM)-Lookout Mountain (LM) (Iron, Alum, and Bitter Creeks basins of Bove et al., 1994); (3) Crater Creek: (4) Platoro district (just south of Platoro); and (5) Summitville district.

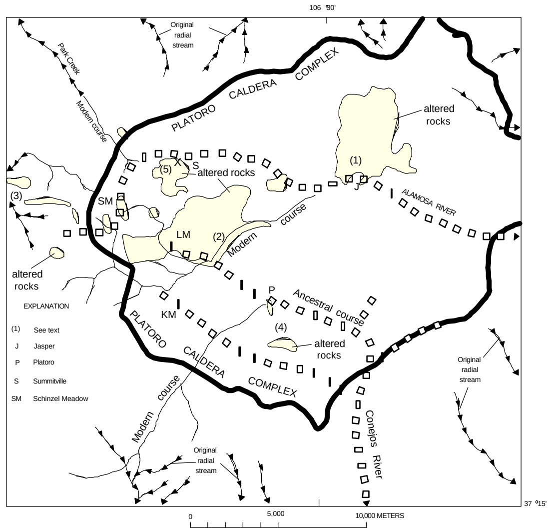

Figure 2. Relationship of drainage changes to geologic features in vicinity of Summitville Mining District, Colorado.

The Platoro caldera complex in early Miocene time probably was characterized by immaturely developed topography only slightly modified from the original constructional volcanic surface. The west-central part of the subsided area was covered by thick lava flows and volcanic domes related to the early Miocene (23-21 Ma) Summitville centers, which covered at least some of the Oligocene altered and mineralized areas (especially area (2)). The early Miocene mineralized area on South Mountain dome (5) was at least in part covered by slightly younger and related lava flows (Steven and Ratte', 1960). What minor external drainage that existed probably breached the wall of the caldera complex near the courses of the ancestral Alamosa and Conejos Rivers (fig. 2).

Most of the Miocene was marked by erosion which established two main outflowing drainage systems from the caldera area, an east-flowing ancestral Alamosa River, which drained the northern and central parts of the complex, and a south-flowing ancestral Conejos River, which drained the southern part of the complex. The divide between these systems was formed mainly by hills residual from the Summitville volcanic domes and lava flows. Both ancestral rivers flowed through broad open valleys flanked by rounded hills that stood from a few tens of meters to as much as a kilometer above the valley floors. Remnants of the valley of ancestral Alamosa River are exceptionally well preserved in the present landscape as the broad meadow just north and west of Summitville, and Schinzel Meadow (Flat) near the western margin of the caldera complex. The ancestral Conejos River valley is best manifested by broad wind gaps across the top of Klondike Mountain (KM on fig. 2) in the south-central part of the caldera complex. Steven et al. (1995) date this high-level late Miocene surface as having reached its approximately present configuration by about 5-4 Ma.

Miocene erosion greatly modified the volcanic domes and lava flows related to the Summitville centers, but did not cut deeply into the underlying rocks of the caldera complex. Thus the early Miocene altered and mineralized rock on South Mountain (5) was exposed over nearly the full topographic range that exists today, but the older altered areas ((1), (2), (3), and (4)) were not deeply incised below levels where original surface-related features have been recognized. In particular, the Klondike Mountain (KM)-Lookout Mountain (LM) area was covered by younger lava flows for much of the Miocene, and as it was progressively exhumed, only the upper parts of the underlying rocks were exposed to weathering and leaching. These considerations (time available vs shallow depth of erosion) suggest that pollution during Miocene erosion was at a relatively low ebb, and perhaps came mostly from the more deeply exposed Summitville area (5). Whatever contributions came from the Jasper area cannot be assessed, but here also they would have been limited to those available in the upper and originally near-surface parts of the body of altered rocks.

Beginning after 5 Ma (latest Miocene), the San Juan volcanic field was uplifted sharply and tilted eastward toward the San Luis Valley (Steven et al., 1995). The late Miocene surface described above now can be recognized from altitudes of near 2,500 m at the east edge of the mountains, to 3,500 m in the paleovalley near Summitville. The uplift rejuvenated erosion along all streams in the mountain area, and caused sharp downcutting of canyons. Depth of erosion is everywhere approximately proportional to uplift shown by relative levels of the late Miocene surface. Within the caldera complex, these canyons are now steep-walled, as much as a kilometer deep, and except where widened by glaciers, show little evidence for lateral erosion. Downcutting still dominates erosion.

Accelerated downward and headward erosion was strongly influenced by differential rock resistance to erosion, and this has resulted in some dramatic changes in stream courses. Most important in influencing changes in natural pollution, a minor western tributary to ancestral Alamosa River tapped headward into soft highly altered rock in the Klondike Mountain-Lookout Mountain area (2) which was vastly more susceptible to erosion than the resistant andesite lava flows underlying the broad valley east of Summitville. This tributary extended rapidly headward and downward, and captured in turn the headwater tributaries of ancestral Conejos River, and then the uppermost parts of ancestral Alamosa River in Schinzel Meadow (Flat). The captured water enhanced erosion even more, and the sharp canyon between Klondike Mountain (KM) and Lookout Mountain (LM) was cut to a depth of more than a kilometer, exposing walls of soft highly altered and pyritized rock (Bove et al., 1995; this volume).

At the same time, the diminished ancestral Conejos River was unable to maintain its course across Klondike Mountain (KM), and a tributary from the west that entered near the present town of Platoro became the dominant source of water, creating the present anomalous U-shaped (plan view) headwaters configuration of modern Conejos River. Park Creek on the northwest side of the caldera complex did not breach into the caldera area until after uplift and rejuvenation; at that time it extended into the area of the late Miocene valley west of Summitville to capture a short segment of the greatly underfit stream that then flowed there.

Downstream from the area of complex stream captures, the Jasper area (1) was deeply entrenched during rejuvenation, and the north wall of the resulting canyon exposes highly altered rock to a height of nearly 1.5 km.

The net effect of enhanced erosion during the last 5 million years has been to divert a significant amount of water from ancestral Conejos River to a realigned Alamosa River, a miniscule loss of water to Park Creek, and deep erosion and exposure of several highly altered and mineralized areas that formerly were relatively minor sources of natural pollution. Alamosa River thus gained not only water, but progressively increasing contributions of polluting acid and metals. Bove et al. (1995; 1996; this volume), Walton-Day et al., (1995), and Barry (1996) have documented the sources, components, and concentrations of this natural pollution from the Klondike Mountain-Lookout Mountain area (2) under modern conditions. Comparisons with similar factors in adjacent areas are difficult because of the many independently acting geological, chemical, environmental (largely weather) variables (see cited references for details); however, as a not necessarily typical example, Bove et al. (1996, pl. 9) show that at least in the summer of 1994 the loading factor (mg/sec) of sulfate in the Alamosa River just above the inflow of water from Summitville was about a quarter of that below that inflow.

The upper Alamosa River area thus has been a source of pollutants for nearly 30 million years. Rates, quantities, and concentrations have varied according to vagaries of weather and geomorphic evolution, but even total mitigation of present-day mine-related pollution (Gray et al., 1994) would only partly modify what has been and will continue to be a naturally inhospitable environment.

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