Anatomy of Ivanpah Spring,

Clark Mountain, San Bernardino County, California

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Abstract

Ivanpah Spring is located in Precambrian gneissic granite in the eastern foothills of Clark Mountain within the Mojave National Preserve. The country rock has been modified immediately upstream and downstream of the dike, the down stream portions being heavily altered by hydrolysis of country rock to a yellowish-brown dusty coating of quartz, caliche and clay. Spring hydrology appears to be associated with or controlled by a pegmatite dike of K-feldspar and quartz.

1. Introduction

Ivanpah Spring[1] is one of many seeps in the Clark Mountain area. The spring is 15 kilometers (km) SW of the intersection of I-15 and the California-Nevada border (Primm), and 8 km north of Mountain Pass, CA (Figure 1). It is about two km northeast of the Clark Mountain Fault System[2] and a km southwest of the Ivanpah Fault[3] in a former gold and silver mining area with many diggings and ruins[4]. The Ivanpah ghost town at Willow Spring is 0.7 km northwest of Ivanpah Spring. *Ivanpah* means "good water" in southern Piute[5].

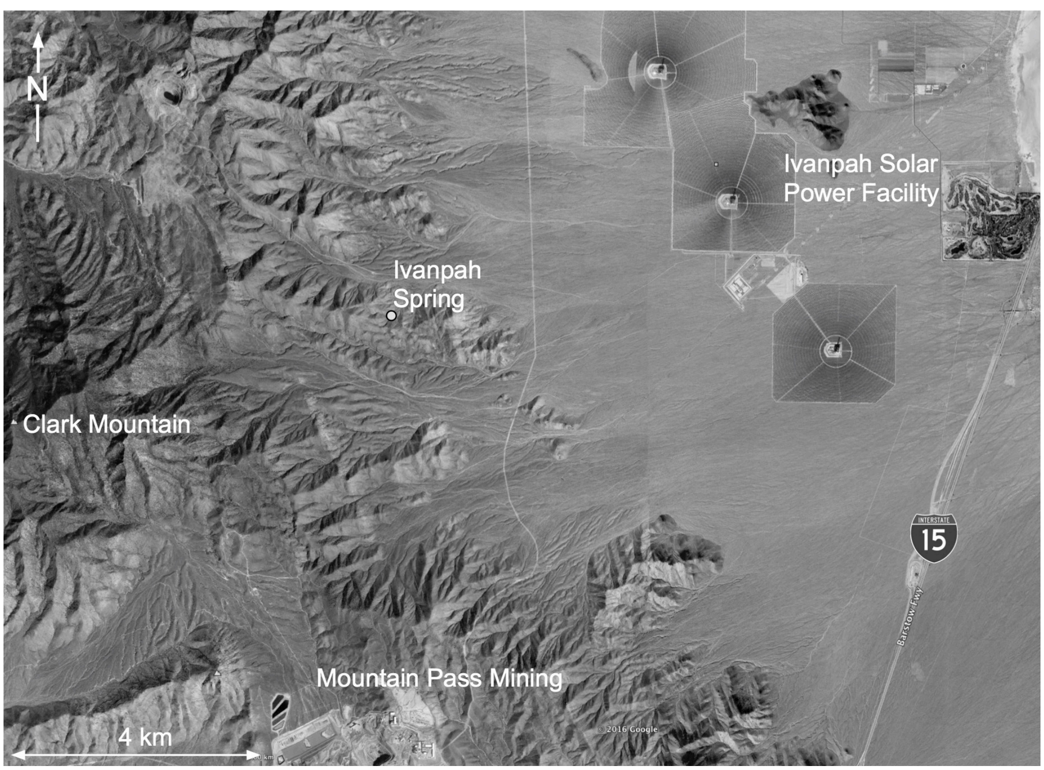

Figure 1. Location of Ivanpah Spring (adapted from Google Earth imagery). The NNW trending Clark Mountain Fault system is evident SW of Ivanpah Spring.

The spring lies in a Precambrian metamorphic complex of foliated gneissic granite with occasional pink K-feldspar pegmatite dikes[3]. In this paper we describe the spring's geology and topographic setting, present a geologic section sketch and discuss a number of aspects of water movement in the spring's vicinity.

2. Methods

The site was visited several times during the winter of 2016-2017, both before and after heavy rains in the area. The elevation profile along the lowest part of the ravine (thalweg) was measured, the surface geology mapped and rock samples were taken from outcrops above and below the spring for laboratory analysis. Samples were cut and polished to expose the mineralogy. Field tools were a Garmin 60csx GPS receiver, laser range finder and surveying equipment. In the laboratory we used a tile saw and polishing tools, a scanning electron microscope (SEM) and an energy-dispersive X-ray spectrograph (EDS) for elemental composition and for general mineral identification.

3. The spring and its immediate surroundings

Figure 2 shows a surveyed geological sketch map that summarizes our main findings. We present it here to identify different rock units in the figures that follow.

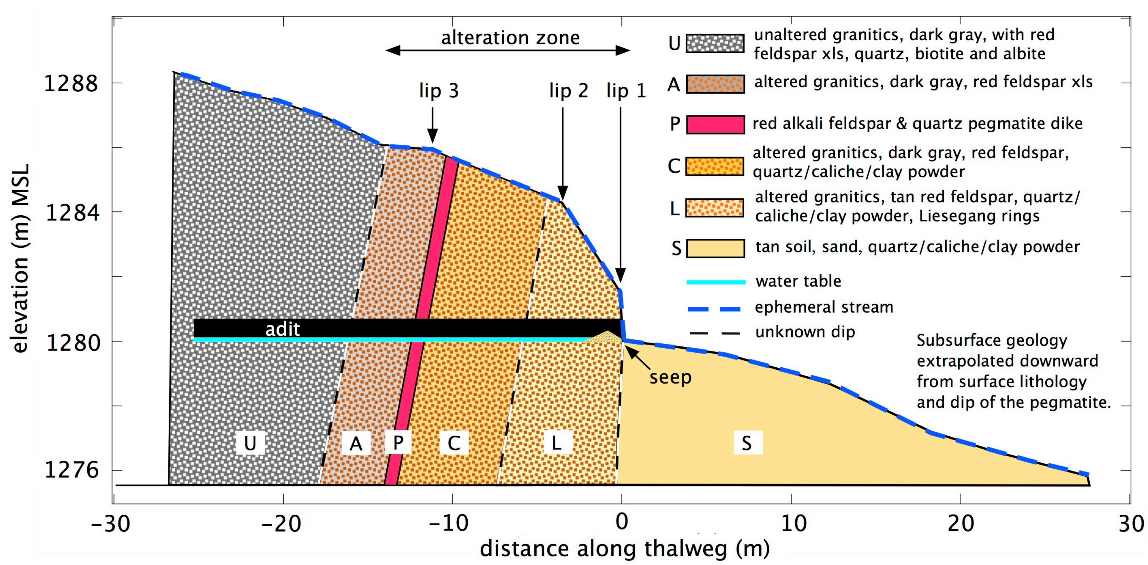

Figure 2. Surveyed elevation profile of the thalweg with rock units and water levels. Ivanpah Spring is indicated as the "seep". As judged by eye based on color, texture, gross mineralogy and the presence of yellow-orange powder, there were six different rock units (U, A, P, C, L and S). None of the subsurface dips are known, so the U-A, C-L and L-S contact dips are indicated with dashed lines. The A-P and P-C

contact dips are also similarly uncertain because the shape of the subsurface pegmatite could not be determined.

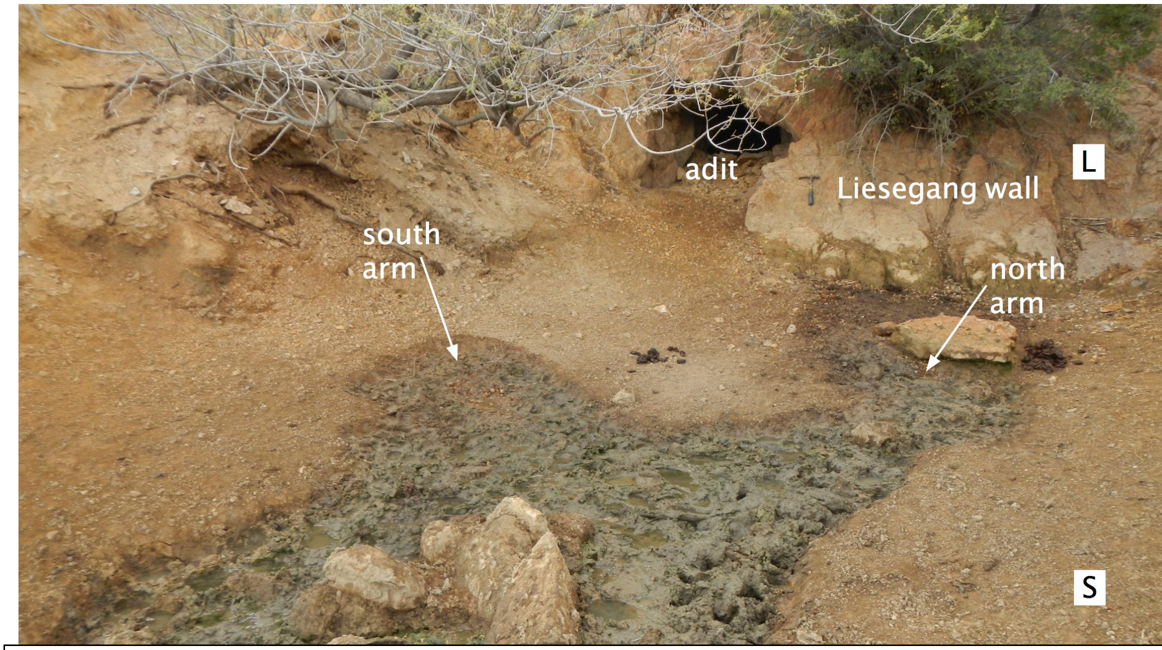

Figure 3. Mouth of Ivanpah Spring. Two seep arms merge to form the spring. One emerges from the base of the Liesegang wall, the other surfaces through tan-yellow soil that is sometimes covered in cow dung, as seen here as dark mud. The surface topography just below the adit changes as the ephemeral spring cascades down over its mouth and deposits sediment, sometimes making the two arms appear to merge. Note rock hammer on Liesegang wall for scale. Labeled rock units are from Figure 2.

The spring, a low flow rate (~1 liter/minute) seep, emerges from near the base of a rock wall (Figure 3) and flows down a linear ravine (heading of 56° E of N) for about 60 meters before sinking below ground into alluvial soil. Both upstream and downstream, the ravine wall contains competent outcrops. Float has been carried from the mountains above by the ephemeral stream that appears to be responsible for cutting the ravine. The rock in the spring's vicinity upstream and down stream and including the alteration zone is heavily jointed gneissic granite.

The spring has two branches, one emerging from soil adjacent to a well dug by miners (south arm) and the other (north arm) surfacing at the base of a vertical wall (~2 m high) of altered granite containing abundant Liesegang Rings[6,7] (Figure 4). The mouth of the spring lies within what appears to be a hydrologic alteration zone (Figure 2). It extends about 14 m along the ravine, which contains an obvious red pegmatite dike transecting the ravine (Figure 5). The surface exposure of the dike is about 11 m (horizontally) upstream of the seep.

Figure 4. Small area of the Liesegang wall showing concentric ring structure. The parent rock is gneissic granite and it has been chemically altered by hydrolysis. Labeled rock unit is from Figure 2.

The dike is hard and compact, and is composed of K-feldspar and quartz (leucogranite, also called alaskite). Its surface exposure is about half a meter wide. With a dip and strike of 79°S and N30W, the dike is nearly perpendicular to the direction of stream flow.

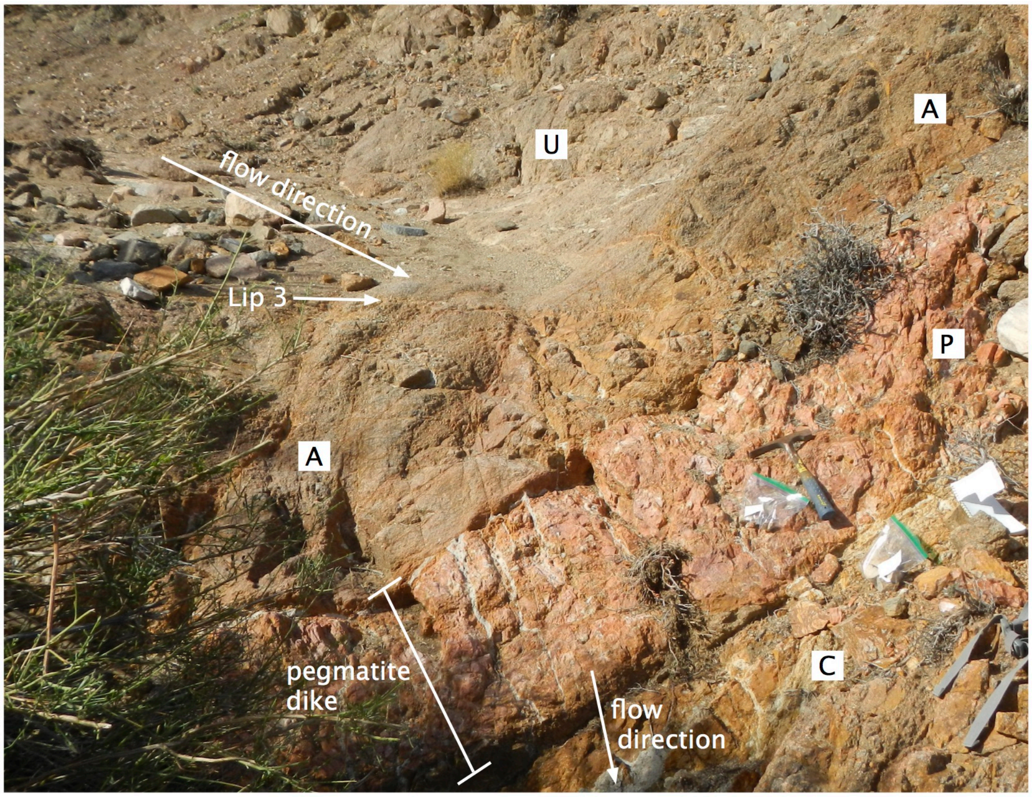

Figure 5. View of altered region. Note rock hammer (right) for scale. The red K-feldspar pegmatite dike P has been intruded into the gneissic granite country rock U, A and C. Rocks A and C appear to be altered by hydrolysis and C seems to have been more heavily or differently altered. Labeled rock units are from Figure 2.

The colors of the exposed rocks along the thalweg are markedly different above and below the dike (Figure 6). Outcrops lining the ravine downstream of the dike and extending about eighty meters show significant coatings of yellow-orange powder composed of clay, quartz, caliche (effervesces in HCl) and possibly minor amounts of Fe_XO_Y. Rocks above the dike do not have this coating. Some of the downstream deposits were seen above the elevation level of the present day spring.

The adit is 26 m long and extends horizontally into the rock with a bearing from the entrance of about 230°. Although there is water on the adit floor, water does not flow out because a small mound of local rock rubble has been piled against the entrance. An open well sits atop the southern shoulder of the ravine approximately 13 m east of the seep. The well water's surface elevation is the same as the water in the adit and the seep to within the measurement uncertainty (±10 cm). Well water depth is unknown. At no location above the seep was any water seen coming out of the rock, nor was there any standing water or wet soil upstream of the dike except immediately following a rain.

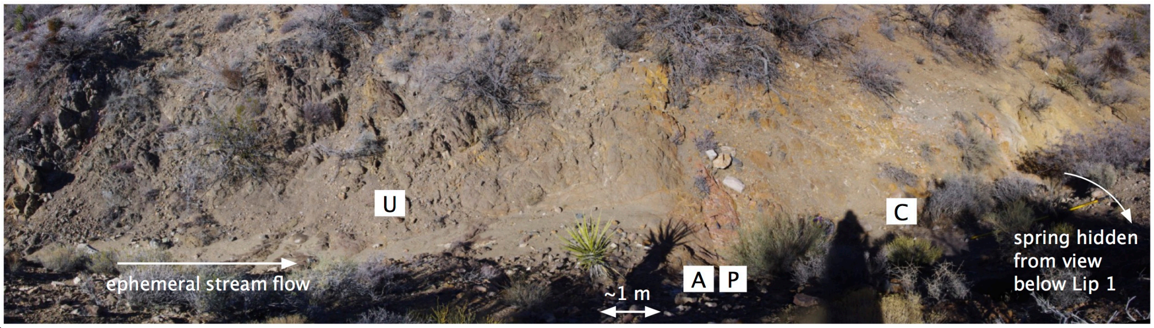

Figure 6. Panoramic view of the ravine and alteration zone. Labeled rock units are from Figure 2. The pegmatite P is slightly right of center and is exposed for several meters on either side of the ravine. To the left (upstream), the unaltered country rock U is more or less uniformly brown at this scale, but to the right of the pegmatite (downstream) the surface rock is heavily coated with yellow-orange powder C. Both components persist for about eighty meters downstream before gradually disappearing as the original unaltered country rock becomes evident, the same as the unaltered rock about five meters upstream of the dike. Photograph taken upstream of the spring, here hidden from view below Lip 1 (Figure 2). The enhanced vegetation at far right marks the spring's emergence.

Thalweg soils differed markedly above and below the dike. The upstream soil is sandy, well drained and the grains do not adhere to each other. It is composed of quartz and feldspar, small amounts of biotite and a number of components that probably originated upstream, perhaps from a significant distance. The downstream soil is soft, crumbly and somewhat cohesive, though easily reduced to powder between the fingers. It is composed of the same material that coats the downstream granite: powdery quartz, caliche and clay. The downstream sample was taken as close as possible to the thalweg, but owing the presence of manure, it was necessary to scrape it from the surface about a meter to one side of the spring flow. The overall impression is that the differences in soils are the result of hydrolysis by the spring. The downstream soil is most likely a groundwater discharge deposit, the evaporation of water from the seep leading to deposition of metal cations, carbonates, etc.

4. Discussion

As exposed on the surface, the pegmatite dike is the hardest and least fractured unit, and together with an altered unit A it forms a lip (Lip 3, Figure 2) with a sharp drop in the thalweg. With an obvious dike immediately upstream of the Liesegang wall and seep, the spring would seem to be a *joint or fracture* spring[8]. Furthermore, the sharp topographic change of the thalweg in the alteration zone seem unlikely to be coincidental to the spring's emergence. In view of the dike's apparent water impermeability, its location suggests that it is acting as an aquatard to ground water. Yet water is getting though the dike to form the seep, so there are probably cracks in the dike below the surface through which water can pass to the mouth of the spring.

It also seems likely that groundwater encountered the dike and was forced upward to discharge on the surface. Such a mechanism could explain the yellowish deposits downstream of the dike.

The spring was undoubtedly present before any mining activity in the area. Topography and Liesegang rings tell us that. The reason why the adit was dug is not known but it could have been to increase the flow rate of the spring and to supply miners with water. The adit and drainage mechanism is similar to excavations known as qanats that have been used for thousands of years in desert regions to passively extract water from sloping terrain[9]. Regardless of the reason, the adit may have locally modified the geometry of underground water movement and the seep itself.

The yellow powder (quartz, caliche and clay) is seen on downstream outcrops that are above the elevation of the current seep. This may suggest that the water table and/or seep were once at a higher elevation. This could be explained by down cutting by the ephemeral stream that lowered the ravine's elevation, leaving exposed the outcrops with yellow powder on either side that we see today. Alternatively, the current location of the nick point at the Liesegang wall could be the result of headward erosion by the ephemeral stream that is slowly moving upstream, especially if the stream flow rate was much higher during the last glacial period.

Although the dip of the pegmatite at the surface has been measured (~79° S), its subsurface geometry is not known. Therefore the dips of the U-A, C-L and L-S contact are uncertain. It may be possible to retrieve the dips by measuring where the contacts intersect the adit. Being 26 meters long, the adit would appear to extend through the entire alteration zone.

Acknowledgements

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