PAINTING YOSEMITE VALLEY: A CASE STUDY OF ROCK COATINGS ENCOUNTERED AT HALF DOME

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Abstract: No prior research has documented the different types of rock coatings in Yosemite Valley, despite the evident black streaks down Yosemite Falls, the light granitic rock exposed by recent rock falls contrasting with dark rock coatings, and the millions of visitors who have photographed the coated rocks of Yosemite. This paper identifies the types of rock coatings found on Half Dome, in Yosemite Valley, assesses the hypothesis that the rock coatings of Yosemite are consistent with the landscape geochemical model of rock coating formation, and considers the relevance of equifinality. Eight types of rock coatings were identified: case-hardened surfaces, heavy metal skins, iron films, lithobiontic coatings, oxalate crusts, manganiferous rock varnish, silica glaze, and anthropogenic pigments. The landscape geochemical model of rock coating formation and the concept of equifinality both proved useful in this investigation.

INTRODUCTION

Visitors to Yosemite Valley viewing bare rock granitic monuments (Fig. 1) are told in signage and interpretive talks of its glacial history, of the pressure release shells of Royal Arches, of rock falls, and sometimes of the possible explanations for dome forms. Rarely mentioned, however, are those streaks that paint Half Dome, El Capitan, and every other bare rock surface. Yet, Yosemite Valley would look very different if all rock surfaces had the light color of granite. Consider a recent rock fall and Yosemite Falls, where the black rock coatings contrast with fresh exposures of granodiorite (Fig. 2).

This research sought, first, to identify the different types of rock coatings that may be found in Yosemite Valley. There are 14 basic types of terrestrial rock coatings, and each basic category contains dozens of variations in chemistry and structure (Dorn, 1998). No prior research has established the nature of rock coatings that paint Yosemite Valley. As a start to this basic identification of Yosemite's biogeochemical landscape of rock coatings, we focus on one particular landform—Half Dome. After documenting the different types of rock coatings on Half Dome, we assessed whether Yosemite's rock coatings falsify or are consistent with the landscape geochemical model of rock coating formation (Dorn, 1998). We also present preliminary thoughts on the hypothesis of equifinality—that in an open system,

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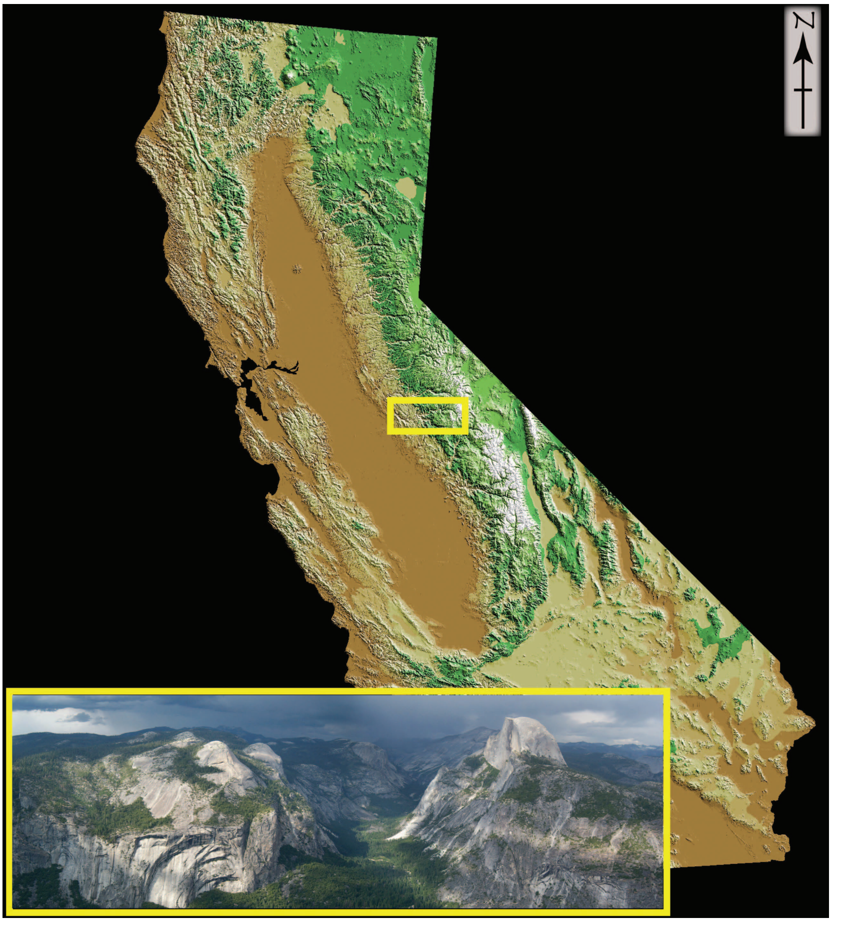

Fig. 1. Yosemite Valley, located in the western Sierra Nevada Range, California. The photograph at the bottom is Yosemite Valley as viewed from Glacier Point. Half Dome is the largest peak exposed on the right (south) side of the valley. Photo by Phillip H. Larson.

the end state of rock-coating development in Yosemite can occur through different processes.

STUDY SITE

The rock coatings examined in this study could not have existed without the geomorphic events that transformed the landscape into what we observe today. Many of the processes that shaped Yosemite Valley continue to create a new canvas for future rock coatings. Therefore, the rock coatings on Half Dome, and within Yosemite Valley as a whole, are inherently tied to the story of Yosemite's landscape evolution.

The Sierra Nevada largely consists of a Mesozoic granitoid batholith that was not exposed until extensive uplift, tilting, and erosion of overburden brought it to

Fig. 2. Rock coatings provide a dramatic contrast in Yosemite Valley. Left: A recent rock fall in Yosemite Valley generated a talus cone, where talus and the source area display the classic light appearance of granodiorite. The adjacent bare rock faces, however, are blackened by rock coatings. Right: The water spray zone of Yosemite Falls displays a much darker surface due the formation of rock coatings. Photo by Phillip H. Larson.

the surface. Substantial argument exists over the timing of the uplift (Henry, 2009), but the resulting morphology of the Sierra Nevada is highly asymmetric. Gentle western slopes (~3°) of the range contain valleys and canyons, such as Yosemite Valley, carved out by westward-draining streams, whereas the eastern slopes are significantly steeper (up to 25°), with just a few large drainages flowing into the Great Basin (Matthes, 1930; Ericson, 1999).

Extensive periods of Pleistocene glaciation (Muir, 1912; Matthes, 1930; Ericson, 1999; Schaffer, 1999) were responsible for the removal of soil and regolith, exposing fresh surfaces to coating processes. At least three major episodes of glacial advance and retreat are readily accepted for the western slope: Tioga (35–3 thousands of years ago, ka), Tahoe (75 ka–60 ka), and Sherwin (>700 ka). Many other glacial events have been identified on the eastern slope of the range (Bach et al., 1996; Dorn, 1996; Phillips et al., 1996). Schaffer (1999) argued that glaciation had a much smaller impact in carving out the valley than previously thought, an argument that we feel deserves a greater degree of attention than it has received from the Earth science community. For understanding the rock coatings on Half Dome, weathering and mass wasting may be more important than glaciation.

According to the landscape geochemistry model of analyzing the geography of rock coatings, the first and primary consideration is whether rocks are exposed at the surface (Dorn, 1998). Figures 1–4 show that the prerequisite of subaerial exposure

Fig. 3. Photograph taken from the top of Half Dome looking up Yosemite Valley. Note the sheet fractures on Half Dome's vertical face on the right side of the image. Also note the abundance of granitoid domes, or bornhardts, as seen in the center left of the image. Photo by Phillip H. Larson.

was met in Yosemite. In the case of Half Dome, exposure of bare rock faces is the result of a long chain of events.

Along with many of the other granite landforms within the valley, Half Dome is likely a bornhardt (Le Conte, 1873; Twidale, 2007). Bornhardts are domed hills that most commonly occur in plutonic lithologies (King, 1948). Half Dome contains an abundance of sheet fractures (Fig. 3), typical of bornhardts (King, 1948, 1966; Twidale, 2007). These sheet structures, common throughout Yosemite (Bahat et al., 1999), are likely pressure release fractures that occur due to the release of confining pressure on the once deeply buried granite. The vertical sheeting maintains the overall shape of Half Dome over time and creates new surfaces for rock-coating processes (Fig. 4).

Also of importance to weathering and rock coatings is the local climate within Yosemite Valley. Yosemite resides within a Mediterranean climate zone, with most precipitation falling in the winter and early spring. Temperature in the valley bottom (1,209 m elevation) ranges from 8° to 32°C, with annual temperature ranges decreasing with elevation. Precipitation totals increase substantially with elevation, and snow can persist in the higher elevations into August. Precipitation and snowmelt supply water to the ephemeral flows that mobilize and deliver rock-coating constituents. Rock coatings, however, are more dependent on microclimate than

Fig. 4. Half Dome's form is best seen on the left side of the image with the near vertical escarpment on the right. Sheet fractures are common on all aspects of the bornhardt. A line of hikers (center) provides scale. Photo by Phillip H. Larson.

general regional climate. Whether a location receives perennial, intermittent, or no regular overland flow is far more important than, for example, temperature or total precipitation. Unfortunately, we are not aware of the existence of any microclimatic data for our collection sites.

METHODS

Understanding different types of rock coatings found on Half Dome requires a mixture of field work, laboratory preparation, and light and electron microscopy. Field work provides the overall geomorphic context of each small rock chip; thus the field sample needs to be representative of different rock coating contexts found on Half Dome. The lab work provides imagery and chemical analyses of these samples.

Centimeter-sized rock chips were collected from different settings on and immediately proximate to Half Dome. The sample sites were selected per National Park Service guidelines at locations not visible to park visitors, in locations away from the general public, and with reasonable margins of safety. Collection sites included rock surfaces in contact with perennial stream flow, in the splash zones of active waterfalls, from streaks on cliff faces where water flows only occasionally during intense precipitation events, on talus boulders, from vertical joint face surfaces that have spalled recently, from pressure release shells recently exposed by mass wasting of the overlying shell, from pressure release shells that display weathering features such as gnamma pits, from gnamma pits, and within centimeters of anthropogenically emplaced metal undergoing decay where the iron is re-precipitating nearby as an iron film.

The National Park Service required that the rock chips had to be taken from rocks that were almost ready to detach. A rock hammer could not be used, and sampling had to be conducted in a way that was not to be seen by the public. Thus, if a centimeter-sized sample could be removed by simply snapping off a rock fragment with minimal pressure using fingers, the presumption was that it was almost ready for detachment and suitable for sampling.

Rock chips were then subject to a variety of microscopic tools. Rock chips were placed in epoxy and then thin sections and cross sections were prepared. Light microscopy of rock coatings requires that the section be ultra-thin in order to make manganese and iron light transparent; thus, these sections were on the order of under 10 μm in thickness. Secondary electrons (SE) used in a scanning electron microscope (SEM) provide topographic-type images of surfaces and the underlying rock material. Back-scattered electron (BSE) microscopy requires polished, flat cross-sections to image the atomic number (Z), where higher average Z is brighter than lower average Z. The net effect is a BSE image that reveals chemical composition. Energy dispersive spectroscopy (EDS) was used to measure elemental composition of rock coatings. These EDS analyses are pinpoint analyses typically on the scale of a few micrometers.

RESULTS

Eight different types of rock coatings were observed in the field and through microscopic study (Table 1). Figures 5 through 10 exemplify the microscopic views of observed Half Dome rock coatings. These images do not display the full range of textures and chemistries. Rather, they are intended to provide a view of the mode, or the most common expressions of the different natural rock coatings.

The most common rock coatings on Half Dome consist of organisms growing on surfaces, or lithobiontic coatings. Lichens, moss, cyanobacteria, bacteria, and algae all coat segments of Half Dome. However, dark-colored fungi are the most dominant lithobiont form observed. Analysis of samples from black streaks, indicating minor waterfalls, reveals the prevalence of fungi (Fig. 5). Although the fungal mat is only about 10 μm thick, it turns the granite surface completely black.

Rock varnish is not a common rock coating on Half Dome, although it does occur in most of the different geomorphic settings (Table 1). Varnish thicknesses range from less than a micron to more than 50 μm. One of the thicker varnishes observed was collected from the top of a pressure release shell displaying the weathering form of abundant grussification (Fig. 6). This sample came from a small channel a few centimeters wide and deep that hosts snowmelt and ephemeral flow. Note that the biotite had begun to split apart before varnish began to accrete. Biotite oxidation and hydration are important processes in grussification (Isherwood and Street, 1976). The accretion of rock varnish, though, appears to have enveloped the weathered biotite

Table 1. Rock Coatings Observed at Half Dome

Coating	Description	Observed settings
Case hardening	Addition of cementing agent to rock matrix material; the agent may be manganese, sulfate, carbonate, silica, iron, oxalate, organisms, or anthropogenic	On eroding surfaces of pressure release shells, as well as inner joint surfaces of pressure release shells, talus
Heavy metal skins	Coatings of iron, manganese, copper, zinc, nickel, mercury, lead, and other heavy metals on rocks in natural and human-altered settings	In splash zone of intermittent water flow, on eroding surfaces of pressure release shells, on the rims of gnamma pits, and near rusting metal (e.g. fences, railings, signs)
Iron film	Composed primarily of iron oxides or oxyhydroxides	In contact with perennial stream flow, streaks on cliff faces experiencing ephemeral flow, pressure release shells recently exposed, pressure release shells undergoing weathering, talus
Lithobiontic coatings	Organisms forming rock coatings; for example, lichens, moss, fungi, cyanobacteria, algae	In contact with perennial stream flow, splash zone of active waterfalls, streaks on cliff faces experiencing ephemeral flow, talus, vertical joint faces surfaces recently spalled; pressure release shells recently exposed and that display weathering features such as gnamma pits and from gnamma pits
Oxalate crust	Mostly calcium oxalate and silica with variable concentrations of magnesium, aluminum, potassium, phosphorus, sulfur, barium, and manganese; often found forming near or with lichens	In splash zone of intermittent water flow, on eroding surfaces of pressure release shells, on the rims of gnamma pits, streaks on cliff faces experiencing ephemeral flow, talus
Pigment	Human-manufactured material placed on rock surfaces by people	Graffiti painted on rocks
Rock varnish	Clay minerals, Mn and Fe oxides, and minor and trace elements; color ranges from orange to black in color produced by variable concentrations of different manganese and iron oxides	In contact with perennial stream flow, in splash zone of active waterfalls, streaks on cliff faces displaying ephemeral flow, vertical joint faces undergoing recent spalling, pressure release shells recently exposed and undergoing weathering
Silica glaze	Usually clear white to orange shiny luster, but can be darker in appearance, composed primarily of amorphous silica and aluminum, but often with iron.	In splash zone of active waterfalls, streaks on cliff faces displaying ephemeral flow; vertical joint faces undergoing recent spalling, pressure release shells recently exposed and undergoing weathering, talus

grain and temporarily stopped the splitting. This secondary electron image shows textures, indicating that the varnish is not biogeochemically stable. There are pockets of ongoing dissolution, indicated by holes in the varnish. No age control exists; thus, it is not possible to estimate rates of varnishing.

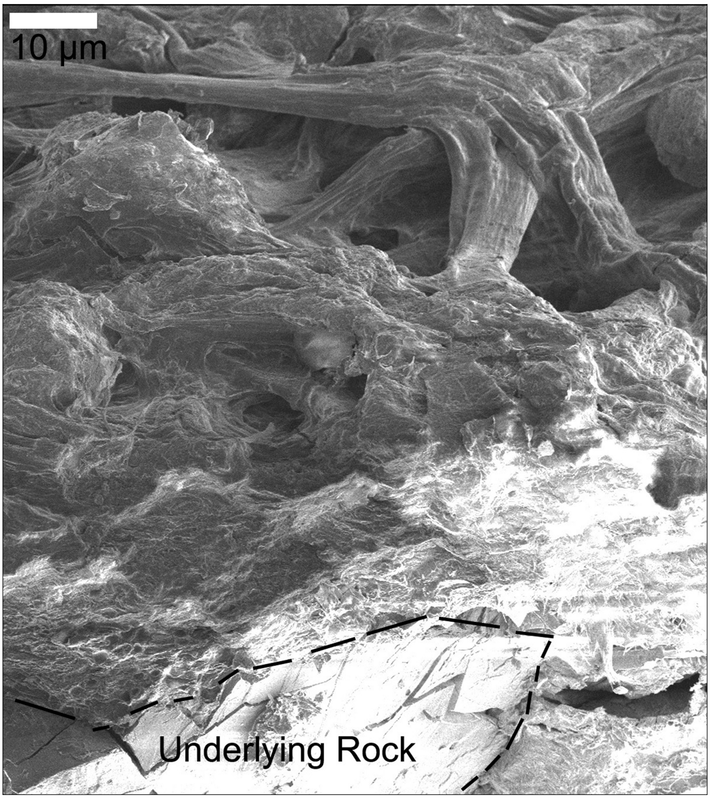

Fig. 5. Lithobiontic coating dominated by fungi, as viewed in secondary electrons. The material above the underlying rock consists almost entirely of fungal filaments and decaying fungi.

Half Dome's silica glaze is a combination of silica and some aluminum, typically appearing as a lustrous white coating. However, it can have more of a reddish appearance if enriched with iron hydroxides, or a darker appearance if enriched in manganese or organic matter. Silica glaze coatings are typically just a few microns thick, with lamellar textures (e.g., Fig. 7), suggesting deposition assisted by gently flowing water. In some instances, silica glaze appears to be entombing manganiferous-enhancing bacteria. After being entombed by the silica glaze, the bacteria died, and the cell interior was replaced by a mix of materials with a composition similar to rock varnish (Fig 7).

Oxalate minerals consist of carbon, oxygen, and water. A common oxalate mineral found on rock surfaces is whewellite ($CaC_2O_4 - H_2O$). One source of oxalate minerals are lichens (Syers et al., 1967; Russ et al., 2000; Bjelland et al., 2002). Much of the research on oxalate coatings has been conducted in association with rock art shelters (Russ et al., 2000; Spades and Russ, 2005). The oxalate crusts observed in Yosemite are typically streaks that can be traced upslope to patches of lichens. The oxalate is mobilized from lichens and is redeposited on rock surfaces by overland flow. The most common appearance at Half Dome is a milky white coating,

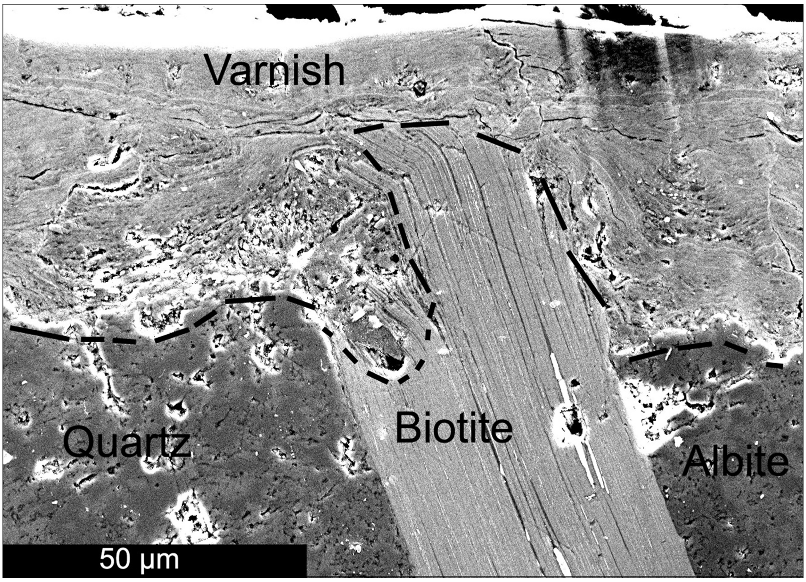

Fig. 6. Manganiferous rock varnish formed on a 20 cm clast located in a small channel that experiences ephemeral flow from snowmelt and intense rainfall events. Six EDS analyses reveal an average elemental abundance of 0.33% Na, 1.04% Mg, 8.96% Al, 14.22% Si, 0.65% P, 1.29% K, 0.54% Ca, 0.47% Ti, 20.62% Mn, 16.90% Fe, 0.69% Zn, and the remainder is O.

consisting of a mixture of calcium oxalate and silica glaze (Fig. 8), with both precipitating from water. Some oxalate coatings, however, can be darker if they contain organic matter or manganese as the cation in the oxalate.

Half Dome's iron films appear as orange, red, or dark brown coatings. The brightness of the color depends on the degree of hydration of the hydroxides, where redder colors are more dehydrated (Dorn, 1998). The iron films of Half Dome can appear as very thin coatings of just a few microns, but they can also express themselves as accretions greater than 0.1 mm (Fig. 9). Such accretions are similar to the iron films observed in northern Scandinavia (Dixon et al., 2002), where the process of precipitation physically weathers the rock. The physical separation of grains through the inter-grain penetration of the iron film in Figure 9 shows this physiochemical weathering process. As in Scandinavia, these iron films are found in acidic microenvironments. The pH values ranged from 3.4 to 5.7 in intermittent water flow over the 30 cm cobble sampled for Figure 9.

Heavy metal skins often look similar to rock varnish in that they are often rich in manganese and iron. The oxidized manganese darkens the appearance of the rock coating. Clay minerals are key in rock varnish accretion (Potter and Rossman, 1977; Dorn, 2007) and, without clay minerals, heavy metal skins form. Heavy metal skins also form much thicker coatings than varnish, and these coatings often penetrate deep into the rock. In a light microscope image (Fig. 10), this heavy skin is being re-precipitated in pore spaces and along grain boundaries in the weathering rind of the rock. Thus, a heavy metal skin can act as a case-hardening agent.

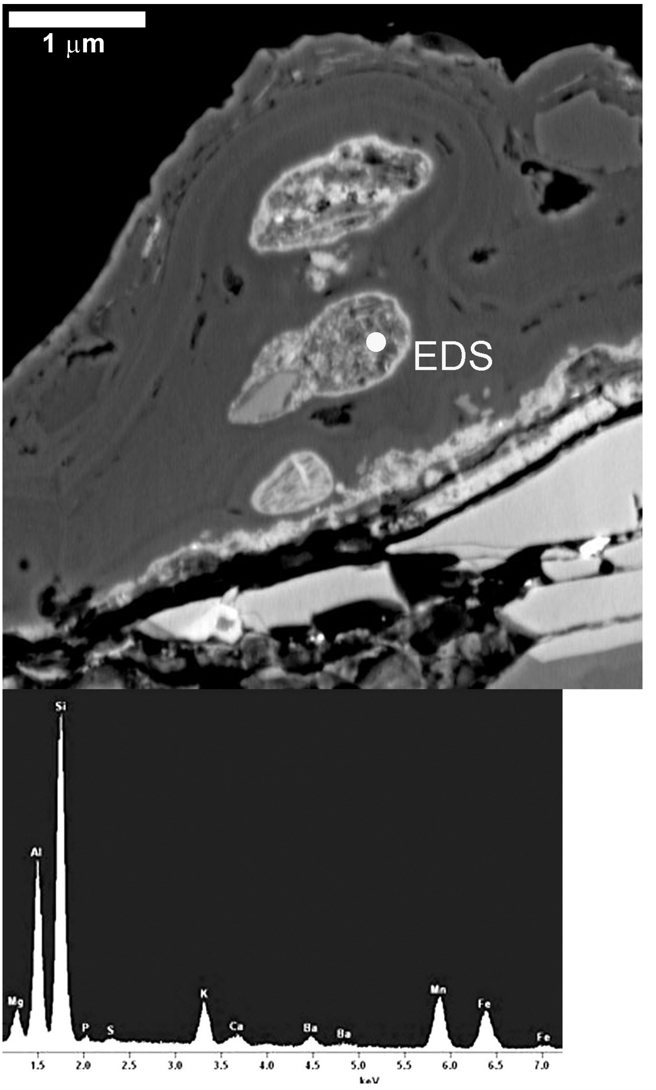

Fig. 7. BSE image and corresponding EDS analysis of a bacterial-sized cocci oval form. This silica glaze was collected from the inside of a pressure release spall in a location that experiences overland flow during precipitation events and snowmelt. The outermost portion of the bacterial cocci forms are brightest, because they contain the most manganese (Mn) and iron (Fe) enrichment, likely representing the Mn-Fe–enriched sheath.

DISCUSSION

This research first sought to identify the different types of rock coatings found in Yosemite Valley through the study of coatings found at Half Dome. Out of 14 types of rock coatings, Half Dome hosts 8: case hardening, heavy metal skins, iron films, lithobiontic coatings, oxalate crusts, anthropogenic pigments, rock varnish,

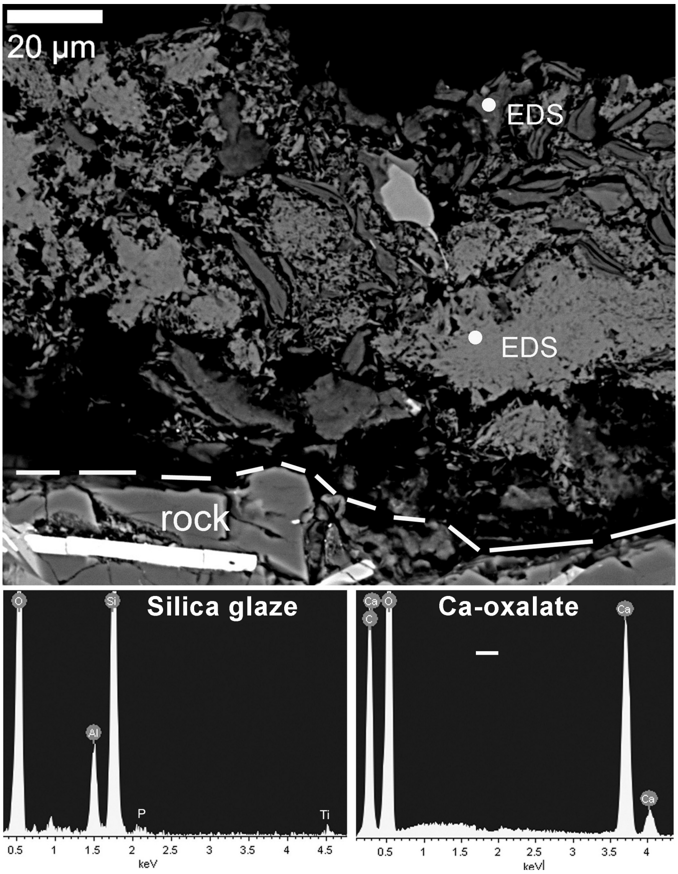

Fig. 8. Back-scattered image of the most common type of oxalate crust observed at Half Dome. The brighter sections of the rock coating are calcium oxalate, as suggested by the EDS measurement that consists of calcium, oxygen, and carbon. As is common at Half Dome, silica glaze is found as a precipitate mixed in with the oxalate. The silica glaze in the BSE image appears darker, because its composition is dominated by the lighter elements of silicon and aluminum. The porous texture of the oxalate crust suggests that components are in an open system undergoing dissolution and likely re-deposition elsewhere.

and silica glaze. The initial light and electron microscopic observations of rock chips revealed a great complexity in the texture and chemistry of the selected samples. This initial study achieved its first goal of identifying some of the rock coatings, but it is likely that we did not obtain samples of all of the different types of rock coatings that exist on Half Dome, let alone in all of Yosemite Valley. Additional samples would be expected to contain different types of coatings, as well as different variations of the observed types.

The different types of coatings at Half Dome (Table 1) are often found in different environmental settings. The most common types encountered at Half Dome are lithobionts, including moss, lichens, cyanobacteria, algae, and, most commonly, fungi. These organic coatings occur most commonly where water is retained, such

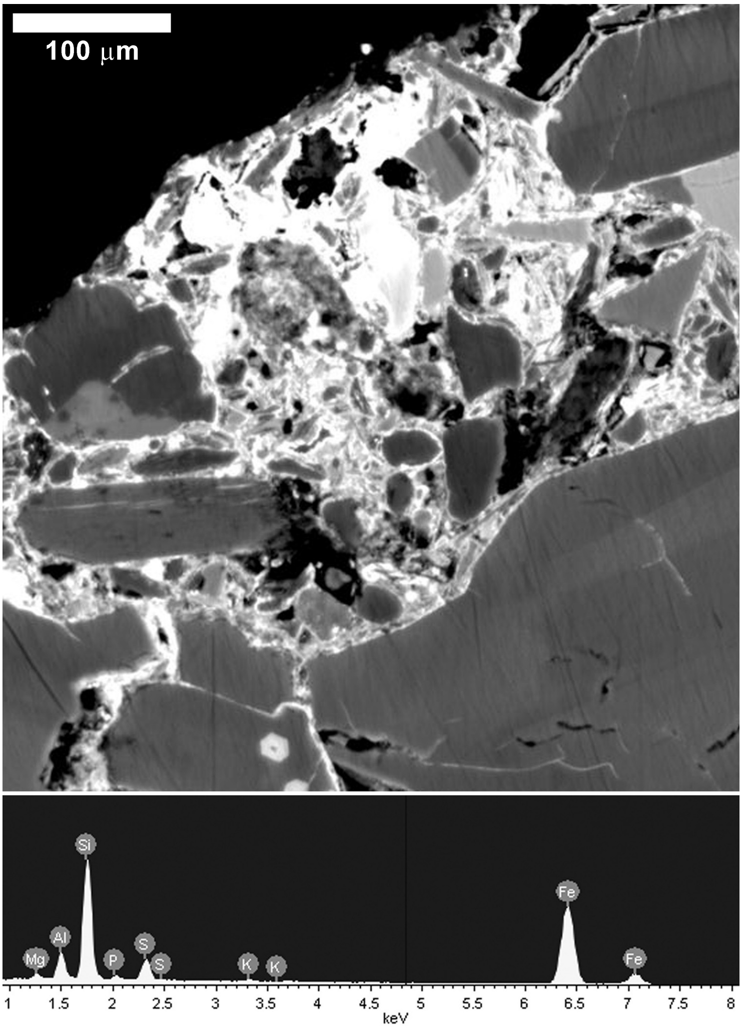

Fig. 9. BSE image of iron film collected from a 30 cm cobble in a location where water flows intermittently. A patch of moss exists up-flow of the sample location, and moss can greatly increase the acidity of water. The corresponding EDS analysis of this iron film reveals an even mixture of iron and silica, or a type of iron film between Type II and Type III (Dorn, 1998).

as the splash zones of waterfalls, where water flows intermittently, and gnamma pits. However, lichens do occur in more xeric sites. Dark-colored heavy metal skins, most typically iron- and manganese-rich, occur in the splash zone of intermittent streams, on the rims of gnamma pits, and also as anthropogenically derived coatings next to rusting metal. Orange iron films most commonly occur on pressure release shells and as streaks on cliff faces. Oxalate crusts derive from decaying lichens on Half Dome and are most commonly seen on the rims of gnamma pits and as streaks downflow from lichens. Lighter-colored silica glaze is seen in the splash zone of active

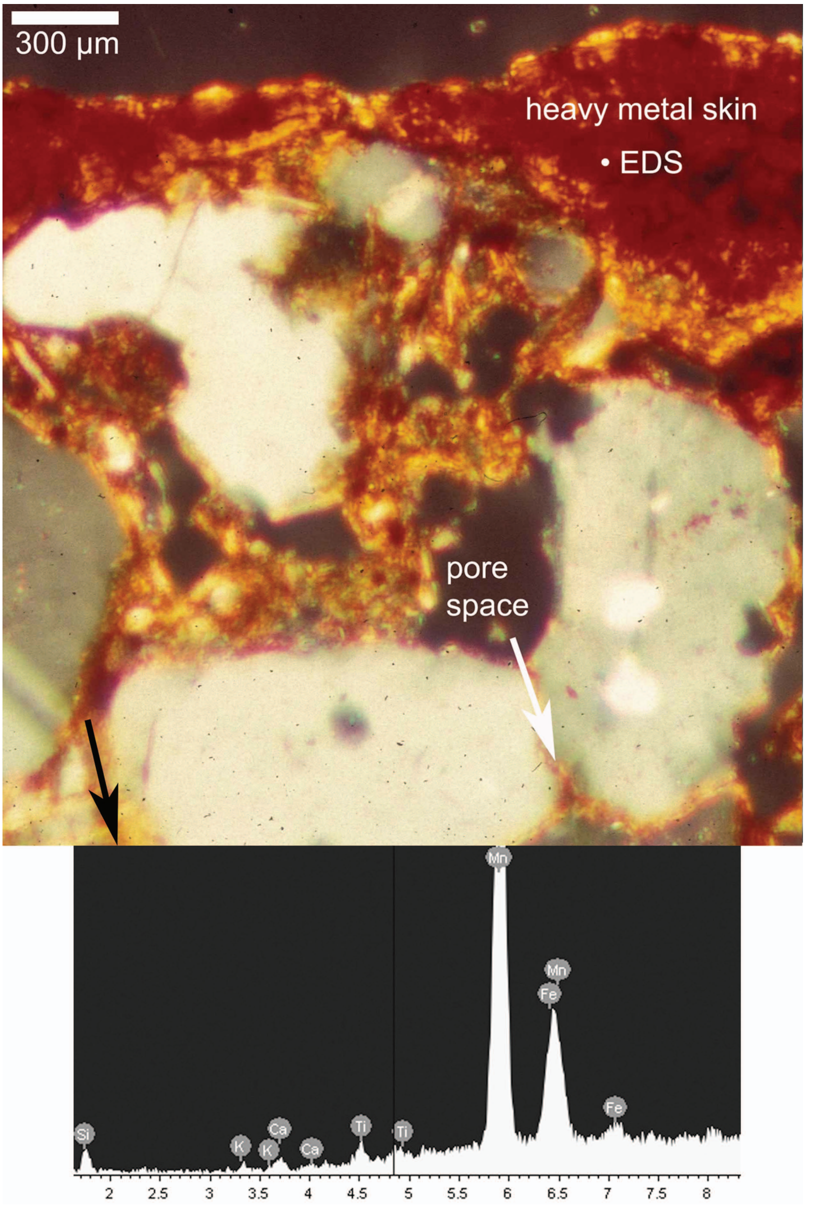

Fig. 10. Heavy metal skin, visualized in an ultra-thin section. The iron and manganese have been remobilized and re-precipitated in pore spaces and also along grain boundaries. In this way, rock coatings such as this heavy metal skin can case harden the outer shell of rocks. The EDS analysis of the heavy metal skin at the identified spot reveals that the coating is composed almost entirely of manganese (Mn) and iron (Fe).

waterfalls, on recently spalled cliff faces, and on the weathered surfaces of pressure release shells. Manganese-rich rock varnish is infrequently found at Half Dome, but is interwoven with other rock coatings in the splash zone of active waterfalls,

Table 2. Landscape Geochemistry Analysis of the Hierarchical Orders that Explain Rock Coating Distribution at Half Dome

Order	Synopsis	Half Dome examples
First	Exposure of rocks on the land surface	The bare rock landscape of Half Dome is a product of glaciation in some sections, removing prior soil and rock material, of mass wasting, and periglacial processes.
Second	Coatings are formed in the subsurface in joints, later exposed by first-order processes.	Recently exposed pressure release shells show that silica glaze, iron films, and rock varnish have all formed in the subsurface prior to detachment of the overlying rock.
Third	Lithobionts often grow faster than abiotic coatings.	Rapid growth of fungi, algae, moss, and lichens in such settings as where water flows on Half Dome means that other rock coatings that might accrete do not. In addition, some lithobionts generate ingredients that promote the formation of abiotic coatings such as oxalate crusts and iron films that are promoted by strong acidity.
Fourth	Transport pathways must exist to supply constituents of rock coatings.	Half Dome and other monoliths in Yosemite exemplify the importance of this order of control, because the dark and light colored streaks are so noticeable; all of the abiotic rock coatings are influenced by pathways of water flow that supplies such ingredients as silicon, aluminum, oxalate, manganese, and iron.
Fifth	Barriers to transport can be biological, chemical, and physical.	In the splash zones of active waterfalls, the physical process of evaporation limits the transport of constituents. Chemically, abiotic constituents such as manganese and iron are fixed by bacteria because the acidity of the water is such that abiotic physiochemical oxidation of manganese is not possible (Dorn, 1998). Biologically, lichens form a barrier to the transport of carbon and calcium when they secrete oxalate minerals.

in streaks on cliff faces, and on weathered surfaces such as pressure release shells and talus. Case hardening (Dorn et al., 2012) typically occurs on the weathered and eroding surfaces and also the inner joint surfaces of pressure release shells. A variety of different rock coatings can cover the case hardened outer shell of rock surfaces.

According to the landscape geochemistry model (Dorn, 1998), there are five general orders or hierarchies to explain the spatial distribution of rock coatings. Half Dome provides an opportunity to assess the usefulness of this landscape geochemistry model in interpreting Yosemite's natural paint job (Table 2). As the first order in a decision tree of rock coating interpretation, bare rock faces must be exposed by geomorphic processes. Half Dome and other bare faces in Yosemite exemplify this concept extremely well. Rock coatings do not occur where soil and vegetation covers bare rock.

The second order in the decision tree is whether rock coatings were "born" in the subsurface prior to geomorphic exposure of the bare rock. This is the case for the silica glaze in Figure 7, where we examined the inside of a joint separating two pressure release shells. The outer shell was fractured enough to permit water flow during snowmelt and precipitation events, and this water flow would have promoted the development of silica glaze. In addition, iron films and heavy metal skins can be found inside joints. These coatings are then subject to different conditions after detachment of the overlying rock material. For example, subsequent lichen growth on these abiotic coatings ends up chemically dissolving the joint-developed coating, resulting in a patchwork of lichen colonies and chemically eroding the abiotic rock coatings.

Once a rock face is exposed at the surface of Half Dome, lithobionts colonize its surfaces. Moss grows along the lines of fractures where some gruss and fines have accumulated. Lichens attach in loci of water flow, around gnamma pits, and in other locations. Fungi grow rapidly in locations of water flow. The speed of lithobiont growth is much faster than that of abiotic rock coatings, and thus lithobiont growth is the third order in the type of rock coatings that can be seen.

In locations where lithobionts have not yet grown, rock coatings such as rock varnish, silica glaze, iron films, and oxalate crusts can accrete, but only if two conditions are met. The fourth-order condition is that a transport pathway must exist for the constituents of the rock coating. A good example at Half Dome is water flow between a lichen patch that is secreting oxalate minerals and the rock coating where oxalate minerals are re-precipitated as a rock coating.

In addition, the fifth order precondition must also exist—that some barrier fixes the coating constituents. For the manganese in rock varnish, this is a difficult barrier because the acidic waters on Half Dome do not allow for the abiotic fixation of manganese. In natural waters, Mn (II) oxidation requires pH values > 8.5 to oxidize homogeneously without microbial assistance (Morgan and Stumm, 1965). Microbial oxidation of Mn (II) to Mn (IV) is quite rapid at Half Dome pH values (Tebo et al., 1997, 2004). Environmental and laboratory studies suggest that the microbial oxidation of Mn (II) results in the formation of Mn (IV) without lower Mn (III) valences (Tebo and He, 1998; Tebo et al., 2004). Thus, manganese-oxidizing organisms, such as the cocci-forms seen in Figure 7, are required for Mn fixation in rock varnish. In summary, the landscape geochemistry model of rock coating spatial distribution does offer a useful explanation for the occurrence of Half Dome's rock coatings.

Equifinality is the theory in physical geography that similar forms can be produced by very different processes (Haines-Young and Petch, 1983; Phillips, 1997; Turkington and Paradise, 2005; Beven, 2006). Equifinality could apply to the rock coatings seen at Half Dome. The dark streaks that are so visually apparent on many of Half Dome's surfaces might be composed of different types of rock coatings. Fungal mats are the most common cause of the dark appearance, but rock varnish, heavy metal skins, manganese-rich oxalate crusts, and organic-rich silica glaze can all result in dark streaks. At Yosemite, equifinality does not support simplistic interpretations, such as that all black streaks down Half Dome's faces are composed of fungi—they are not. Many different rock coatings can have a similar appearance due to different processes in different micro-environmental circumstances.

CONCLUSION

Yosemite Valley is a unique icon of bare rock grandeur in California's Sierra Nevada. Nowhere else in the western Sierra are so many bare-rock surfaces with dramatic relief visible in a single vista. These bare-rock faces establish the canvas for rock coatings that paint monoliths such as Half Dome. Exactly why Yosemite Valley generated Half Dome and other similar forms, while other western drainages did not, involves a combination of different geologic and geomorphic processes. Some of these processes are still modifying the landscape today. Thus, the link between the unique circumstances creating Yosemite Valley and prevalence of various rock coatings comes together in the overall story of the landscape's evolution.

The granite, granodiorite, quartz monzonite, and quartz diorite found on Half Dome and other rock faces of Yosemite Valley do not look like the clean cross-sections of rocks shown to students. Instead, the granitic minerals have been "painted" by case hardening, heavy metal skins, iron films, lithobiontic coatings, anthropogenic pigments, oxalate crusts, manganiferous rock varnish, and silica glaze. The most noticeable rock coatings are black streaks, but a host of colors alter the appearance of rocks, ranging from the bright green of lichens, the dull orange of an iron film, to the white luster of silica glaze. The distribution of different types of rock coatings is consistent with the landscape geochemistry model of rock varnish formation. Equifinality, the notion that forms that appear similar, such as the black streaks of Half Dome, can be produced by different processes, is relevant at Half Dome. Lithobiontic coatings of fungi can look similar to rock varnish and other dark-colored coatings, even though they are made by very different processes. This initial study of rock coatings in Yosemite has shown that rock coatings form a complex biogeochemical landscape and merit more thorough study.

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