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Socio-technical context of the interactions between large-scale and small-scale mining in Marmato, Colombia

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ABSTRACT

This paper identifies the intersecting technical and social factors that have fueled a history of conflict between artisanal and small-scale mining (ASM) and large-scale mining, and more recently, their potential coexistence, in Marmato, Colombia. At Marmato, a vertically zoned ore body and corresponding vertically stacked land claims have in part fueled tensions between ASM and large-scale mining. These same characteristics have also given rise to a scenario which could facilitate the coexistence of both parties. The case of Marmato has implications for policy and decision-making around relations between ASM and large-scale mining elsewhere, notably: 1) how a politicization of natural hazards can exacerbate existing asymmetries in power, wealth, and risk; 2) some deposit types such as epithermal veins may be particularly suited to coexistence, but site-specific characteristics determine whether the technically feasible mining methods could facilitate or preclude coexistence; 3) how equity is central to successful coexistence; and 4) how approaches such as contract mining will need to integrate social and technical considerations.

1. Introduction

Marmato, Colombia is the location of one of the oldest active gold mining sites in South America (Table 1), and the site is a test case for modern interactions between artisanal and small-scale mining (ASM)[1] and large-scale mining. The deposit being mined is located on Cerro El Burro, on the eastern flank of Colombia's Cordillera Occidental, Department of Caldas, approximately 120 km south of Medellín (Fig. 1). The mining in this area dates back to at least 500 B.C., when the indigenous Quimbaya people worked as miners and goldsmiths (Redwood, 2009). Marmato has been mined nearly continuously since the 1500s (SRK, 2017), the deposit itself is specifically mentioned in reports from the first European colonization of Colombia (Morales, 1995; Restrepo, 1952). The name comes from "marmaja," which is a historic Spanish term for pyrite. Marmato played a major role in history in the 1820s, when Simón Bolívar borrowed against the mines to obtain British funding for Colombia's war of independence from Spain (Gallego and Giraldo, 1984). Marmato has seen episodic conflict between parties representing foreign and local mining interests since at least the early 20th century (Robayo, 2012).

Today, the veins found at the highest elevations of Cerro El Burro are exploited by hundreds of active small-scale underground workings, in a zone designated for ASM in 1954 by National Decree 2223. The middle elevations of the mountain were designated for medium-scale mining, which has occurred episodically below the town since the early 19th century. Since 1993, the medium-scale Colombian company Mineros Nacionales S.A. has been producing about 22,000 ounces of gold annually from the Maruja mine in that zone, also referred to by interviewees as La Palma.

Various large-scale mining companies have explored Marmato since 1995; this has been the underlying cause of over two decades of tension between small-scale and large-scale mining parties. The Marmato locality is naturally prone to landslides, which have been exacerbated by small-scale mining activity. In 2006, the large-scale mining company Colombia Goldfields co-opted this geological hazard as an impetus to resettle the community away from the proposed open pit site. Although the company socialized their proposed project with local leaders and authorities, conflicting ideas about land ownership fueled tensions

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[1] In this paper, we follow the convention in the literature by using *artisanal and small-scale mining (ASM)* as an umbrella term that encompasses various scales of labor-intensive mining operations that largely take place informally with minimal technologies (Hilson and Maconachie, 2019). Many countries distinguish between artisanal and small-scale operations by the quantity of minerals produced, the land area that is being mined, and the technologies employed. In Colombia, the miners at Marmato are technically classified as small-scale operators; however, they also fall under the *traditional* miner classification. This is examined later in this paper.

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Table 1
Key events in the mining history of Marmato.

Date	Event
500 B.C.	Quimbaya mining in the region
1525	Colonization of Colombia
1537	Spanish claim the town of Marmato
1634	First centralized processing plant in Marmato
1825–1925	British mining at Marmato
1925–1938	Marmato mines expropriated
1946	Law 66 divides Marmato into the Zona Alta and Zona Baja, laying the foundations for Decree 2223
1954	Decree 2223 designates the Zona Alta for small-scale mining and the Zona Baja for medium-scale mining
1960	Open pit mining potential recognized at the Marmato deposit
1980s	Phelps Dodge explores Zona Baja for underground resource
1991	Mineros Nacionales S.A. purchases 30 year concession
1993	Mineros Nacionales begins producing gold from the Zona Baja
1996-2000	Exploration by Conquistador Mines Ltd
2005	Colombia Goldfields buys and closes 82 mines and 11 processing centers in the Zona Alta
2006	Debris flows inundate the historic town in April and May, resettlement initiative begins
2006	ASM community forms the "Comité Cívico Pro Defensa de Marmato"
2010	Medoro Resources Ltd purchases Mineros Nacionales S.A. and Colombia Goldfields Ltd
2010	Small-scale operators reopen mines in the Zona Alta
2011–2012	Gran Colombia Gold and Medoro Resources Ltd merge
2012	Gran Colombia Gold reports an open pit resource at Marmato
2017	Gran Colombia Gold's CFO states that the company is in dispute with the Colombian government
2017	Constitutional Court of Colombia upholds Decree 2223 in Judgment SU-133
2017	Gran Colombia Gold reports an underground resource at Marmato including the Deeps Zone discovery, proposes contract mining of the Zona Alta
2020	Gran Colombia Gold spins off the Zona Baja mining licenses and mine into a separately listed company Caldas Gold Corp. in order to fund underground expansion and mine the Deeps Zone

among the company, government, and local communities.

Through a series of mergers and acquisitions, the large-scale mining company Gran Colombia Gold (GCM) acquired the La Palma/Maruja mine, as well as other properties in Marmato (Table 1). In 2011, the company discovered a deeper mining target, subsequently identifying a resource in 2017 (Gran Colombia Gold, 2017a). The company is now focused on expanding the underground operations in the Zona Baja with a view to exploiting the new discovery, forgoing open pit development based on economics and the social complexities at the site. The company has proposed a contract mining model, in which collectives of small-scale miners would operate above the elevations of the intended expansion. The company would then purchase and process the ore (Gran Colombia Gold, 2017a). Similarly, in Segovia, GCM has overseen the formalization of several small-scale mining collectives which work under contract on the company's titled land (Gran Colombia Gold, 2017b, Section 9.3). Not all deposits are naturally suited for a model of coexistence, but Marmato's vertically zoned orebody and vertically stacked mining rights are permissive of simultaneous underground mining by large-scale mining and ASM. Open pit mining in the same area, however, would result in competition for the same parts of the resource.

In this paper, we explore the ways in which geological and mining engineering characteristics have intersected with conceptions of land claims, equity, and livelihoods to shape the interactions between large-scale mining and ASM in Marmato. We demonstrate that the geology and the regulatory framework create a scenario ripe for coexistence between ASM and large-scale mining. However, these very factors have also contributed to tensions between ASM and large-scale mining in Marmato. The relationship between ASM and large-scale mining is shaped heavily by small-scale miners' perceptions that their activities are characterized by equitable labor conditions and serve as a foundation for community cohesion. In essence, the social, economic and political context in Marmato present challenges for coexistence.

The Marmato case study is part of a larger study by the authors on the sustainability of ASM and its socio-technical dimensions (Smith et al., 2018; Smits et al., 2020). The case presented here draws upon findings from site visits, mine and processing plant tours, and stakeholder interviews. Site visits and informal interviews were conducted in July 2018. Supporting data were also gathered during a workshop on ASM which was held in Medellín, Colombia in July 2018, organized by the multi-university team leading the larger study. The workshop attendees included small-scale miners, residents from the community, regulators, representatives from NGOs and academics. Moreover, in-depth semi--structured interviews were conducted in 2018 and 2019, including 10 members of the small-scale mining community in Marmato, two of whom are community leaders, and two representatives of GCM. The study also draws material from technical reports on the Marmato deposit published by GCM and other entities; legal and regulatory information from the government of Colombia; scholarly literature; news articles; and other information in the public domain.

Following a literature review on the interactions between ASM and large-scale mining, the paper details the important geological characteristics of the deposit and critically examines the political-economy of mining in Marmato. This information is used to contextualize summaries of small-scale and medium scale mining at the site. The dynamics of the conflict are discussed in a section on large-scale open pit mining, and the possibility of coexistence is presented in a section on large-scale underground mining. The paper concludes by reflecting on the implications for relations between ASM and large-scale mining at other sites.

2. Conflict and coexistence between ASM and large-scale mining: A review of the literature

The interaction between large-scale mining companies and ASM has become strained in many parts of the world (Kemp and Owen, 2019; Katz-Lavigne, 2019, 2020; Kemp and Owen, 2019; Pedersen et al., 2019; Rosales, 2019). The broad consensus in the literature is that these conflicts stem from incompatible views over land ownership where both parties claim access to the same mineral resources (Aubynn, 2009; Ramírez Guerrero, 2012). New approaches are needed to ensure the sustainable operation of both sectors in a given area. This issue is particularly important in nations such as Colombia, where both sectors are currently expanding (Betancur-Corredor et al., 2018). Although in recent years the Colombian government has promoted foreign investment in large-scale mining, the ASM sector continues to account for the majority of Colombia's gold production and is an important source of employment for many people in rural areas (Jonkman, 2019; Veiga and Marshall, 2019).

In Colombia and around the world, governments often award large-scale mining companies with mining concessions in areas where small-scale miners have long been operating. This is generally facilitated by investor-friendly policies that tend to favor large-scale mining over ASM as a catalyst for regional and national socio-economic development (Hilson, 2004; Ramírez Guerrero, 2012; Verbrugge, 2017; Van Bockstael, 2019; Hilson, 2019; Sauerwein, 2020). Large-scale mining companies have, historically, attempted to address ASM activities taking place on their concessions by evicting miners. These initiatives have generally occurred in partnership with local and national governments, in some cases involving the forceful removal of ASM activities from large-scale mining sites (Hilson et al., 2007). Some large-scale mining companies have resettled ASM communities, either at the start of a project or during a previously unforeseen project phase (e.g. Owen and Kemp, 2016). During this process, conflicts between mining companies and communities have resulted in significant impacts to both parties including slowdowns or stoppages of the large-scale production, harm to people or equipment, jeopardization of the company's ability to gain or maintain the social license to operate, and dissolution of opportunities for building trustful relationships between the two sectors (Hilson and

Maponga, 2004).

In light of the problems associated with involuntary eviction or resettlement, large-scale mining companies are beginning to recognize that it is necessary to improve relationships with small-scale miners and ASM communities. They also recognize that they have a role to play in contributing to sustainable development in the regions where they operate (Aubynn, 2009; Teschner, 2013). As a result, some mining companies have begun to conceptualize how "coexistence" models can play a role in addressing the conflicts between large-scale mining and ASM.

The general objective of a coexistence model is to accommodate ASM operators by providing a viable locale for them to continue mining in the same general area as the large-scale mining operation. Some of these initiatives have aimed to support small-scale miners in obtaining mining concessions and becoming formalized. Other initiatives have focused on purchasing gold from ASM operators and establishing alternative livelihood programs for resettled communities (Amankwah and Anim-Sackey, 2004; Aubynn, 2009; Teschner, 2013; Bury, 2004; Hilson et al., 2007; Hilson and Yakovleva, 2007; Hilson and Banchirigah, 2009; Nana, 2014; Smith et al., 2017; Temeng and Abew, 2009). Although elements of a successful collaboration have been achieved in some cases, many coexistence schemes have failed to be sustainable over the long term (World Bank, 2009). Some of the reasons included a lack of gold in the areas in which ASM operations were resettled, challenges obtaining government support in formalization efforts, and alternative livelihood programs that were not able to sustain the local economy after the closure of the large-scale mining operation (Hilson et al., 2007; Smith et al., 2017).

These are all critical issues that underlie the often-contentious nature of the relationship between large-scale mining and ASM. Some ASM scholars have briefly alluded to the importance of geology and ore body characteristics in the success of ASM (Hentschel et al., 2003), and others have called upon governments to provide such geological data (Hilson and Maponga, 2004; Hilson et al., 2020). However, there is a paucity of work on the relationship between geological or engineering factors and the social or political aspects of ASM. In Marmato, all of these factors intersect to drive the interactions between ASM and large-scale mining.

3. Setting the stage: Marmato geology

Two particular geological features of the Marmato deposit set the stage for the interactions between large-scale mining and ASM: the area's propensity for landslides and the vertical zonation of the ore body geology.

3.1. Landslides

The terrain in the middle Cauca belt of the Colombian Andes is steep, mountainous, and deeply incised (Fig. 2). At Marmato, the relief is roughly 1,600 m from the nearby Cauca River to the mountain peaks. The historic town of Marmato and much of the small-scale mining are located on Cerro El Burro at 1300 m elevation and above. This zone is in

Fig. 1. Location of Marmato, Colombia.

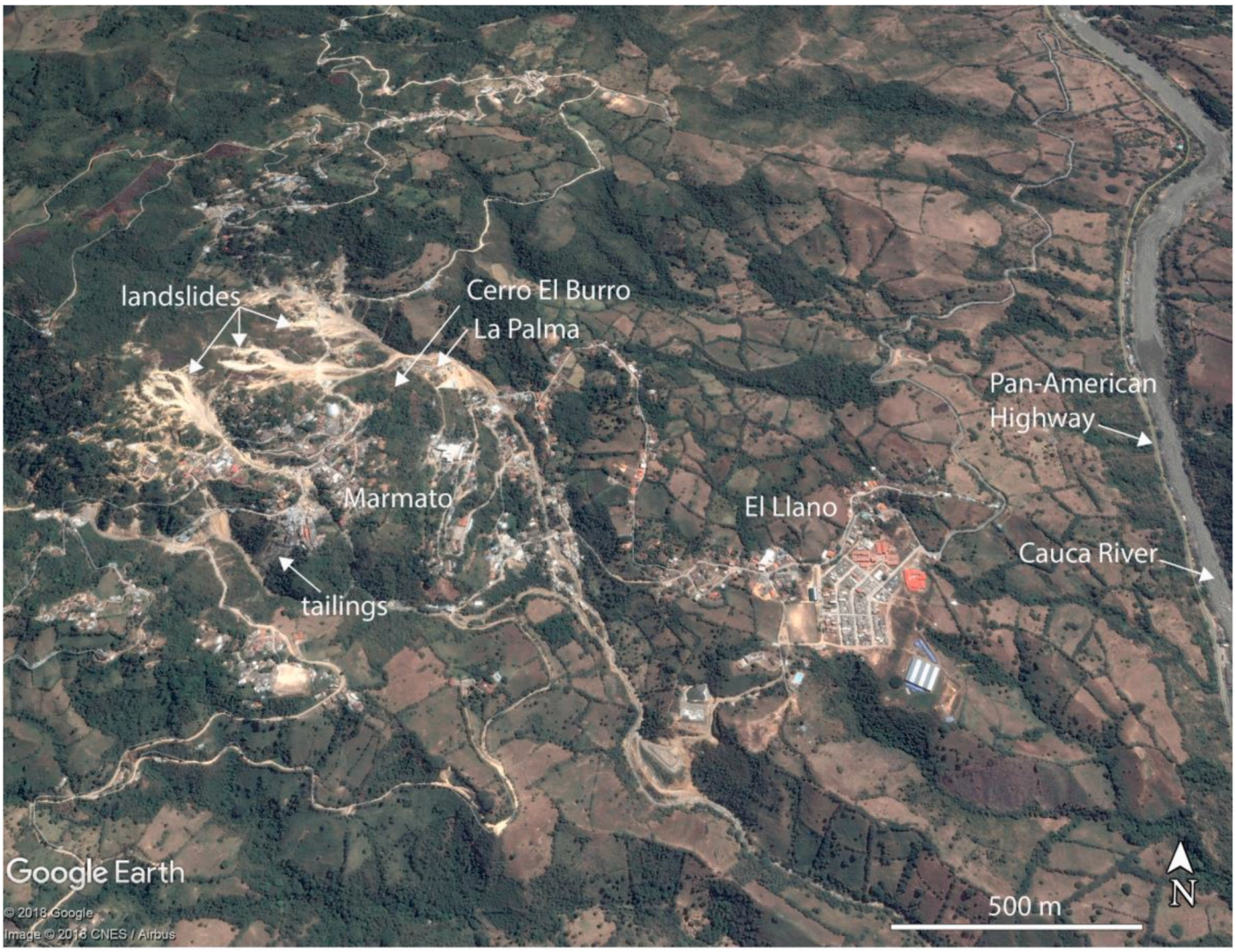


Fig. 2. Location of key features near the Marmato townsite and deposit, overlain on satellite imagery from Google Earth.

temperate, premontane subtropical wet forest, with 2,000 to 4,000 mm of annual rainfall (SRK, 2017). Natural landslides are common in the region due to the steep topography, the wet climate, the deeply weathered soil profile, and planes of weakness in the rock, including faults.

In Marmato, natural landsliding has been exacerbated by agricultural and mining-related deforestation (Figs. 2 and 3). Many of the steep hillsides have been deforested for cattle grazing or crops of citrus, coffee, sugar cane, and bananas. Mining-related deforestation occurs at the mine site excavations, as well as dispersed through the region due to the harvesting of timbers for underground support. According to Colombian law, the miners are prohibited from felling native hardwood and must use only non-native species such as pine or eucalyptus, but the level of adherence to this requirement is not well documented.

Small-scale miners around the world commonly live near their excavations, in many cases due to the lack of formalized land claims or the risk of equipment theft. For this reason, the historic Marmato townsite is located high on the flanks of Cerro El Burro. The area is vulnerable to landslides, including rock avalanches and debris flows. Civil works, mining tunnels, and human lives are at risk, as the former Colombian Bureau of Mines noted in an environmental assessment of the small-scale mining in Marmato (Geosismica y Ambiente, Minerales de Colombia, 1996). During the wet season in 2006, major mudslides inundated the historic central plaza of the town. Residents were evacuated, and the local government decreed the zone uninhabitable although people still continue to live there illegally. Official signs around the town now mark geologically unstable areas. Homes and infrastructure were relocated to a nearby plateau known as El Llano, in a contentious initiative partly directed by the large-scale mining company.

3.2. *Vertically zoned ore body*

The geological characteristics of the Marmato ore deposit are transitional between epithermal and mesothermal-style mineralization (Tassinari et al., 2008; SRK, 2012, 2017; Redwood et al., 2018; Santacruz et al., 2018a,b). The transitional nature imparts a vertical zonation to the grades of gold and other metals, the morphological styles, and the spatial distribution of the ore. At any particular elevation, ore zones will have relatively similar characteristics. However, a vertical transect through the area would encounter ore zones of distinctly different characteristics, each of economic interest but requiring different mining styles. Many epithermal deposits display vertical zonation, but not every zone is necessarily economic for exploitation. Other deposit styles such as orogenic gold veins do not have dramatic vertical zonation, meaning that one mining style could be effective over the entire vertical extent of the deposit.

The geological Upper Zone refers to the epithermal portions of the deposit, extending from 900 m above sea level all the way to the mountaintop (Fig. 4). This zone is characterized by steep to moderately dipping, northwest to west-northwest trending sheeted or anastamozing

Fig. 3. Small-scale mining at Marmato. The top image shows numerous mine workings scattered across the upper elevations of Cerro El Burro in the Zona Alta, above the Marmato townsite; note landslides and the discharge of dark gray tailings from a processing facility. The bottom left image shows miners unloading an ore cart at a mine portal. The aerial tramway system can be seen above the landsliding waste rock material, some of which is supported by timber structures. A second adit is located behind the timber structure at the top of the image. The bottom right image shows a gold processing facility (*entable*) with several ball mills and gravity separation tables. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

intermediate sulfidation state quartz-carbonate veins (SRK, 2012). The veins are commonly 10–30 cm wide and contain electrum (gold-silver alloy), arsenopyrite (an arsenic sulfide), sphalerite (zinc sulfide), as well as pyrite, marcasite and pyrrhotite (iron sulfides).

In the shallowest portions of the Upper Zone, the veins are exposed at the surface around the sides of Cerro El Burro, and they are attractive targets for ASM as well as large-scale mining (Fig. 4). The veins are large enough to be mined individually, and they are commonly of similar orientations to one another. This makes the ore relatively easy to find and follow horizontally into the mountain using underground prospecting and mining methods employed in ASM (Section 5). The vein mineralogy is suitable for gold recovery by gravity separation and hydrometallurgical techniques that are feasible on small, medium, or large scales. This portion of the deposit has generated interest from large-scale mining companies because the veins are closely spaced and could be a bulk-mineable open pit target. In the lower portions of the epithermal Upper Zone, the same veins are continuous at depth but do not crop out on the hillsides. The ore in this part of the deposit is therefore more difficult to find and access, so this area is better suited to medium-scale or large-scale mining.

The Deeps Zone comprises the mesothermal portions of the deposit from 200 to 900 m above sea level (850–1550 m below the mountain top; Fig. 4). From a technical perspective, this zone is only suited to large-scale mining. The ore mineralogy includes native gold, chalcopyrite (a copper-iron sulfide), pyrrhotite (an iron sulfide), and bismuth minerals. The ore is spatially distributed in microscopic disseminations and small veinlets rather than continuous large veins. Compared to the shallow veins, the ore in this zone occurs at lower grades within a large volume of rock and is only economic to mine at large scales.

The legal designations for mining in Marmato map onto the geological and mining engineering characteristics of the deposit. Unlike anywhere else in Colombia, mining concessions in Marmato are defined by elevation (Fig. 4; Section 4.2). The combination of a vertically zoned ore body, vertically stacked mining rights, and vertically segregated mining scale helped establish the long tradition of ASM. This technical and legal framework also generated continued interest in large-scale development by multinational corporations. These characteristics helped drive conflict between ASM and large-scale mining in the open pit scenario, and they also create possibilities for coexistence in the case of underground development. However, the social, political, and economic context of ASM in Marmato emerges as a potential impediment to coexistence.

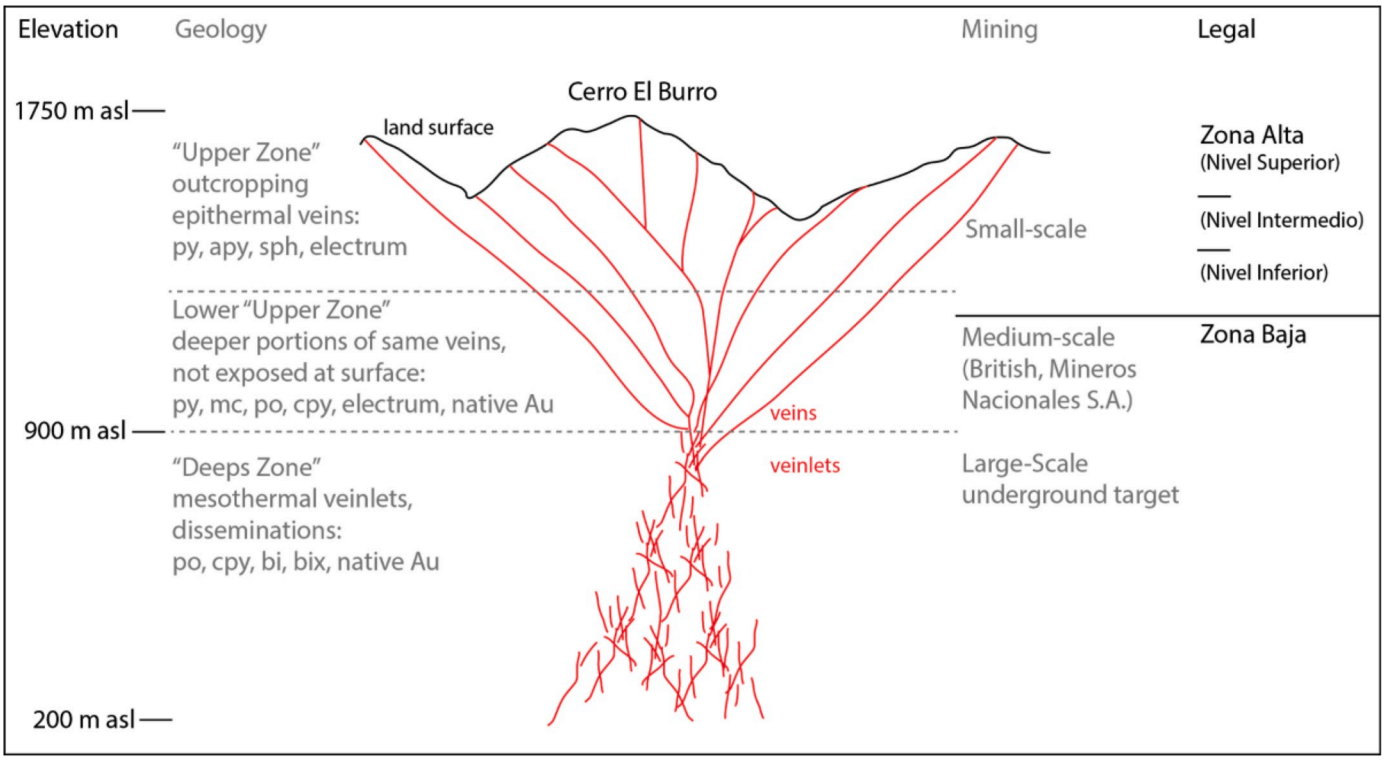


Fig. 4. Schematic cross-section through the Marmato deposit, showing geological, mining engineering, and legal zones. The geological zones are adapted from Santacruz et al. (2018a). Outside Marmato, the legal designation of the Zona Baja continues to surface. Apy = arsenopyrite, Bi = bismuth, Bix = bismuth minerals, cpy = chalcopyrite, mc = marcasite, po = pyrrhotite, py = pyrite, sph = sphalerite.

4. Political-economy of mining in Marmato

The political-economy of mining in Marmato is characterized by fluctuating regimes of land and resource ownership and use, within an evolving national framework for mining.

4.1. Historical context

In 1537, during the colonial period in Colombia, the Spanish claimed the town of Marmato. At the time, Marmato was part of the Popayan political-administrative unit (Rochlin, 2015b).[2] The Spanish subjected the Catamas Indigenous peoples, who had been mining gold prior to Spanish arrival, to a system of forced labor in agriculture and mining (Rochlin, 2015a). Gold mining took place on a relatively small-scale during this time, focused on the shallowest portions of the Upper Zone where the veins outcrop. A few larger workings emerged, and a centralized processing plant was constructed in 1634 (SRK, 2017).

By the early 17th century, the indigenous population had significantly declined because of the harsh working and living conditions and the presence of disease (Rochlin, 2015a). At that point, the Spanish embarked on a campaign to import about a quarter of a million slaves from western and central Africa to the region (Lopera Mesa, 2015). By the late 18th century, there were approximately 500 slaves in the town of Marmato, and a small group of Spanish elite controlled the land, the mines, and the labor (Robayo, 2012). The Popoyan province accounted for about half of Colombia's gold production at that time.

In the early 1800s, during the Wars of Independence from Spain, gold from Marmato was used to support the war efforts. In 1825, the mining rights in Marmato were given to the British company Goldschmidt & Company, whose successors operated there until 1925 (Robayo, 2012).

[2] In 1910, the area was redistricted, and Marmato became part of the newly formed Caldas district (Rochlin, 2015a).

The British companies mined the shallow portions of the Upper Zone where the veins outcrop, as well as the deeper extensions of these veins in the lower Upper Zone. When the British left the area in 1925, the Lower Zone portals were abandoned until they were officially reopened by Mineros Nacionales S.A. for commercial medium-scale underground mining in 1993 (Fig. 4).

During the British operations, a number of national and international mining interests visited the region. By 1857, the area was known as the mining district of "Gran Cauca" because it was the largest and richest (Robayo, 2012). However, the majority of the mining took place on a relatively small scale, outside of the Marmato concession. The miners were Afro-Colombian descendants of ex-slaves who had bought their freedom by mining gold from the tailings during the Spanish rule, along with ethnic groups, including Indigenous, Mestizos, and Spanish Creoles (Rochlin, 2015b).

4.2. Land designation based on ore body characteristics

After the British left, the state sent the military to Marmato to evict the small-scale miners in an effort to secure mining concessions in the region (Robayo, 2012). This invasion marked the often violent scramble to redefine the mining activities in Marmato in line with national and multinational interests, fueling the social conflicts that lasted throughout the 20th century (Robayo, 2012).

In response to the continued conflict, the 1946 Law 66 divided the Marmato area into two zones based on the geological characteristics: the Zona Alta and the Zona Baja (Fig. 4). In 1954, Decree 2223 reserved Zona Alta for small-scale mining and Zona Baja for medium-scale mining. Marmato is the only location in Colombia where mining rights are vertically stacked. The Zona Alta is essentially equivalent to the shallower portions of the geological Upper Zone, where the veins outcrop. Since the decree, the legal Zona Alta has been divided into three subconcessions (Fig. 4). Some small-scale miners who acquired mining concessions under this decree view it as a legal mechanism through

which they can prevent large-scale multinational companies from exploiting the Zona Alta (Lopera Mesa, 2015). The deeper "Zona Baja" is essentially equivalent to the lower portions of the geological Upper Zone where the veins do not outcrop. It also encompasses the Deeps Zone which is characterized by disseminated mineralization. The legal designation of the Zona Baja continues infinitely to depth. In Marmato proper, the upper limit of the Zona Baja is defined by the road, which varies from 1207 to 1298 m elevation. Outside Marmato, the Zona Baja's upper limit extends to the land surface. This means that in the area around Marmato, near-surface mineralization would not be reserved for small-scale exploitation. In addition to the different types of land designations, mining activities in Marmato are also governed by the state's legal and regulatory framework.

4.3. Legal and regulatory framework for "traditional mining"

All mineral resources in Colombia legally belong to the state. Formalized mining in Colombia is administered by the Ministerio de Minas y Energia (Ministry of Mines and Energy) and overseen by the Agencia Nacional de Mineria (National Mining Agency). The state grants concessions on a single 30-year contract which covers exploration, mine construction, and mineral exploitation; this contract is renewable for an additional 30 years. During the exploration and construction stages, concession owners are required to pay annual taxes based on the land area. There are royalties but no annual tax during exploitation. For gold and silver mines, the state collects a royalty of 4% of the gross value at the mine mouth (Ernst and Young, 2017). An environmental impact assessment is required thirty days before the end of the exploration stage, an environmental impact statement is required in advance of construction, and an environmental license and annual environmental insurance policy must be carried during mining.

The National Mining Code of 2001 defined categories of small-, medium- and large-scale mining based on annual production (Table 2). Operators at all scales are obligated to adhere to the same requirements for securing and retaining their concessions, including environmental permitting. This legal and regulatory framework makes it difficult for small-scale miners to become formalized, and only 7% of the total registered mining units in the country are formal (Veiga and Marshall, 2019). Relative to large-scale companies, small-scale miners do not have the resources to conduct environmental impact studies, manage the health and safety or environmental impacts of their work, or apply for permits. In Colombia, there is a trend towards privatization of formalization, wherein large-scale companies help with the logistics of formalizing small-scale miners who are operating on or near their concessions. This is the case in Segovia and Buriticá, where the companies allow contract mining by formalized collectives of small-scale miners. Both projects have been marred by disputes between ASM and large-scale mining (Section 9.3).

The National Mining Code of 2001 also established categories of *traditional operations* and *traditional mining*. Traditional operations were defined as activities conducted by individuals, groups, or associations native to the area who have been mining continuously or discontinuously since before the code was enacted (Mining and Energy Ministry of Colombia, 2015) and where these activities are the only source of minerals in the region (Colombian Congress, 2001). It is usually the main livelihood in these areas, as well as a significant source of the minerals supplied by the region. Traditional mining is subject to the formalization process outlined in the Mining Code. The Mining Code directs the mining authority to define areas where traditional mining is taking place and prioritize granting of mining titles to the representative community and/or associations. These groups are then supposed to continue the process of becoming formalized. The inclusion of traditional mining in the Mining Code is important in Marmato because it mirrors the miners' claims that they are *mineros tradicionales* or "traditional miners" with specific rights to the land (Rochlin, 2018).

In addition to recognizing traditional mining, the Mining Code of 2001 decreased state ownership and limited state influence over mining activities. As a result, the region saw an influx of multinational mining companies in the early 2000s. With these changes, the small-scale miners in Marmato were often treated as illegal and felt that their *traditional* rights to mine Cerro Burro were not protected by law. Of the approximately 500 small-scale mines operating in Marmato in 2019, only 122 had legal mining titles according to the Catastro Minero Colombiano, the entity that maintains information on mining in Colombia. The miners formed an *Asociación de Mineros Tradicionales de Marmato* in order to advocate for their rights. However, they have not been officially recognized as traditional miners by the State and still lack the title to the land and the legal right to mine at Marmato. As one of the miners interviewed for this study explained: "… the Colombian State went from being protective to a persecuting State that makes legislation to put small miners to jail. They make laws so that we remain in a legal limbo and cannot obtain guarantees to work."

5. Small-scale mining

This section documents the characteristics of the ASM community and the practices of modern ASM at Marmato, drawing from interviews (Table 3), site visits, and publicly available data. The geological and legal frameworks intersect with the social context to drive the particularities of ASM, as well as its interactions with large-scale mining.

The current population of Marmato is approximately 9,000, including 4,000 to 5,000 miners and their families. Some families have been there since before colonial times, and others have migrated to Marmato more recently from the Pacific coast and other towns in Antioquia. The region is characterized by a mix of ethnic groups, including approximately 54% Afro Colombians and 20% Indigenous peoples. The ASM miners operate about 500 mines and 100 processing plants in Marmato (Colombia Plural, 2018). Up to 90% of the community is economically dependent on gold (Rochlin, 2015a: 740).

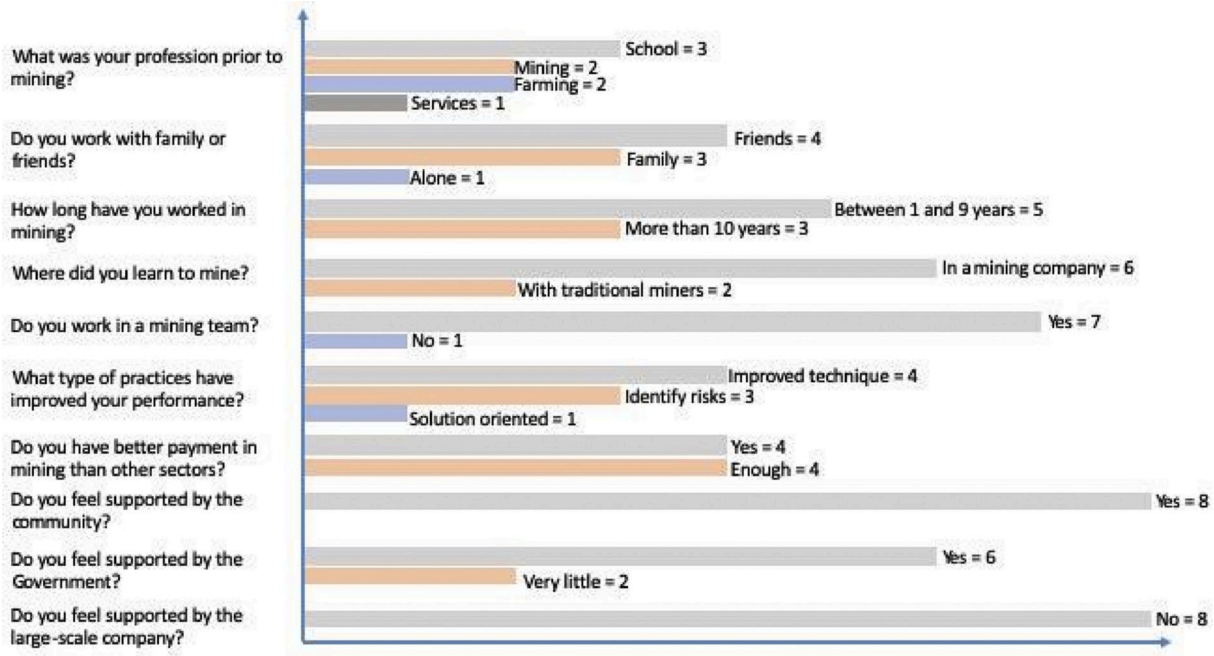
The town still thrives despite the fact that the old town center has been mostly abandoned since the 2006 landslides. There are several schools, a library, and a prominent Catholic church. Outside the church there is a statue of Santa Barbara, who is the patron saint of miners and users of explosives. There is also a cultural center that explains the area's mining heritage. Outside the cultural center, the long history of conflict between local and foreign mining is exemplified by a mural depicting the legend of *La Bruja de las Minas* (the witch of the mines). The legend comes from a 1938 novel by Colombian author Gregorio Sánchez, who tells a story set in Marmato in the 1920s. In the story, an English mining company takes over the small-scale operations with the help of military force. A woman is murdered, and she becomes a witch who haunts the foreigners and protects the local miners.

In Marmato, the small-scale mines and processing facilities are operated by individuals, collectives, and corporations. Most of the

Table 2
Classification of gold mining activities in Colombia. "Traditional" mining is not included here because it is not characterized by tonnes or m^3/year. Adapted from Mining and Energy Ministry of Colombia (2015).

	SMALL		MEDIUM		LARGE	
	Underground	Surface	Underground	Surface	Underground	Surface
Ore production from precious metal deposits (Au, Ag, Pt)	Up to 15,000 Tonnes/Year	Up to 250,000 m^3/Year	>15,000 to 300,000 Tonnes/Year	>250,000 to 1,300,000 m^3/Year	>300,000 Tonnes/Year	>1,300,000 m^3/Year

Table 3
Summary of ASM interview questions and responses relevant to this study.



miners interviewed in this study learned to mine by working for Mineros Nacionales S.A. or its large-scale mining owners (Table 3). Despite the knowledge they gained from mining companies, all of the miners interviewed for this study stated that they did not feel supported by the large-scale mining companies that have had a presence in Marmato (Table 3). Several interviewees emphasized the equitable structure of ASM operations, and many now work in teams with friends and family members. One miner interviewed for this study contrasted the ASM approach to his perception of large-scale mining in Marmato.

> There are around 4000 miners, and the vast majority of them work as independents. They have their business inside the mines and participate in the production. The design of the system is [that] we all work, we all distribute the gains and losses equally. Unlike the company … [where] I work as a donkey and [the company] take all the profits; you [the company] take all the products, you [the company] take the development.

This miner explains the perceived benefits of working as an "independent," rather than for a company. He indicates that there is a certain degree of fairness built into working with local teams, as well as economic and development benefits. Resonant with the concept of equity that appears to be central to ASM, the concepts of risk and profit are also approached collaboratively at Marmato, with the greatest risk being personal safety.

> How is participation in the business? Everything is managed based on equitable terms: we all invest, we all start equally, no matter if he has the compressor or has the mill; I [the miner] am also putting the most valuable thing which is the work and the risk of being inside the mine, so we have to distribute equally. So in those cases the worker inside the mine has an advantage over the one outside because here the risk is taken very seriously.

Interviewees also highlighted the importance of mining as both a tradition and a source of opportunity: "… the miner sticks to both the mining tradition and his work, his mill and his mine because not only [does it] mean economic well-being but it means quality of life and opportunities to share with his family," and "I have learned many things about mining, especially the social sense of mining; not only the resource but also the culture and the risks."

The small-scale miners in Marmato see themselves and the broader community as deeply integrated, in part because of the economic relationships between mining and other activities, and in part because of the cultural tradition which has evolved around mining (cf. Toledo Orozco and Veiga, 2018 in Tambogrande, Peru; Cortés-McPherson, 2019 in Madre de Dios, Peru). All of the miners interviewed stated that they felt supported by the community (Table 3), demonstrating the meaningful role of mining in Marmato.

> [We miners feel the support of the community in Marmato] in the protective sense that the miners have about their leaders, which is expressed in respect … if you defend the [small-scale] miners, you are a hero in the town; that is clear when you interact with them. There is an attitude of respect and admiration from miners [for their leaders] because they [the miners] feel that in some way or another leaders contribute so that they can work.

To the people interviewed, ASM is characterized by equitable working conditions and practices. Mining represents an economic opportunity, and it is a source of community cohesion. Given the ways in which miners spoke favorably about ASM in contrast to large-scale mining, community members may not want to work for a company operating a large-scale mine (Table 3).

The modern technical practices of ASM at Marmato (Fig. 3) are rooted in the geological characteristics of the deposit. The miners extract gold and silver from veins in the shallow portion of the Zona Alta, in total producing 5,000 to 30,000 oz of gold per year at an average grade of 4–5 g/t (Gran Colombia Gold, unpublished data). Many of the mines exploit only one vein or a single zone. Underground development of drifts and crosscuts is conducted by hand, by jack leg drilling and blasting, and with small mechanized equipment. These relatively simple and small-scale methods are feasible because of the specific characteristics in this part of the ore body, including the vein shape, size, orientation, and mineralogy. Many parts of the underground workings are unsupported. Where support is necessary, it is limited to wooden cribs made from milled or unmilled timbers, and cave-ins do occur. The

timbers are harvested locally in the district, trucked to the Marmato townsite, and carried to the adits by burros. Because many of the small mines operate individually, ore transport occurs on a small scale by relatively rudimentary methods. Ore is transported from the active workings to the surface by hand in sacks, as well as in hand-pushed carts on a metal rail system. The ore is then transferred to local processing facilities by hand, on burros, in light vehicles, and in small trucks. Some mines also transport ore using small buckets and cables on aerial tramways. Waste rock is stored underground or disposed of near the adits, most commonly off the sides of roads, in ravines, and on hillsides with or without timber retention structures.

Numerous *entables* (mineral processing facilities) exist in Marmato, ranging in scale, throughput, and degree of mechanization. The facilities are typically built on the sides of steep hills above ravines, and material is transported between processing stages by gravity without handling, or in buckets carried by hand. Most of the facilities employ crushing, milling, gravity separation, cyanide leaching in agitation tanks, and zinc precipitation (Salgado et al., 2019). Some of the operations add mercury, cyanide, or both to the ball mills, although the extent of mercury usage is unknown since the 2018 Colombian federal ban on mercury amalgamation. Miners purchase the cyanide in Marmato as NaCN pellets in 10 gallon buckets. The zinc precipitate is smelted in a furnace to produce a precious metal doré. Liquid and solid tailings from processing are discharged directly into the ravines. The cyanide leaching and zinc precipitation method requires infrastructure beyond the capacity of an individual miner, which partly explains why many have organized into companies and associations. Several domestic companies operating in Marmato, such as the Manizales-based Sky Group Minerals, have invested large amounts of money into their processing facilities.

The doré produced in the Marmato *entables* is sold locally or transported to Medellín, where it is refined to remove silver, copper, and other impurities. At least 80% of the gold produced in Colombia is exported legally and purchased by large refineries or their brokers (OECD, 2018), which means that a large percentage of gold produced by informal ASM exits the country legally.

Environmental concerns have been central to interventions and programs intended to manage ASM (e.g., CIRDI, 2017; Cortés-McPherson, 2019), and ASM operators are required to comply with environmental regulations as part of becoming formalized. The miners interviewed in this study commented that formalization is a heavy burden, and the requirements should not be the same as for large-scale mining. This is a contentious point: governments seek to mitigate the environmental effects of ASM, but if the bar is set too high, ASM will continue to operate outside the law and environmental management strategies cannot be enforced. In Colombia, few miners formalized by the Ministry of Mines and Energy have had their permits approved by the Ministry of the Environment and Sustainable Development (Veiga and Marshall, 2019).

The most salient environmental effects of ASM in Marmato are deforestation, waste rock disposal, and tailings discharge. Deforestation occurs locally at the sites of excavation and dispersed where timber is harvested for underground support. Waste rock is material that must be removed in order to access the zones where the targeted commodity occurs at economic concentrations. In accordance with environmental regulations, small-scale miners who become formalized are required to store their waste rock underground. However, this has the potential of reducing access by *chateadoras*, who are women who sort through the waste rock to find gold. In 2016, in the emerald mining industry in Colombia, concerns about the environmental impacts of waste rock led the government to ban *voladoras* or events where waste rock was "thrown" to local communities (Caraballo, 2019: 1041). This resulted in a reduction of the local population's access to emeralds (Caraballo, 2019).

Marmato's Zona Alta mineralization is characterized by numerous small veins. This mineralization style lends itself to a large number of small-scale mines and processing facilities. Therefore, there are many point sources for potential contamination from waste rock and tailings. The ravines and waterways adjacent to and downstream of the mineral processing facilities are visibly contaminated by the direct discharge of tailings and process waters. In the late 1990s, waters flowing from the Marmato site were characterized by high total suspended solids. Cyanide and heavy metals were above the background levels in the area (Prieto, 1998). At that time, suspended stream sediments contained Ag, As, Bi, Cd, Cu, Hg, Sb, Pb, and Zn. Elevated levels of dissolved As, Cd, Cu and Zn were observed in the water, and Bi, Cd, Pb and Zn were bioavailable in the Cauca River (Prieto, 1998). Dissolution of sulfide minerals caused local acid mine drainage, although at that time the Marmato stream which captures all of the mining drainage had a neutral pH upstream of its confluence the Cauca River, due to buffering by the host rocks (Prieto, 1998). A more recent study demonstrated that mercury levels were high (up to 142 ng/L) in surface waters at Marmato and in the Cauca River (Torrance et al., 2013). The point sources identified in that study were spatially related to *entables* and small mines, and the authors attributed the contamination to the use of mercury amalgamation during small-scale gold processing. The water samples also showed elevated levels of As, Cd, Pb and Sb, likely related to the dissolution of sulfides in discharged tailings.

Health and safety concerns for the small-scale miners in the processing plants include exposure to heavy metals, inhalation of dust or hydrogen cyanide gas, and exposure to other mineral processing reagents. In the mines, health and safety concerns include explosions, ground control failures, heavy equipment accidents, and other injuries and fatalities related to insufficient safety measures and lack of adequate personal protective equipment. Of these, explosions are the primary concern in the ASM community. The explosives necessary for blasting are tightly regulated by the Colombian army due to the history of armed conflict in the country. The legal process is onerous for small-scale miners to obtain explosives and can take six months if all the requirements are fulfilled, requiring the approval of the Ministry of Mines and Energy (Ministerio de Minas y Energía), the environmental authority (in this case the Corporación Autónoma Regional), and the department of arms control (Departameto Control de Comercio de Armas). The applicant must have a mining title, a semi-annual operational plan, official permission to transport the explosives, and an approved powder magazine in which to store the explosives. The lack of access to explosives is a pressing concern for ASM miners because it limits gold production and increases the health and security risks. An explosives black market exists in Colombia, and in some mining communities there are linkages between mining and terrorist groups or criminal bands (El Colombiano, 2017). The interviewees in the present study were adamant that there is no presence of such illegal groups in Marmato because of strong efforts on the part of the community. The safety issues arise because some miners in Marmato manufacture their own explosives, and these have unpredictable detonation times. In a radio interview, one small-scale miner stated that homemade explosives have caused 80 to 100 accidents in Marmato, resulting in 20 fatalities and 50 long-term disabilities (Caracol Radio, 2019). Without access to a mining title, the miners must resort to black market sources or dangerous homemade explosives, highlighting the imperative to create a functional legal framework for ASM in Colombia.

6. Medium-scale mining

In 1991, the Colombian company Mineros Nacionales S.A. was awarded a 30-year concession contract from the state to explore and mine in the Zona Baja, which had been designated for medium-scale mining by Decree 2223 (Fig. 4). Early 20th century portals left by the British company in 1925 were reopened, and the mine has been in operation since 1993. The mine is known in the community as La Palma (Fig. 2), which is the portal near the mine gate; the company refers to the mine as Maruja, which is the main access. Marmateños also call the mine *abajo* (below) in contrast to the small-scale mining which occurs at

higher elevations. This mine exploits the deeper extensions of the ASM veins, in the geological "lower Upper Zone." Approximately 1,200 miners are employed in the medium-scale mine (Colombia Plural, 2018), many of whom reside in Marmato. Several small-scale miners interviewed in this study attributed their current technical expertise to past experiences working for "the company," meaning Mineros Nacionales S.A. and its large-scale mining company owners.

The medium-scale mine produces approximately 22,000 ounces of gold per year, processing approximately 800 to 1,200 tonnes of material per day for a total of 250,000 to 300,000 tonnes per year (SRK, 2017). Gran Colombia Gold's 2011 acquisition of this mine contributed significantly to its portfolio, accounting for about 10% of the company's total annual gold production (SRK, 2017; Gran Colombia Gold, 2019a). Gran Colombia Gold is presenting its proposed exploitation of the newly discovered Deeps Zone as an expansion of the La Palma underground workings (Gran Colombia Gold, 2019b). In order to provide context for the discussion of this proposed plan, the mining and mineral processing at the current medium-scale La Palma mine are summarized from the technical report produced for GCM (SRK, 2017).

Ore with a target head grade of 2.5 g/t Au is exploited from a 900 m wide by 300 vertical meter zone, using conventional cut and fill sublevel stope mining (SRK, 2017). Explosives for conventional drilling and blasting are purchased from a military magazine on site. Mining is by jack leg drilling, air-powered overshot muckers, and small hydraulic equipment. Ore is moved between levels via inclined shafts and skips, and then moved to surface in 10-tonne cars on battery locomotive trains. Unlike the ASM operations, the use of wooden cribs for ground support is temporary, and the cribs are followed by bolts, mesh, shotcrete, and steel arches. Parts of the mine are dewatered, and the water is used for mineral processing. Most of the waste rock is used as backfill, and little is brought to surface. Tailings management is distinctly different from the ASM operations. At La Palma, 80% of the tailings are used as backfill, pumped underground from the processing plant as a slurry without any cement added. The tailings are drained until they will support mining of the next stope. Excess tailings not utilized as backfill are trucked 2 km to a permitted tailings storage facility. The storage procedure involves drying of the tailings in ponds behind a gabion and earth embankment dam, followed by transfer of the material to lower sections of the facility where it is covered with crushed rock for final storage. However, the previous La Palma operations also generated unprotected waste rock dumps, as well as makeshift tailings storage from which discharge still overflows directly into tributaries of the Cauca River (SRK, 2017).

The ore from the medium-scale mine is processed at an onsite plant with a capacity of 1,500 tonnes/day (SRK, 2017). The process is relatively similar to that used in the ASM *entables* at Marmato, consisting of crushing and grinding, followed by gravity concentration, flotation and cyanidation of the flotation concentrates. The solubilized gold and silver are precipitated using zinc dust in a Merrill-Crowe process. The precipitate is smelted to produce doré. The average feed grade reported for the Zona Baja mill is approximately 2.5 g/t Au and 9.5 g/t Ag, and recovery averages 87% for the Au and 40% for the Ag. The company ships the doré by helicopter to Medellín, where it is sold to third parties on the Colombian market.

7. Large-scale open pit mining

It was not until 1960 that the potential for open pit mining of Marmato's shallow veins was first recognized (Hall et al., 1970). In the 1980s, the Colombian branch of Phelps Dodge Corporation evaluted the veins. Starting in 1995, the Marmato site attracted serious attention from modern large-scale mining companies interested in pursuing open pit development at the site. In the 1990s and early 2000s, several other companies conducted exploration in the Marmato area. These activities included exploration for a bulk mineable target by Minera de Caldas, as well as property acquisition in the Zona Alta by Colombia Goldfields Limited, a Canadian junior company that subsequently sold its interests to Mineros Nacionales S.A. (Table 1). In 2010, the Canadian company Medoro Resource Limited consolidated the three largest gold properties in Marmato by purchasing Mineros Nacionales S.A., Colombia Goldfields Limited, and Echandia. At that time, Medoro Resource Limited commenced scoping studies for large-scale open pit mining. In 2011, Gran Colombia Gold (GCM) acquired the concessions by merging with Medoro Resource Limited. Gran Colombia Gold is a Canadian gold and silver company traded on the Toronto stock exchange as "GCM." The company's focus is on exploration, development, and production in Colombia. From 2011 to 2017, GCM produced gold from the La Palma/Maruja mine in the Zona Baja via its subsidiary Mineros Nacionales S.A. as described in the previous section, while pursuing open pit studies.

The 2012 scoping for the open pit development case identified a mineral resource of 495.8 million tonnes at a grade of 0.94 g/t Au, for a total of 14.96 million ounces of gold in the measured, indicated and inferred categories (SRK, 2012). In the preliminary resource study, SRK (2012) found that there is a large volume of uneconomic or subeconomic material which would have to be mined to reach the main part of the ore body. This means that a large open pit would be economic but a medium-sized pit would not. It is important to note that an open pit which exploits the Zona Baja would involve mining through the upper portion of Cerro El Burro, thus removing the Zona Alta (Fig. 4).

7.1. Landslides and resettlement

The Marmato area's natural geological, topographical, and climatic propensity for catastrophic landslides is accentuated by ASM activities, and the hazard has become politicized by both large-scale mining and ASM in the context of the initially proposed open pit mine. The 2017 Technical Report prepared on behalf of GCM describes the long history of ASM as "unrestrained mining activities which led to large scale environmental deterioration which threatens the stability of higher portions of Cerro El Burro above Marmato and the infrastructure and lives of the inhabitants of Marmato" (SRK, 2017: 151–152).

> Three small-scale miners spoke explicitly about landslides, highlighting the interplay between natural and anthropogenic phenomena:
>
> There is some kind of instability in the mountain. This time I speak not of a natural instability, but one caused by the accumulation of waste rock on the hillside. Normally we have had problems with some low cohesion material. We have had landslides, but only until it reaches the intact rock. But a big one which puts the town in a high risk? Not really. It is very difficult, because we know the rocks inside and they are very fine. The advantage is that the distance between veins is high, which leaves some safety pillars and gives stability to the terrain.
>
> Yes [there are landslides]; all loose material [on the hillsides] is a product of landslides from the top of the hill, but it happens mainly in winter due to the action of water. In winter it is dangerous outside [the mine tunnels], but inside it is safer.
>
> Yes [there are landslides], mainly the waste rock that moves with the rain. It is because during the summer the hillside dries and cracks, and when it rains, water infiltrates and moves the material.

Santi et al. (2011) and Faber (2016) observed that vulnerable populations living in close proximity to landslide hazards may be economically restricted to the area, living in structures that are not robust, and lacking the technical knowledge, resources, or political power needed to mitigate their risk. At Marmato these factors are augmented by the central role of ASM-based livelihoods in the communities, which provides the impetus to live and work in hazardous zones.

The 2006 debris flows that inundated the town made national news in Colombia. The federal government called for risk mitigation and took

the lead on the resettlement project, but an independent news source suggested that this was in order to pave the way for large-scale mining (Colombia Plural, 2018).

> But the transfer project had nothing to do with the [mud] avalanche, which was only the pretext used by the Government. Colombia Goldfields, an Anglo-Canadian capital company, landed a year earlier in Marmato buying the mines and gold production sites of the hill. In 2009, the Canadian multinational Medoro Resources acquired all the rights of this company in the region for 333 million dollars, with this legally seizing 95 mines in the upper part of the hill and also the old mills in which the ore was processed. The company offered to move the entire municipality and pay with its money for the construction of a new town in El Llano, which would allow an open pit operation on the hill.

An ASM miner interviewed for the present study highlighted the common perception that the large-scale mining company was behind the move. The actual level of company involvement in the move remains unclear. Regardless of the veracity, the perception of the interviewed miner is representative of the conflict's tone:

> They [Colombia Goldfields] shrewdly financed the campaign for a mayor, and for every institution that went down [to El Llano], they received a significant sum of money … that guy got a lot of money. All transfers were made at night. Court, notary, registry, hospital … It [the resettlement] was also going to take the schools … and the parish, the place that miners used to do meetings and demonstrations.

The possibility of company-driven resettlement resonates with critiques of how "corporate social responsibility" can result in private industry co-opting the role of the state (Rolston, 2015).

Many Marmato inhabitants and members of the small-scale mining community were strongly opposed to the resettlement activities. Over the years, residents have responded to government and large-scale mining interests in the area by using litigation strategies, forming the *Asociación de Mineros Tradicionales de Marmato*, and filing public reports to claim territory and draw attention to the situation. In 2006 the ASM community formed a civic association "Comité Cívico Pro Defensa de Marmato" expressly to oppose both the resettlement and the proposed open pit initiatives, which had become inextricably tangled. In a newspaper article, a community leader was quoted as follows (Colombia Plural, 2018):

> "We were contestants; the way in which the company moved, we moved likewise" explains José Yamil Ammar, the leader of a Civic Committee [Comité Cívico Pro Defensa de Marmato] that since the arrival of the multinational [company] began to oppose the large mining project. If the company offered money to the owners of the mines, they [the committee] tried to convince people not to sell. If they [the company] promised to build a new town hall, in El Llano, they [the committee] proposed better to refurbish some of the historical buildings built two hundred years ago by the English. If the company talked about evicting because of risk, they [the committee] organized groups to clean up the avalanche waste, to work on the improvement of the slopes, or gathered to beautify the town square.

In the 2017 technical report for GCM, SRK notes that involuntary resettlement should be accomplished through a Resettlement Action Plan (SRK, 2017). In order to comply with IFC guidelines, this plan would need to align with the Equator Principles, which include requirements for social infrastructure and accommodations of labor influx, access to replacement agricultural and pasture land (although not necessarily replacement mining land), census of affected people, a fair compensation strategy developed with all stakeholders that would include coverage of the loss of income from ASM, urban planning of the host area, and monitoring. If ASM activities were moved to a different portion of GCM's concession, the company and the government would have to work together to avoid the pitfalls that have plagued other ASM resettlement initiatives (Hilson et al., 2020). This would include ensuring that there is a viable gold deposit for ASM activities, as well as gaining the government's support in formalizing artisanal and small scale operations. This option is also not likely to be well received among the community members and small-scale miners at Marmato.

One particularly critical issue in the resettlement discussion is the provision of alternative livelihoods for displaced artisanal and small-scale miners. The miners' claims that they are traditional miners emphasizes the longevity of their activities in the area and asserts their rights to the land and resources. These claims constitute identity politics that will complicate any efforts to resettle people who are living and working in Marmato. Mining-based livelihoods are not just a source of income. These livelihoods are also intricately tied to residents' identities as family and community members and Colombians. If resettlement efforts include replacing ASM activities with alternative livelihoods, it will be no surprise if these efforts receive strong opposition from community members in Marmato. Also, the town site itself is part of the cultural identity of Marmateños, representing the long heritage of mining as well as a lynchpin in the conflict with large-scale and foreign interests. The interviews from the present study captured these sentiments, as in a statement that an interviewee addressed to the company:

> Your worst mistake was trying to end a town with a 500-year mining tradition. We are the fourth oldest town in the country … and this town is so important for the Colombian nationality because this town was given as a pledge by Simón Bolívar, to guarantee a loan to finance the emancipatory war.

In 2008, four small-scale miners in Marmato brought a lawsuit against the open pit initiative. On February 28, 2017, the Constitutional Court of Colombia decided in favor of the miners in Judgment SU-133, essentially upholding the 1954 Decree 2223 which reserved the Zona Alta for ASM. The court resolution was as follows and concludes with a quotation directly from Decree 2223 (Corte Constitucional de Colombia, 2017):

> They [the miners] indicated that the four have been working in the Villonza mine since 2011 and the mine, like the others located in the upper part of the El Burro hill, has historically been used for the exercise of small mining by the inhabitants of Marmato. The lower part of the hill has been reserved for medium-scale mining. The social order of the municipality is based on that territorial and democratic distribution of its mining resource, which was endorsed by Law 66 of 1946 and by Decree 2223 of 1954, and which seeks to guarantee the right of Marmateños to undertake small-scale mining enterprises in the upper area of the hill, preserving a source of employment in the lower area, "where one or two companies would be responsible for carrying out the exploitation with the technique, volumes and efficiency criteria that the mining country intends to reach".

This decision is broadly thought to rely on the research of a lawyer who cited the original decree as an attempt to enable coexistence between different scales of mining (Lopera Mesa, 2015). That study also suggested that Marmato may be relatively free from armed internal conflict because the vertical segregation of mining rights facilitates more symmetrical labor relations than is typical in other mining areas.

Shortly after the 2017 ruling was made, Gran Colombia Gold's CFO stated that the company was in dispute with the Colombian government based on perceived lack of support in the conflict with small-scale miners at its operations (Moss, 2017). At that time, the company requested military intervention at Marmato, as well as in Segovia and Remedios where its projects have also encountered intense community resistance (El Colombiano, 2019). Since then, Gran Colombia Gold has shifted its priorities away from open pit development at Marmato, and

the resettlement project has lost momentum. Now the company is focused on developing a large-scale underground mine.

8. Large-scale underground mining

Gran Colombia Gold's discovery of the Deeps Zone made large-scale underground mining a viable option for consideration. In 2017, the company announced a new development plan exclusively focused on underground mining of this zone (Gran Colombia Gold, 2017a). In order to raise funds for the development, in early 2020 GCM spun off its Marmato assets into a subsidiary company Caldas Gold Corp., in which GCM retains a major stake (Gran Colombia Gold, 2019b).

In October of 2019, Gran Colombia Gold announced an underground mineral resource at Marmato, constituting 17.3 Mt at 3.7 g/t Au in the measured and indicated category, with an additional 44.9 Mt at 2.3 g/t Au in the inferred category, for a combined total of approximately 5.3 Moz Au and 12.5 Moz Ag (Gran Colombia Gold, 2019c). Because underground mining is more costly than open pit mining, it requires a higher cut-off grade. Therefore, the calculated underground resource is smaller than the previously reported open pit resource (14.96 Moz Au in the measured, indicated, and inferred categories). The company also reports an additional 1.9 Moz of Au (measured, indicated and inferred) in the Zona Alta, but this does not appear to be included in the Preliminary Economic Assessment. The proposed development would include two operations: the existing La Palma/Maruja mine operated by GCM's subsidiary Mineros Nacionales S.A., and a new Deep Zone extension which lies below. The original Mineros Nacionales S.A. license to mine in the Zona Baja is set to expire in 2021, and GCM is in the process of renewing this contract for another 30 years (Gran Colombia Gold, 2019c). In the expansion, the company is proposing a 19-year mine life to process 26.4 Mt of material, for a total of 2.2 Moz of Au (Gran Colombia Gold, 2019c). For a sense of scale, this would require quadrupling the current production rates from the current La Palma/-Maruja mine (SRK, 2017). The plan is to achieve some of the increased production by optimizing the mine plan for more efficient operation. The remainder would come from the new development in the Deeps Zone, which would require construction of a new processing plant.

As of 2017, GCM was relying on preliminary environmental baseline data conducted by Minera de Caldas during their exploration program at Marmato in the early to mid-2000s, as well as various federal, state, and municipal studies (SRK, 2017). Without an environmental impact statement or a draft mine plan, it is difficult to predict the environmental effects of large-scale development at Marmato. However, some potential issues can be highlighted. The anticipated surface footprint for underground development is smaller than that of the originally proposed open pit. The proposed mining method of longhole stoping is less likely to cause instability at higher elevations than methods such as block caving, but the implications for safety in the Zona Alta would need to be investigated in detail. Environmental issues around surface and groundwater would be significant, including dewatering of the excavation, use of water for mineral processing and dust control, as well as water storage, purification, and disposal. Dewatering at depth could theoretically help shallower ASM operations remain dry. At present it is not clear whether the large-scale operation could also inherit antecedent environmental liabilities from the small-scale mining in the Zona Alta.

The excess tailings from La Palma/Maruja are stored as a slurry behind a tailings dam (Section 6). An expansion of this facility to accommodate the projected amount of material from the planned large-scale mine would be classified as a "large dam," subject to environmental, economic, and social impact studies according to the World Commission on Dams (SRK, 2017). The IFC and other major lenders to mining projects would require adherence to these guidelines, which constitute international best practices. Any tailings storage dam has the potential for breach and contamination of waterways and downstream habitat as well as loss of life, particularly in a seismically active region such as the Colombian Andes. At Marmato, conventional tailings storage would require inundation of a large area to contain the proposed volume of tailings, due to the volumetric inefficiency of storing material in steep-sided valleys.

In the Preliminary Economic Assessment, the company is investigating a "drystack" alternative for storage of filtered tailings (Gran Colombia Gold, 2019c). About half of the anticipated tailings would be stored in this manner. The remainder of the tailings would be used as paste backfill in the mine, and waste rock would presumably also be stored underground as required in Colombia. Filtered tailings are not completely dry but can be stored in a self-supporting stack at their ideal water content of 70–85% saturation (Davies, 2011), so that a tailings dam is not required. Water management is the most critical aspect of this tailings storage method, and this can be difficult in wet climates such as the Colombian Andes. Surface and groundwater would need to be diverted, and the stack would likely need to be placed on a liner to control underdrainage. Precipitation which contacts the tailings would have to be controlled and treated to prevent discharge of contaminants. Although water retention structures would be required, these are potentially less vulnerable to catastrophic failure than the large dams which impound slurries. Another major advantage of the drystack method is that the tailings can be progressively reclaimed, which may lessen the short and long-term environmental impacts.

Concerns over large-scale mining's potential environmental impacts are often the basis for community mobilization against mining developments (Kirsch, 2002; Li, 2015; Welker, 2009). These disputes are either fueled by fears of negative environmental impacts or a perceived lack of participation in decision making regarding these developments (Conde, 2017). In many cases, tailings management and disposal are central to these debates, and recent tailings dams failures have increased global awareness about their management (Armstrong et al., 2019). In Indonesia, tailings and waste rock disposal into rivers by a large-scale gold mine spurred local campaigns and a lawsuit against the company (Kirsch, 2002). In 2008, the government of Peru declared a state of emergency at a large-scale mine over fears that recent seismic activity would weaken the tailings dam and contaminate Lima's water source (Bebbington and Williams, 2008). However, the community members interviewed for this study supported their claims against large-scale mining by focusing on the positive aspects of ASM rather than positioning large-scale mining as a potential environmental polluter, a fact that further emphasizes the importance of ASM to local livelihoods and community cohesion.

8.1. *Ore characteristics and mining rights*

The combination of a vertically zoned ore body, vertically stacked mining rights, and vertically segregated scales of mining is unique to Marmato, where the technical and legal frameworks helped establish the long tradition of ASM as well as continued interest in large-scale development by multinational corporations. This architecture drives conflict between ASM and large-scale mining in the open pit development scenario and creates possibilities for coexistence in the underground development case.

In the geological Upper Zone of the Marmato deposit (Fig. 4), competing interests in the same natural resource intersect with competing understandings of land ownership. The veins in the shallowest portion of the Upper Zone are the only parts of the Marmato resource that could be viable for both ASM and large-scale mining, making conflict inevitable if the open pit option is pursued by a large-scale mining company. No large-scale company has been able to make open pit development economically viable thus far, and it is clear that the social risks associated with resettlement and ASM displacement are significant.

Despite the contentious nature of the open pit scenario, this history played an important role in generating possibilities for coexistence at Marmato. Large-scale mining's long-standing interest in open pit development at the site resulted in extensive exploration, drilling, and

geological investigations by GCM and its predecessors over many years. Although these efforts were conducted with the focus of defining an open pit resource at Marmato based on the technical characteristics that were recognized at the time, such activities eventually also led to the discovery of the Deeps Zone.

Possibilities for coexistence between large-scale mining and ASM arise because the Deeps Zone is amenable to mining by a large-scale underground operation. The ore differs in morphology and composition, requiring economies of scale that would not be possible for ASM. If underground development is pursued by a large-scale company such as GCM, and if coexistence is prioritized in the large-scale mine's design and operation, small-scale mining could feasibly continue at shallower depths in the Zona Alta concession. In 2017, Gran Colombia Gold stated that it intends to implement contract mining from Zona Alta, thereby incorporating gold production from the "ancestral and artisanal miners operating within GCM titles" (Gran Colombia Gold, 2017a). The contract mining is not mentioned in the 2019 Preliminary Economic Assessment, so it is unclear whether GCM intends to recover any proportion of the 1.9 Moz Au resource in the Zona Alta or whether the ASM operations will continue independent of GCM.

The economics of large-scale open pit and underground development are different from one another. In addition to other technical and social considerations, commodity prices weigh heavily in any company's decision to focus on one method or the other at a particular point in time. Bulk mining of a larger tonnage and lower grade target is feasible when the commodity price is high, whereas more selective underground development of a smaller and higher grade resource may be more profitable when prices are lower. Rochlin (2015a, b) cites the boom-bust cycle of fluctuating commodity prices as a key factor in the history of interactions between large-scale mining and ASM at Marmato. Indeed, gold price volatility may hinder stable long-term relationships between large-scale companies and ASM (Hilson et al., 2020).

In both the open pit and underground development scenarios, small-scale miners refer to the relatively short proposed mine life as a point of conflict with large-scale mining interests. Mining at Marmato highlights different views of territory and livelihood (e.g. Ramírez Guerrero, 2012). The relatively rapid pace of large-scale resource extraction which maximizes the net present value of a finite ore deposit is fundamentally at odds with the view of mining as a traditional livelihood which is passed down from generation to generation. By enabling mining of different parts of the ore body at contrasting scales and paces, models for coexistence between large-scale mining and ASM should ideally create opportunities for different conceptions of natural resource extraction. The themes of community cohesion, livelihood, and equity are central for the small-scale miners in such conceptions:

> [In Marmato], there is also a culture of mining solidarity, generating bonds of partnerships that in addition acts on the harmony of people.

> We have always insisted on this … the only option to maintain peace and stability within a region is to generate employment. In Marmato there is employment and it is an example. When people have equitable characteristics in terms of work, people tend to be peaceful, and over time "El Marmateño" has had a culture of peace and tranquility.

9. Implications

The Marmato case study shows that the technical and social contexts intersect in the interactions between ASM and large-scale mining. The following discussion highlights how this perspective can be used to understand these interactions at other sites, providing guidance for scholars and practitioners in the field.

9.1. Politicization of natural hazards

The politicization of natural hazards is by no means a new phenomenon. Natural and technological disasters are invariably politicized almost immediately after they occur. Olson (2000) presented the idea that disasters represent "agenda control and accountability crises" for political leaders, meaning that disasters put new issues and demands on the political agenda. Some groups are empowered and others are weakened by the changed agenda, and new developmental and financial possibilities arise during recovery and reconstruction (Olson, 2000). The Marmato case study highlights the idea that natural disasters may also be "agenda control opportunities." After the 2006 landslides, Colombia Goldfields and public officials capitalized on the new agenda in order to push the resettlement initiative, and the civic group that formed in response to resettlement also used this momentum to further the anti-large-scale mining movement. The possibility of open pit mining thus became what Olson (2000) refers to as a "new developmental possibility" in the aftermath of a disaster.

Natural disasters are known to be asymmetric in their impact on ethnic groups or social classes, and this is particularly true for landslides (e.g., Santi et al., 2011; Faber, 2016). The Marmato case study shows how politicization of a disaster can further entrench this asymmetry. The groups most impacted by the safety hazard of the Marmato landslides are also those whose livelihoods are most vulnerable to the proposed mitigation strategy. The Marmato case study also demonstrates how natural hazards may be politicized by groups with competing land claims.

The Marmato case study has important implications for decision-making in locations where natural or environmental hazard mitigation is beyond the capacity of the government. If this function is privatized, it is difficult to prevent real or perceived abuse of power. At Marmato, community perception might have been different if resettlement had been decoupled from the open pit initiative. Instead, the open pit controversy was fueled, and people continue to demonstrate resistance by living in hazardous zones and exposing themselves to risk.

Landslide hazards, mining, and poverty are co-located in many parts of the world, and governments should consider carefully whether the role of hazard mitigation should be delegated to large-scale mining companies. A parallel issue is that the environmental impacts of ASM have been used as an argument in favor of large-scale mining (e.g., Owusu et al., 2019). In some cases large-scale mining companies are called upon to mitigate or remediate the environmental effects of ASM, framed as formalization schemes using a contract mining model for coexistence (Veiga and Marshall, 2019), or positioned as corporate social responsibility. Large-scale mining companies may ultimately face more resistance if they absorb the role of the state, and as at Marmato the hazard mitigation efforts may further exacerbate existing power and wealth asymmetries.

9.2. Importance of deposit style

The importance of deposit style in interactions between ASM and large-scale mining has been implicitly recognized by practitioners around the world, but this idea has not been explicitly articulated prior to this study. Certain deposit styles and mining methods lend themselves to competing claims for the same natural resources in the same target area, such as the shallow epithermal veins at Marmato. These veins are amenable for small-scale underground mining, and they have simultaneously been targets for potential large-scale open pit mining. Using the nomenclature that Kemp and Owen (2019) developed to describe the interfaces between large-scale mining and ASM, this scenario constitutes competition for the same commodity in the same target area.

There also exist particular geological settings that create possibilities for coexistence. At Marmato, the vertically zoned deposit also contains the mesothermal-style Deeps Zone. This disseminated ore would only be economic for large-scale exploitation, and it could be mined at large-scale while the shallow veins are mined by ASM. Farther north in Antioquia, Colombia, the Buriticá deposit is characterized by epithermal veins. Some of these are amenable to large-scale mining; others are too

narrow to be mined with large-scale equipment and are more suitable for ASM. At the Bonanza deposit in Nicaragua, epithermal veins are exploited by both large-scale mining and ASM. Together these examples suggest that epithermal deposits may be promising for coexistence. In West Africa, orogenic gold deposits and placer gold deposits occur in close spatial proximity because the placer gold was eroded from similar orogenic veins upstream, creating another geological setting permissive of coexistence. For example at Yanfolila in Mali, the shallow Bolon placer deposit has been mined by ASM only a kilometer from the large Komana East open pit which exploits the orogenic gold (Teschner, 2014). Such examples highlight instances where the two parties are seeking different commodities in different areas, or the same commodity in different areas (e.g., Kemp and Owen, 2019).

Other examples need to be identified in order to develop a comprehensive framework which integrates suitability for coexistence into the conceptual "mineral deposit models" that are traditional in geology. This type of framework would be a useful lens through which to examine interactions between ASM and large-scale mining, as well as a possible source of information in decision-making. For example, large-scale mining companies should consider whether the deposit type and site-specific characteristics are amenable to mining methods which are likely to facilitate coexistence or conflict. ASM communities may be able to identify strategic targets in negotiations with large-scale companies or governments by articulating the suitability of a particular zone for ASM rather than large-scale mining. A proactive approach by all parties may help avoid tensions and pave the way for productive collaboration. However, the same geological arguments could be misused in order to disrupt ASM activities or threaten traditional land claims.

Lastly, governments should consider the geological setting when designating land for a particular scale of mining, such as Decree 2223 at Marmato. Unfortunately, there is no simple strategy by which such data can be obtained. Some authors have suggested that governments themselves should generate geological data to identify land suitable for ASM (e.g., Hilson and Maponga, 2004; Hilson et al., 2020). However, the Marmato case study demonstrates how this may be impractical. Despite centuries of small- and medium-scale mining at Marmato, the Deeps Zone was unknown when Decree 2223 was made. The Deeps Zone was ultimately discovered after more than 30 years of exploration by large-scale companies, and it is only by chance that this large-scale mining target is located in the appropriately designated zone. Regional-scale surveys are unlikely to differentiate between favorability for large-scale mining versus ASM and would need to be followed up with site-specific subsurface exploration, which is iterative and costly. It is unrealistic to expect that governmental institutions could generate such data at a resolution equivalent to that produced by the private sector. This lack of capacity is particularly evident in the developing world (e.g., Corbett et al., 2017), even when donor funding has been directed towards such programs (e.g., the World Bank's 1992 capacity building project in Mali). Armed with insufficient information, governments then risk reserving land that may be unfavorable for ASM (Corbett et al., 2017; Yankson and Gough, 2019), or underexplored for large-scale resources. In the latter case, land allocation strategies may alleviate local conflict, but ultimately policy-makers will face pressure from large-scale companies seeking to explore within the ASM concessions. If governments resist such pressure, policy-makers risk that their jurisdictions may be perceived as unattractive for large-scale mining investment.

9.3. Models for coexistence

The Marmato case study highlights the imperative to develop effective legal frameworks for ASM that help balance mitigation of the environmental and safety risks of ASM with reasonably attainable standards for small-scale operators. Contract mining is one model of coexistence that has been proposed for Marmato. However, even when both the ASM and large-scale mining parties are prepared to operate fairly, equity can be difficult to achieve based on technical constraints. For example, when a small-scale miner brings ore to a large-scale mining company to be processed, the quantity of gold (or other commodity) contained in the rock is unknown. The grades of all ore deposits vary spatially, so the quantity of gold in the ore from a single vein might vary from one day's production to the next. Therefore, it is unclear how much a large-scale mining company should pay for a delivery of ASM ore. A simple solution would be for the large-scale mining company to pay the contract miner a pre-negotiated percentage of the value of the gold that is produced. However, an ASM miner's ore cannot necessarily be processed individually, because large-scale mineral processing and extractive metallurgy are typically designed based on continuous throughput and economies of scale. In order to determine the value of a contract miner's ore, it is common for a large-scale mining company to assay a random sample and weigh the total delivery of the ore. The company then uses the assay value to estimate the total gold contained in the tonnage of rock delivered. This strategy requires that the contract miners trust the company, trust the sampling and assaying process, and accept an estimate of the contained gold as a suitable determination of payment. Various technical procedures may help build trust, such as at Bonanza in Nicaragua, where the large-scale mining company HEMCO uses a computer to select random samples generated by an automatic disc splitter. One sample is assayed by the company, one is assayed by the miner, and the third is assayed by an independent party if there is a discrepancy.

Gran Colombia Gold is pursuing the coexistence model via contract mining at several mines on its titled land in Segovia, about 300 km northeast of Marmato. ASM collectives totaling 2,500 miners exploit portions of the veins under contract (Gran Colombia Gold, 2017b). The company assisted at least some of the contract miners in becoming formalized. Like the resettlement in Marmato, the large-scale mining company's role in formalization of ASM essentially privatizes the role of the state. The contract miners bring the ore to GCM for processing. The delivery is weighed, and an automatic sampler selects an ore sample which is then split into thirds. Similar to Bonanza, the company assays one third to estimate the gold contained in the delivery, one third is given to the miner for assay, and the remaining third is used as a reference if the assay values are different. GCM pays the contract miners 10 to 60% of the spot gold price for each ounce (Gran Colombia Gold, 2017b). Negotiations between the company, the small-scale collectives, and other small-scale miners have been tense and marred by periods of civil unrest (Gran Colombia Gold, 2017b). Despite these challenges, GCM's contract mining strategy has been credited with observable reductions in mercury use by ASM (Cordy et al., 2015; García et al., 2015). One miner interviewed in this study noted that in Segovia, several factors which make it difficult to operate independently therefore support the contract mining model: the relatively low grade ore, the lack of access to explosives in a conflict-plagued area, and pressure from regulatory authorities.

Continental Gold employed a contract mining model at the Buriticá project, in the middle Cauca belt about 200 km north of Marmato. Large-scale production is scheduled to begin in 2020, and formalized collectives of ASM miners are already exploiting the narrow parts of the veins. When details of the vein discovery became public at the start of the large-scale project, a humanitarian crisis occurred due to the sudden influx of thousands of small-scale miners and their families (El Tiempo, 2016). Since then, the site has been plagued by violence attributed to criminal groups, as well as tense relationships with small-scale miners (Cardona, 2017). In late 2019, Continental Gold was bought by a Chinese mining company called Zijin. The future of the contract mining at the site is unknown, highlighting that coexistence arrangements are acutely vulnerable to changes in ownership of the large-scale project (e.g., Hilson et al., 2020).

These examples demonstrate that peaceful collaboration is not guaranteed even when the technical architecture is permissive of coexistence between large-scale mining and ASM. There are ever-

present power differentials between large-scale mining and ASM operators rooted in neoliberal systems of resource governance that make coexistence models especially challenging (Verbrugge, 2017). Lessons might be gleaned from other case studies of coexistence (e.g. Aubynn, 2009; Davidson and Wotruba, 2004; and Teschner, 2013), highlighting the work to be done by both large-scale mining and ASM groups. These examples show that large-scale mining and ASM stakeholders must work together to develop a collaborative approach that encompasses both technical and social considerations. Any proposed models for coexistence between large-scale mining and ASM must integrate the historical and cultural context with the technical framework of geological, engineering, and legal characteristics.

10. Conclusion

Intersecting technical and social factors create the architecture for conflict or coexistence between large- and small-scale mining at Marmato, Colombia. This case study demonstrates that the technical aspects of ore body zonation engender the particular land tenure policies at Marmato, and that the geological propensity for landslides has enabled the politicization of geological hazards around the concept of forced resettlement. These factors converge with the social context, where a history of exploitation of people, competing perceptions of land and resource rights, and identity politics related to mining livelihoods result in competing rather than coexisting large- and small-scale mining interests.

However, as discussed, these same circumstances may also set the stage for a future relationship based on coexistence between large-scale mining and ASM at Marmato. As large-scale and small-scale resource development continues to expand both in Colombia and globally, these two sectors will increasingly converge. Examining the intersections among the technical and social drivers of conflict reveals that new approaches to coexistence models must be based on a participatory approach where both large- and small-scale operators have an equal voice and can work together toward mutually beneficial relationships.

CRediT authorship contribution statement

Elizabeth A. Holley: Conceptualization, Writing - original draft. **Nicole M. Smith:** Conceptualization, Writing - original draft, Formal analysis. **Jeison Alejandro Delgado Jimenez:** Writing - review & editing, Data curation. **Isabel Casasbuenas Cabezas:** Data curation. **Oscar Jaime Restrepo-Baena:** Writing - review & editing.

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Appendix A. Supplementary data

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