The influence of geomorphology on the role of women at ASM sites: integrating physical science data into the ASM discourse

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Abstract

The geologic and geomorphic expression of a mineral deposit determine its location, size, and accessibility, characteristics which in turn greatly influence the success of artisans mining the deposit. Despite this critical information which can be garnered through studying the surficial physical expression of a deposit, the geologic and geomorphic sciences have been largely overlooked in artisanal mining-related research. This study demonstrates that a correlation exists between the roles of female miners at artisanal diamond and gold mining sites in western and central Africa and the physical expression of the deposits. Typically, women perform ore processing and ancillary roles at mine sites. On occasion, however, women participate in the extraction process itself. Women were found to participate in the extraction of ore only when a deposit had a thin overburden layer, thus rendering the mineralized ore more accessible. When deposits required a significant degree of manual labor to access the ore due to thick overburden layers, women were typically relegated to other roles. The identification of this link encourages the establishment of an alternative research avenue in which the physical and social sciences merge to better inform policy-makers, so that the most appropriate artisanal mining assistance programs can be developed and implemented.

Keywords: Artisanal mining, geomorphology, gender roles

1. Introduction

Artisanal and small-scale mining (ASM) is a global phenomenon with a significant economic, social, and cultural impact. Artisanal mining is typically identified by the utilization of rudimentary tools and labor-intensive techniques for extracting and processing mineralized ore. ASM occurs predominantly in rural areas of developing countries where the population is poor and mining offers an additional source of income, often to supplement subsistence agricultural production. The International Labour Organization (ILO) estimates that between 10 and 13 million people are directly involved in the ASM sector worldwide (ILO, 1999). There has been an increased interest in ASM among social scientists and non-governmental and governmental agencies within the past decade, in particular among those concerned with the livelihood and sustainable development issues associated with this unique and often under-represented population.

The importance of physical sciences, particularly geology and geomorphology, has been largely overlooked in artisanal mining related research, despite the fact that such data is critical to understanding the characteristics of the deposits artisans mine, and the success of the miner. An improved understanding of the geologic and geomorphic nature of artisanally-mined deposits would greatly assist a diverse array of actors ranging from international development agencies, national governments, and individual miners. Geologic and geomorphic knowledge is critical for

the implementation of effective assistance programs, the regulation of the ASM sector by national governments, understanding the economic potential of deposits, and for the success of the individual miner.

This study highlights the applicability and effectiveness of geomorphology, the study of landforms and the processes that shape them, as a tool for examining women's gender roles at artisanal mine sites. We argue that artisanal mining should be researched through a combined social and physical science lens, in order to comprehensively investigate the variety of multi-faceted and complex issues that concern this population. The study demonstrates that the roles of female miners at alluvial diamond and gold mining sites are greatly influenced by the physical expression of the deposit, specifically the geomorphic deposit type and the thickness of the overburden layer, as these characteristics determine the accessibility of the sought-after mineralized ore. Research conducted over a period of five years in West and Central Africa finds that women participate in extraction processes only when a deposit is relatively easily accessible. When deposits require a significant degree of manual labor to access the ore, women are typically relegated to ore processing activities and ancillary roles such as washing and sorting gravel, cooking, and commerce. The application of an integrated socio-physical approach to artisanal mining can generate a more robust understanding of the sector, thus enabling more effective and appropriate policies to be designed and implemented targeting artisanal miners; However, researchers within the field have yet to integrate the physical sciences with the predominantly socio-economic analyses of artisanal mining. This study highlights several key physical science components of ASM and their relationship to gender roles, and suggests methods for expanding a more integrated approach to the field.

2. Background

2.1 Introduction to ASM

The population dependent on ASM continues to trend upwards as mineral ore prices continue to rise (Van Bockstael and Vlassenroot, 2008). The market price of gold, for example, has increased fourfold over the past eight years, leading to a significant increase in the number of people engaged in the ASM sector. While ASM is associated with environmental, health, and safety related problems, the potential economic gains for local and national economies are substantial (Hilson, 2002). ASM involves the exploitation of deposits that have often been deemed unprofitable by large-scale mining companies, and therefore may result in additional revenues that would otherwise not have been generated (Labonne, 1996). Of equal importance is the degree to which ASM supports local economies through the creation of job opportunities and the augmentation of the demand for goods and services. Miners chose to become involved in this sector for a variety of reasons, ranging from cultural traditions to financial demands. In particular, money for school fees, medical emergencies, marriages and other important events is frequently sought through artisanal mining. Despite its associated risks, ASM is frequently perceived as an attractive livelihood option due to its low entry barriers and potential for high earnings (Jønsson and Fold, 2011).

2.2 The roles of female miners

According to the ILO, 30% of artisanal miners are female. The percentage of female artisanal miners in Africa exceeds the global average, and is estimated to be 40-50%. The participation of women in ASM has been steadily increasing in recent years. The roles and degree of participation of women differ from country-to-country and site-to-site, though typically women serve as ore-processing laborers and providers of goods and services, in conjunction with performing domestic household responsibilities (Hinton et al., 2003; Centre for Development Studies, 2004). In the case of alluvial diamond and gold mining, ore-processing activities include the transport of excavated ore to designated washing sites, carrying water, and the washing and sorting of gravels in search of minerals. Secondary roles consist of babysitting, cooking, and engaging in small-scale commerce through the sale of food and other goods (Hinton et al., 2003). In some cases, mainly in Africa, women have been able to achieve the authoritative role of claim-holder (ILO, 1999). Men typically perform the role of extracting the mineralized ore, however they often perform processing activities in conjunction with women. Table 1 describes in further detail the typical jobs performed by men and women at artisanal diamond and gold mining sites, as categorized by this study.

Table 1.

Women's roles in this sector have frequently been explained by researchers through the examination of social and cultural norms, governance, and income inequality. The potential economic benefits of artisanal mining are clear; however, due to numerous barriers, women are often prevented from taking full advantage of these benefits. Women have been relegated to secondary roles in many economic sectors in societies throughout the world, and artisanal mining follows this trend (Labonne, 1996). This is due in large part to a combination of cultural perceptions of what types of work are deemed appropriate for women, as well as the barriers women face in accessing assets (Centre for Development Studies, 2004). Women interested in concession ownership, for example, face numerous obstacles as a result of gender discrimination. Women have difficulty obtaining loans due to a lack of assets for collateral, a lack of formal education, and the general reluctance of male bankers to engage in business with women (Hentschel et al., 2002). In fact, in many societies, as men are seen as the head of household, a husband's permission is required in order for a woman to obtain financing (Hilson, 2002). Cultural perceptions constitute another obstacle to achieving equity, as certain jobs are regarded as being suitable for women, such as gold panning, while others, such as digging, are not. For example, in the West African gold mining sector, the role of women as panners is a well-established tradition, as the mining of gold has been carried out in the region for over 2,000 years. More often than not, however, cultural and traditional barriers result in the relegation of women to more menial, unskilled tasks such as transporting or washing ore (Hinton et al., 2003).

Some attention has been focused on the participation of women at artisanal mine sites within particular countries, including Ghana (Yakovleva, 2007), Guinea (Sow, 2003), Burkina Faso (Werthmann, 2009), Kenya (Amutabi and Lutta-Mukhebi, 2001), Uganda (Hinton, 2011), Suriname (Heemskerk, 2000), Papua New Guinea (Moretti, 2005), and Brazil (Graulau, 2001). These studies provide insight into women's roles within particular ASM communities and provide socio-cultural explanations for their roles, at a detailed scale. However, a major gap shared by these and many other ASM studies is the lack of attention given to the physical characteristics of the deposits in the researched communities.

3. The role of geomorphology

While socio-economic justifications for women's roles at ASM sites have been substantiated by numerous researchers, this study expands upon existing analyses of gender roles in the ASM sector by examining geomorphology as a determinant of women's roles. Geomorphology concerns the study of how natural forces such as wind, water, and gravity shape and alter a landscape. These forces also control mineral deposition to a large degree; therefore, a study of diamond and gold mining would not be complete without addressing geomorphology.

Diamond and gold deposits may be divided into primary occurrences and secondary occurrences. Primary mineral occurrences are those found in the source rock. Primary diamond deposits are found mainly within kimberlite pipes, dikes and lamproite dikes, while primary gold deposits are most commonly found in association with quartz veins. Secondary mineral occurrences are those which have been removed from their source rocks due to processes of weathering and erosion, and are subdivided into eluvial, colluvial, or alluvial deposits. Eluvial deposits are developed in situ from the weathering of the primary source rock. Colluvial deposits consist of weathered rock which has been transported downslope by gravity, and are typically found at the foot of slopes.

Alluvial deposits, which are the focus of this study, are those which have been transported downstream from their source rock by river systems, and are eventually deposited over potentially vast areas within a river's channel bed, alluvial flat, or terraces. Channel deposits are those which are found in bedrock potholes of the active channel's river bed, while alluvial flat deposits are those located in the current flood plain. Terraces are formed by either a decrease in stream base level, which results from sea level or climate changes, or as a result of the tectonic uplift of the landscape. In either case, downward erosion occurs and terraces develop in what was once the former floodplain, above the newly formed floodplain and channel.

The thickness of overburden, the unconsolidated sediment layer that lies above the mineralized gravel, is an important characteristic which greatly influences the accessibility of a deposit, as the thinner the overburden layer, the more easily exploitable the deposit (Bardet, 1974). Primary and eluvial deposits generally have minimal overburden, and mining takes place in the

consolidated or semi-consolidated source rocks. Secondary alluvial deposits have varying overburden thicknesses, though in general, high terraces have the thinnest overburden layers, followed by low terraces and alluvial flats. Overburden thickness in West and Central Africa can range from several centimeters to more than 30 meters. In most cases, the overburden of the alluvial deposits in the study areas consist of an upwardly fining alluvial sequence of unconsolidated gravels, sands, silts, and clays, rendering this material easily exploited with simple tools. Often, the top portion of the gravel layer is sterile and must be removed prior to washing the mineralized ore. It is also possible for several mineralized alluvial sequences to be stacked on top of one another; however, this is not typical of the diamond and gold deposits of West and Central Africa.

In the physical science literature, the importance of using a geomorphological approach to study alluvial placer deposits has been highlighted by several researchers, as this information is particularly valuable for effectively and efficiently evaluating the economic potential of deposits (Teeuw et al., 1991). It is important to note, however, that while such information is commonly collected by geologists, it is rarely applied to or shared with artisanal miners.

Deposition must be examined at a variety of spatial and temporal scales, in order to gain a comprehensive understanding of events which have led to the present depositional patterns. These range from the watershed scale to the regional scale. Examining drainage basin evolution at both scales provides insight into mineral concentration and their distribution from their source rocks, which is influenced by rates of erosion, the rate of basin lowering, and sediment retention (Sutherland and Robinson, 1996; Marshall and Baxter-Brown, 1995). Of additional importance to deposition are the regional and continental-scale historic climatic fluctuations and lithological, stratigraphic, and tectonic settings (Sutherland, 1993; Teeuw et al., 1991; Marshall and Baxter-Brown, 1995).

The richness or grade (expressed as carats of diamond or grams of gold per cubic meter) of the gravel layer varies by geomorphic expression, due to the differing erosional histories and clustered nature of alluvial diamond and gold deposits. However, bedrock faults, channel confluences, low gradient slopes, incised channels, and bedrock traps tend to be sites of increased mineral concentration (Teeuw et al., 1991). Several studies have also found that lower average grades are found in terrace deposits as compared to alluvial flat deposits, and that mineral retention appears to decrease as slope increases (Hall et al. 1985, Chirico et al. 2010).

The importance of geomorphology has been clearly outlined in studies concerning the development and formation of alluvial deposits. Geomorphology influences the location and grade of deposits, information which is crucial in determining their economic potential, and thus the likelihood of whether the mining of a particular zone is foreseeably profitable. As such, geomorphology can be a useful tool for prospecting purposes, assisting with the identification of mineralized zones. Overburden thickness is also determined based on the geomorphic expression of a deposit, with the thickest overburden layers found in alluvial flats and the thinnest in terrace

zones. Overburden thickness is a critical characteristic of a deposit, affecting its accessibility, and in turn the amount of financial support, labor, tools, and organization required to extract the material. Therefore, the ability of artisanal miners to exploit a particular deposit, their methods of extraction, and inevitably their success, are largely controlled by a deposit's geomorphic expression.

3.1 Data gaps

Geomorphic deposit type and overburden thickness have not been previously examined in the ASM literature as being possible determinants of the roles of women at mine sites. Hinton et al. (2003), however, do cite commodity type as influencing women's roles. The authors conclude that in the extraction of high value products, such as gold, men have greater control over the site and are involved in digging, while women typically only wash, pan, and transport. Meanwhile, women are more involved in the extraction of high volume, low yield commodities such as clay, limestone, and dimension stone, and have greater control of the land and more involvement in decision-making processes.

The adaptation of a comprehensive approach integrating the physical and social sciences could provide new insight and improve the current understanding of the ASM sector, through the examination of alternative variables, such as geologic and geomorphic expression. Hilson and Maponga (2004) highlight the lack of accessible geologic information pertaining to mineral reserves, and argue that such data would assist ASM regularization and formalization efforts by identifying appropriate licensing strategies, equipment provision programs, and solutions to land use conflicts. Furthermore, such data is a prerequisite for identifying locations that are appropriate for artisanal mining activities, and the lack of geologic information forces miners to operate inefficiently, with little awareness of the location or value of mineral deposits (Hilson and Maponga, 2004). It is also possible that the inclusion of geologic and geomorphic data could assist with the explanation of variations that occur from site to site in organizational and operational structures, differences which have been identified by previous researchers, such as Jønsson and Fold (2009). Our current understanding of the ASM sector is far from complete; this study seeks to identify the influence of variables related to the geologic and geomorphic expression of deposits, in order to further our knowledge of the sector and support the creation and implementation of policy and development initiatives. By providing a more complete understanding of artisanal miners and the deposits they mine, the incorporation of geologic and geomorphic data would result in increased benefits from formalization and assistance programs.

4. Research methods

4.1 Fieldwork

A total of 135 artisanal diamond and gold mining sites were visited in Mali, Ghana, Guinea, and the Central African Republic (CAR), during fieldwork missions conducted from 2007-2012 (see Figure 1). In Mali, a total of 57 gold and diamond mining sites were visited in the southwestern

regions of Kenieba and Bougouni. In Ghana, 13 diamond and gold mining sites in the Birim River and Bonsa River mining areas were visited. A total of 40 diamond mining sites in Guinea's most heavily-mined western and southeastern prefectures were visited, and 25 diamond mining sites were visited in western and eastern CAR.

Fieldwork sites were chosen by selecting those located within the major diamond mining regions of each country. The majority of the visited sites were exclusively mined for diamonds. However, the diamond mining regions of Mali, Ghana, Guinea, and CAR are also the location of artisanal gold mining activities. As a result, 38 of the visited sites were those in which both gold and diamonds were mined, and 31 of the sites were gold mining operations.

Figure 1.

4.2 Data collection

During each fieldwork mission, data was collected through the use of a structured data sheet to gather both quantitative and qualitative data about the mine site and the miners themselves. The data sheets are separated into three tiers. Tier one is referred to as the "Mine Site" data sheet, the focus of which is to collect both quantitative and qualitative data that pertains to the entire site, and can be used to summarize a site's characteristics. Data is collected based on observations by the researchers and includes the thickness of the gravel layer, the thickness and description of the overburden layers, the size of the site, its geomorphic zone (active channel, alluvial flat or terrace), the number of men, women, and children, jobs performed by men, women, and children, and the types of tools used. Tier two is known as the "Mine Manager" survey, the goal of which is to interview the site's manager to collect data pertaining to how the site is run and operated. The focus of this survey is on characteristics of the commodity mined, the operational history of the mine, the legal situation of the mine, and information detailing ways in which the commodity is valued and sold. Tier three, known as the "Miner Life" survey, is a detailed structured interview with an individual miner at each site. The interviewee, typically male, was randomly selected and asked a mixture of close and open-ended questions which include their reasons for mining, how often they mine, what additional income-generating activities they are involved in, and migration questions.

Because the focus of this study is to examine the relationship between geomorphology and gender roles, it was necessary to visit as many different sites as possible within the limited amount of time allowed for fieldwork. By visiting a multitude of sites (n=135), more accurate conclusions could be drawn from the data, as it is representative of a larger area. This approach was chosen over visiting a small number of sites, but interviewing multiple miners at each site. An example of such methods are presented by Ingram et al. (2011), in which 131 miners were interviewed at 17 sites. While such an approach provides a very detailed portrait of each site, in order to meet the goals of this study, it was of greater importance to visit as many sites as possible, accepting the tradeoff that a larger sample size might result in a more cursory

examination of the visited sites. Of equal importance was the necessity for surveys to be carried out at the mine sites themselves, rather than within the communities in which miners live, as was done by Yakovleva (2007) and Hinton (2011). These authors strongly believed in the need to observe and interview miners within the mining environment. Doing so was entirely necessary to complete tier one, and allows us to visually and quantitatively verify the accuracy of responses to particular questions in tiers two and three.

4.3 Data analysis

The first step of data analysis was to determine the frequency at which men and women participate in various mine site jobs. Data on the jobs performed at each site was collected using the Mine Site data sheet at each site. Several predetermined job categories are listed on the data sheet for the convenience of the researcher. Any additional jobs observed by the researcher at the site were listed in an "other" category. A frequency distribution displaying the percentage of men and women that participate in excavation, transport, washing/sorting, carrying water, supervision, babysitting, cooking, recycling, and other jobs was created. Three variables were then closely examined: the average overburden thickness of the deposit, the geomorphic zone in which the deposit is situated, and the type of commodity being mined. Basic summary statistics were calculated to analyze the average, minimum, and maximum overburden thicknesses at sites where women were extracting, and sites where women do not extract. Frequency distributions were created to analyze the distribution of sites in which women extract among the different geomorphic zones (active channel, alluvial flat, or low terrace) and the commodity type mined at these sites (diamond or gold).

5. Results

5.1 Summary of the roles of men and women at mine sites

The consensus in the literature is that, in general, men are primarily engaged in extraction activities, while women are primarily engaged in ore processing activities (Hinton et al., 2003; ILO, 1999). The results of this study largely coincide with this trend. Across all the sites visited, women reported participating in the extraction of ore only 13% of the time, while men reported participating in extraction 95% of the time. Both women and men most frequently participated in washing and sorting, followed by transport. Both women and men also participated in commerce and supervision, while only women were reported to participate in recycling, babysitting, and cooking activities. Overall, women were involved to a much higher degree in the processing activities of washing/sorting and transport, as well as the additional, secondary mine site activities. While women are frequently cited in the literature as participating in the role of carrying water, women were not observed participating in this job at any of the sites surveyed in this study. This is likely due to the fact that the sites surveyed were alluvial deposits in which water was readily available either from a nearby river or stream or from previously-mined pits filled with rain water. In fact, carrying water was only reported as a mine site job at six sites,

indicating that the transportation of water was not a requisite task at the majority of sites; therefore, conclusions concerning the role of men and women in the performance of this job cannot be made from the data.

Interestingly, men were involved to a high degree in both extraction and processing activities. This apparent dual role is likely due to the fact that many of the sites that were visited are operated exclusively by men, or have a very low percentage of female workers, requiring men to participate in all mining-related tasks. At sites with female participation, men played a lesser role in processing activities. Jønsson and Fold (2011) note a high degree of fluidity of workers between the hierarchical roles typical of mine sites, including financiers, claim-holders, pit operators, and workers. It appears that this trend is also evident among those occupying the role of "worker" at many sites, as individuals perform multiple roles, rather than being restricted to a single specialized task. Also of importance is the finding that at eight sites, women were reported to participate in the supervision of the mine site, putting them in positions of power by acting as claim-holders and/or financiers. This finding supports conclusions of the ILO (1999) that while women most often perform mineral processing-related tasks, they have in some cases breached tradition and taken on financial roles, placing themselves in positions of authority. The distribution of jobs performed by men and women is displayed in figure 2.

Figure 2.

5.2 The effect of geomorphology on women's roles

As previously stated, women participated in extraction at 13% of the surveyed sites. As was expected based on conclusions in the literature, the participation of women in extraction activities is a relatively rare occurrence; therefore, it is necessary to identify explanatory variables which may lead to conclusions as to why women extract at some sites, and not at others. Based on the hypothesis that the physical expression of a deposit influences women's roles, the following geomorphic and geologic variables were analyzed: overburden thickness, geomorphic zone, and commodity type.

The examination of the average thickness of the overburden layer at sites in which women extract and sites in which they do not, clearly demonstrates the existence of a relationship. Of the sites sampled, overburden thickness ranged from 0 m to 12 m, with the average being 4.37 m (see Table 2). The average overburden thickness at sites in which women do not participate in extraction is 4.72 m, while the average at sites in which women do participate in extraction is 1.52 m. From this, it can be concluded that the average overburden thickness at sites where only men extract is near or above the overall average, while the average thickness at sites where women extract is well below the average (2.85 m below the overall average).

Table 2.

Naturally, sites with shallow overburden require less labor to reach the ore layer, as there is less material to remove. Sites with deep overburden require large groups of workers which must be well-organized in order to efficiently mine, and often require semi-mechanized equipment such as water pumps. As overburden thickness decreases, the amount of labor and the complexity of required tools decreases, diminishing the demand for financing and organization. Such sites render themselves more easily exploited by both men and women, and it is at such sites that women have been observed taking on a larger role in the extraction process.

The activity known as "recycling" supports this conclusion. In this activity, performed frequently by women, workers re-wash and sort through gravel and spoil material piles that have been left exposed by previous mining activities, in the hopes of finding small diamonds or gold particles missed during the first washing and sorting phase (Mwaipopo et al., 2004). It is not a particularly lucrative activity, as the gravels have been previously sorted through and the largest minerals extracted. However, artisans are able to bypass the time-consuming and labor-intensive step of overburden removal. Furthermore, due to the relatively small pay loads, there is little or no competition between artisanal miners for these deposits. Together, these factors make the deposits particularly appealing to female miners who tend to be more willing to spend the time meticulously sorting through the gravels in search of small diamonds, or who may view recycling as their only opportunity to engage in mineral extraction. Women are often able to work at such sites independently, usually as a part-time or seasonal activity. While occurring at a micro-scale, recycling is a mining activity nonetheless, one that is typically dominated by women, and is a source of supplemental revenue used to pay for basic necessities.

While the data demonstrate that women participate in the extraction process only at sites with thin overburden layers, this is not always the case. For example, the occasional use of earth-moving equipment at sites to remove the majority of a very thick overburden layer can render a once inaccessible deposit accessible. One pertinent example is a diamond mining site in Guinea, in which a thick overburden layer had been removed from a deep alluvial flat deposit using a bulldozer, and women were observed extracting the near-completely exposed gravel layer. This situation supports the conclusion that women extract when a deposit is accessible; however, this was a unique instance in which the deposit was not naturally accessible, but rather had been rendered accessible through the use of mechanized equipment, a relatively rare occurrence at artisanal mining sites.

The geomorphic zones of the sites in which women extract were analyzed using a frequency distribution. Women were reported to extract at sites in which mining was occurring within each geomorphic setting (the active channel, alluvial flats, and low terraces). Women were found to extract in active channel deposits 56% of the time, in alluvial flat deposits 33% of the time, and in low terrace deposits 44% of the time. Geomorphic zone is closely correlated to overburden thickness. Active channel deposits have no overburden layer, alluvial flat deposits have variable overburden thicknesses, and low terrace deposits generally have thinner overburden layers than

alluvial flat deposits. Based on the accessibility argument, it is expected that women participate in extraction in geomorphic zones with typically thin overburden thicknesses, such as active channel or low terrace deposits, which was the case for the majority of sites visited in this study. Of the sampled alluvial flat deposits in which women participated in extraction, overburden thickness ranged from 2 to 5.5 m, and of the sampled low terrace deposits in which women participated in extraction, overburden thickness was 2 m or less. It is important to note that mining frequently occurs within multiple geomorphic zones within the same site, particularly at larger sites. At such sites, if women participate in extraction, it is common that they do so within the more accessible active channel or low terrace deposits, rather than the alluvial flat deposits.

Sites in which workers recycle tailings do not fall under the typical geomorphic zone categories. In such cases, the gravel layer has been removed through excavation and sorting and has been left as spoil material piles, making them anthropogenic landforms, rather than fluvial geomorphic landforms created through the typical processes related to drainage patterns. These deposits form their own category of geomorphic zone, and have no overburden layer.

The final variable examined in detail is commodity type. This was the only geologic variable that has been mentioned in the literature as impacting gender roles. Hinton et al. (2003) argue that women participate in the extraction of low value commodities, and are typically relegated to ore-processing activities in the mining of high value commodities. This study examined the mining activities of two high value commodities, and found that women participated in extraction 13% of the time.

A degree of variation was noted between female participation in extraction and commodity type. Of the sites in which women participate in extraction, 67% were diamond mining sites, 22% were gold mining sites, and 11% were sites in which both gold and diamonds were mined. It is possible that gold is perceived by miners as being the more lucrative commodity, due to the steadily rising market price of gold within the past decade, while the market price of diamonds is more susceptible to fluctuation. The results therefore would support Hinton et al.'s argument when comparing female participation in diamond and gold extraction, as participation is lower in the supposed higher value commodity, gold. It can also be argued, however, that while success from gold mining is perhaps more predictable, diamond mining has the potential, however small, of being extremely lucrative, if good quality deposits are discovered. Another possible explanation for the disparity of female participation in extraction among diamond and gold mining sites is the long-established tradition of gold mining in the region, and the traditional roles of women in this sector as ore-processers.

The artisanal mining of gold has been carried out for over 2,000 years throughout the former West African kingdoms, and therefore the roles of men and women are well-established. The mining of diamonds, in contrast, is a relatively modern activity, developed in the region only

within the past hundred years, and consequently has less-well defined gender roles. While both the perceived economic value of the commodity mined and traditional values likely influence the degree of female participation in extraction, commodity type is not the sole geologic variable that explains the variations in gender roles that occur from site to site. The accessibility of a deposit is equally influential, and therefore the geomorphic variables which determine accessibility must be examined, in addition to commodity type, when explaining gender role variations.

5.3 Profile 1: Female participation in gravel extraction: Bamara, CAR

The following is a profile of a site that is representative of the many of the sites in this study in which women participate in extraction. Bamara is a diamond mining site located in eastern CAR's Mouka-Ouadda sandstone formation, which is thought to be the secondary host rock of the region's alluvial diamond deposits. Both alluvial flat and low terrace deposits were being mined here, with overburden thickness ranging from 2-3 m in the alluvial flat deposits and from1-2 m in the low terrace zones. The miners here, a total of 120 men and 10 women, were operating in informal groups, not as part of a larger formal mining collective, and were using shovels, rods, jiggs, and pumps to mine. This site had only been under operation for one month at the time of fieldwork, and the mine manager did not possess a permit to mine the site. The principle role of women at this site was transporting gravel, though women occasionally participate in extraction, as evidenced in plate 1. Several variables help explain female participation in extraction at this site. First, the site does not have a formal hierarchy of miners; rather it is operated by individuals who work in small, informal groups in order efficiently access the mineralized gravel. The lack of a hierarchical structure results in a greater opportunity for women to involve themselves in the extraction process. Furthermore, this site has low terrace deposits with thin overburden layers, which are more easily accessible than alluvial flat deposits, and require less physical labor to reach the mineralized ore. It is these low terrace deposits that women were observed extracting at the site, supporting the conclusion that women participate in extraction only when the ore is relatively accessible.

Plate 1.

5.4 Profile 2: Mining activities in the Bonsa River, Ghana

The following is a profile of two sites that are representative of female participation in extraction activities in the Bonsa River region of Ghana—at one site women are recycling previously mined deposits, and at the other women are participating in the extraction of active channel gravels. Both sites are located along the Bonsa River, in southwestern Ghana. Gold mining has been the more viable economic activity in this region, with diamond mining never having been commercially sustainable. Diamond mining in the region is presently mainly limited to individuals who are extracting, washing, and sorting through previously extracted gravel and spoil materials from former artisanal or industrial gold dredging operations (Chirico et al., 2010).

At the first site, two women were observed participating in this activity, searching for diamonds that remain in the old tailings around a previous washing site (see Plate 2). The process involves removing the gravel from spoil piles and transporting it to the Bonsa River, several meters nearby, for washing and sorting. At the second site, two women and one man were observed wading into waist and chest deep water to extract channel gravels by the bucket-full, then transported them to the river bank for washing and sorting (see Plate 3). Both sites are mined by no more than three miners, the majority of which are female. The sites are not well-mineralized, and the miners are searching for the few diamonds that may remain in the gold spoil piles. The fact that the miners are choosing to work these poorly-mineralized diamond deposits, rather than at one of the numerous well-mineralized gold deposits in the region, suggests that they are working with the goal of supplementing their family's income and view mining more as a short-term revenue-generating activity, rather than as a long-term career.

Plate 2.

Plate 3.

6. Discussion

The results of this study reveal the degree to which geomorphology impacts the direct participation of women in mineral extraction activities. The demonstration of this link encourages the establishment of an alternative research avenue, in which the physical and social sciences merge to produce the most complete understanding of the ASM sector. However, it is also recognized that geomorphic expression is not the only factor influencing women's roles. A deposit with a thin overburden layer is not necessarily a predictor of female participation in extraction. Cultural norms, traditional values, and economics, to name a few, are also important determinants. Both social and physical components play critical roles; however, the latter has been nearly completely overlooked in the current ASM literature. Since artisanal miners seek to make a living off of extracting material from the earth, it is remarkable that the factors which determine the location, extent, and value of the commodities they extract have been largely omitted from ASM research. The inclusion of geologic and geomorphic data will only strengthen our current knowledge of this sector and the complex issues that surround it, while enhancing the success and impact of policy and development programs.

The incorporation of geologic information offers numerous contributions of interest to policy makers, development organizations, and academics focused on the ASM sector. The first of these is the current debate as to whether artisanal mining is a sustainable livelihood practice. Developing an understanding of a particular deposit's underlying geology and geomorphic expression will provide data on the richness of the deposit and the amount of labor, financing, and types of tools required to access the deposit, information which will help determine both whether an artisan can afford to mine a deposit and whether the deposit can be mined sustainably. The acquisition of such data would greatly assist development programs with

identifying regions in which mineral deposits can be promoted as a sustainable livelihood activity, or where an alternative livelihood practice may be developed instead. Closely related to sustainability is the concern over whether artisanal mining activities trap miners within the poverty cycle. The degree to which a miner is successful is determined in large part by the size of the deposit mined and its economic value, factors which are governed by the underlying geologic and surficial geomorphic expression of the deposit.

For example, the eastern region of Guinea is exponentially more well-endowed with diamond deposits than the western region. Miners in the eastern region reported in the mine sites surveys as earning enough money to purchase motor bikes, build houses, and support their families. Such financial success was not reported in the western region, evidence that the eastern deposits may be more economically valuable and the mining of these deposits more sustainable. The ability to predict the success of miners at the site and regional levels would greatly assist development agencies in more efficiently targeting assistance programs and identifying locations in which resources would best be allocated towards promoting alternative livelihood practices.

Mine claim rehabilitation programs may also benefit from researching the target deposit's geologic and geomorphic expressions, to assure that the most suitable rehabilitation practices are administered. Such programs seek to restore the original ecosystem of a mine site while at the same time providing a complimentary livelihood practice, such as vegetable farming, agroforestry, or aquaculture, once mining activities are completed. The practicality of such rehabilitation programs may be determined in part by site geomorphology. For example, a deep, mined-out alluvial flat deposit would lend itself well to fish farming, while a shallow, terrace deposit would not. Site geomorphology could be mapped prior to program implementation, to ensure that the most suitable rehabilitation practices are administered.

Furthermore, site geology and geomorphology should be researched in the context of formalization efforts promoting the organization of licensed mining cooperatives. First, the geomorphic expression of a deposit determines to a large degree the level of organization and cooperation among miners required to efficiently mine the deposit. Deposits located beneath thick overburden layers inherently require a larger number of miners who must be well-organized in order to successfully mine the deposit. Second, geologic and geomorphic data can help locate economically viable deposits. Therefore, well-mineralized sites with thick overburden layers could be identified as sites where miners will have greater incentive to acquire a cooperative license, as the financial requirements of licensing are more likely to be perceived as an investment, rather than as an unnecessary burden.

Developing a core understanding of the underlying geology and geomorphic expression of artisanally-mined deposits could lead to new, integrated, multi-disciplinary approaches for evaluating human activities at artisanal mine sites. A proven methodology for the implementation of such an approach is the development of research teams composed of both social and physical scientists working together in the field. Depending on their background, each

person provides a unique perspective and breadth of knowledge pertaining to the many different aspects of ASM. Using such an approach, researchers will gain a more comprehensive understanding of the ASM sector, and will acquire more accurate information which can be used to develop and implement the most appropriate policy and development initiatives.

7. References

Amutabi, M., Lutta-Mukhebi, M., 2001. Gender and mining in Kenya : The case of Mukibira mines in Vihiga District. *A Journal of Culture and African Women Studies*, 1(2).

Bardet, M.G., 1974. *Géologie du diamant, gisements de diamants d'Afrique*. Mémoires du Bureau de Recherches Géologiques et Minières (BRGM), Orléans, France.

Centre for Development Studies, 2004. *Livelihoods and policy in the artisanal and small-scale mining sector: An overview*. Centre for Development Studies, University of Wales Swansea.

Chirico, P.G., Malpeli, K.C., Anum, S., Phillips, E.C., 2010. Alluvial diamond resource potential and production capacity assessment of Ghana. *U.S. Geological Survey Scientific Investigations Report 2010-5045*.

Graulau, J., 2001. Peasant mining production as a development strategy: The case of women in gold mining in the Brazilian Amazon. *European Review of Latin American and Caribbean Studies*, 71.

Hall, A.M., Thomas, M.F., Thorp, M.B., 1985. Late Quaternary alluvial placer development in the humid tropics: the case of the Birim Diamond Placer, Ghana. *Journal of the Geological Society*, 142: 777-787.

Heemskerk, M., 2000. *Gender and gold mining: The case of the Maroons of Suriname*. Working Paper No. 269. University of Florida.

Hentschel, T., Hruschka, F., Priester, F., 2002. *Global Report on Artisanal and Small-Scale Mining*. Working Paper No. 70. Mining, Minerals, and Sustainable Development (MMSD) Project, International Institute for Environment and Development (IIED), London.

Hilson, G., 2002. Small-scale mining and its socio-economic impact in developing countries. *Natural Resources Forum*, 26: 3-13.

Hilson, G., Maponga, O., 2004. How has a shortage of census and geological information impeded the regularization of artisanal and small-scale mining? *Natural Resources Forum*, 28: 22-33.

Hinton, J.J., 2003. Women and artisanal mining: Gender roles and the road ahead. In: Hilson, G.

(Ed.), *The Socio-Economic Impacts of Artisanal and Small-Scale Mining in Developing Countries*. A.A. Balkema, The Netherlands.

Hinton, J.J., 2011, *Gender differentiated impacts and benefits of artisanal mining: Engendering pathways out of poverty a case study in Katwe Kabatooro Town Council, Uganda*. Thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, University of British Columbia, Vancouver.

International Labour Organization (ILO), 1999. *Social and labour issues in small-scale mines*. Report for discussion at the Tripartite Meeting on Social and Labour Issues in Small-scale Mines. Sectoral Activities Programme, International Labour Organization, International Labour Office, Geneva.

Ingram, V., Tieguhong, J.C., Schure, J., Nkamgnia, E., Tadjuidje, M.H., 2011. Where artisanal mines and forest meet: Socio-economic and environmental impacts in the Congo Basin. *Natural Resources Forum*, 35: 304-320.

Jønsson, J.B., Fold, N., 2009. Handling uncertainty: Policy and organizational practices in Tanzania's small-scale gold mining sector. *Natural Resources Forum*, 33: 211-220.

Jønsson, J.B., Fold, N., 2011. Mining 'from below': Taking Africa's artisanal miners seriously. *Geography Compass*, 5(7): 479-493.

Labonne, B., 1996. Artisanal mining: an economic stepping stone for women. *Natural Resources Forum*, 20(2): 117-122.

Marshall, T.R, Baxter-Brown, R., 1995. Basic principles of alluvial diamond exploration. Journal of Geochemical Exploration, 53: 277-292.

Moretti, D., 2005. *The shifting gender of gold: Assessing female participation in artisanal and small-scale mining among the Anga of Mount Kaindi, Papua New Guinea*. Paper presented at a workshop on Community and State Interests in Small Scale Mining: Sharing Experiences from the Asia, Pacific Region 7-12 June 2005, Manila.

Mwaipopo, R., Mutagwaba, W., Nyange, D., Fisher, E., 2004. *Increasing the contribution of artisanal and small-scale mining to poverty reduction in Tanzania: Based on an analysis of mining livelihoods in Misungwi and Geita Districts, Mwanza, region*. Report prepared for the Department of International Development (UK).

Sow, N.O., 2003. *Women activities in artisanal mining in Guinea*. Paper presented at the Women

in Mining Conference: Voices of Change 3-6 August 2003 Madang, Papua New Guinea.

Sutherland, D., 1993. Drainage basin evolution in southeast Guinea and the development of diamondiferous placer deposits. *Economic Geology*, 88: 44-54.

Sutherland, D.G., Robinson, A.D., 1996. Characteristics of alluvial diamond deposits in the River Sarabaya, SE Guinea. *Africa Geoscience Review*, 3(2): 317-329.

Teeuw, R.M., Thomas, M.F., Thorp, M.B., 1991. Geomorphology applied to exploration for tropical placer deposits. In Sutherland, D.G. (Ed.), *Alluvial mining*. Elsevier Science Institute of Mining and Metallurgy, London.

Van Bockstael, S., Vlassenroot, K., 2008. Setting the scene – Perspectives on artisanal diamond mining. In: Vlassenroot, K., Van Bockstael, S. (Eds.), *Artisanal Diamond mining: Perspectives and Challenges*. Academia Press, Gent, Belgium.

Werthmann, K., 2009. Working in a boom-town: Female perspectives on gold-mining in Burkina Faso. *Resources Policy*, 34: 18-23.

Yakovleva, N., 2007. Perspectives on female participation in artisanal and small-scale mining: A case study of Birim North District of Ghana. *Resources Policy*, 32: 29-41.

Figure and Plate Captions

Figure 1. Figure showing the location of fieldwork sites in Mali, Ghana, Guinea, and CAR.

Figure 2. Histogram showing male and female participation in mine site jobs.

Plate 1. Photo of a female miner removing the overburden layer to access the mineralized gravel layer.

Plate 2. Photo of two women recycling gold tailings in search of diamonds.

Plate 3. Photo of miners wading into the Bonsa River to extract the gravel bed.

Table Captions

Table 1. Table detailing typical mine site jobs.

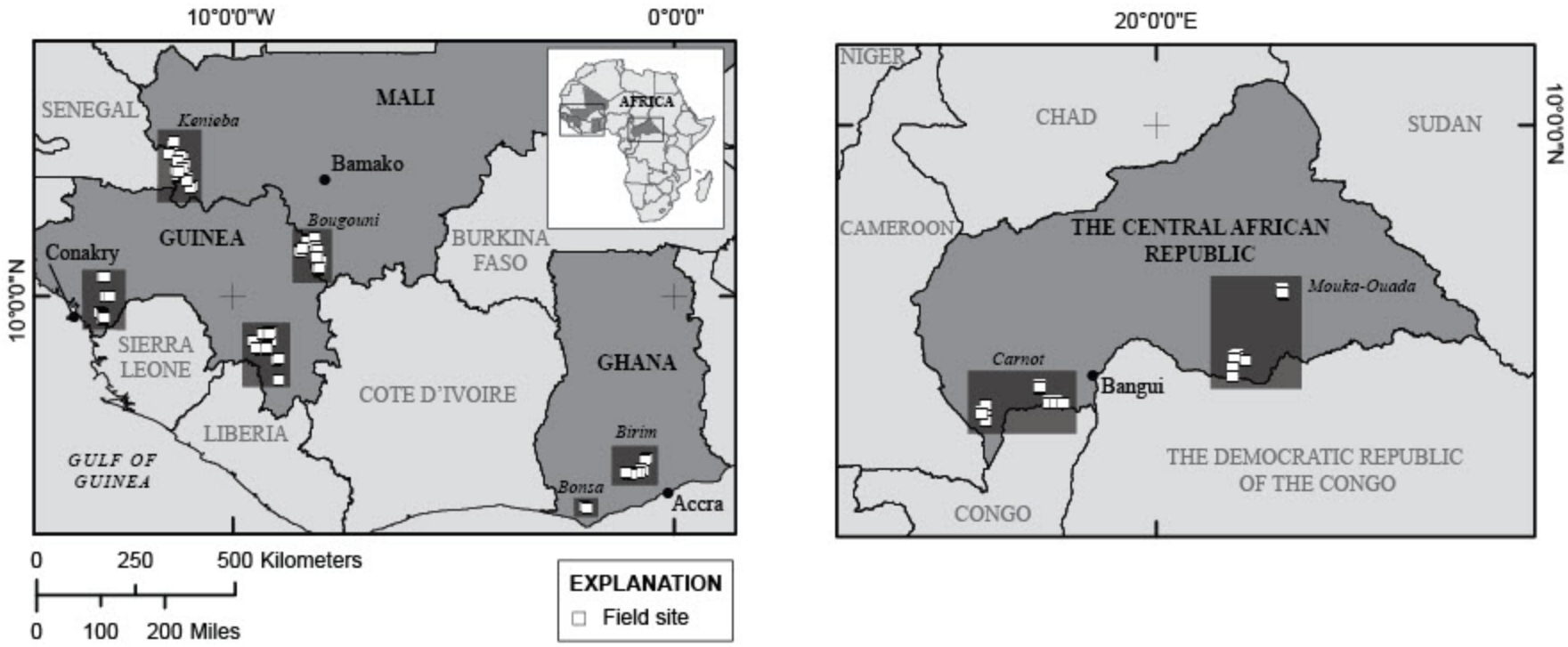
Table 2. Table comparing the overburden thickness at all sites, at sites where women participate in extraction, and at sites where women do not participate in extraction.

Table 1. Table detailing typical mine site jobs.

Extraction Activities	**Description**	**Tools Used**
Excavation	The removal of the overburden layer access the mineralized gravel layer. There are three main types of extraction used in the region (1) open-pit excavation (2) underground shaft excavation, and (3) diving.	Picks, shovels
Recycling	Panning the tailings of gravel or spoil material piles that have already been washed at least once.	Shovel, pan, sieve
Ore-Processing Activities		
Transport	The excavated raw ore material is transported from the site of excavation to the designated washing site.	Empty sacks, bags
Washing & Sorting	This involves the agitation of pans and sieves to collect heavy gold or diamonds at the bottom of the pan, while lighter materials are washed away. The remaining materials are sorted through by hand to pick out any gold or diamond particles.	At the most basic level, pans, calabashes, sieves/screens are used. Some sites may have manual jiggs or sluice boxes.
Carrying water	Water is required for washing and sorting, and at some sites must be transported from the nearest water source.	Buckets
Ancillary Activities		
Supervision	Supervision includes activities that involve overseeing, running, and or financing the activities at a mine site.	NA
Commerce	Petty commerce may take place at sites, involving the sale of food and other goods. Commerce activities are particularly prevalent at isolated sites that are not located near a permanent village.	NA

Table 2. Table comparing the overburden thickness at all sites, at sites where women participate in extraction , and at sites where women do not participate in extraction.

	Overburden thickness (m)		
Statistics	**All sites**	**Sites where women extract**	**Sites where women don't extract**
Average	4.37	1.52	4.72
Standard deviation	2.95	1.65	2.84
Minimum	0.00	0.00	0.00
Maximum	12.00	5.50	12.00



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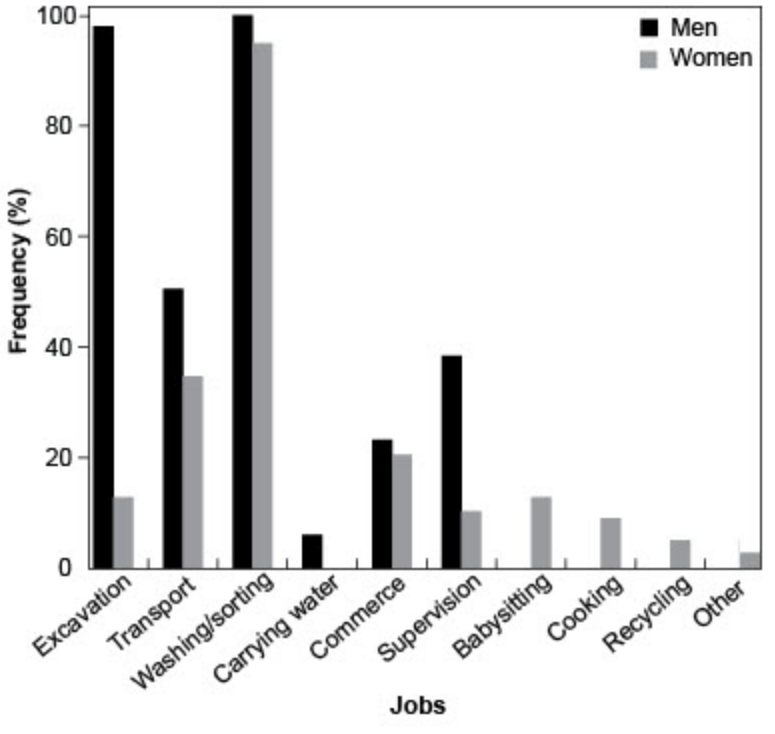

Figure 2. Histogram showing male and female participation in mine site jobs.

Plate 1.

Plate 2.

Plate 3.