Image 1. A testament to past gemstone mining activity: deforestation, pits, habitat changes, and stagnant waters.

Environmental Stewardship in Gemstone Mining: Quo Vadis?

Our choices at all levels—individual, community, corporate, and government—affect nature. And they affect us.
– David Suzuki, Canadian environmentalist

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Introduction

Gemstones and the environment share an intrinsic relationship. Gemstones themselves are a product of temporary geological conditions and environments. They can be found on earth's seven continents. They can be found in primary or secondary deposits, at the bottom of seas and on the top of mountains. The combinations of magmatism, metamorphism, and sedimentation have given us the treasures that we, for millennia, have valued as gems. The forces of tectonics and erosion have brought these to the surface, and within reach of humans. Humanity's consumption of these precious minerals and the drive to extract them from the lithosphere has grown tremendously in recent times. There are many reasons for this voracious pursuit of gemiferous resources and this pursuit has had both beneficial and deleterious impacts. The extraction, trade, and consumption of gemstones affect the natural environment that surrounds us and us directly as humans, in multiple ways. This article seeks to explore the complex and dynamic linkages between gemstones and the fragile ecologies from which they are extracted.

There is an imperative need for the industry to examine the social and environmental responsibilities that come with the production, trade, and consumption of colored gemstones. There has been a lamentable lack of proactive progress with respect to the mitigation of factors that degrade vulnerable regional environments. The complex and fragmented nature of gemstone supply chains has long meant that inaction has been the norm. This is, specifically in regards to environmental concerns, not necessary. Many of the ecological problems associated with the world of mining can be overcome by designing sensible resource management frameworks. Planning and effectively managing sustainable frameworks in colored gemstone mining and trading environments remains challenging and must be complemented by understanding regionalized issues through further research.

Past, present, and future

Industry should be just as concerned with its past activity as it is with present or future scenarios. Macfarlane et al. (2003) pertinently observe that "In many cases, the real environmental impacts relate more closely to past, rather than present activities. The industry should therefore explore regulatory, voluntary, and fiscal approaches to the gradual reclamation of those historic and abandoned operations that are likely to impact on its ability to operate in the future. The remediation of existing mine sites represents a significant opportunity." Images such as Images 1 and 5 attest to the environmentally destructive forms that mining can take. The deleterious impacts are well reported (Hilson 2002; Macfarlane et al., 2003; Cardiff 2007). At present, many communities suffer from irresponsible environmental management practices that are linked to gemstone mining activity from the past. The rise of pot-holed landscapes, farmland rendered infertile through mining, destruction of endangered fauna's habitats, and unfilled pits that nurture the spread of malaria are but a number of the specific problems, which require pressing resolution.

Therefore, it is crucial to both resolve detrimental environmental consequences of past activity and to formulate strategies that improve ecological sustainability of present and future gemstone mining activity. Industry stakeholders and governments must determine who is responsible for the ecological ramifications that are associated with gemstone extraction and consumption, how damaging environmental consequences can be averted, and how ecosystem management can be improved.

The myriad realities of gemstone mining

In a sector that includes over 50 producing countries, a multitude of cultures, environments, geologies, and minerals, it is no overstatement to suggest that the situation is complex. Although a number of large-scale and medium-scale mining companies operate, colored gemstones extraction is characterized by the fact that 80 percent of production comes from artisanal mines (Michelou, 2010). Artisanal mining is an often informal and migratory activity typified by its rudimentary production methods. There are different categories of artisanal mining such as seasonal mining and rush mining, among others. Note that it is artisanal miners and not artisanal mining companies that are often referred to since most of these stakeholders are informal and can work as individuals. For a detailed description and discussion of artisanal mining, see Hentschel (2003) and Hinton (2006). It is important to realize that many gemstone deposits would not be profitable if worked on a large scale but are viable on a small scale. This distinguishes gemstones from many other mineral resources (e.g. bauxite, ilmenite, etc.).

The mining techniques adopted to extract gemstones invariably reflect the nature of the deposit: primary deposits (in hard rocks, worked underground or in open pits) and secondary deposits (found in sedimentary, soft-rock, placers). The mineralogy of a gem dictates the type of geological environment in which it can be found. The necessary chemical ingredients, temperatures, and pressures were required in order to allow gems to grow. This means that the rocks and placers hosting gemiferous resources vary widely. Whereas important emerald sources all constitute primary deposits, ruby, sapphire, spinel, and other gems can often be found in secondary alluvial deposits (Image 2). Considering that miners follow tectonic structures, the geology of gem deposits is central to subsequent extraction methods and intrinsic to the environmental consequences that can potentially arise. A notable difference between primary and secondary deposit is the use of explosives in the former but not the latter. This means that different regulatory approaches are required, e.g. for the regulation of excessive use of explosives. Furthermore, authorities should clearly seek to seal access to underground mines

Image 2. Secondary deposit alluvial mining activity near Ilakaka, Madagascar. Diversion of watercourses, slope instabilities, and scarring of landscapes are the main environmental impacts.

Image 3. Underground mining in a primary corundum deposit. Chiseling in such mica-rich layers presents an important environmental health risk for workers due to resulting dust that contains fine silicate particles.

once they have ceased to operate to reduce risk for local populations.

Emeralds are often found in mica-schist shales and the subsequent processing of these mica-schists is not without environmental concerns. They can have potentially deleterious impacts on turbidity levels in rivers and streams. Puppim de Oliveira (2005) describes cases in Campos Verdes, Brazil where inexpensive projects have resulted in concrete environmental improvements in emerald mining through, for example, the installation of common pools for the community to wash schists. This shows that the implementation of basic assistance mechanisms can markedly reduce environmental impacts. Underground mining can, in general, be hazardous if shafts and adits (horizontal tunnels) are not correctly planned. With this in mind, it is clear that explosives used in such environments should be used with care, geological stabilities should be assessed beforehand, and adequate ventilation, and the risk of flooding must be evaluated.

An example of the close link between geology, gemstones, and environmental health are artisanal tanzanite mines. Studies have shown that miners working in Mererani (Tanzania) at great depths in graphite-rich environments have a high risk of developing chronic silicosis due to the mining techniques applied in this geological context (Bråtveit et al., 2003). The greatest cause for concern is the important dust produced by drilling and occasional use of explosives. Workers were asked to wear dust sampling equipment and analysis of dust samples showed that exposure to breathable crystalline silica of miners was about 50 times higher than the general threshold limit value. The authors suggest that risks can be lowered by introducing preventive measures, such as improving ventilation and wetting ore materials (that contain the unsafe minerals) at the processing stage. The above-described examples of schist washing and the processing of certain ores (Image 3) show that geology not only has local ecological consequences (e.g. siltation of streams or pot-holed landscapes) but can also result in very direct impacts on mining workers.

Sustaining sustainability

The core question regarding the sustainability implications of gemstone extraction is: *Has the extraction led to a viable natural and social environment, which can support livelihoods in the long-term, following the cessation of mining?* With respect to the environment, gains and losses can be specifically determined by a number of factors. Any efforts to improve environmental stewardship in the short-term are guided by this long-term aim of reaching equilibrium between human activity and ecological diversity. Mining will always be accompanied by negative impacts; the objective must be to reduce these as much as possible through sensible resource management.

The short-lived character of many gemstone deposits and the fact that miners are often transient stakeholders means that mitigating damage to vulnerable ecologies is not a high priority. Migrant miners generally do not experience the same sense of responsibility towards the environment in comparison to locals who are wholly dependent on thriving lands (e.g. for agriculture) after the cessation of mining. This migratory activity (in the form of "mining rushes") has been very pronounced in Tanzania, Madagascar, and more recently in Mozambique (Mutagwaba, 2006; Cartier, 2009; Pardieu, 2010).

Identifying environmental challenges

Exploring the environmental challenges associated with gemstone mining requires an identification of the factors, impacts, agents, and consequences that (potentially) threaten surrounding ecosystems. Table 1 provides a summary of these points, each of which deserves individual elaboration, a task that goes beyond the scope of this overview article. The table also includes a "mitigation" column, which offers some constructive suggestions of how impacts can be minimized or eliminated. This last column must be further researched and elaborated upon if the industry is serious about overcoming the environmental challenges that plague the production level.

Sphere	Potential impact through mining	Causes	Long-term consequences	Mitigation strategies
Water	Contamination of rivers, lakes, groundwater.	Discharge of tailings, sediments, chemicals (e.g. acid from batteries), explosives, diesel, rubbish disposed into hydrological environment.	Siltation of land with contaminated water that is used for agriculture. Turbidity and salinity levels have effects on fauna and flora. Drinking water is contaminated. Water pollution.	Discharge and disposal of materials are correctly managed (e.g. communal washing ponds for tailings).
	Alteration of surface and groundwater flow.	Rivers and lakes are diverted. Groundwater tables lowered due to unrestrained pumping of water for mining activity.	Flooding patterns are altered; water is diverted from where it is needed. Groundwater levels are put at risk of depletion.	Water courses are re-diverted following the cessation of mining. Excessive pumping of water is regulated.
Soil	Erosion and Instability.	Water jets (hydraulic mining), open pit methods, excessive use of explosives.	Erosion, landslides present a risk for mining and community population.	Correctly assess geological stabilities, fill/seal mines post-operation, train in correct use of explosives, improve extraction techniques.
	Loss of soil.	Depletion of soil nutrients through mining.	Infertile soil.	Limit damage to topsoil and remediate appropriately post-mining.
	Material contamination.	Discharge of sediments, chemicals (e.g. acid from batteries), explosives, diesel, rubbish.	Siltation and pollution of land with water that is used for agriculture.	Manage water used for mining more adequately through use of ponds and basins. Design solutions to deal with discharge issues.
	Improper sanitation.	No sanitation facilities.	Water contamination and environmental health problems.	Build sanitation facilities.
Air	Increased dust.	Deforestation and lack of topsoil (due to wind erosion).	Further erosion and desiccation of land.	Replanting trees.
Fauna and Flora	Loss of faunal and floral habitats.	Landscape destruction and human activity.	Biodiversity loss.	Formalize mining activities and regulate ecosystem management pragmatically.
	Overuse of timber resources.	Deforestation for building pits, firewood, houses.	Erosion, deforestation, more arid land.	Reduce deforestation and introduce replanting schemes.
	Destruction of forest and savannah.	Mining and linked human activities.	Destruction of landscapes, habitats and rise of barren lands.	Participative ecosystem management.
	Poaching.	Miners hunt wildlife for food.	Migration and possible endangering of species.	Limit hunting.
Humans	Contaminated drinking water.	Material contamination from mining-related activities.	Serious health problems for humans.	Separate water that is used for mining.
	Land rendered infertile for agriculture.	Pitting and trenching, removal of topsoil.	Livelihood source (agriculture) disappears for post-mining phase.	Encourage correct remediation of lands.
	Safety hazard of pits during and after mining.	Improperly constructed pits, slope failures, mine collapse.	Dangerous for humans and cattle.	Pits and shafts should be closed after mining has ceased.
	Relocation of populations.	Mining activity drives local population away.	Social and economic problems.	Include local authorities in decision-making, formalize mining activities.
	Adverse environmental health conditions.	Geology, mining techniques, unremediated pits.	Silicosis and other lung diseases, malaria.	Encourage health measures and refill mining pits.
	Land-use conflicts.	Mining activity conflicts with local populations' livelihood activities or with large-scale mining.	Social and economic ills.	Formalize activities and improve stakeholder participation in planning mining activities.
Landscape	Landscape destruction.	Constant pitting and trenching.	Scarred pot-holed landscapes.	Pits must be reclaimed post-mining, mining techniques improved.

Table 1. List of environmental challenges associated with gemstone mining (from Macfarlane et al., 2003; Tilghman et al., 2005; Hilson et al., 2006; Hinton, 2006).

It is important to note that, although mines are generally small and often located in remote regions, they are numerous focal points, which can compound and multiply regional environmental impacts. Contamination of watercourses (e.g. through siltation) through mining activity can lead to deleterious environmental conditions (i.e. unusable water for drinking or agriculture) in areas located at great distances from mining areas. Such impacts represent a further environmental externality that directly affects ecologies and populations not involved in mining activity. Sindling (2003) calculated that different sources of environmental externalities in (artisanal) mining "cause social costs that for some countries may reach 10 percent of annual GDP." Externalities, in the case of gemstone mining, are benefits and costs that arise for actors that are not involved in the extraction of these resources. The mismanagement of the common resource that is the environment results in considerable costs and these figures put into perspective the urgency with which environmental impacts should be addressed.

Image 4. What consequences does gemstone mining have on disappearing fauna and flora in vulnerable ecosystems as a result of changes to their habitats?

Ideas such as "conservation gemology" seek to address the pressures that mining activity has on the habitats of sensitive and sometimes endangered wildlife in Mozambique and elsewhere (Pardieu, 2010). Habitat fragmentation and destruction are serious environmental issues (Image 4). Tilghman et al. (2006) noted that hunting is an important activity linked to artisanal gemstone mining, especially as a source of food for remotely located and often undernourished miners.

In the face of these problems, solutions may seem elusive and vague. But one concrete and crucial aspect that stakeholders at all levels could and should think about is the reclamation and remediation of the tens of thousands of unfilled pits that riddle the globe. Considering that many are the result of unlicensed mining activity, there are no longer actors that can be held accountable for these consequences. Remediation costs both time and workers' wages and this is the main reason why many pits are not filled after mining has ceased, which means that the financing of reclamation efforts is a central issue, and one that should be explored by industry.

Could industry find a way to generate funds for a fund that would strive to remediate these pits? Technical assistance is also required to assure that the earth and soil used to fill the pits have the potential to renew topsoil, which is so crucial to agricultural activity. Encouraging reforestation in mining sites would hinder further erosion, minimize landslides, reduce dust problems associated with increasing aridity of land, and solidify topsoil.

Improving management through formalization

Many gemstone-producing countries are struggling to formalize and regulate mining activity, especially if it is of artisanal nature. Most countries do not make specific provisions in their laws for artisanal and small-scale mining and this is regrettable. Several governments are implementing changes in this regard and they must also strive to improve the enforcement of laws (Lawal, 2006; Mutagwaba, 2006; Sarassin 2006). This is a core issue in many producing countries. Sluggish enforcement of environmental regulations due to chronic understaffing of departments coupled with significant corruption have greatly hindered environmental auditing and monitoring procedures.

It is well documented that if regulations are to be realistically implementable by miners, these must be adapted to the size and nature of their activities because many do not have the knowledge or resources to abide by environmental regulations. Large-scale mines have much more expertise and capital to conform to these rules and a greater capacity to assume environmental responsibility than artisanal miners. Artisanal mining activity is increasing globally as an increasing number of people engage in mining in their search for sources of much-needed income. Environmental problems linked to mining will also continue to grow and this is why governments in collaboration with industry need to be proactive in managing these challenges. Hilson (2002) argues rightly that "it is truly cynical to assume that the governments of the developing world are incapable of facilitating such changes because in most cases, they are the only bodies capable of directing operations along an efficient and sustainable course."

Interactions between miners and fragile ecosystems are not negligible and cases in Ankarana (Image 6) and Isalo national parks in Madagascar and Niassa National Reserve in Mozambique have shown that anything other than a pragmatic approach to accommodating the needs of both miners and the habitats of vulnerable species is very likely to fail (Cartier, 2009; Pardieu 2010). It is not international institutions or military interventions that can prevent miners from entering these spaces; environmental responsibility must be fostered at a grassroots level through innovative local governance and continuing efforts to formalize operations (Canavesio, 2009). Admittedly, the challenge lies in finding strategies to harness the complex and dynamic nature of artisanal mining and formalizing it in order to improve socio-economic and environmental sustainability. Finally, what has become obvious in a number of countries, most notably Madagascar in recent times, is that reforms of mining sector regulations and initiatives that seek to improve sustainability cannot be successful if the necessary national and local political will is not present (Dickinson DeLeon, 2008). Promoting environmental governance requires for all stakeholders to be integrated in the process and hold a real sense of responsibility.

Examples of coal mining in Colombia (Zamora, 1999) and diamond production in Guyana (Blore, 2010) have shown that artisanal and small-scale mining can be governed efficiently and environmental impacts can be managed accordingly if the necessary assistance is supplied, specific problems are addressed, and there is a governing will to improve conditions.

Ecosystems and livelihoods: the case of malaria

Environmental complexities are inextricably interwoven with environmental health and socio-economic realities (Kitula, 2006). An extensive environmental epidemiology study (Yapabandara et al., 2004) on the link between gemstone mining activity and the growing incidence of malaria in the famous gem-producing region of Elahera, Sri Lanka provides sufficient evidence for governments, donors, and industry stakeholders to realize that there is an imperative in finding solutions to problems created in the past. Malaria incidence has greatly increased due to the presence of stagnant waters as a result of non-remediated pits. Yapabandara et al. (2004) go as far as stating that: "Unless proper management of closure of gem pits and implementation of suitable larval control methods are carried out in the gem mining area, there is danger of a spread of malaria infections throughout the country as many migrants move in and out of this area. A clear policy with regard to closure of licensed and illegal gem pits is needed." The fact that populations not engaged in mining are also increasingly affected by malaria is another source of aforementioned externalities.

Image 5. Scene of environmental destruction as a result of artisanal small-scale mining. Environmental impacts include excessive use of groundwater, pollution through diesel discharge, deforestation, and subsequently unreclaimed pits.

Elusive lessons and finding solutions

There is no panacea for all environmental problems related to mining. Gemstone mining has one advantage—environmental impacts associated with the processing stage of extraction are much easier to control than for gold because chemicals, such as cyanide or mercury, are not used. Reform should be implemented at two levels, correct enforcement of regulations and more importantly, increasing the efficiency of mining operations. Improving mining techniques and environmental technology (e.g. drilling, use of explosives, pitting techniques) at artisanal and small-scale levels would make extraction both more efficient and less harmful to both the environment and worker safety. A very different case is sanitation, which plays an important part in the lives of mining communities but is a rarely addressed issue with respect to artisanal mining. This, even though if appropriate technology is used, environmental impacts—such as water contamination—related to insufficient sanitary measures can be averted (Tilley et al., 2008).

Tanzania introduced small-scale mining legislation and has attempted to improve environmental management through a number of capacity-building steps, all the while admitting that miners lack the capital and expertise to carry out environmental impact assessments (EIA). Tanzanian regulations set requirements for construction of washing ponds, restricting vegetation clearing near rivers, refilling pits, preventing child labor, construction of pit latrines, and ensuring miners would have protective gear. (Mutagwaba, 2006).

The hope was that gradual formalization would improve the situation but, with respect to artisanal mining, this remains a considerable challenge. Mutagwaba (2006) studied the Tanzanian case in detail and argues that, for environmental legislation in mining, "the problems that limit effective enforcement of the regulations are a result of the weaknesses inherent within the legislation itself, and those associated with the system responsible for its execution." Ghana and Zimbabwe have also made efforts to improve the situation and develop EIA mechanisms with mixed results (Hilson, 2002). Gemstone miners in the USA and Australia are subject to environmental regulation that prescribes reclamation bonds as a means of financing future land reclamation requirements (ICA, 2006). It would be important to investigate how the concept of reclamation bonds could be adapted to developing country contexts as a means of financing environmental remediation.

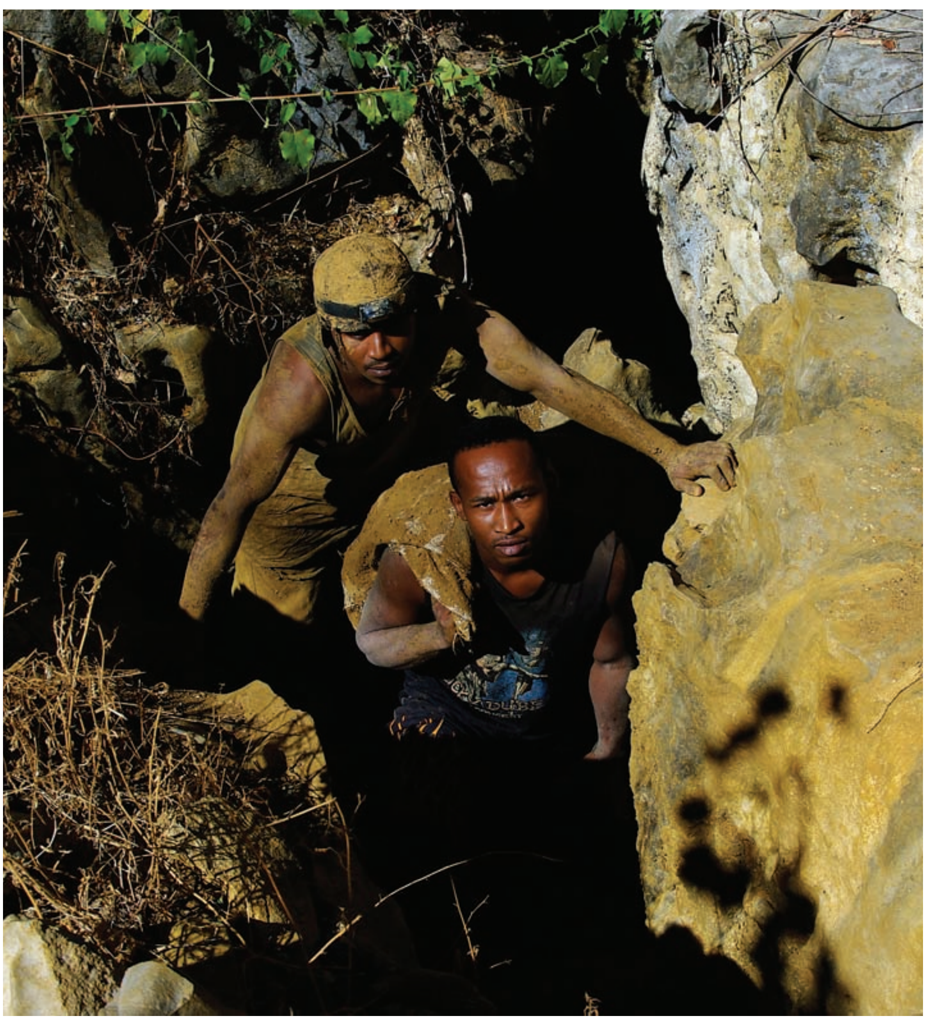

Image 6. Artisanal mining within the Ankarana national park in northern Madagascar. The Ambondromifehy experience shows that expulsion of miners from areas under environmental protection rarely works. Other solutions need to be explored of how fragile ecosystems can thrive alongside responsible mining activity.

Solutions put forward to artisanal miners on improving environmental conditions need to be pragmatic and cost-effective. Hinton et al. (2003) frankly assert that "for an artisanal miner, this means a method must be fast, easy and cheap…an artisanal miner will not pay out a dollar for a piece of equipment or technique that does not return two dollars." It is vital to bear this in mind. Both regulation and incentivization need to be adapted to local realities. Cleaner production methods should be explored as a means of increasing yields and reducing waste and an emphasis should be placed on the mitigation of impacts during the activity period of the mine.

Recommendations and conclusions

The environmental consequences of gemstone extraction and consumption are the responsibility of all industry stakeholders. This ranges from miners to traders to jewelers to consumers to industry bodies and governments. The environment is a vital source of income and will sustain livelihoods long after the cessation of mining activity. This too is why environmental impacts must be mitigated. General recommendations in reaching this goal are:

- Governments should clearly promote formalization of the sector and should make specific provisions for artisanal and small-scale mining in national regulations, with a special focus on environmental management.
- Government authorities, miners and traders should work towards greater transparency at the production and trading levels.
- Industry should respect the respon-

sibility of governments in the management of gemstone resources.

- Policy makers should ensure that regulatory mechanisms are adapted to local realities and that laws and guidelines are realistically enforceable.
- Development organizations and researchers should design initiatives that focus on proactive environmental stewardship; this means prioritizing training and assistance rather than classic enforcement.
- All actors should realize the role that gemstone production can have as a catalyzer for local development, and attempt to take advantage of this.
- Researchers should devise mechanisms that would add value to the environment and incentivize miners to improve environmental management.
- Governments and development organizations should encourage the formation of artisanal and small-scale mining organizations.
- Researchers and development agencies should develop programs that assist miners in cleaner prodution methods, by optimizing current techniques.
- Researchers should investigate what sanitation technologies would be appropriate for different mining area contexts.
- Regional researchers should collaboratively pilot and validate practical mitigation technologies in the form of pilot projects in mining regions.
- Researchers should devise simple environmental reclamation processes, and industry should determine ways of funding land reclamation as a result of past gemstone mining activity.

Ecological impacts are not purely local. Improving environmental sustainability in gemstone mining is not simply about safeguarding virgin landscapes. It is about conserving fragile ecologies that are vital for the present and future livelihood bases of fauna, flora, and humans. Strengthened institutions that focus on integrated management schemes are required to manage environments and the livelihoods that depend on them. Adopted strategies invariably and inevitably affect the environment. What is important is to demonstrate concerted commitment in improving environmental sustainability within gemstone mining. A number of larger-scale gemstone mining operators are now actively promoting environmental sustainability. Hopefully, these efforts can be widened to include the artisanal mining sector and improve environmental stewardship throughout gemstone production networks.

(All images are courtesy of Laurent E. Cartier.)

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