Improvement of Quarrying Techniques for the Extraction of Ornamental Quartzite in Northeast of Brazil

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Keywords: Mineral Research; Quarrying; Quartzite; Exploitation.

Abstract. The area of study is located in Várzea County, State of Paraíba, Northeast Region of Brazil. Ornamental quartzite has been quarried in that area for many decades, using artisan methods. The rudimentary methods adopted in the past for quarrying quartzite caused significant damage to the environment and depredation of mineral reserves, as well as health and safety concerns for the workers involved in the extraction activities. In order to overcome those detrimental effects, a research project was funded by the Brazilian agencies cited at the end of this paper. The scope of the project included both quarrying and beneficiation of quartzite. The present publication addresses only the quarrying issues of the project. In order to identify the promising target areas for quartzite extraction, and to guide the operation of active quarries, a detailed geologic map in the scale of 1:2,500 was constructed. The map contains the following features: lithologic units, contacts, folds, foliation and faults. Many deficiencies of the current quarrying practices have been identified through intensive field work. Some of the major deficiencies are the following: accumulation of water at trenches bottom, because of poor drainage practices; the widespread use of explosives for loosening the rock, causing intensive damage to the quartzite slabs, and consequently generating large volumes of waste rock; partial removal of soil from the top of the fresh rock, causing contamination of the quartzite and loss of reserves; and the adoption of slopes hanging to working area, posing significant rock falls risks to the miners. The main improvements consisted in the following: completely uncovering the fresh rock, avoiding contamination of the quartzite during the extraction stage; efficient drainage of trenches, avoiding accumulation of water at trench floor; adoption of slopes inclination smaller than 90°, substantially decreasing the risks associated to rock falls; use of a specially conceived rock saw, in order to reduce the use of explosives from the extraction process. Details about the performance of the technical improvements implemented at pilot scale are provided in the current publication. Besides the above mentioned technical improvements, socio-economic aspects of the quartzite quarrying activity have also been addressed in the project. Among those improvements, the following should be highlighted: training the artisanal miners about good safety practices, including the preparation and distribution of a quarry safety booklet; organization of the artisanal miners in cooperatives and producing associations; and presentation of short courses about environmental conservation and good quarry practices. At the completion of the research project, recommendations have been issued for implementation of the major findings into the daily practice of quartzite quarrying operations in Northeast Region of Brazil, including support actions that should be taken by governmental organizations and by the artisanal miners themselves.
Introduction

This paper aims to present quarrying improvements developed within the “Advanced Technology for Quartzites Production” Project. This project main goal was the technical support to small producers of quartzite from a local cooperative (COOPVARZEA) of Várzea County (State of Paraiba, northeastern Brazil). The activities consisted of the development of geological research, geological survey for quarries' planning, trying to reduce environmental impacts in the extraction of quartzite, health and safety at work and preparation of pilot quarries with innovative technology specifically developed for this project.

Várzea County (Fig. 1), of 147 sq. km area, is located in the “Droughts Polygon” in the Northeastern Region of Brazil. The county is limited at North by the counties of Ouro Branco and São José do Sabugi, at East by the counties of Ouro Branco again and also Santa Luzia. Its southern border faces the Santa Luzia and São Mamede counties and its western border faces the counties of São Mamede and São João do Sabugi.

The main deposits of quartzites of the state of Paraiba are in the municipalities of Várzea and Seridó and occur associated with Precambrian rocks of Upper Proterozoic, correlated with the Equador Formation of the Seridó Group. These quartzites are recovered in the form of square or rectangular rough tiles and used in various sectors of construction industry. They present varied coloration, granuloblastic texture, fine to medium grain size and well developed foliation. It is a rock resulting from sandstone metamorphism, being quartz its main component (80%) and carrying other minerals such as silicates (tourmaline) and micas (biotite, sericite, and muscovite).

The quarries have been worked, by manual methods, for over twenty years. In recent years, there was a considerable increase in production scale in these municipalities, as evidenced by expansion
of consumption in new markets. So many years of predatory mining, without the necessary techno-economic withdrawals, have generated various environmental impacts and wastes that undermine sustainable development in the region.

On the quarries quartzite is manually split with handy tools (picks and sledge hammers). The irregular plates obtained are cut afterwards in commercial sized tiles with diamond saws in processing units. The main use of these quartzites is ornamental, as external coverings and pavements but its use in ornamental mosaics is also spreading.

Geological Aspects

Regionally, the area is inserted in the Borborema Province, of pre-Cambrian age, and quartzite is part of the sedimentary cover of the Seridó Group. This region has gone through several phases of tectonic deformation resulting in folding, faulting and shearing of existing rocks, including the quartzite. [1, 2]

The quartzites occur in the Equador Formation, a geologic unit measuring about 400 m wide and longer than 1 km in NE-SW direction. The outcrop is partially capped by small residual soil cover, with an average thickness of 0.50 m. The foliation appears subvertical, at angles of between 70 and 90 degrees. The thickness of the quartzite layers range from 1.8 to 3.5 cm. There is a zone with a very strong partition, probably due to a large faulting, where the existence of fractures parallel to foliation, sharp and intense, spaced 3 to 4 cm was verified. Although foliated, the quartzites are highly resistant to breakage and impact, which ensures their durability.

Traditional mining method

The extraction method traditionally used is open pit mining, occupying long and narrow areas, following the ore body (Fig. 2). The dismantling of waste is carried out manually by small producers, and then, with the aid of explosives, the quarry front is opened [3, 4]. The rock drilling, for charging the explosive (black powder) is performed using pneumatic hammers, without blast planning, being performed according to miners’ experience. This practice usually leaves negative slopes, from which are extracted manually with spikes and sledgehammers, large irregular slabs of quartzite. This way, miners seek explosives saving and easy separation of the quartzite plates by collapse. However, it generates large amounts of residue that accumulates on the quarries’ fronts, making difficult their development and leaving the work places with high risk of accidents (Fig. 3 and 4).
**Figure 2** – Sequence of quartzite quarries
Figure 3 – Quarry front

Figure 4 – Irregular slabs extracted in the quarries
**Pilot Quarry**

In order to reorganize and automate the extraction, a detailed geological survey was performed, allowing the delimitation of the area of exploitation, the calculation of reserves and selection of preferred direction of advance of fronts. The ore body exploited is a geologic unit measuring approximately 400 m wide and longer than 1 km towards SW - NE. The existing quarries, around 15, are on the top of the unit and their advance toward the base is being hampered by the negative dip of the body. Based on this research, a new front to serve as pilot quarry was prepared. It was opened in the NE extreme point of the cooperative area and will become an example of good operating practices to achieve the best possible recovery of the deposit, from the bottom of the mineralized body (SE) toward the host rock (NW).

In the pilot project developed, after clearing the area, the overburden is removed using earthmoving equipment such as bulldozers and excavators. The waste material removed is deposited in piles to be used to fill in the pits when quarrying is ceased. Each quarry front will have 3 benches of at least 2 meters wide to facilitate personnel access, drilling and blasting. [4]

Drilling operations will use 4 pneumatic hammers with a hydraulic compressor of 63 liters per second of nominal flow capacity. The holes will have 1” diameter and 3.42 m depth, a 0.84 m drill spacing and 0.65 m of burden. It will be used quartzite waste for a 0.65 m stemming, and ammonium nitrate and detonating cord for a light blasting.

In order to enhance productivity and reduce environmental impact, several ways to automate the extraction of quartzite were studied. A cutting machine similar to that used in other quarries of foliated materials, like slate in Minas Gerais State or limestone in Ceará State, was considered the best solution. Several tests and adaptations were carried out with a Tyrolit diamond saw cutting machine, being the main problems found the quartzite hardness for manual sawing and the layers position (almost vertical). Thus, with the help of a local businessman, Engineer João Bosco, a circular diamond saw machine with a fixing system was built and tested in an already open front of the cooperative. The machine consists of a diamond saw with an electric 5 CV motor (three-phase) and an electric 1 CV motor (monophasic) both of 1740 rpm, a speed reducer and a frame of carbon steel tubes with adjustable sliders. The machine is water cooled and fed by a mobile diesel generator of 10kVA of capacity (Fig. 5). Several sawing disk diameters, from 250 mm, can be used, depending on the thickness of the layer to be cut. This machine was tested successfully making straight vertical cuts with high speed rate, proving that its use can enhance productivity and drastically reduce quartzite wastes [4].
However the machine still needs two important improvements in order to be useful for small producers: a rotating mechanism to perform also horizontal cuts and a lighter and more flexible settling system as the prototype is heavy and hard to position on the front.

**Loading and transport**

The loading and transport operations carried out in the exploitation of quartzite are the most rudimentary possible. The whole process is done manually with the aid of handcarts, and in some fronts also with a winch, which poses many risks of accidents (Figure 6). To redefine the reality of work, it shall be opened access ramps with smooth angles of up to 15 degrees to allow the traffic and operation of mechanized equipment such as: forklifts to carry the load on trucks with the help of wooden pallets and hydraulic excavators to clear the quarry fronts and open new ones. This way
it would be also possible to quarry different varieties (in color and shade) of quartzite simultaneously.

![Winch used to lift quartzite slabs from the pit. Source: CETEM/MCTI](image)

**Figure 6.** Winch used to lift quartzite slabs from the pit. Source: CETEM/MCTI

**Wastes management**

As a result of rudimentary quarrying for many years, huge amounts of quartzite wastes are deposited on the sides, or even inside the fronts (Fig. 2 and 3). Because the development of the quarries here proposed is from the base of the quartzite body (starting from the opposite side of which they are now), it was suggested to halt this extraction sites until the new fronts reach them. Whilst this happen some of the wastes will be recovered for other uses, because within this project some industrial uses for quartzite wastes were also developed, such as mosaic manufacturing units, aggregates and a mortar plant. Regarding the wastes that will be generated by the new quarries, they will be deposited in wastes piles whose location has been projected and prepared with the appropriate embankment and drainage structures [5].

**Health and safety**

Health and safety conditions should be improved by the new quarrying practices, especially regarding the risk of accidents. However, many additional recommendations must be followed such as the use of Personal Protective Equipment (PPE) and proper safety signs on and around the quarries. Brazilian legislation demands also the implementation of a Health and Safety Committee, within each organization, and a Medical Control and Health and Safety Program, in order to follow all the existing regulations. During the development of this project some recommendations were made, including training and the distribution of a booklet of safety and health for small quarries.
workers; but to attend the legislation there is still a lot of work of training to be made within the cooperative.

Conclusions

The objectives of improving the mining operations have been achieved: topography, geological local and detailed mapping, mine planning, preparation of a pilot quarry and development of mining equipment to automate the extraction. Among them, stands out the development of a cutting machine with diamond disk specially designed for the quarries’ fronts of Várzea. Yet, this was only a first collaborating work of several institutions, aiming to technically assist the small quartzite producers in the culture of sustainable mining. Therefore, many studies still must be continued, such as new pilot-scale tests of the cutting machine developed and new research to improve this technique, or studying more suitable alternatives. It will also be required an effort by the cooperative and the local government to implement the recommendations of this work, with investments in basic infrastructure and training.

Acknowledgments

The authors would like to thanks the colleagues Julio César Correia Guedes, Michelle Babisk, Antonio Pedro Souza and Ranieri Pereira, the funders (FINEP and Ministry of Science, Technology and Innovation), the producers’ cooperative (COOPVARZEA), the local company TECQUIMICA; and the following governmental and academic partners: Paraiba Government, Várzea Municipality, Brazilian Geological Service (CPRM), National Department for Mineral Production (DNPM), Paraiba State Company of Mineral Resources (CDRM), Brazilian Service for Supporting Micro and Small Businesses (SEBRAE), the Center for Mineral Technology (CETEM) and the Federal University of Campina Grande.

References


