Modes and Experience of Green Mine Construction in Yunnan, China: Case Studies

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Abstract. Yunnan is one of most important provinces with mineral resources and exploration in China. Meanwhile, Yunnan is Chinese ecological protective screen and try to be Pacesetter of ecological civilization. However, mining industry always disturbs ecological environment seriously. So green mine construction is inevitable and the best choice for Yunnan. In this paper, achievement of green mine construction in Yunnan was summarized. Then the paper takes two mines from Dahongshan and 4 mines from Yunnan Phosphate Chemical Group Co., Ltd (YPC for short) as case studies. Technological innovation in Dahongshan Fe Mine and Dahongshan Cu Mine guarantees their success of green mine construction. Land rehabilitation and harmonious community are highlights of 4 mines from YPC. These modes and experience could be referential to construct green mine.

1. Introduction

In order to resolve serious environment problems of mining, green mining industry development and green mine construction has been carried out since 2007 in China. Known as “kingdom of nonferrous metals”, Yunnan is located in southwest of China with large scale mining, mineral processing and smelting. Meanwhile, Yunnan is trying its best to be Pacesetter of ecological civilization because of its special location. So, it is inevitable and the best choice to develop green mining industry and construct green mine for Yunnan, which is the important platform and key point to convert development pattern, improve the image and promote development of mining industry. There are 28 national level green mines as pilot units in Yunnan up to now, and series of green mine models have emerged in large numbers [1]. Based on the background, the paper takes two mines from Dahongshan and 4 mines from Yunnan Phosphate Chemical Group Co., Ltd as case studies. Their modes and experience could be helpful to construct green mine.

2. Current situation of green mine construction in Yunnan

2.1. Brief introduction of green mine construction in China

In 2007, CHINA MINING was held in Beijing with the theme of “insisting on scientific development, propelling green mining industry”, which marked the beginning of green mining industry development and green mine construction in China.
In 2008, “mineral resource planning in China (from 2008 to 2015)” put forward definitely overall goal of “devote major efforts to propelling green mine construction, and until 2020 the pattern of green mine will be constructed fundamentally”.

In 2010, China's Ministry of Land and Resources (MLR for short) published “Guidance on the work of green mining industry development and green mine construction to implement mineral resource planning of China”, which put forward that green mining industry development and green mine construction was the important platform and key point to convert development pattern, improve the image and promote development of mining industry. In 2011, green mining industry development was brought into the twelfth five years plan of China, becoming national strategy.

From 2010 to 2013, MLR announced four batches including 661 national level green mines as pilot units successively, and nine requirements were necessary, namely legal mining, standard management, comprehensive utilization, technological innovation, energy saving and waste reduction, environmental protection, land reclamation, harmonious community and enterprise culture [2].

In May 2017, MLR and other five ministries published “implementation suggestions of speeding up the construction of green mine” together, which pointed out that the government would increase policies support and speed up the progress of green mine construction, and try to form a new pattern of mining industry according with the requirement of ecological civilization construction until 2020. The implementation suggestions proposed three goals: the first is to form a new pattern of green mine construction; the second is to establish a new approach of transformation in development mode for mining industry; the third is to build a new mechanism of green mining development.

2.2. Brief introduction of green mine construction in China

The progress of green mine construction in Yunnan is synchronized with the whole China. There are 28 national level green mines as pilot units in Yunnan, accounting for 4.24% (totally 661 in China). Most of 28 pilot units distribute in central Yunnan (figure 1). According to mineral types, there are 17 metal mines (6 copper mines; 4 tin mines; 2 lead-zinc mines; 1 manganese mine; 1 germanium mine; 1 gold mine) and 11 nonmetal mines (5 phosphorite mines; 6 coal mines) (table 1). Large enterprise groups pay close attention to green mine construction relatively. For instance, 6 pilot units belong to Yunnan Copper Co., Ltd; All 4 phosphorite mines of Yunnan Phosphate Chemical Group Co., Ltd are pilot units; Yunnan Dongyuan Coal & Power Co., Ltd, Yunnan Tin Company Group Limited and Yunnan Metallurgical Group have 3 pilot units respectively.

By means of making experiments construction, there are many achievements for 28 pilot units as follow: (a) legal mining becomes a self-conscious choice; (b) scientization and normalization of management come true; (c) comprehensive utilization has been improved; (d) technological innovation has been stimulated; (e) put energy saving and waste reduction into effect; (f) awareness of environmental protection strengthen; (g) land reclamation ratio becomes higher; (h) to fulfil social responsibility actively, and harmonious community building effect obviously; (i) enterprise culture good for development has been set up. In a word, series of green mine models have emerged in large numbers.

3. Successful modes of 2 national level green mines from Dahongshan Fe mine and Dahongshan Cu mine

3.1. General introduction of Dahongshan Mines

As a paragenetic mine of ferrous metal and nonferrous metal, Dahongshan Mines are located in Gasha Town, Xinpeng County (N101°37′, E24°6′), where iron ores and copper ores are mined (figure 1-A). The iron ores come under Yuxi Dahongshan Mining Co., Ltd. (Dahongshan Fe mine for short). The copper deposit is run by Dahongshan Copper Mine, Yuxi Mining Co., Ltd. (Dahongshan Cu mine for short). Mangang River is the boundary between two mines. They share one common tailing pond.
Figure 1. Distribution of 28 national level green mines as pilot units in Yunnan (A- Relationship of Dahongshan Fe Mine and Dahongshan Cu Mine; B- Distribution of 4 mines from Yunnan Phosphate Chemical Group Co., Ltd)

Both Dahongshan Fe mine and Dahongshan Cu mine began their infrastructure construction in 1990s. At present, Dahongshan Fe mine is a business group of mining and processing with more than 1.2×10^7 t/a scale respectively, while Dahongshan Cu mine is a large scale underground mining nonferrous metal mine.

3.2. Technological innovation guaranteeing success of green mine building

Dahongshan Fe mine makes much account of technological innovation, which helps the mine be a model enterprise in China. Many advanced processing equipment and technology have been used in Dahongshan Fe mine, which created the leading role in China even in the world, such as opencast working and underground mining with space-time synchronization for multiple ore bodies, stope structure parameter (20m×20m) of pillarless sublevel caving with high sublevel and large drive interval, absolute hoisting height of 2# sealing-tape machine under the shaft (421.15m), large equipment of semi-autogenous mill (Φ8.8×4.8m), 171km pipage laying and control for long distance ore pulp and so on.

3.3. To persevere in the concept of green, circulation and sustainability

Both Dahongshan Fe mine and Dahongshan Cu mine try their best to develop the circular economy. For instance, Dahongshan Fe mine have used tailing in many ways for the circular economy [3]. Firstly, tailing grade has reduced from 16% to 10% by means of three stages technical transformation, while use ratio of tailing has attained 90%. Secondly, tailing was solidified and piled to dry; some tailing was used to fill under the shaft with utilization amount of 162t/a. Thirdly, gold was recycled from tailing (mainly recycling gold concentrate of 120t/a with grade of 30-50g/t to get economic benefit of 1.5
million RMB per year. Fourthly, tailing was used to make brick. To persevere in the concept of green, circulation and sustainability has made the goal of Dahongshan Fe mine come true, namely four types of resource-saving, environment-friendly, development-safe and knowledge autonomous mine.

| No. | Name of mine                                                                 | Mineral type | Scale of mine | Batch number |
|-----|------------------------------------------------------------------------------|--------------|---------------|--------------|
| 1   | Yangla copper mine of Yunnan Dqing Mining Development L.L.C                  | copper       | large         | 1st          |
| 2   | Liuji copper mine of Yunnan Chuxiong Mining & Metallurgy Co. Ltd             | copper       | middle        | 3rd          |
| 3   | Dongchuan Xinshan gold mine of Yunnan Jinshan Mining Co. Ltd                 | gold         | middle        | 3rd          |
| 4   | Huize lead & zinc mine of Yunnan Chihong Zn & Ge Co. Ltd                     | lead & zinc  | large         | 2nd          |
| 5   | Zhaotong lead & zinc mine of Yunnan Chihong Zn & Ge Co. Ltd                 | lead & zinc  | middle        | 3rd          |
| 6   | Mengnuo lead & zinc mine of Yunnan Yongchang lead & zinc Co. Ltd            | lead & zinc  | middle        | 4th          |
| 7   | Dazhai germanium mine of Yunnan Lincang Xinyuan Ge Co. Ltd                  | germanium    | small         | 3rd          |
| 8   | Jucaiba coal mine of Lincang Jucaiba Coal Co. Ltd                            | coal         | small         | 4th          |
| 9   | Dapingzhang copper mine of Yunnan Simao Shanshui Copper Co. Ltd             | copper       | middle        | 4th          |
| 10  | Dahongshan Copper Mine of Yuxi Mining Co., Ltd                              | copper       | large         | 2nd          |
| 11  | Dahongshan Fe Mine of Yuxi Dahongshan Mining Co., Ltd                       | iron         | large         | 3rd          |
| 12  | Mouding Haojiahe copper mine of Yunnan Chuxiong Mining & Metallurgy Co. Ltd | copper       | small         | 4th          |
| 13  | Yipinglang coal mine of Yunnan Dongyuan Coal & Power Co., Ltd               | coal         | small         | 3rd          |
| 14  | Shizishan Copper Mine of Yuxi Mining Co., Ltd                               | copper       | middle        | 3rd          |
| 15  | Haikou phosphorite mine of Yunnan Phosphate Chemical Group Co. Ltd          | phosphorite  | large         | 1st          |
| 16  | Kunyuan phosphorite mine of Yunnan Phosphate Chemical Group Co. Ltd         | phosphorite  | large         | 1st          |
| 17  | Jiangshan phosphorite mine of Yunnan Phosphate Chemical Group Co. Ltd       | phosphorite  | large         | 2nd          |
| 18  | Jinning phosphorite mine of Yunnan Phosphate Chemical Group Co. Ltd         | phosphorite  | large         | 2nd          |
| 19  | Xiaolongtan coal mine of Yunnan Xiaolongtan Mining Bureau                   | coal         | large         | 3rd          |
| 20  | Buzhaoba coal mine of Yunnan Xiaolongtan Mining Bureau                      | coal         | middle        | 3rd          |
| 21  | Kafang tin mine of Yunnan Tin Company Group Limited                          | tin          | large         | 4th          |
| 22  | Laochang tin mine of Yunnan Tin Company Group Limited                       | tin          | large         | 4th          |
| 23  | Songshejiao tin mine of Yunnan Tin Company Group Limited                    | tin          | middle        | 4th          |
| 24  | Dounan manganese mine of Yunnan Wenshan Dounan Mn Co., Ltd                  | manganese    | large         | 2nd          |
| 25  | Tongjie & Manjiazhai zinc & tin mine of Yunnan Hualian Zn & In Co., Ltd     | zinc & tin   | large         | 4th          |
| 26  | Xianfeng open pit coal mine of Yunnan Coal Exploration Co., Ltd             | coal         | middle        | 3rd          |
| 27  | Mozushao phosphorite mine of Sinochem Yunlong Co., Ltd                      | phosphorite  | middle        | 4th          |
| 28  | Housuo coal mine of Yunnan Dongyuan Coal & Power Co., Ltd                   | coal         | middle        | 2nd          |

Dahongshan Cu mine has carried out the circular economy and cleaner production, which made “copper-iron commingling”, “barren rock filling”, “wastewater reclamation” and “tailing backfill” come true. According to characteristic of open stope method, milltailings and barren rock under the shaft were used as filling material in Dahongshan Cu mine [4].

3.4. Land rehabilitation

Dahongshan Fe mine implemented afforest and land rehabilitation following procedures and by stages. The area of land rehabilitation mainly included the open pit, industrial site and tailings pond (figure 2). In Dahongshan Fe mine, vegetation recovery and land reclamation adopted the policy of grass going ahead, wood mainly and arbour combining with shrub.

Dahongshan Cu mine has made production, construction and reclamation simultaneously come true. Five trees culture has been popular in Dahongshan Cu mine for a long time, namely new employee planting trees taking root, newlyweds planting trees with one heart, bearing couple planting trees with hope, organization members planting trees with ideality and retirement staff planting trees with commemoration.
4. Successful mode of 4 national level green mines from Yunnan Phosphate Chemical Group Co., Ltd

4.1. General introduction of 4 phosphate mines

As the largest modern open mining and processing of phosphate base and phosphate chemical enterprise, Yunnan Phosphate Chemical Group Co., Ltd (YPC) pay equal attention to the benefits on resource, enterprise, environment and society and promote green mining development. With excavation capacity 35 million m$^3$/a and raw phosphate rock 8.2 million t/a, YPC has 4 phosphate mines, namely Haikou Phosphate Mine, Kunyang Phosphate Mine, Jianshan Phosphate Mine and Jinning Phosphate Mine, all of which are national level green mine in China (figure 1-B). In 4 phosphate mines, more than 70 regulatory regime including exploitation of mineral resources, safety production, environmental protection, land rehabilitation and ecological civilization construction were formulated. Large scale mechanized mining and scientific intensive production and operation were carried out.

4.2. Land rehabilitation

The work of land rehabilitation and environmental protection has begun since 1980s in YPC. Especially after 2004, reclamation has formed long-term mechanism by increasing reinforce, input and innovation management. The vegetation covering ratio of land rehabilitation in 4 phosphate mines attained more than 90%, which guaranteed 4 national level green mines to come true. Forest planting month is held annually in May, while March 12$^{th}$ and September 30$^{th}$ are Employee Protecting Day. Up to 2016, YPC spent more than 200 million RMB accumulatively on reclamation, forming 17.3 million m$^2$ forest planting and 6.7 million m$^2$ grass planting.

Kunyang phosphate mine, built in 1965 with annual production capacity of 1.6 million ton, is located nearby southwest of Dianchi Lake which is the largest lake in Yunnan. So the regional environment is
very sensitive. In addition, the Meishucun section, considered as one of the best candidate for the international strato-type of the Precambrian-Cambrian boundary, is located in the mining area. However, geological environment of Kunyang Phosphate Mine used to be disturbed seriously by long term mining (figure 3). Since 2004, Kunyang phosphate mine has carried out the policy of synchronous harmonious development between exploitation of phosphorus resource and environmental protection (figure 4). From 2004 to 2014, 90 million RMB were spent on reclamation. Forest planting in reclamation mining area attained 5.7 million m² and reclamation vegetation coverage attained 97%. Mining wasteland has become Sinian geological & ecological garden.

![Figure 3. Photo of Kunyang Phosphate Mine before green mine construction](image1)

![Figure 4. Photo of Kunyang Phosphate Mine when mining with land rehabilitation](image2)

Furthermore, other three mines adjust measures to local conditions and used reclamation vegetation region resource for secondary development and utilization. For instance, Haikou phosphate mine has built Forest Lake Ecological Garden which merged trees of economic value, fruit & vegetable and relaxation together.

4.3. Harmonious community

In recent years, YPC has spent 5 billion RMB totally on territorial economic and social development in forms of labour service, talent training, roads construction, drinking water project, irrigation project and education subsidization, which made local people share resource earnings and harmonious community come true.

YPC considers “supporting new rural construction, developing territorial economy and establishing harmonious mine” as purpose and follows the principle of mutual understanding, mutual support, good-neighbourliness and win-win development. Based on above, YPC focuses on “industry re-feeding agriculture, ecological environment construction, supporting collective economics, rendering of service employment, sponsor compensation, enterprise-village cultural exchange, communication-coordination mechanism” as key points, which drives the development of surrounding villages. Gradually, YPC-
Hanying model has taken shape, which enriches the enterprise value idea of mutual improvement of enterprise and society.

Kunyang Phosphate Mine is wholly situated in the Hanying Village, which possesses land ownership for the production and construction of Kunyang Phosphate Mine. The mine has to need land for open mining from Hanying Village, which makes inevitable the connections between the two parties. YPC-Hanying model integrates the community's economic, environmental and cultural development [5]. The mine carries out main construction projects of environment and community together with Hanying Village, which promotes cultural exchanges among enterprises, local communities and administrative departments.

5. Conclusion
Green mine construction is inevitable and the best choice for Yunnan for the balance between mining industry development and ecological civilization. The progress of green mine construction in Yunnan is synchronized with the whole China. There are 28 national level green mines as pilot units in Yunnan up to now, and series of green mine models have emerged in large numbers. Large enterprise groups pay close attention to green mine construction relatively. Technological innovation in Dahongshan Fe Mine and Dahongshan Cu Mine guarantees their success of green mine construction. Land rehabilitation and harmonious community are highlights of 4 mines from Yunnan Phosphate Chemical Group Co., Ltd. These modes and experience could be referential to construct green mine.

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