Research on the Mining Methods of the Deep Orebody of No.six pit of Jingning Phosphate Mine of Yunnan Phosphate Chemical Group Co.,LTD

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Abstract— The mining method of the deep slowly inclined-thin to medium thick-soft interlayer ore body is of No.6 pit in Jingning phosphate mine of Yunnan Phosphate Chemical Group Co.,LTD., has been studied, though the research techniques of field investigation, theoretical analysis and scheme comparison, on basis of the comprehensive analysis of the occurrence characteristics of ore body mining engineering, the technical conditions and the bottom characteristics of surrounding rock. The results show that:(1)the mixed mining way of ① seam, ①1 seam and ①2 seam should been carried out, as the ore grade could reach 22.97% and the high resource recovery. (2) for the typical hard-to-mine ore body of No.6 pit in Jingning phosphate mine, it is very difficult to obtain the ideal economic and technical index by using a single mining method. The section shrinkage-caving method is the right one to take as the mining method to the hanging wall seam, and duo to the seam is thin, for the footwall seam, it should take shallow-hole shrinkage mining as the mining method. The related results provides certain reference for the mining way of the deep mining of Yunnan phosphate group corporation and similar conditions of open pit mining of phosphorus mine.

Keywords-mining methods; deep orebody; phosphate mine;field investigation; theoretical analysis and scheme comparison.

I. INTRODUCTION

In recent years, with the increasing of mining depth of open phosphate mine surrounding the Dianchi lake area of Yunnan province in China, phosphorus mines gradually entre a stage of deep mining. Then, the production stripping ratio increased sharply, and the dump and soil forest land leasing fees, the environment and the cost of soil and water conservation and the labor cost, material and diesel price are all rapidly rising. The surface mining cost increases rapidly, and the original advantages of open mining are gradually losing [1-8]. The problem of mining method of the deep ore body is one of the major problems to be solved, It has seriously affected on the future sustainable development of phosphate mines surrounding the Dianchi lake area [9-13].

II. MINE ENGINEERING GEOLOGY

A. *Seam features*

Phosphate deposits mainly occur in the second and three litho logic section of the plum tree schiscosomiasis, the distribution of Ⅰ grade phosphate is discontinuous, and the pinch phenomenon of it appears in diagonal line of WN—ES and EN—WS of the ore field. The thickness of Ⅰ grade phosphate is arrange from 1.20 m to 28.40 m, and the average thickness of it is 5.33 m. And the pinch phenomenon of Ⅱ grade phosphate is very common, especially in the range of No.56 to No.57 exploration line, the thickness of Ⅱ grade phosphate is arrange from 1.00 m to 20.80 m, and the average thickness of it is 6.03 m. But the distribution of Ⅲ grade phosphate is continuous, the thickness of Ⅱ grade phosphate is arrange from 1.00 m to 28.42 m, and the average thickness of it is 13.09 m.

The underground mining method test area located in the region that between No.58 and No.59 exploration line. The elevation range of phosphate is +2 220 to +2 270 m, the ore body dip angle of it is 45° to 54°, and the burial depth of it is 50m to 100m. The thickness of Ⅰ grade phosphate is 4.80 m to 7.70 m, and The thickness of Ⅱ grade phosphate is 1.90 m to 6.00 m.

B. *Engineering geologic condition*

The rock formation in the experimental zone of underground mining engineering can be divided into 5 groups, according to the mechanics characteristics of rock and rock mass, geological structure and engineering

occurrence conditions. The first group is Quaternary loose soil, the second group is the intact seam floor with hard structure, the third group is relative broken direct roof with weak to semi hard structure, the fourth group is the semi hard to hard indirect roof, and the fifth group is semi hard to hard indirect soleplate.

The overall stability of phosphate and rock body in the underground mining engineering test area is poor, due to the shallow burial depth and strong weathering. But the stability of seam floor is good. The geological condition of the ore body of No.6 pit in Jing ning phosphate mine is shown in Fig .1 and the rock physical and mechanical parameters is shown in Table.1.

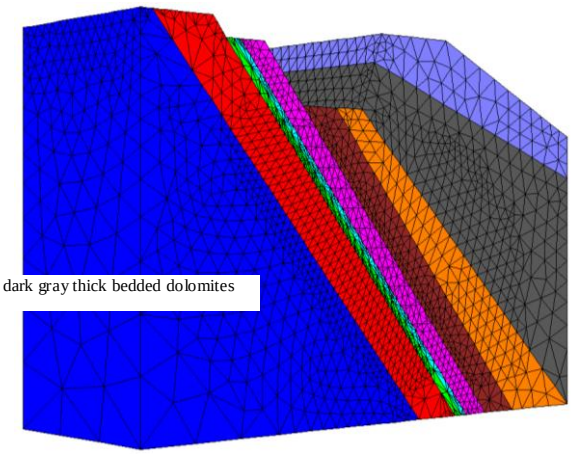

Figure 1. The geological condition of the ore body of No.6 pit in Jingning phosphate mine

TABLE I. PHYSICAL AND MECHANIC PARAMETERS OF ROCK MASS

Lithology	Uniaxial compressive str ength /MPa	Elasticity modulus /GPa	Strength of extension /MPa	Poisson's ratio	Cohesion /MPa	Internal frictional angle/ (°)
The Quaternary overburden layer	*5.02*	*4.14*	*0.87*	*0.42*	*1.11*	*19.1*
Medium to coarse crystalline dolomite	*48.82*	*12.82*	*3.39*	*0.44*	*8.16*	*32.10*
Laminated shaly dolomite	*19.07*	*8.08*	*0.69*	*0.48*	*1.14*	*17.20*
Quartz sand with gravel	*42.08*	*13.39*	*3.15*	*0.42*	*11.20*	*42.20*
Upper and down seames	*50.35*	*16.40*	*5.64*	*0.31*	*13.84*	*42.20*
Low grade sheet mine	*51.20*	*18.26*	*4.86*	*0.32*	*12.08*	*38.12*
Dark gray thick bedded dolomites	*59.10*	*16.26*	*6.18*	*0.28*	*13.05*	*47.23*
Mud soft interlaye	*1.11*	*1.12*	*0.09*	*0.52*	*0.46*	*8.34*

III. RESEARCH ON THE MINING METHOD OF DEEP ORE BODY

A. *The selection of industrial test section*

The test section has two alternatives, one is the north of No.58 exploration line and the other one is the south of No.58 exploration line.

1) Plan of the north of No.58 exploration line: according to the geological section map, the thickness of phosphate which locating in the region that between No.57 and No.58 exploration line is too thin, it should not be typical. And the goldmine main locates in the region that between No.56 and No.57 exploration line and the industrial ore becomes poor and thin under +2200m, which is not conducive to industrial production. So, it is unsuitable of the north of No.58 exploration line for underground mining test.

2) Plan of the south of No.58 exploration line: according to the geological section map, the phosphate which locating in the region that between No.57 and No.58 exploration line has the following characteristics: simple ore body occurrence conditions, large reserves, high grade, and a multilayer ore, it has a very strong representative. Whether south or deep of the phosphate rock, its continuity is better, which is beneficial to the industrial production after late stage testing. In consequence, it is rational to taking the south of No.58 exploration line as the underground mining test zone.

B. *The selection of mining object*

Continuous sedimentary rock deposits appears in the test area of phosphorus, which between lean ore layer and rich ore layer, the material component changes gradually, and the ore grade transits gradually. According to the ore grades division, the Ⅰ grade phosphate (P2O5≥ 27.8%) is located in the upper part of phosphate seam, Ⅱ grade phosphate (P2O5 is 15% to 25%) is located in the central part of phosphate seam, and Ⅲgrade phosphate (off-balance-sheet ore, P2O5 is 8% to15%) is located in the lower part of phosphate seam. The mining object in the test area is Ⅰ and Ⅱ grade phosphate, and through the scheme comparison, it is reasonable to implementing slicing mining.

Under the condition of without considering filling mining method, when the slicing method has been carried out that mixed mining method using for the upper ore bed of ①seam, ①1 seam and ①2 seam, and the ②3 seam extraction individually. In order to ensure the safety of mining, the isolation thickness between upper seam and down seam should not be less than 20m. But according to the No.58 and No.59 prospecting line profile maps, the actual isolation thickness is less than 20m, so the slicing method cannot be carried out for the unsafely mining.

In view of the distribution of the ore grades in the experiment mining area, the following two schemes has been designed. The test section reserves estimation is shown in Table 2 and the mining design proposal is shown in Table 3.

Plan 1: The mixed mining method is used for the mixing layer of ①seam, ①1 seam, ①2 seam, ②seam, ②1 seam, ②2 seam and ②3 seam, the total quantity of phosphate ore is 294 622.0 t, the geologic average grade of P2O5 is 17.78%, and the mining grade of P2O5 is 15.11%.

Plan 2: The mixed mining method is used for the mixing layer of ①seam, ①1 seam, ①2 seam , the total quantity of phosphate ore is 96 855.9t, the geologic average grade of P2O5 is 27.02%, and the mining grade of P2O5 is 22.97%.

By comparison of plan 1 and plan 2, it is confirmed that the plan 2 is more suitable to the mining conditions, as the mining grade of plan 1 is too low to using under the current economic and technical conditions.

TABLE II. RESOURCES AND RESERVES ESTIMATION

Seam No.	Ore typies	Ore tonnage /t	Average grade /%
①1	Ⅱgrade	558.41	22.16
①	Ⅰgrade	74 482.99	30.02
①2	Ⅱgrade	218 14.51	16.89
Subtotal		96 855.91	27.02
②	Ⅲgrade	133 137.41	11.47
②1	waste rock	2 688.45	7.39
②2	Ⅱgrade	20 640.82	17.13
②3	Ⅱgrade	41 299.43	17.49
Subtotal		197 766.10	13.26
Total		294 622.01	17.78

TABLE III. SCHEME COMPARISON

Plan	Seam	Ore tonnage /t	Geologic average grade of P_2O_5/%	Mining grade of P_2O_5/%
1	①、①1、①2、②、②1、②2、②3	294622.0	17.78%	15.11%
2	①、①1、①2	96855.9	27.02%	22.97%

C. The comparison of mining method

According to the technical conditions of the ore body, it may adopt three mining methods, which contains sublevel open stope method, shallow hole shrinkage stoping method, and sublevel shrinkage caving method. The main technical and economic indicators of three methods are shown in Table 4.

According to the main technical and economic indicators of three methods which has been shown in Table 4, it draw the following conclusions:

1) Shallow hole shrinkage method is applicable to inclined and steeply inclined ore body with basic stability ore rock, it is a kind of mature technology, simple process mining method. The disadvantage is the worker's labor intensity is big, the stope production capacity is low, and the mining safety is poor. The shrinkage method can only be used for horizontal ore ore body whose thickness is less than 4m.

2) Sublevel open stooping method is applicable to inclined and steeply inclined ore body with stability ore and ore rock, but rock hardness of test section ore roof is small to medium, and the rock integrity is poor. So, Considered from the aspect of security, the sublevel open stope method should not be used.

3) Sublevel shrinkage - caving method is a variety of non pillar sublevel caving method. Segmentation points shrinkage - caving method is all the production process adopting the sublevel caving method except forming a covering layer before mining the ore, and instead of leaving a certain amount cap pillar. The shortcomings of this method are the need to adopt trackless LHD to convey ore, and the equipment purchase cost is high. But the ore recovery rate is high, and the dilution rate is low.

According to the above comparison, the upper ore body should adopt sublevel ore caving method, and the shallow hole shrinkage stooping method should be used in footwall ore body.

TABLE IV. MINING METHODS COMPARISON

Mining method / Comparision item	Shallow-hole shrinkage mining	Sublevel open stoping method	Sublevel ore caving method
Ore mining cutting quantity /(m/m3)	*625/3 856.4*	*1 074/6 375*	*790/6 411*
Drilling equipment	*YSP-45 Rock drill*	*YGZ-90 Rock drill*	*YGZ-90 Rock drill*
Stope ore handling equipment	*2m3 Electric LHD*	*30kW Scraper hoist*	*2 m3 Electric LHD*
Ore block production capacity /(t/d)	*70*	*150*	*300*
Ore loss ratio /%	*15*	*15～20*	*15～20*
Ore dilution rate /%	*10*	*12*	*10～12*
Safety evaluation	*Ore is not solid, and has poor security.*	*Ore roof is not solid, and has poor security.*	*Ore roof is solid, and has good security.*

IV. SUMMARY

On the basis of full investigation of geological and mining conditions of of the deep slowly inclined-thin to medium thick-soft interlayer ore body is of No.6 pit in Jingning phosphate mine of Yunnan Phosphate Chemical Group Co.,LTD., the analysis of appropriate underground mining method has been done from the perspective of safety economy and resource utilization, and other technical condition. Through the comparison of more alternatives, it seem that upper plate seam should adpot subsection ore caving method as a key test of underground mining method, while the thin lower plate seam, it would be recommended by shallow hole shrinkage stoping method as an auxiliary test of underground mining method.

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REFERENCES

[1] Xiaoshuang Li, Yaoji Li. Phosphate rock resources exploitation status and prospect in China [C] //China's mining technology conference corpus in 2012.Ma Anshan : Metal mine magazine, 2012 : 20-23 (in Chinese).

[2] Xiaoshuang Li. Study on Stability of the open pit slope and deformation and failure rule of the underground stope and overlying rock strata after transformation from open-pit to underground Mining [D]. Chong Qing : Chongqing University, 2010 (in Chinese).

[3] Peruzzini M. White phosphorus and green chemistry : Towards an eco-effiiciently catalysed oxidative phosphorylation [J]. Speciality chemicals magazine , 2003, 23（1） : 32-35.

[4] Zaretskii Yu K, Karabaev M I. Feasibility of face sureharging during deep settlement—Free tunneling in dense urban settings [J]. Soil Mechanics and foundation engineering, 2004, 41（4） : 1136-1149.

[5] Wang Shaodong, Zhang Hongying. Phosphate rock resources and phosphate fertilizer production and its consumption in China [J]. Industrial Minerals & Processing, 2007, 36（9） : 30-32(in Chinese).

[6] Yaoji Li , Xiaoshuang Li , Zhang Dongming. Underground mining technology of deep phosphate orebody [M]. Bei Jing : Metallurgical Industry Press, 2013(in Chinese).

[7] Yaoji Li, Xiaoshuang Li, Huang Gun. Open-pit to underground mining technology of large open-pit phosphate mine [M]. Chong Qing : Chongqing University Press, 2011(in Chinese).

[8] Walz R. New developments in phosphorus flam retardants [J]. Speciality chemicals magazine, 2002, 22(2) : 23 -25.

[9] Wen Qian. Chinese phosphorite type and resources potential analysis [D]. Bei Jing : China University of Geosciences（Bei Jing）, 2011(in Chinese).

[10] Sun X M, Cai F, Yang J., et. al. Numerical simulation of the effect of couoling support of bolt-mesh-anchor in deep tunnel [J]. Mining science and technology, 2009, 19（3） : 352-357.

[11] Kriiger J. Copper mining and metallurgy in prehistoric and the more recent past [M]. Netherlands : Springer, 2004.

[12] Xu Shuai, Li Yuanhui, Gao Zhenling, et.al. Study on the extension mining method without expansion side slope during transition from open-pit to underground Mining [J]. Metal Mine , 2011, 46（8） : 41-44(in Chinese).

[13] Yang Li, Wang Xinming, Zhao Jianwen. Production steady and slope stability analysis during the transition period of open pit to underground in Miaogou Iron Mine [J]. Metal Mine , 2013, 48（1） : 7-10(in Chinese).