Comprehensive treatment and ecological restoration of mine geological hazards for Yanchi mountain in Jinan City

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Abstract: The mining of underground iron ore in Yanchi mountain causes many geological disasters, such as mountain collapse, ground fissures, collapse and unstable slope, which threatens the safety of people's lives and property, and causes ecological environment problems such as soil erosion, topographic landscape destruction and vegetation damage. According to the causes and current situation of geological hazards and ecological environment in Yanchi mountain, comprehensive treatments such as filling goaf and ground fissures, cutting slope to eliminate danger, building retaining wall and drainage ditch, hanging net spraying and slope greening have been taken to eliminate hidden dangers of geological hazards and restore ecological environment. These measures have achieved remarkable governance results, which can provide reference for comprehensive control and ecological restoration of mine geological hazards in similar areas.

1. Introduction
Yanchi Mountain is located in the central urban area of Jinan, and is rich in mineral resources of iron ore underground. If non-filled mining is performed, geological disasters including mined out area breakdown, mountain cracks, and collapse will be caused after the pit is closed, leading to ecological and environmental problems including soil and water loss, topographical landscape and vegetation damage [1]. In order to eliminate the hidden dangers of geological disasters, restore the geological environment, and beautify the mountains in central urban areas, it is necessary to organically combine the treatment of geological disasters and the restoration of the ecological environment. It means that engineering governance is adopted to eliminate mine geological disasters, and effective mountainous afforestation projects are implemented to restore the ecological environment. Mine geological disaster control and ecological restoration are affected by various factors such as geographical location, population economy, land and space planning, policy support, disaster types and ecological damage status, topography, climate, and precipitation. Governance methods should be adapted to local conditions, and it is not appropriate to apply it mechanically [2-3]. At present, many methods are used in China such as slope cutting and drainage, building retaining walls and drainage ditches, suspended net spray-sowing, planting on fish scale pits, greening of slopes, artificial lake formation, and rock wall carving[4]. For example, the quarry formed in the open-pit mines of the Xuzhou Economic Development Zone adopts the methods of slope reduction, net spray-sowing, and artificial lake formation to implement mine afforestation; after the geological disaster management of the limestone mine in Fengshan, Guangxi Province, the tunnel face is rock-carved to promote folk culture; the Wulaga gold mine in Heilongjiang Province adopts slope-cutting to eliminate geological disasters, and is restored the ecological environment through tree planting and artificial lake formation, which is mainly composed of engineering disaster relief, ecological restoration, and biological restoration [5].
This paper starts with the comprehensive control measures for the geological environment of Yanchi Mountain Mine in Jinan Province, continuously observes the control effects and summarizes the experience. By looking into the comprehensive management control of mine geological disasters and ecological restoration, it is aimed to form a systematically and universally efficient environment restoration model for mines.

2. Project overviews
Yanchi Mountain is located in the east of Jinan city center. The mountain is spreading from northeast to southwest, with a length of about 650m and a width of about 430m, covering an area of about 0.28km². Stratigraphic lithology is composed of Quaternary loose deposits and Ordovician limestone. The magmatic rocks mainly intrude in layers in the form of rock beds with the lithology of diorite. On the north side of the mountain is the inkstone Spring, one of the 72 famous springs in Jinan, with an air-raid shelter dug inside the mountain. Mining and excavation of the slope foot cause steep facings in the western and northern parts of the mountain, which results in unstable slopes, so rock collapses occur from time to time. In addition, huge and unknown underground goafs can easily lead to mountain collapse and trigger mountain cracks. Besides, the slag pile consisting of slag, household and construction waste has a large volume and forms a steep slope, indicating that there are hidden dangers of collapse.

![Figure 1 Prospective map of Yanchi Mountain](image)

3. Mine geological disaster characteristics and ecological environment problems

3.1 Goaf collapse
The goaf of Yanchi Mountain iron mine is mainly distributed from the western side of the mountain to the margin. Its plane distribution area is 9709.56m², the east-west length is 164.03m, the north-south width is 92.43m, and the total capacity is 2-20m. The total volume of the goaf is 103271.8m³. An overall collapse occurred in the upper part of the goaf, with an area of 4500m² and a maximum subsidence distance of 1.0m. There were also many mountain cracks inside the subsidence body.

3.2 Mountain cracks
There are 17 cracks in the rock mass on the northwestern slope of Yanchi Mountain, and many cracks run through the mountain. They form high, steep and unstable slopes, with hidden dangers of collapse and landslides. Among them, there are a total of four first-level main cracks. These are large in scale and run through the mountain mass, which control the stability of the rock mass. There are 13 second-level cracks. Some penetrate the mountain masses, and some are connected with the main cracks, which have a significant impact on the stability of the unstable rock mass. The investigation finds that the maximum vertical fall distance of # 1 main crack is 1.5m, the maximum width is 2.1m, and the extension length is 180m. The lower part penetrates the goaf, the west side is connected to the western edge of the mountain, and the north side is connected to the bottom of the south bank of the Inkstone Spring. The upper part in the goaf is separated from the main body of Yanchi Mountain, and the geological model is summarized as follows.
3.3 Collapse
The collapse is mainly distributed in the cliff distribution area of the edge of Yanchi Mountain. Open-pit mining forms a high and steep free surface, 80-121m long from north to south, and 15-60m wide from east to west. It has a height difference of 83.1m from the water surface of the Inkstone Spring, and the total volume is estimated to be about 18180m³. There have been four large-scale collapse geological disasters here, with a cumulative collapse volume of about 13300m³. The largest collapsed boulders are more than 20 meters long, nearly 10 meters high, and more than 10 meters wide, with a volume of more than 2000m³.

3.4 Unstable slope of slag heap
The slag heap is mainly composed of rubble, cohesive soil, and construction waste. They are distributed on the east, south and west sides of the mountain, forming a number of steep ridges with a total volume of 121×10⁴m³. The slag heap has a loose structure and strong permeability, leading to the poor body stability, which hides potential dangers of landslides. Not only does it take up land, it also destroys surface vegetation.
3.5 Destruction of landform and mountain vegetation
Due to the large-scale collapse of the mountain and the development of cracks in the mountain caused by mining, open-pit mining forms a cliff about 80m high on the north side of the mountain. At the same time, the artificial accumulation also forms a slag heap with a height of about 10-16m, which causes damage to the mountain landscape, vegetation.

3.6 Soil and water loss, and atmospheric dust
Mining forms bare high and steep facades and destroy mountain vegetation. The slag heap is accumulated intentionally, which causes soil erosion under the rain. In addition, under windy conditions, dust is likely to occur around Yanchi Mountain, which has a serious impact on the daily life and the work of nearby residents, including teachers and students of school and unit employees. Moreover, the geological environment tends to deteriorate.

3.7 visual pollution
Yanchi Mountain is located in the center of the city. The mining has caused damage to the landform and vegetation. The visual pollution caused by the damaged mountain has a destructively unfavorable effect on the overall urban image and planning development of Jinan.

4. Comprehensive control measures

4.1 Goals
Yanchi Mountain is located in the center of Jinan, and the Inkstone Spring is one of the famous springs in Jinan. Because of its high social sensitivity, the selection, operability, effects and impact of control measures are important factors that must be fully considered, which are the key for the restoration project. According to the causes of the geological hazards and status quo of the ecological environment, the goal is to completely eliminate hidden dangers of geological disasters and build mountain parks after considering urban planning, population economy, and climatic conditions. The engineering treatment adopts goaf and crack filling, slope cutting, retaining wall and drainage ditch masonry. Ecological restoration are combined with suspended net spray-sowing and seedling planting.

The filling material and technology of the goaf should lower its cost and meet the environmental protection standards on the premise of ensuring the strength of the filling body. Materials including the high-water rapid-setting material, cement powder, whole tailings, construction waste, commercial concrete, commercial cement mortar are compared and analyzed. In the end, commercial concrete and cement mortar are selected as the filling materials, as its filling process is simple, operationally convenient, and short time-consuming with high strength and low pollution.
The core of goaf filling is to ensure the roof-contacted filling \cite{6}. A combination of internal and external filling is adopted for the goaf here in Yanchi Mountain. The internal filling is to use the air defense passage to fill the goaf below the elevation of the bottom of the air defense tunnel. The filling volume can reach more than 95% of the field survey for the goaf. The filling material is C10 concrete, with a expansion degree of larger than 600mm and a slump larger than 250mm. The external filling is carried out through grouting holes on the mountain to ensure the roof-contacted filling. The filling material is mortar, labeled M5, with a consistency larger than 200mm.

4.2 Mountain crack filling
In order to facilitate mountainous afforestation later, filling materials with good water permeability and easy plant to grow should be adopted. Filling of grouting, crushed stones, or planting soil are selected. Crushed stone filling should be small in the lower part and large in the upper part, and the maximum diameter is smaller than the crack width by 2-3cm. When the gravel filling reaches 500mm from the ground, the planting soil is back-filled.

4.3 Collapse treatment
Because the rock mass on the slope is extremely broken, weathering and stress-release cracks are developed in large numbers, and the local slope section is inverted, it is unlikely to depend on one single solution to work out the situation. After analyzing and calculating of slope stability, the comprehensive treatment plan of slope cutting, talus consolidation, and permeable retaining wall is required for the treatment of unstable rock masses.

For potential collapses on the north, south, and east sides of Yanchi Mountain, slope-cutting and rock cleaning will be carried out. After the slope is cut, the slope is less than 70°, and some are 50°-70°, which shall remove the danger of the unstable rock masses. The dangerous rock collapsed on the south side of inkstone Spring is huge, so the boulder is crushed to prevent instability and damage. The high-pressure spraying is used to cast the talus above the water surface with M10 fine sand cement mortar with a pouring depth of 4m and a porosity of 25%. The front permeable retaining wall is arranged to cover the talus so as to prevent dangerous rocks from falling into Inkstone Spring to hurt the tourists. A continuous arched permeable retaining wall cast for reinforced concrete should be adopted for the retaining wall structure. Behind the wall is back-filled with planting soil and suspended net spray-sowing. Besides, evergreen, drought-tolerant and barren-tolerant plants should be selected for afforestation.

4.4 Treatment for slopes of the slag heap
The slope of the slag heap is treated by load reduction, drainage ditches, retaining walls, suspended net spray-sowing and latticed setting. Blocking is based on adapting to natural slopes and eliminating cliffs by reducing the height of the slag heap. It is intended to improve the natural slope shape on both sides to reduce soil erosion and facilitate afforestation.

4.5 Drainage
The drainage system is designed according to the intensity of heavy rain that has 1% probability of occurring in any given year in Jinan. The horizontal intercepting ditch and the vertical drainage canal shall be laid. Masonry stone is used as the channel construction material, and cement mortar is used as the trowel. The horizontal intercepting ditch is arranged along the contour line and is mainly used to intercept rainfall runoff on the slope surface. The bottom of the intercepting ditch should have a certain slope so that the intercepted rainwater can be discharged intensively along artificial channels with good anti-seepage performance. Through the intercepting ditch, the upper catchment will be concentratedly introduced into the artificial channels on both sides and the Inkstone Spring for drainage. This can lower the impact of fissure water pressure on the stability of the slope and reduce the erosion of the ecological matrix by surface runoff.
4.6 Ecological restoration

Yanchi Mountain is located in the northern part of China. Ecological restoration should be adapted to local conditions. Different planting styles and seedling species should be determined according to the characteristics of various blocks. On the basis of coordination with the overall environment, plant landscapes with high standard and class are designed.

For rock slopes with bare rock surfaces and good stability, liana plants are used for greening here. Soil is placed near the slope or at the bottom of the slope. Climbers are planted to cover the slope, including parthenocissus semicordata, hedera helix, parthenocissus tricuspidata. For rocky slopes with more developed joints and more severe fractures, in order to ensure the greening effect of mountain parks, suspended net spray-sowing is used, along with the maintenance of automatic drip irrigation system watering. Suspended net spray-sowing technique has the advantages of quick greening and not occupying land space on the slope foot. However, there are also shortcomings such as poor project durability, high requirements for soil and water, and large maintenance investment in the later stage. In order to ensure the greening effect and durability, it is selected to be used on slopes with a slope of 45°-70°, and the maintenance intensity is increased. For slag slopes, digging high and filling low is used for leveling treatment. Platforms and retaining walls are set up at the slope surface and foot. Tree holes are set up on the platform and soil is filled by planting shrubs and vines. After the retaining wall of the slope foot, a slightly taller and drought-resistant tree species is planted, thereby forming a green effect with a combination of upper and lower levels. The plants focus on the seasonal and hue landscape changes, so that the canopy line is combined with the mountain skyline, and finally the plant landscape with flowers in three seasons and scenery in four seasons is achieved. The selected plants are mainly juniperus chinensis, cotinus coggyria, forsythia suspensa, jasminum nudiflorum, prunus cerasifera, platycladus orientalis, styphnolobium japonicum, melia azedarach, cedru, ginkgo biloba, cherry blossom, robinia pseudoacacia, koelreuteria paniculate, oysia japonica, phiopogon japonicus. The effect of the control project is shown in Figures 5 and 6.

Figure 5 Yanchi Mountain before the control project

Figure 6 Yanchi Mountain after the control project
5. Conclusion
Mine geological disaster control and ecological restoration involve multiple disciplines such as engineering geology, environmental geology, environmental engineering, and landscape engineering. On the basis of multiple factors including ecological damage status, geographical location, population economy, national spatial planning, policy support, climate, and precipitation, the determination of control goals and effects should be combined with the type of disaster. The main types of mine geological disasters in Yanchi Mountain are goaf collapse, mountain cracks, and unstable slag heap slopes. Eco-environmental problems are mainly landform damage, land and vegetation resource occupation damage, water and soil loss, and fugitive dust. The design of the control project aims at eliminating hidden dangers of geological disasters and constructing mountain parks, which includes cracks filling in goafs and mountains, cutting slopes, leveling the slopes, latticework, suspended net spray-sowing, drainage constructing, retaining wall, and greening landscape. This is enabled to clear up the hidden dangers of major geological disasters and restore the ecological environment. At the same time, it provides scientific reference for similar comprehensive control projects of mine geological disasters and ecological restoration.

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