Distribution Characteristics of Geological Disasters and Main Control Measures in Shandong Province

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Abstract. The landforms and geological structures in Shandong Province are relatively complex, and the complex topographical conditions and geological structures have caused a series of geological problems. This article outlines the main types of geological disasters in Shandong Province through literature research and geological survey, summarizes the distribution characteristics and causes of different types of geological disasters in Shandong Province, describes the prevention and control status of various geological disasters, and proposes future research recommendations on geological disaster management. Through the analysis and data compilation of a large number of geological disaster cases in Shandong Province, the research results show that the hidden dangers of geological disasters in Shandong Province are mainly subsidence, landslides, debris flows and ground subsidence, which are mainly distributed in the eastern, southern and central parts of Shandong Province. Its development law is closely related to the topography, stratum lithology, and geological structure, engineering geological characteristics, hydrogeological characteristics and human-made engineering activities of the study area. Existing geological disaster control measures focus on eliminating hidden dangers, but the results of environmental management are few. Therefore, in the future, efforts should be made to research on geological disaster prevention and control engineering based on ecological protection and form ecological management that combines management engineering with natural and human engineering technology. This article aims to systematically introduce the major geological disasters and their distribution characteristics in Shandong Province, make up for the lack of existing research results, and provide a scientific basis for future research on geological disasters.

Keywords: Shandong Province, geological disasters, distribution characteristics, control measures

1. Introduction
China has a vast territory, complex natural geography and geological structure conditions, extensive distribution of geological disasters, and frequent human engineering activities, which have increasingly intensified the development of geological disasters. China has become one of the countries with serious geological disasters in the world [1]. Shandong Province's landform is complex,
consisting of low hills in the east, plains in the west, and staggered topography in the middle [2]. The complex topography and geomorphic conditions, and geological structure have caused a series of geological problems. This article summarizes the geological disasters in Shandong Province through literature research and geological survey, analyzes and elaborates the distribution of geological disasters, and proposes control measures for the geological disasters. The paper aims to systematically understand the main geological disasters and their distribution characteristics in Shandong Province, make up for the lack of existing research results, and provide a scientific basis for future research on geological disasters in Shandong province.

At present, many scholars have carried out a lot of research on geological disasters in Shandong Province and have achieved certain results. Chang Yunxin et al. [3] took Heshanzi Village, Xintai City as an example, summarized and analyzed the impact of geological disasters such as mining subsidence, and provided a reference for the prevention and control of geological disasters. Yang Quancheng et al. [4] conducted a correlation analysis between the development of geological hazards and topography, landforms to reference future work on geological hazards. Hu Yulu et al. [5] carried out dangerous zoning of geological disasters in Shandong Province, laying the foundation for the early warning and detection of geological disasters. Yao Chunmei et al. [6] discussed the geological disasters in typical hilly areas in Shandong Province, analyzed the development status of different types of geological disasters, and proposed specific prevention and control measures.

2. Main disaster types and their distribution characteristics

According to statistical analysis, the hidden danger points of sudden geological disasters in Shandong Province are distributed in other regions except for northern Shandong, mainly in eastern, southern and middle Shandong. The development law of various geological disasters is closely related to the local topography and slope gradient [7]. The main types and distribution characteristics of geological disasters in Shandong Province are as follows:

2.1. Collapse

Collapse is a geological phenomenon in which the rock and soil on a steep slope suddenly break away from the parent body under the action of gravity, roll, and accumulate at the foot of the slope. Collapse disaster has the characteristics of instantaneous, high destructive and strong sudden, which will cause a great threat to people's lives and property.

Collapse geological disasters are the main types of geological hazards in Shandong Province, which are densely distributed in the mountainous areas of central and southern Shandong Province and the Jiaodong Peninsula. The mountainous areas of central and southern Shandong Province have high terrain, complex geological structures such as folds, joints and faults. The Jiaodong Peninsula is located in the fault segmentation zone, and the terrain is broken due to long-term erosion and segmentation, which is easy to cause collapse.

Typical collapse geological disaster in Shandong Province takes Anzigou Village, Rizhao City (Figure 1) as an example. The area is located in a hilly area, and the landform type is micro cutting-strong erosion hilly landform. The mountain rock is composed of hornblende biotite monzogranite of the Neoproterozoic Rongcheng super unit silk mountain unit. Due to its long-term weathering and erosion, thin layers of residual slope deposits are formed on the surface. Because the rock mass can be cut by the structural plane, there is no relative displacement on both sides of the fracture surface, and the developed cracks to form collapse. In addition, the villagers did not remove the broken and dangerous rock during the excavation of the foot of the slope, and the manual excavation increased the instability of the rock and soil blocks of the slope, resulting in collapse.
2.2. Landslide

Landslide is generally manifested as the destruction of deep rock and soil mass. Landslide is caused by gravity, making the rock and soil mass slide slowly along the weak structural plane to the slope toe. The generation and development of landslides can be divided into three stages. The first stage is the creeping stage, which lasts a long time and is crucial for predicting and preventing landslides. The second stage is the sliding failure stage, which has high speed, high risk and severe damage. The third stage is the gradual stabilization stage. Large landslides have the characteristics of large scale, complex mechanism and substantial hazard.

The development of landslide is mainly affected by topography and geomorphology [8]. The landslide occurrence is also related to the lithologic conditions of slope and rock and soil structure such as joints and cracks. Moreover, the landslide is related to the slope of the terrain. The stronger the terrain cutting is, the greater the height difference is and the greater the possibility of the landslide is [9]. Besides, human activities such as road repair, mining and canal excavation can also cause landslides.

The landslide hazards in Shandong Province are mainly distributed in the central, southern and eastern parts of Shandong Province. There are mountain hills and austere basins in the eastern part of Shandong Province. The terrain is high and low, the valleys and rivers are staggered, the geological structure is developed, and landslide geological disasters are prone to occur.

The typical landslide geological hazard in Shandong Province takes Shangjian Village, Rizhao City (Figure 2) as an example. The hidden danger point is located in the east of Shangjian Village, which belongs to high earthquake intensity and has a cliff topography. There are ginger pits excavated by villagers on the upper part of the landslide. Rainwater in the rainy season penetrates into the loose layer, and the adhesion friction decreases after encountering water, resulting in the slope sliding along the distribution of this layer. The landslide is a medium-sized sliding landslide, and there is still the possibility of disasters. The overall movement may occur due to factors such as heavy rainfall.
2.3. Debris flow
Debris flow is a kind of short-term rapid water flow that often occurs in mountainous areas with many sediment and stones, a geological disaster caused by gravity. The formation conditions of debris flow must include several conditions such as abundant solid sources, high runoff intensity, and high terrain vertical drop ratio. It has the characteristics of a sudden outbreak, significant harm and a wide range of influence.

The hidden danger points of debris flow in Shandong Province are mainly distributed in the piedmont areas of central, southern and eastern Shandong. These areas have complex terrain, numerous joints and fissures, and large ground fluctuations, then debris flow is prone to occur with considerable precipitation. Debris flow will cause tremendous losses. It will destroy the subgrade, and the solid carried will impact and damage the bridges and culverts downstream of the river. The downstream clogging will increase the water level, resulting in the flooding of bridges and roads.

The typical debris flow geological disaster in Shandong Province takes Shiwuzi Village, Jinan City (Figure. 3) as an example. This area is located in the middle-low mountain area cut by the erosion structure, with sizeable relative elevation differences, large ground undulations, and intricate structures. The structure type is mainly fault, followed by fold. Due to the indiscriminate mining of iron ore in this area, the surface rock and soil are loose, the ecological environment is damaged, and forests are scarce. When the rainfall is heavy, the loose rock and soil on the surface will slide down, affecting Shiwuzi Village residents’ lives.

![Figure 3. Shiwuzi Village, Dawangzhuang Town, Laiwu District, Jinan City](image)

2.4. Ground subsidence
There are ground subsidence disasters in Shandong Province. According to the engineering geological and hydrogeological conditions, natural and human activities, ground subsidence can be divided into mining subsidence, karst subsidence and Quaternary subsidence. The distribution characteristics of each collapse type are as follows:

Mining subsidence: Mining subsidence is one of the most serious geological and natural disasters, which may cause many economic and environmental problems [10]. The occurrence of mining subsidence is mainly related to coal, gypsum and other solid mineral exploitation. The hidden danger points are mainly distributed in Linyi City, Yantai City, Jinan City, Zibo City, Zaozhuang City and Weifang City.

Karst subsidence: The hidden danger points of karst subsidence in Shandong Province are mainly distributed in the karst development areas under the jurisdiction of Taian City, Zaozhuang City, Linyi City, Rizhao City and Jinan City, Yantai City, Jining City.

Quaternary subsidence: The occurrence of quaternary subsidence is related to the development of expansive soil on the surface. The hidden danger points are mainly distributed within the jurisdiction of Heze City.
The typical ground subsidence disaster in Shandong Province takes Jining coal mining area (Figure.4) as an example, the region is located in the Yellow River Plain and piedmont alluvial plain, the coal mine formation period is not long ago. Ground subsidence is due to the increase of mining volume year by year to form the goaf. The overlying layer's lithology in the goaf is mainly alluvial soil, sandstone, marl, etc., which are relatively loose. In addition, the coal seam mining will also affect the overlying soil layer's stability, causing it to sink and form the surface subsidence phenomenon.

![Figure 4. Coal mining subsidence in the coal mining area of Jining City](image)

3. Geological disaster prevention and control measures

In recent years, Shandong Province has achieved remarkable results by increasing financial investment and focusing on prevention and control of various geological disasters. Large losses caused by geological disasters have been avoided, and a lot of experience has been accumulated in prevention and control technology. The typical prevention and control situations of geological disasters are as follows:

3.1. Causes of collapse and its complications

The formation of collapse disasters includes two reasons: ①Internal causes, when joints are developed, weak structural planes are interspersed with massive or layered rocks and the slope is high and steep, it is easy to form collapse; ②External causes, the influence of natural environment and human activities, Natural rainfall effects such as rainwater infiltrating the rock mass and water scouring the toe of the slope, as well as human activities such as manual excavation of the slope and blasting, will increase the instability of the rock and soil blocks of the slope and cause collapse.

For example, Anzigou Village, Rizhao City, this area is located in a low mountain and hilly area. The formation of avalanches is due to long-term weathering and denudation of mountain rocks, which form thin-layer residual slope deposits on the surface. Because the structural surface can cut the rock mass, there is no relative displacement on both sides of the fracture surface of these blocks, and the cracks are well developed, so it is easy to form collapse. Secondly, the villagers excavated the slope toe and built houses without breaking the rock and dangerous rock mass. For clearing, manual excavation increased the instability of the rock and soil blocks on the slope, leading to collapse. The main collapse prevention measures adopted in the project area are: slope broken rock cleaning, slope cutting and unloading, platform arrangement, mortar arch-type skeleton slope protection, construction of retaining walls, and drainage ditch.

Combining the above cases, to collapse disasters, the damage degree should be analyzed based on the collapsed body's specific characteristics and the actual local engineering geology and hydrogeological conditions, and corresponding measures should be taken to carry out the comprehensive treatment. In general, the collapse prevention measures are as follows:

1. Stabilization measures: Considering the specific conditions of the site, the scale of the collapsed body, and the cost-effectiveness of treatment, first consider the treatment through removal, support, and reinforcement, and strive to eliminate the hidden dangers of collapse from the source. For the dangerous rock mass, consider whether it can be removed. If it is not suitable or difficult to remove,
consider enhancing the rock and soil integrity through measures such as grouting reinforcement, anchoring and spraying slope protection, and lattice protection, strengthening the slope and rock mass. Measures such as supporting the roof and supporting (supporting piers and supporting columns) can be adopted, taking into account the protection of the ecological environment.

2. For relatively stable rockfills, measures such as concrete retaining walls, dry-laid rubble, mortar rubble or other measures are usually taken.

3. Set up sheltering buildings: set up a sufficient thickness, its length should be set according to the actual situation of the collapse, and its length should cover all unsafe areas. If this measure does not work in the actual project, frame shed holes can be used; if the foundation cannot be set outside due to special engineering conditions, reinforced concrete cantilever shed holes can be used; open tunnels can also be used if actual conditions permit.

4. Set up interception buildings: usually set in the lower part of the collapse path, with sufficient strength to resist the impact energy of the collapse, and used to protect the small and medium-sized collapses affected by the collapse range. Rock-block walls, rock troughs, rock-fall platforms, and rock-block nets are often used.

3.2. Causes and prevention of landslides

The formation of landslide disasters includes two reasons: ① internal factors, when the structure is loose, the shear strength and weathering resistance are low, the weak structure surface is interspersed with rock and soil, and the slope is high and steep, it is easy to form a landslide. ② external factors, natural environment and The impact of human activities, the natural effects of rainfall causing rainwater to infiltrate the rock and soil, river erosion, and human activities such as artificial excavation of slopes, blasting, and mining, will reduce the strength of rock and soil and cause landslides.

For example, in Shangjian Village, the hidden danger point of landslides is located in the east of Shangjian Village, in an area with high seismic intensity and cliffs. There is a ginger cellar dug by the villagers on the upper part of the landslide body. The rainwater in the rainy season penetrates the loose layer. After encountering water, the adhesive friction is reduced, causing the slope's distribution to slide along this layer. The landslide is a medium-sized sliding landslide, and there is still the possibility of disasters. The overall movement may occur due to factors such as heavy rainfall. The main landslide prevention and control measures adopted in the project area are: cutting slopes to reduce the burden, building retaining walls, and leveling greening in combination with the external and internal conditions that caused the landslide.

Combined with the above cases, in response to landslide disasters, the landslide body should be analyzed and treated according to the specific development characteristics of the landslide body and the actual local engineering geology and hydrogeological conditions. In general, landslide prevention measures are as follows:

1. Water interception and drainage: When the landslide is greatly affected by rainfall, it is necessary to set an interception ditch on the stable stratum at the back; divert and drain spring water to reduce the impact of spring water exposure on the landslide. According to specific conditions, different measures can be taken to intercept and drain the shallow groundwater that affects the landslide body, such as grouting enclosure, seepage tunnel, shallow buried seepage ditches, deep buried seepage ditches, etc.; remediate the land outside the landslide area and remove the paddy field Transform into dry land, plant trees and grass to improve the local natural environment.

2. Slope cutting and backfilling: When the main sliding section of the landslide body is thick, the slope should be cut to reduce the load on this section based on the landslide's stability and the mountain. If conditions permit, a back pressure protection track can be set at the landslide's front edge. When conditions do not permit, the backpressure protection road can be used together with the retaining project. For safety protection engineering and emergency engineering, measures such as backpressure protection or landfill can be adopted.

3. Support: For small-scale shallow landslides, when the ground is relatively stable, a gravity-type anti-skid retaining wall with sufficient strength and stability can be set. The construction requirements
should be consistent with relevant regulations. For large-scale medium-thick layers or deep-embedded landslides, one or more rows of anti-slide piles should be set up according to the landslide body's actual sliding characteristics. When necessary, a slope protection project or a supporting project should be installed between the anti-slide piles to prevent the soil from collapsing. When the landslide thrust direction is clear, the selected anti-slide pile should be selected according to the landslide body's thrust direction; when the anti-slide pile cross-section is rectangular, it should be used when the thrust direction is clear, and when the cross-section is circular, it should be used for thrust. When the direction is not clear. When the supporting structure is combined with a prestressed anchor rod or a non-prestressed anchor cable, it can be used in the case of relatively large landslide thrust.

3.3. Causes of debris flow and its prevention

The debris flow formation conditions must include abundant solid sources, enough runoff intensity, and high terrain vertical drop ratio. Debris flow occurs in steep terrain, which is a kind of rapid water flow with high potential energy, straightness and pulsation. It carries much solid matter and is extremely destructive. When rainfall is heavy, it will produce extreme surface runoff. Under the action of rushing downstream, the impact force is large.

For example, Shiwuzi Village, Jinan, this area is located in the middle-low mountain area cut by the erosion structure, with sizeable relative elevation differences and large ground undulations; the structure is complex, and the structure type is mainly faults, followed by folds. The area's surface is to loose rock and soil, ecologically damaged, and forests are scarce. The indiscriminate mining of iron ore causes this. When the rainfall is heavy, the loose rock and soil on the surface will slide down, affecting Shangshiwiuzi Village residents' lives.

The primary debris flow prevention measures adopted in the project area are gullies cleaning, bank repairs, rock dam masonry, slope protection walls, and vegetation greening.

The degree of damage should be analyzed to debris flow disasters according to the development of debris flow ditches and the actual local engineering geological and hydrogeological conditions, and corresponding measures should be taken for comprehensive management. In general, the prevention and control measures for the three sections of debris flow are as follows:

Debris flow formation areas are generally surrounded by mountains in three directions, with steep slopes and large confluence areas. Plant trees in broad areas, build terraces on slopes, and comprehensively manage slope farmland. To prevent heavy rain from flowing along the slope of the debris, which flow to the main ditch, water diversion, water storage, drainage and other measures can be adopted, and if necessary, reinforcement works are also built to control the amount of solid source of the debris flow.

The debris flow circulation area's valley slope is steep, with a large vertical drop ratio, and is usually located in the middle reaches. In this area, the water and sediment carried by the debris flow should be reduced, and the flow speed should be reduced. Therefore, measures must be taken to change the flow direction of the debris flow, to dredge, and to strengthen the channel. A large number of solid objects such as crushed rocks are easy to deposit on certain parts of the bottom of the ditch, which can be intercepted by setting up ballast dams. To prevent debris flows from affecting the stability of bridges and subgrades, culverts and drains can also be set. If the debris flow does not occur frequently, measures can be taken to intercept relatively large stones and other solid objects to prevent large impact damage to the downstream and can be intercepted by installing wooden piles and stone piles in the middle and downstream channels.

The debris flow accumulation area is large, usually located downstream. Comprehensive management should be based on "prevention first, avoiding weak coercion," and focusing on resisting and eliminating debris flow hazards. The construction area's construction should be designed according to the morphological characteristics of the debris flow and the local engineering characteristics. It mainly includes two major types of engineering: ① Silt engineering, which is to set up silt sites in different directions according to the terrain to store silt And ballast; ② Diversion
projects, this type of project mainly includes drainage channels and aqueducts, which are used to control the flow path of the debris flow to guide the debris flow to the downstream area smoothly.

3.4. Causes and prevention of ground subsidence

According to the engineering geology, hydrogeological conditions, natural and human activities that caused the ground collapse, the ground collapse can be divided into two types: karst collapse and non-karst collapse. There are two reasons for karst collapse: one is the natural effect, rainfall, drought and ground motion will cause ground deformation. The second is human factors. Human activities, especially the excessive extraction of underground liquids, are prone to cause ground collapse.

The formation of non-karst collapses, such as mined-out collapse, is due to the large underground mined-out area caused by human mining activities, making the upper rock and soil layer instability collapse and form collapse the surface.

For example, the coal mining area of Jining City, which is located in the floodplain and piedmont alluvial plain. The formation of ground collapse is due to the increase in mining volume year by year to form goaves. In addition, the overlying layers of the mined-out area are mainly alluvial soil, sandstone, marl, etc., which are relatively loose. When the coal seam is mined, it will affect the overlying soil's stability, causing it to sink and cause surface subsidence.

The paramount ground collapse prevention and control measures adopted in the project area are shallow leveling method, deep excavation and shallow cushion method, waste discharge filling method and farming method.

Combined with the above cases, in response to ground collapse, the hazard degree should be analyzed according to different local collapse degrees and actual engineering geological and hydrogeological conditions, and corresponding measures should be taken to carry out the comprehensive treatment. In general, the ground collapse prevention measures are as follows:

1. Engineering measures for karst collapse control: when the ground collapse is caused by excessive exploitation of groundwater, which reduces the groundwater level and causes immense stress on soil skeleton, it can be treated by dredging and guiding groundwater. When the rock layer at the top of the cave is thin, the soil layer can be collapsed by blasting and then filled. To prevent the collapse of the ground caused by the punching effect of external atmospheric pressure on the topsoil layer, the internal and external pressure can be balanced by drilling. When the influence range of ground collapse is small, soil or other materials should be backfilled and rammed to improve the compactness to reinforce the ground. If necessary, cement mortar should be injected into a certain depth below the ground to improve the bearing capacity.

2. Engineering measures for mining subsidence control: when the depth of goaf is small, soil and rock can be backfilled repeatedly according to the regulations. After each backfill, cement mortar is poured after mechanical compaction, which can improve the foundation stiffness. When the mined-out area's depth is considerable, filling grouting method, overburden structure reinforcement method and cast-in-place pile method are used to seal the two ends of the mined-out area and reinforce the stratum to avoid the occurrence of surface subsidence. When the mined-out area's depth is considerable and the distribution area is too large, viaduct crossing measures can be taken or combined with other methods to deal with.

4. Conclusion

This article comprehensively summarizes the types, distribution characteristics and causes of geological disasters in Shandong Province, expounds on the prevention and control of different geological disasters, and puts forward research suggestions for geological disaster management.

Geological disasters in Shandong Province are mainly collapsing, landslides, debris flows and ground subsidences. The collapses are mainly distributed in the mountainous areas of southern central Shandong and the Jiaodong Peninsula. Landslides are mainly distributed in the central, southern and eastern areas of Shandong; Debris flows are mainly distributed in the piedmont areas of central, southern and eastern Shandong; Ground subsidences are mainly distributed in Linyi City, Yantai City,
Jinan City, Zibo City, Zaozhuang City, and Weifang City. Karst subsidences are mainly distributed in karst Development areas within Taian City, Zaozhuang City, Linyi City, Rizhao City, Jinan City, Yantai City and Jining City. The development law of geological disasters is closely related to topography, lithology, and geological structure, engineering geological characteristics, hydrogeological characteristics and human engineering activities in the study area.

According to the characteristics of geological disasters and environmental geological conditions, in the study area of Shandong Province and the shortcomings of existing research results. Future research should focus on the transformation from eliminating hidden dangers to ecological governance, research on geological disaster prevention and control projects based on ecological, environmental protection, and form an ecological governance technology that integrates governance projects with nature and human settlements.

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