

# Thinking on Effective Methods of Successful Prediction of Geological Hazards in Shaanxi, China

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## Abstract

In the process of human survival and development, it is inevitable to transform the original state of the world, thus forming a contradiction between the earth and the earth. The violent form of this contradiction is geological disasters. Geological disasters pose a threat to human life and property, and cause damage caused by natural or human factors, often causing casualties. The destruction process of geological disasters is usually a gradual process, showing many pre-disaster symptoms, such as local landslides, surface cracks, building deformation, tree skew, and ground sound. Evacuation can be avoided in advance according to the disaster precursors, so as to avoid casualties and achieve successful prediction. By reviewing the general situation of geological disasters in Shaanxi Province and the casualties in 2020, the difficulties in the prevention and control of geological disasters are summarized. In view of these difficulties, an on-site investigation, visit and analysis of geological disaster points and successful forecast points in Shaanxi Province in 2020 were conducted. In addition, combined with actual cases and years of work experience, the successful prediction experience of geological disasters was discussed from 8 aspects. Finally, the "Regulations on the Reward for Successful Geological Disaster Forecasting in Shaanxi Province" was revised in order to improve the successful prediction ability of geological disasters in Shaanxi Province and even the whole country, provide reference for future prevention and control of geological disasters, and effectively protect the safety of people's lives and property.

## Keywords

Geological Hazards, Successful Forecast, Shaanxi Province, China

## 1. Introduction

As the main body, human beings are characterized by initiative and creativity; As an object, the world is the objective thing corresponding to the subject, the external world, and all the objects that the subject knows and transforms. While transforming the world object, the human subject is also constantly restricted and restricted by the object, thus affecting the development of the subject. This impact is manifested in the contradiction between human and land in terms of geological environment. The most severe manifestation is the casualty geological disaster [1] [2], and the number of casualties is as small as one person. For example, on January 12, 2019, a landslide disaster occurred in Pinganzhai, Longji Terrace Scenic Area, Guangxi Autonomous Region, China, resulting in one person's death [3]. More than one thousand people, for example, at about 22:00 on August 7, 2010, the town of Zhouqu County, Gannan Tibetan Autonomous Prefecture, Gansu Province, China was attacked by a geological disaster of debris flow, resulting in 1557 deaths and 284 missing [4]. According to the definition of geological hazards in the Regulations on the Prevention and Control of Geological Hazards issued by the State Council of China in 2003, geological hazards are disasters related to geological processes, such as mountain collapse, landslide, debris flow, ground collapse, ground fissure, ground subsidence, etc., which are caused by natural factors or human activities and endanger the safety of people's lives and property [5], and also clearly highlight the important role of human subjects in the hazards of geological hazards.

Geological disasters are very harmful, but there are often many imminent disasters before their occurrence, such as local landslides, surface cracks, building deformation, tree skew, and ground sound, which can be avoided in advance according to the sign information. After finding the precursor of impending disaster, transfer the threatened personnel in time, and achieve remarkable results in disaster prevention and mitigation. The number of casualties avoided by the successful prediction of geological disasters is far greater than the number of casualties caused by disasters. For example, in 2019, there were 6181 geological disasters such as landslides, collapses and mud-rock flows, resulting in 224 deaths (missing) and 75 injuries, with a direct economic loss of 2.77 billion yuan; 939 geological disasters were successfully predicted, and 24,753 people successfully avoided risks, avoiding direct economic losses of 830 million yuan [6]. In 2020, a total of 7840 geological disasters occurred in the country, resulting in 139 deaths (missing) and 58 injuries, and a direct economic loss of 5.02 billion yuan; 534 geological disasters were successfully predicted, 18,239 people successfully avoided risks and avoided direct economic losses of 1.02 billion yuan [7].

From the human-centered perspective, a geological disaster also occurred. If the personnel can evacuate in advance and avoid casualties, it is a successful prediction; If people are not evacuated and cause casualties, disaster will occur. Following the principle of "people first, life first", based on the casualty geological disaster data and successful prediction data of Shaanxi Province in 2020, this paper discussed the current situation of geological disasters in Shaanxi Province,

the difficulties of prevention and control work, and the current situation of successful prediction from the actual cases. In addition, the successful prediction experience was discussed from eight aspects, in order to improve the successful prediction level of geological disasters in Shaanxi Province, try our best to reduce the casualties caused by geological disasters, and effectively protect people's lives. In terms of geological safety, it contributed to the people's living and working in peace and contentment, and also hoped to provide reference for the prevention and control of geological disasters in other regions. We also hope to provide reference for geological disaster prevention and control in other regions.

## **2. Current Situation of Geological Disasters in Shaanxi Province**

### **2.1. Overview of Geological Disasters in Shaanxi Province**

Shaanxi Province is located in the hinterland of China, with high terrain in the north and south and low terrain in the middle. The Beishan Mountains and Qinling Mountains divide Shaanxi into three major geomorphic units: the loess plateau in northern Shaanxi, the Guanzhong fault basin, and the Qinba Mountains in southern Shaanxi. The geological environment conditions are complex, coupled with the superimposed effects of extreme weather and human engineering activities [8], geological disasters are sudden, frequent, and frequent. The total area of Shaanxi Province is 205,600 km<sup>2</sup>, and the area of geological disaster area is 189,300 km<sup>2</sup>, accounting for 92.07% of the total area of the province. The area of high-risk areas is 37,000 km<sup>2</sup>, accounting for 18.00% of the total area. The medium-prone area covers an area of 71,400 km<sup>2</sup>, accounting for 34.72% of the total area. The area of low-risk area is 80,900 km<sup>2</sup>, accounting for 39.35% of the total area [9].

The province has a large number of geological hazards hidden dangers and a wide distribution. According to the 2019 dynamic update data of geological hazards group survey and prevention in Shaanxi Province, there are 9870 geological hazards hidden danger points in Shaanxi Province, with 340,281 people in 65,996 households and 20.2681829 billion yuan of property threatened. The three cities in southern Shaanxi have the most potential geological hazards, including 2571 in Ankang, 1694 in Hanzhong and 1423 in Shangluo. Moreover, there are 1390 in Yulin and 680 in Yan'an in northern Shaanxi. Besides, there are at most 729 in Baoji, 507 in Weinan, 370 in Xi'an, 201 in Xianyang, 178 in Tongchuan, 98 in Hancheng and 29 in Xixian New Area in Guanzhong. According to the type, the hidden danger points of geological disasters can be divided into 6863 landslides, 2306 collapses, 408 debris flows, 231 ground collapses, 6 land subsidences and 56 ground cracks. According to the scale, it is divided into 116 giant, 505 large, 2456 medium and 6793 small. According to the risk level, it is divided into 46 large, 61 large, 748 medium and 9015 small.

### **2.2. Geological Disasters in 2020**

In 2020, there were 161 geological disasters in Shaanxi Province, including 72

landslides, 71 collapses, 10 mudslides, and 8 ground collapses. These disasters caused 7 deaths and 1 injury, the direct economic loss was 46.6843 million yuan, and the death rate was 4.35 persons per 100 deaths.

The number of disasters in 2020 increased by 18.21% compared with the average annual value of 136.2 in the “13th Five-Year Plan” in Shaanxi Province, and decreased by 44.86% compared with the average annual value of 292 in the “12th Five-Year Plan”. The number of dead and missing persons decreased by 47.76% compared with the average annual value of 13.4 persons in the “13th Five-Year Plan” and 84.09% compared with the average annual value of 44 persons in the “12th Five-Year Plan”. The death and disappearance rate per 100 deaths decreased by 55.79% compared with 9.84 persons per 100 deaths during the “13th Five-Year Plan” period and 71.13% compared with 15.07 persons per 100 deaths during the “12th Five-Year Plan” period.

In 2020, there were 4 disasters causing casualties, including 1 in Yulin City and 3 in Ankang City. A total of 7 people were killed and 1 injured, as shown in **Table 1**.

### 3. Status of Successful Forecast in Shaanxi Province in 2020

In 2020, the death and disappearance rate of every 100 geological disasters in Shaanxi Province reached the lowest level in the past years, which is inseparable from the successful prediction of geological disasters in Shaanxi Province for many years. Article 19 of the Regulations on the Prevention and Control of Geological Disasters in Shaanxi Province clearly stipulates that “units or individuals are encouraged to provide precursor information of geological disasters

**Table 1.** List of casualty geological hazards in Shaanxi province in 2020.

Disaster name	City and county	Death toll	Number of injured	Hidden danger or not	Date of occurrence	happen time	Disaster bearing body and disaster Location relationship
Caojiagou Village, Zhuanmiao Town collapsed	Zizhou County, Yulin City	2 persons	0 person	no	May 17th	05:30	Households are located below the collapse
Landslide in Group 5, Liangshui Village, Gouyi Town	Baihe County, Ankang City	1 person	0 person	no	July 22nd	00:10	Residents are located under the landslide
Landslide on the west side of Li Huifu’s house, Group 13, Xinhua Community, Shuanglong Town	Hanbin District, Ankang City	2 persons	1 person	no	July 22nd	08:50	Households are located on the landslide mass
Landslide in Group 6, Xiangrong Village, Chengguan Town	Baihe County, Ankang City	2 persons	0 person	no	August 8th	03:17	Residents are located under the landslide

to the local people's government and relevant departments. Units or individuals who successfully forecast geological disasters and avoid or reduce casualties and property losses by providing precursor information in a timely manner shall be rewarded" [10].

In 2020, Shaanxi Province successfully predicted 16 geological disasters and avoided 131 casualties, as shown in **Table 2**. According to whether there are registered hidden dangers, there are 8 registered hidden dangers and 8 non-registered hidden dangers; According to the occurrence time, there are 14 flood seasons and 2 non-flood seasons; According to disaster types, there are 4 collapses and 12 landslides. According to the disaster level, there are 1 large, 3 medium and 12 small.

Among them, the three disasters that avoided the largest number of casualties were the landslide in Group 3, Tongmu Community, Tongmu Town, Xunyang County, Ankang City, the landslide in Group 4, Zhujixi Village, Chengguan Town, Zhenping County, Ankang City, and the collapse in Xujiahe Village, Miaojiaping, Zizhou County, Yulin City, which respectively avoided 39, 23 and 14 casualties, accounting for 58.02% of the total number of casualties avoided.

#### **4. How to Make a Successful Prediction**

By comparing the situation of casualty geological disasters and successful prediction in Shaanxi Province in 2020, it is found that unfavorable factors such as heavy rainfall and freeze-thaw frequently occur in successful prediction points of geological disasters. For example, a group of landslides in Huaishu Village, Dazhuyuan Town, Hanbin District, Ankang City, and thirteen groups of Li Huifu Houses in Xinhua Community, Shuanglong Town, Hanbin District, and five groups of landslides in Liangshui Village, Goupa Town, Baihe County, Ankang City, suffered heavy rainfall on the same day on July 22. The collapse of Xujiahe Village, Miaojiaping Town, Zizhou County, Yulin City and the collapse of Caojiagou Village, Zhuanmiao Town, Zizhou County, belong to the same area and the same stratum, both of which are loess cave collapse caused by freezing and thawing factors in northern Shaanxi. There were two successful prediction points of landslides in Lueyang County, Hanzhong City at night. How they overcome difficulties to achieve successful prediction, and what experiences are worthy of reference and promotion in the successful prediction, which has very important discussion value for the successful prediction of geological disasters in Shaanxi Province and even the whole country in the future.

Through a large number of field investigations and visits to these points, combined with actual cases and years of work experience, the author believes that Shaanxi Province experienced severe weather, and 16 successful forecasts correctly dealt with all common adverse factors in 2020, so the geological disasters reached the lowest rate of death and disappearance per hundred over the years. The eight representative experiences formed have strong guiding value for the prevention and control of geological disasters in the future.

**Table 2.** List of successful prediction of geological hazards in Shaanxi province in 2020.

Disaster name	city and county	Hidden danger or not	Avoid casualties	Forecast date	Evacuation time	Date of occurrence	Time of occurrence	Disposal measures
Xiaobailou landslide of Wangjiahe Street Building Materials Factory	Wangyi District, Tongchuan City	no	6 persons	July 7th	14:00	July 10th	16:00	Warning signs, warning lines, evacuation organization, and relocation plan in the later stage  Organize personnel to evacuate, evacuate part of property, cut slope, intercept and treat drainage
Landslide in Hongliugou Village, Zhouhe Town	Jingbian County, Yulin City	yes	12 persons	April 2nd	09:08	April 5th	11:30	Organize personnel to evacuate, evacuate part of property, cut slope, intercept and treat drainage
Collapse in Xujiage Village, Miaojiaping Town	Zizhou County, Yulin City	no	14 persons	February 7th	10:30	February 7th	17:40	Organize personnel evacuation  Organize personnel to evacuate, cut slopes for simple treatment, and block dangerous caves
Laoshe Ancient Convenience Service Center Changjiawa Village collapsed	Qingjian County, Yulin City	no	5 persons	August 5th	16:00	August 6th	13:51	Organize personnel to evacuate and evacuate some properties
Collapse of Wangping Village, Yanxia Town	Liquan County, Xianyang City	yes	2 persons	July 24th	14:20	July 24th	18:12	Warning lines, blocking roads, evacuating drivers and passengers, and clearing up deposits  Organize personnel to evacuate, evacuate some properties, warning signs, warning lines, and assign special personnel to monitor
Collapse of Luopangou Section of Tongluo Highway in Anle Town	Tongguan County, Weinan City	no	4 persons	August 17th	16:54	August 17th	18:58	Organize personnel to evacuate, evacuate some properties, warning signs, warning lines, and assign special personnel to monitor
Landslide in Group 4, Zhujiexi Village, Chengguan Town	Zhenping County, Ankang City	yes	23 persons	July 18th	17:10	July 20th	06:10	Warning signs, warning lines, and assign special personnel to monitor

## Continued

Landslide in Group I, Huaishu Village, Dazhuyuan Town	Hanbin District, Ankang City	no	5 persons	July 22nd	9:00	July 22nd	16:00	Organize personnel evacuation, warning line, specially-assigned person monitoring, retaining wall unloading treatment
Landslide in Group 3, Tongmu Community, Tongmu Town	Xunyang County, Ankang City	yes	39 persons	August 7th	20:40	August 7th	21:20	Organize personnel evacuation, warning signs, warning lines, joint traffic blockade, and special personnel to monitor
Landslide in Group 7, Luotuoxiang Village, Huangjiaying Town	Yangxian County, Hanzhong City	no	3 persons	August 18th	10:23	August 19th	10:23	Organize personnel evacuation, warning signs, warning lines, plastic cloth for simple drainage, and special personnel for monitoring
Landslide in Group 8, Lianhuan Village, Chadian Town	Mian County, Hanzhong City	no	2 persons	August 16th	16:30	August 16th	23:00	Organize personnel to evacuate, evacuate some properties, cordon, and assign special personnel to monitor
Landslide of Dujiazhuang Formation, Zouma Village, Jinjiahe Town	Lueyang County, Hanzhong City	yes	2 persons	August 10th	16:00	August 16th	00:30	Organize personnel to evacuate, evacuate part of property and cordon
Landslide in Guandi Mountain Village, Xingzhou Street Office	Lueyang County, Hanzhong City	yes	4 persons	August 16th	11:00	August 17th	14:00	Joint traffic blockade of roads, warning signs, warning lines, and estimated loss of people from blocked vehicles

## Continued

Xingzhou Street Office New Town Neighborhood Committee Landslide	Lueyang County, Hanzhong City	yes	4 persons	July 25th	10:00	July 27th	05:00	Organize personnel to evacuate, evacuate some properties, warning lines, warning signs, remove the upper dangerous house, and plastic cloth is simple waterproof
Landslide of Jijiashan Formation, Baojiagou Village, Guanyinsi Town	Lueyang County, Hanzhong City	no	5 persons	August 15th	18:00	August 16th	01:00	Organize personnel evacuation and evacuate some properties
Xiangshanwan Neighborhood Committee Landslide of Xingzhou Street Office	Lueyang County, Hanzhong City	yes	1 person	August 5th	11:00	August 15th	09:00	Evacuate personnel

#### 4.1. Listed Hidden Danger Points Are Included in the Network System of Mass Measurement and Mass Prevention

The hidden danger points of geological hazards on the list are the results of geological hazards special survey, detailed investigation, daily inspection and mass report in our province over the years [11], which are the most easily found points. In Shaanxi Province, 100% of the potential geological hazard points found are included in the group monitoring and prevention network system, and warning signs are set up at significant locations of each potential hazard point. Warning signs explain to the masses the progress of disaster prevention work and protection, rescue, evacuation plans, equipped with professionals and grants, and explain to each threatened household how to avoid disasters [12]. The group survey and prevention personnel shall conduct daily observation on the hidden danger points on the list, and conduct intensive observation during special periods of time such as rainfall, and immediately give an early warning once the disaster precursor is found. For example, the landslide of the third group of Tongmu Community, Tongmu Town, Xunyang County, Ankang City was successfully predicted. At about 20:40 on August 7, 2020, there was a heavy rain in Tongmu Town. When the government officials and community officials of Tongmu Town inspected, they found that the tiles of the wall of the house of Yan Zhanqiang, a threatened household in the west of the three groups of two-and-a-half registered geological hazards hidden danger points in Tongmu Community, fell off. When they carefully checked, they found that the wall of several households was deformed, and found that the steps on the street floor moved forward (Figure 1). They immediately shouted and sounded a gong to





**Figure 1.** Images of three groups of landslides in Tongmu community before the occurrence.

warn, 119 people from 35 households were organized to move to a safe area. At the same time, warning lines and no traffic signs were set up at both ends of the two or three highways under the slope. At 21:20 on the same day, a large area of landslide occurred on the west side of the site. The surface rock mass of the original rock landslide on the east side collapsed, resulting in the collapse of three houses at the lower part of the slope, and the damage for four houses (**Figure 2**), with a direct economic loss of about 5 million yuan. The final result was to avoid 39 casualties due to timely evacuation.

#### **4.2 The “Three Inspections” Work Shall Timely Find the Precursor of the Disaster beyond the Hidden Danger**

In view of the counties prone to geological disasters, a comprehensive investigation before flood season, inspection in flood season and reexamination after flood season are carried out every year. It is also necessary to check before heavy rainfall, inspect in the rain and check after the rain according to the weather forecast information. In addition, the dangerous sections with poor geological environment conditions should also be inspected, checked and verified. The above work is called “three inspections” work [13]. The “three inspections” work is a supplementary work to the mass survey and mass defense network system. Once the precursor of disasters is found during the patrol inspection, emergency measures for evacuation can be taken to avoid casualties. The successful prediction of geological disasters in Shaanxi Province in 2020 was mostly found in the “three inspections”. For example, the landslide of Jijiashan Formation, Baojiagou Village, Guanyinsi Town, Lueyang County. At about 10:00 on August 15, 2020, the geological disaster investigation of Lianghekou land location in Lueyang County, Hanzhong City found that the slope of Jijiagou Village had deformation, displacement, and signs of sliding. Immediately notify the households at the foot of the slope to evacuate five people in one household, and help evacuate some properties. Meanwhile, report the situation to the duty room of the County Natural Resources Bureau and the People’s Government of Guanyinsi Town.



**Figure 2.** Images of three groups of landslides in Tongmu community.

After receiving the report, the People's Government of Guanyinsi Town set up warning lines and warning signs around the dangerous area. At 01:00 on August 16, a landslide occurred on the slope, with a volume of about 3500 m<sup>3</sup>. The soil poured into the houses under the slope, causing damage to doors, windows and properties. Due to the timely evacuation, 5 casualties were avoided in this landslide.

#### **4.3. Timely Organize Personnel Evacuation and Properly Arrange**

How to properly arrange the evacuated personnel is also an important part in the successful prediction of geological disasters. Through mass survey, mass prevention and “three inspections”, we can find the precursors of disasters by every means, and organize personnel to evacuate. However, it is undeniable that there are still some people who suffer from geological disasters due to their weak awareness of disaster prevention or reluctant to give up their home property, which eventually leads to the successful prediction of casualties. Therefore, in order to make a successful prediction, we should not only organize personnel to evacuate in time, but also properly arrange them psychologically and materially to solve the worries of the masses. For example, Wangjiahe Street Office in Wangyi District successfully predicted the landslide of Xiaobailou, a building material factory. On July 7, 2020, Wangjiahe Street Office found that the slope of the residential gate building on the back slope of the building material factory in Shishugou Community was vertical and empty, and the soil structure showed signs of further deformation and sliding (**Figure 3**). It quickly reported the inspection to the Wangyi Branch of Natural Resources, and informed the two households of Guo Xiu'e and Liu Nongchang at the slope top to evacuate and set up a warning line. Under the influence of the subsequent heavy rainfall, a landslide occurred in some parts of the slope at about 16:00 on July 10, resulting in the collapse of the building, a resident at the top of the slope (**Figure 4**). Because of the timely evacuation, the life safety of six people was guaranteed. Wangyi District plans to include two households in the resettlement and relocation project in the later stage, properly resettle the people and completely bid farewell to geological disasters.



**Figure 3.** Image before the landslide behind the white building in the building materials factory.



**Figure 4.** Image of the landslide behind the white building in the building materials factory.

#### **4.4. Strong Support of Professional Technical Team**

Due to the limited available space, people in mountainous areas usually need to excavate mountains to form artificial slopes when building houses. Some people can also realize that they need to deal with slopes to eliminate hidden dangers. Because they do not have the ability of slope design, they find a professional design institute but the project is too small. Shaanxi Province took the lead in innovating the “peacetime and wartime combination” geological disaster prevention and control technology support system. According to the characteristics of large number of geological disaster prevention and control technical units, high level of talents and advanced equipment in the province, the relevant prevention

and control personnel and equipment were stationed in cities and counties in the form of contracts. The above practices not only solved the problem of less personnel and weak technology in grass-roots departments, but also enriched the technical services of geological disaster prevention and control to all corners of the province. In addition, providing daily technical services for the masses was of great help to the successful prediction of geological disasters [14]. For example, the landslide in Group I of Huaishu Village, Dazhuyuan Town, Hanbin District was successfully predicted. In July 2020, there was continuous heavy rainfall in Hanbin District. At 9:00 a.m. on July 22 of the same year, the staff of Dazhuyuan Land and Resources Office found that the slope behind the house of Li Zhong'an, a group of villagers in Huaishu Village, Dazhuyuan Town, showed signs of sliding and may collapse at any time. The danger was immediately reported to the main leaders of Dazhuyuan Town Government. The main leaders of the town government asked the staff of the Land and Resources Bureau to closely monitor and prevent the work, and set up warning signs and set up warning lines at the same time. At 14:00 pm on July 22 of the same year, the observation danger of staff of the National Land Institute was further aggravated. Therefore, an emergency evacuation notice was immediately issued to the threatened households, and the village cadres evacuated all five people from the threatened Li Zhong'an household to a safe area for resettlement. At about 16:00 pm on the 22nd, the slope behind Li Zhong'an's house collapsed, damaging the slope retaining wall and house originally built by himself behind Li Zhong'an's house, causing damage to the walls of three houses and small indoor appliances (Figure 5). Due to the timely evacuation, five casualties in one household were avoided. The professional team of "peacetime and wartime combination" in Hanbin District not only participated in daily inspections, but also proposed a combination of slope cutting, retaining wall and interception and drainage for Li Zhong'an's house according to the actual geological conditions after the disaster, which provided technical support for eliminating the geological disaster (Figure 6).



**Figure 5.** Image of Group I Landslide in Huaishu village before treatment.



**Figure 6.** Image of a group of landslides in Huaishu village after treatment.

#### 4.5. Do a Good Job in Mass Publicity and Training

The masses are an important force in the successful prediction of geological disasters. They may be the most direct threat of geological disasters, but also the most likely first to find the precursors of geological disasters [15]. Therefore, in order to make a successful forecast, it is necessary to do a good job in publicizing the knowledge of geological disaster prevention and control. The use of folding, posters, slogans, public service ads, training, drills and other ways to improve the masses of disaster prevention awareness, so that they understand the geological disasters, and master the ability to timely warning and correct evacuation [16]. For example, the collapse of Xujiahe Village, Miaojiaping, Zizhou County was successfully predicted. On February 5, 2020, when Aishaojin went up the mountain to work, he first found that there was a crack in the mountain behind his brother Aishaoqi Kiln, and then informed Aishaoqi, and paid close attention to the change of the crack. On the morning of the 7th, he found that the crack expansion increased. At about 9:00, he reported to the village cadres. After the field inspection, at about 10:00, the village cadres immediately reported to the town government. The town government cadres arrived at the scene at the first time, and after going up the mountain to check the change of the crack, he thought that the mountain was in a very unstable state. Immediately organize all residents to evacuate and implement intensive monitoring of village cadres and residents. At about 5:40 pm, the geological disaster of mountain collapse occurred. At that time, it was during the Lunar New Year, and Eshoch's family was reunited. Because of the timely evacuation, 14 casualties were avoided.

#### 4.6. Scientific and Technological Disaster Prevention and Mitigation

Some mountain areas prone to geological disasters not only have high mountains and steep slopes, but also have dense vegetation on the surface, which has strong concealment. It is difficult to find disaster precursors by manpower alone.

Some geological disasters that occur at night are even more difficult to prevent by manpower. In recent years, with the continuous development of science and technology, unmanned aerial vehicles, three-dimensional laser scanning, InSAR, and professional monitoring instruments were increasingly applied to the prediction of geological disasters [17], which greatly improved the ability of successful prediction of geological disasters. For example, the collapse of Tongluo Highway in Anle Town, Tongguan County was successfully predicted. On August 17, 2020, Tongguan County Natural Resources Bureau, together with the Weinan Branch of the Shaanxi Provincial Emergency Response Team for Geological Disasters, formed a geological hazards inspection team to carry out geological hazard inspection in Tongyu. At 16:54 on the same day, when patrolling the Luopangou section of Tongluo Highway, it was found that there were falling blocks and flying rocks on the highway slope. The inspection team used the drone to inspect the high and steep slope, and found that there was a large amount of loose accumulation of soil and rock on the upper part of the slope, which was considered to be about to collapse. Therefore, it immediately warned and dissuaded passing vehicles, and used drones to monitor the slope. At 18:58 that day, the slope collapsed with a volume of about 100 m<sup>3</sup>, burying the highway under the slope. At that time, the danger had not been lifted, and the rescue vehicles organized by the town government could not clear the road for the time being. The patrol team led the blocked people to abandon their cars and go down the hill along the path to get out of the danger safely. According to the estimation of traffic flow and buried length of this section, the collapse was due to proper measures to avoid 4 casualties.

#### **4.7. Successful Forecast in Special Period**

When a geological disaster occurs, it is often accompanied by other natural disasters. For example, when heavy rainfall causes geological disasters, it often also causes flood disasters, causing traffic and communication interruption, which increases the difficulty of finding and evacuating the precursors of disasters. In more extreme and special circumstances such as earthquakes and epidemics, it also increases the difficulty of successful prediction of geological disasters. For example, the landslide in Guandishan Village, Xingzhou Street Office, Lueyang County was successfully predicted. In addition to the COVID-19 in 2020, on August 10, the rainfall in Lueyang County, Hanzhong City, reached 215 mm in the urban area, and the largest flood peak since 1984 occurred in Lueyang section of Jialing River, reaching 5820 m<sup>3</sup>/s. Limited by the unique topographic conditions of Lueyang County [18], the flood caused widespread disaster in Lueyang County. The county seat was flooded in a large area, and most of the shops on the first floor were flooded, with an average depth of more than 1.5 m. On August 16, 2020, the Lueyang County Chengguan Natural Resources Office found that part of the slope of the landslide in Guandishan Village, Xingzhou Street Office, had slipped, and there was a great possibility of large-scale landslide.

The threatened villagers were immediately notified to evacuate, and the situation was reported to the duty room of the County Dihuan Station and the person in charge of the Xingzhou Street Office, who cooperated with the transportation department to block the road below the slope (Figure 7). At about 14:00 on August 17, a landslide occurred at the hidden danger point, with a volume of about 2500 m<sup>3</sup>. This landslide took timely measures to avoid 4 casualties and economic loss of 300,000 yuan.

#### 4.8. Multi-Department Coordination

Geological disasters can pose a threat to both people and property. The types of threat objects were diverse, often including villages, schools, reservoirs, traffic lines, scenic spots, cultural relics and so on. These threat objects involved various industries, including natural resources, emergency, education, water conservancy, transportation, tourism, cultural relics and other departments. Once the precursor of a disaster was found, it was necessary for multiple departments to work together to prevent and control geological disasters according to the division of responsibilities. In addition, it is necessary to evacuate and relocate the threatened personnel in time to realize the successful prediction of geological disasters. For example, the landslide in Group 4 of Zhujixi Village, Chengguan Town, Zhenping County was successfully predicted. At 17:10 on July 18, 2020, the government staff of Chengguan Town, Zhenping County found that 10 houses such as Xu Longbing, Xu Longguo and Liang Chui'an in Group 4 of Zhujixi Village were cracked and sunk, and the provincial road S225 was cracked (Figure 8), which posed a threat to the Baituling Reservoir at the foot of the slope. Then, the party committee of Zhenping County and the county government led emergency management, highway transportation, natural resources, agriculture, water, public security, traffic police and other departments to the scene to organize the evacuation of people in the upper and lower reaches of the reservoir and the transfer of production and living materials, as well as to block



Figure 7. Landslide road blocking in Guandi mountain village.



**Figure 8.** Traffic interruption due to landslide in Group 4, Zhujiexi village.

the traffic. At 6:10 on July 20, the landslide slipped, and the road surface of S225 Province sank about 1.6 m. Two houses of Xu Longbing and Xu Longguo collapsed, and the other eight houses were subject to different degrees of settlement and damage. After the pavement and houses were deformed and damaged, the traffic and power of S225 Provincial Highway were interrupted. As a result of organizing mass evacuation in advance, 23 casualties in 10 households were successfully avoided, and production and living materials worth about 1.5 million yuan were transferred in advance.

### **5. Regulations on Rewards for Successful Prediction of Geological Hazards in Shaanxi Province**

In 2021, in order to strengthen the prevention and control of geological disasters, the Shaanxi Provincial Department of Natural Resources revised the “Shaanxi Provincial Geological Disaster Successful Forecast Reward Regulations” to encourage and recognize units and individuals that have made outstanding contributions in the prediction of geological disasters. It is stipulated that no matter whether the unit or individual provides geological disaster precursor information, it can accept 1000 - 50,000 yuan reward according to the number of personnel avoiding casualties or property avoiding losses. For example, the prediction, forecast or pre-disaster monitoring of the time, place and scope of geological disasters will occur, so that the threatened personnel or property can be transferred in time, avoiding casualties or property losses. The purpose of this regulation is to fully mobilize and give full play to the enthusiasm and initiative of cadres and the masses in the prevention and control of geological disasters. In addition, it advocates that people can adopt all means of popularization, foresight, timeliness, generalization, specialization, linkage and technology under any circumstances to minimize the casualties and property losses caused by geological disasters.



## 6. Conclusions

In the process of survival and development of human society, it is inevitable to transform the original state of the world, thus forming a contradiction between the earth and the earth. The violent form of this contradiction is geological disasters. Geological disasters pose a threat to human life and property, causing damage caused by natural or human factors, and often causing casualties [19].

The destruction process of geological disasters is usually a gradual process, showing many pre-disaster signs, such as local landslides, surface cracks, building deformation, tree skew, and ground sound. According to the sign information, evacuations can be avoided in advance to avoid casualties and achieve successful prediction. Based on the field investigation and visit of geological disaster sites and successful prediction sites, combined with practical cases and years of work experience, the author summarizes and discusses the successful prediction experience of geological disasters in Shaanxi Province taking 2020 as an example, the successful and reported experience of geological disasters with strong representativeness is discussed from the following eight aspects: including hidden danger points into mass survey and mass prevention, adhering to “three inspections”, decisive evacuation and proper placement, support of professional technical teams, doing well in mass publicity and training, scientific and technological disaster prevention and mitigation, strengthening work in special periods, and multi-department joint disposal. Finally, it will provide reference for the prevention and control of geological disasters in Shaanxi Province and even the whole country [20].

The successful prediction of geological disasters belongs to the behavior that it is not too late to make up. While trying to do a good job of the successful prediction, more geological disasters should be discovered in advance, and measures such as avoidance, relocation, governance and ecological protection should be taken to avoid or completely eliminate geological disasters.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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