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The causes and prevision of mine subsidence in lesser Himalayas, Abbottabad

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Abstract

Numerous Impulsive mine collapses induced by shallow partial mining in the Cambrian Abbottabad formation have caused fatalities, significant property loss and brought harmful results to the environment. Mining subsidence is therefore needed to be monitored on all accounts during mining operations in this area. Based on a long history of soapstone mining in Sherwan, a generic approach is presented in this paper for investigating subsidence related phenomena in the area. This paper demonstrates a time prevision for the future subsidence using an empirical modelling approach EMA. 20 underground drift and shaft mines located in the Sherwan North-West Abbottabad, Pakistan have been studied using EMA. Empirical modelling formula, validated by Distinct Element code UDEC has been used to predict the time of subsidence of these mines. This approach is a factor of width, height and depth of excavation of a mine and it can be applied to area where mines are truly restricted to one locality e.g. Sherwan. The calculated statistical data unconcealed the current state and predicts time for future subsidence of Khanda Khau, Bandi Nikra and Chellether mines within Sherwan. Mines other than these three localities are mostly safe and stable. The major causes of mine subsidence in the area includes both natural and man-made factors which are briefly described in this paper.

Keywords: Mining, EMA, Subsidence, Mitigation.

1. Introduction

The Himalayas of Pakistan is bestowed with the most exotic economic mineral deposits in the world. These deposits are being excavated at different localities in the North Pakistan. Some of the important minerals including Chromite, coal, chromite, mineral salt, bauxite and soap stone. Among them Talc is one the most important mineral used in many industries such as paper making, plastic, paint and coatings, rubber, food, electric cable, pharmaceuticals, cosmetics, ceramics, etc. (Grim, 1968). Pakistan holds one of the best quality Talc deposits in the world, and efforts are considered necessary to capture the international market. In order to increase the Talc export, which is far behind its actual potential, exploration may be carried out in virgin areas for locating additional deposits leading more export and import substitution (Ahmed, 1969). In the Hazara division Khyber PakhtunKhwa, soapstone deposit occurs around Sherwan, to the northwest of Abbottabad. These are probably the largest and economically viable soapstone deposit of the country which is being exploited at several localities in the area around Sherwan for the last several decades. In local language the soapstone is called "Glass Mora". The history of mining in this belt started from 1955 up to now/recent. However, extensive mining and extraction has mostly been done from non-competent beds without any precautionary measures that resulted in the subsidence of the strata. The subsidence in Sherwan started in early 1980s but no proper monitoring of subsidence along with the caving pattern and slippage has been deliberated (Mines and Minerals Abbottabad, 2009).

Near Chellether and their surrounding area such as Nikra, Kangrora there is a wide spread destructive subsidence that can be seen above the underground mines (Fig. 1). Huge disintegrated mass of land has been dislocated moving down along the slopping topography which has cut across the road leading down to the mine areas. As most of these mines are owned by private contractors thus there is no such proper mechanism adopted to prevent economic and social loss due to mine collapsing. So, these mines require a proper monitoring to inhibit future loss. This research

is an effort to calculate the timing and major causes of mine subsidence in the area using empirical modelling approach. Although subsidence cannot be eliminated in this area, yet it can be reduced or controlled by adapting different methods such as proper ground support mechanism, back filling method and blasting controls. In order to develop broadly applicable subsidence prediction, more information is needed on magnitude and timing of ground movement and geologic properties.

Fig. 1. Shows the large-scale mine subsidence in village Bheer, Haripur Hazara (Figure Not according to Scale)

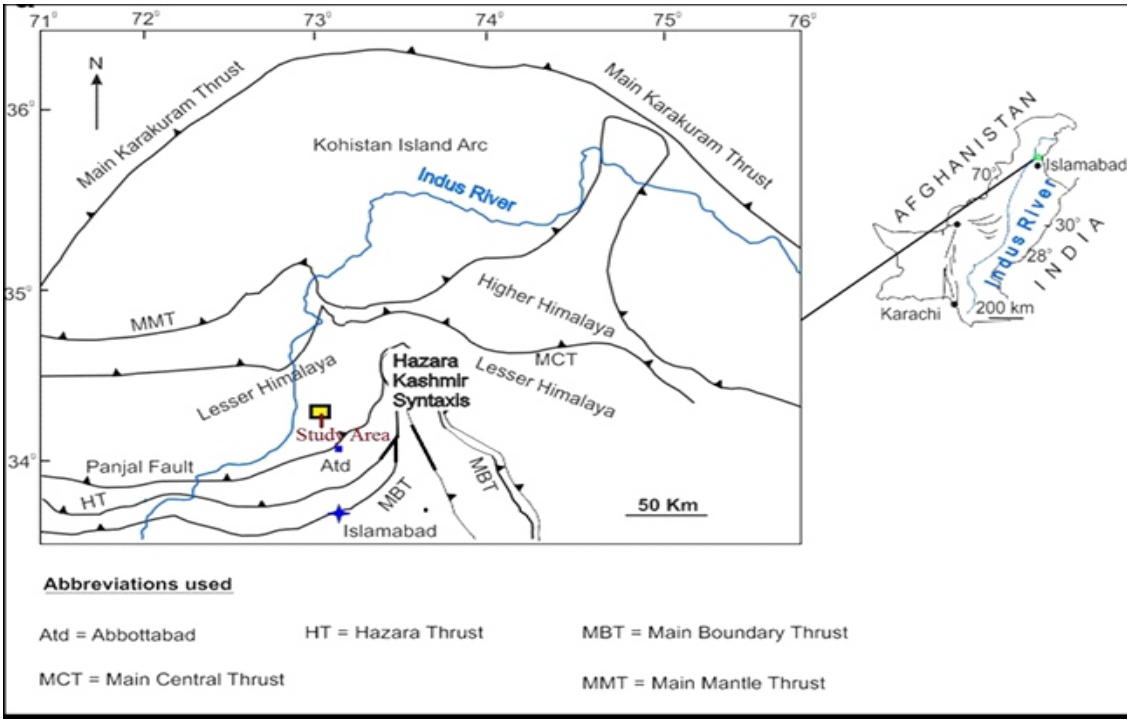

Fig. 2. Generalized map showing major tectonic features and location of study area with yellow box (after Ahsan and Chaudhry, 2008).

2. Geology of the area

Sherwan is located at 35 km to the northwest of Abbottabad. The Sherwan area is bounded by the Panjal Fault in the east and southeast and the Mashera Thrust in the north. To the west, the north trending Indus syntaxis and the associated faults such as the Darband fault separate the Hazara Range from the Swat Ranges west of the Indus River (Dipietro et al., 2000) (Fig. 2). The southern Tanawal Ranges are predominantly covered by the Precambrian lithologies, which include the Tanawal Formation in the hanging wall of the Panjal Thrust and the Hazara Slates in the footwall (Qasim et al., 2017). The Abbottabad Formation unconformably overlies the Precambrian Tanawal Formation in the hanging wall of the Panjal Thrust in the Sherwan area but overlies the Hazara Slates at Soban Gali and Sirban Hill in the footwall of the Panjal Thrust (Pogue et al, 1999).The area of our research work is Bandi Nikra (Sherwan) Geographical coordinates of the areas are 34.185210 N and 73.017802 E, Khanda khau (Sherwan) Geographical coordinates of the areas are 34.166219 N and 73.046751 E and Chellether Geographical coordinates of the areas are 34.187092 N and 73.031284 E (Fig. 3).

3. Methodology

Empirical modelling is the reliable arrangement model technique used for extrapolating accessible information to determine the future pattern. The measure of subsidence, the measure of compaction, and occasionally tidal physique close to the ocean coast, are accessible to plot against time. In this technique, the measure of subsidence is viewed as a component of time, overlooking interconnection of area subsidence. In Sherwan area the mines are mostly restricted to one locality. So, based on the acquired data, we can apply empirical formula to the mines in the Sherwan area for estimation/prediction of their subsidence. To establish an empirical method for a particular mine in an area, a large number of field observations must be carried out first. This study involves data from almost 30 soapstone mines in Sherwan area Abbottabad district. Data for these mines were collected along both a transverse line and a longitudinal line. The data for this mine is of moderate to good quality. Perhaps the most important subsidence relationship documented by the "SHE" work is the relationship between Maximum subsidence, seam height, and the width and depth of the extraction area. The basic Relationship is

Where
S = maximum subsidence,
M = thickness of extraction,
w = width of extraction, and
h = depth below surface.
f = constant and equal to the frequency in which the mine fall in year

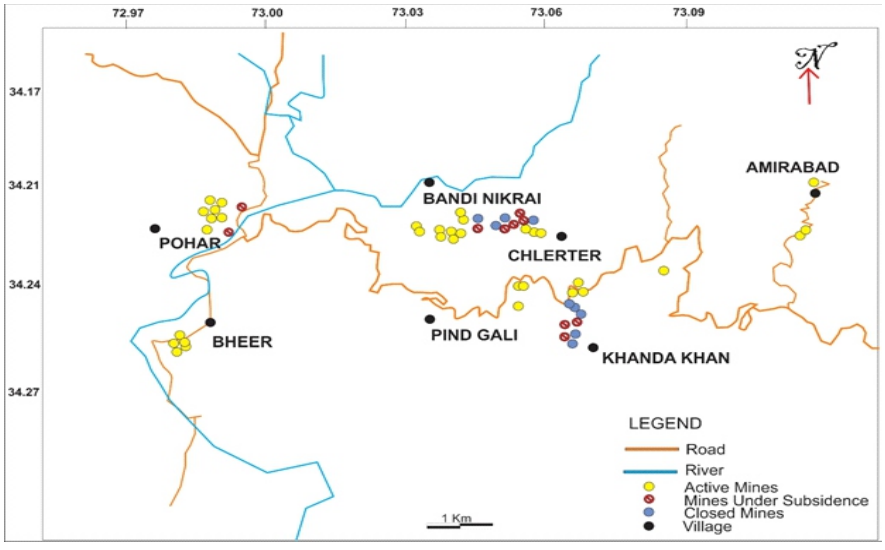

Fig. 3. Image displays the location of soap stone mines in Sherwan area District Abbottabad, KP (using Arc GIS).

4. Results and discussion

4.1. Causes of mine subsidence

Subsidence and collapse of mines are always a combination of hazards and causes. Making the issue more comprehensible is the only reason for presenting the hereafter list of hazards. The collapse and flood of underground workings could be a consequence of a dust or gas explosion. In Sherwan area different geological and physical processes are involved that controls the mine subsidence and are explained in this paper.

4.2. Joint and fractures in Abbottabad dolomite

In Sherwan area much of the soap stone is being excavated from the Abbottabad formation which is mainly dolomite unit. The soapstone deposits are extracted from dolomitic limestone. The Sherwan area is bounded by the Punjal thrust in the East and Manshera thrust in the west. The area falls in Hazara fold and thrust belt (Umar et al., 2014). The presence of these sedimentary rocks in an active tectonic zone may be a cause of development of these fractures/fissures as shown in the (Fig. 4a).

4.3. Timbering / Pillar failure

As for the local miners, to overcome the production costs mining is mostly done using block caving method. In the Sherwan area block caving method has been applied for excavation of soap stone. The average mine opening/mouth height is 6- 7ft and width is 4-5ft and this potentially induced subsidence and also the manner in which soapstone is extracted exerts a large influence on surface deformation. Unfortunately, the supporting mechanism is poor, the size of the pillars was not enough to support or tolerate the pressure of overlying strata as shown in (Fig. 4b). When one pillar collapses, the load it carried transfers to the neighbor pillars causing them to fail and so forth.

4.4. Dissolution or water dripping

The water dripping is the one of the key issue due to which the water penetrates from the fractures and weakens the rocks strength as shown in (Fig. 4c) as the overlying strata are dolomites, limestone. The limestone dissolved with rain water (mainly acidic) decreases the strength between joints/fractures sets. Due to these phenomena the subsidence can occur, the formula shows the consequence when limestone meets water,

$$CaCO_3 + H_2O \text{ ---------- } H_2CO_3 + CaO$$

And when Dolomite reacts with water the following reaction takes place:

$$CaMg(CO_3)_2 + H_2O \text{ ---------- } CaO + H_2CO_3 + Mg$$

4.5. Depth of extraction and overburden rocks

Rocks do not always behave in elastic manner, the effect of shearing in soft rocks is rather higher than the hard rocks. The depth of extraction and overlying rocks can play an important role in subsidence particularly when overlying strata is deformed or weathered. The deep excavated mines are highly prone to subsidence as deformation occurs above the shallowest mines more rapidly. The depth of extraction in Bandi Nikra is approximately 350 feet below surface due to which the subsidence occurs as shown in (Fig. 4d).

4.6. Prediction of subsidence

4.6.1. Khanda khau

In Khanda Khau out of 24 mines 7 mines are under the effect of subsidence. The data used for predicting mine subsidence are collected from three receded mines, two mines were closed due to subsidence. Most of the mines in this area are owned by private sector. Feroze mine company is the leading stake holder of the lease of these mines.

According to Empirical modelling approach the time frame for subsidence of these mines is given in the table 1.

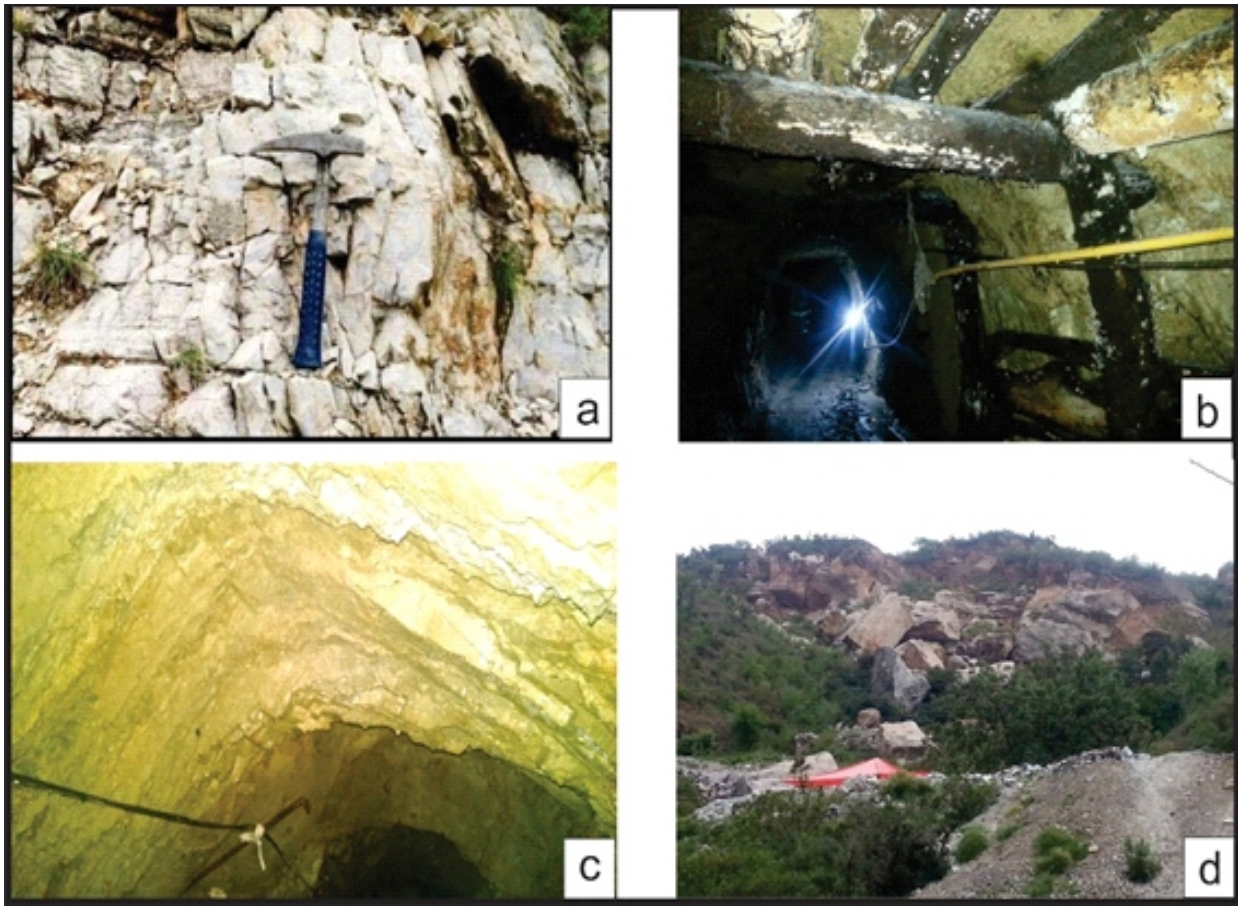

Fig. 4. (a) shows discontinuities in the Abbottabad formation (b) Loose wood pillar support mechanism (c) water dripping inside mine through fractures (d, not to scale) overburden rocks load.

Table 1. Shows the mine subsidence time span for khanda khau mines Sherwan area, Abbottabad.

S.N	Latitude/Longitude	Status	Subsidence prediction (years)
Mine 1	34.16586N 73.04696E	Active	1.74 years
Mine 2	34.1663N 73.04645E	Active	9.3 year
Mine 3	34.1667N 73.04766E	Active	5.6 years

4.6.2.Bnadi Nikra

Out of 5 soapstone mines in Bandi Nikra 3 are currently operative while 2 of them have been collapsed. The width of seam is relatively larger than Khanda khau and height is smaller than Khanda khau mines, but the subsidence is more in Bandi Nikra area. The time prediction for mines subsidence of bandi Nikra is as follows in table 2.

4.6.3.Chellether

Out of 20 mines in the Chellether area 5 mines are under the effect of subsidence. Due to lack of convenience road to the area, empirical modelling is applied on only 3mines of the affected area. The width, height and subsidence in same as in Bandi Nikra but the depth of mines from surface is more than Bandi Nikra and Khanda khau.

Table 2. Showing the mine subsidence time span. for Bandi Nikra mines Sherwan area

S.N	Latitude/Longitude	Status	Subsidence prediction (years)
Mine 1	34.18564N 73.02202E	Active	4.14 year
Mine 2	34.18573N 73.02158E	Active	8.8 years
Mine 3	34.18558N 73.01982E	Active	12.4 years

5. Conclusions

In Sherwan area soapstone is being extensively mined from dolomite beds for last two decades. The companies working on these mines are mostly local and thus lack proper mechanisms and planning to keep these mines safe and stable. The owner's goal is only to reach the maximum production ignoring the lives of miners along with excavation method and safety and stability of an area. Most of the mines are under the danger of subsidence and some are already collapsed in the area.

The conditions of mines in the subsidence area are very critical because of the loose support mechanism. The sizes of pillars are not enough to tolerate the pressure of overburden rocks. The mines can collapse at any time if no precautionary measures taken.

An Empirical modelling approach has been applied to these mines for the near prediction of time of collapse of these mines. The statistical data obtained clearly revealed that mines of Khanda khau are in very critical situation and can collapse at any time even when small scale seismic activity is produced. Overall the Chellether area is stable as compared to Bandi Nikra and Khanda khau. Mitigation and control methods have been recommended to better prevent the near future disaster of these mines. But this all depends upon the owners of the mines to embrace the facts of danger in the area and make aware the local miners to save their precious lives. And also to adapt safety measures to make their investment worthy.

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