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Surficial Impact Assessments on Mawchi Mine Area

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Abstract

Surficial impacts such as crack, subsidence and slope deformation causes of underground mining are very important issues in most countries, and these impacts are very well known in coal, metal and other types of mining. Along with an increase in mining operations, the depth of excavating is getting deeper causing mine stability problems and safety issues. Because of surface deformation, it is a complex phenomenon that may cause to landslides. Mawchi is a lode mine where several parallel veins accompanying minable scale of tin and tungsten occur both in the granite intrusive and in the host sediments. Ore deposit has been developed by five mine levels with underground (Adit-cut) method. Vertical distances between them constitute 30-50 meters. The underground drift covers the work of parallel steeply dipping veins with high grade of mineral ores. Characteristic features of the Mawchi deposits are its highly dissected topography on the one hand, alteration and decomposition of granites, affected by tropical climate, disintegration of preexisting rocks and mining activities on the other hand. All this leads to often landslides in rainy weather and instability of soils and rocks from the slopes. Sometimes, landslides follow in dumping and silting of approaches to the adit portal. Actually, some historical landslides events are recorded as fatal landslides. So, it can be said that the study area is familiar with landslide hazard. Mawchi area is mostly controlled by geological structures where hydrothermal intrusion was taken place. After extraction from vertical veins, it causes the loss of filling in discontinuities and become open joints on the slopes. Those open joints attract the flowing and rain water that affect the stability of slope. That fact also will reduce the values of rock quality and again decreases slope stability. Mostly field observation was basically recorded in landslides, and surface damages are still hitting the mine area. Due to the repetition of failures, the mine area has potential to take ground damages in future, especially in rainy seasons and may cause severe issues to safety of citizens, if there is no action taken. This paper is to provide technical documentation of surficial impacts related to underground mining, to discuss significant impacts on the environment and land-use during or after mining projects. The upshots of this study could provide guidance and reference for the assessment of surficial damage caused by underground mining in mountain areas.

Keywords: Mawchi Mine, Surficial Impacts, Underground Mining, Mine Stability, Landslide

မော်ချီးသတ္တုမိုင်းအတွင်း မြေမျက်နှာသွင်ပြင် ထိခိုက်ပျက်စီးမှုများအပေါ်လေ့လာ ဆန်းစစ် အကဲဖြတ်ခြင်း

ဒေါက်တာဇော်ဇော်သိန်း၊ လက်ထောက်ဘူမိဗေဒအရာရှိ

ဘူမိဗေဒလေ့လာရေးနှင့်ဓာတ်သတ္တုရှာဖွေရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

မြေအောက် သတ္တုတူးဖော်များ၏ အကျိုးဆက်ကြောင့် မြေမျက်နှာသွင်ပြင်ထိခိုက် ပျက်စီးမှုများဖြစ်သော မြေလွှာကွဲအက်မှု၊ မြေကျွံကျမှုနှင့် တောင်စောင်းပြိုပျက်မှုစသည့် မြေသားမတည်ငြိမ်မှုများသည် ကျောက်မီးသွေး၊ သတ္တုနှင့်အခြားသောသတ္တု တူးဖော်ရေးလုပ်ငန်း များလုပ်ကိုင် ဆောင်ရွက်လျက်ရှိသော ကမ္ဘာ့နိုင်ငံအသီးသီးတွင် အစဉ်အမြဲကြုံတွေ့နေရသော သဘာဝ ပတ်ဝန်းကျင် ထိခိုက်ပျက်စီးမှုဆိုင်ရာ စိန်ခေါ်မှုအခက်အခဲများဖြစ်ပါသည်။ သတ္တု တူးဖော်မှုနှင့်ဆက်စပ်၍ တူးဖော်မှု ကြာလာသည်နှင့်အမျှထုတ်လုပ်မှု လုံခြုံစိတ်ချရမှုမှာလည်း အန္တရာယ်ပိုမိုရှိလာမြဲ ဖြစ်ပါသည်။ မြေသားမတည်ငြိမ်မှုများ ပေါင်းစပ်ဖြစ်ပေါ်လာခြင်းကြောင့် ပင် သတ္တုမိုင်း မြေပြိုမှုများကြုံတွေ့ဖြစ်ပေါ်လာခဲ့ရခြင်း ဖြစ်ပါသည်။

မော်ချီးသတ္တုသိုက်ဖြစ်ထွန်းမှုသည် သတ္တုအကြောလိုက် ပြိုင်တန်းပျံ့နှံ့ပေါ်ထွက်မှုမျိုး ဖြစ်ပြီး သတ္တုပါဝင်မှု မြင့်မားပါသည်။ ထိုသတ္တုကြောများကို အမြင့်အကွာအဝေး ၅၀ မီတာဖြင့် တူညီစွာ ခြားနားထားသော အပေါ်အောက် အထပ်အဆင့် ၅ ခု ဖြင့် မြေအောက်တူးဖော်မှု နည်းလမ်းများအသုံးပြု၍ ထုတ်ယူသုံးစွဲနေခြင်းဖြစ်ပါသည်။ မော်ချီးသတ္တုသိုက်သည် မတ်စောက်သော ကမ်းပါးယံ မြေမျက်နှာသွင်ပြင် ရှိရုံသာ မဟုတ်ဘဲ သတ္တုသယ်ဆောင် လာသော တိုးဝင်ကျောက်သားများ ပြိုကွဲပျက်စီးမှု၊ အပူပိုင်းဖုံရာသီဥတုအတွင်း ကျရောက်နေမှုကြောင့် ရာသီဥတုဒဏ်ခံစားရမှုအပြင် အိမ်ခံအနည်ကျကျောက်များ ပြိုကွဲလွယ်မှု အခြေအနေများပါ ပေါင်းစပ်ပြီး မိုးများသော အချိန်အခါမျိုးတွင် မြေပြိုမှုနှင့် တောင်စောင်းမြေပြိုပျက်မှုကို ပိုမို ဖြစ်ပေါ်စေနိုင်ပါသည်။ တစ်ခါတစ်ရံစွန့်ပစ်မြေစာများ စုပုံထားသောကျင်းဝနေရာများတွင် လည်း မြေပြိုမှုများ ဖြစ်ပေါ်နိုင်ပါသည်။ ယခင်မြေပြိုမှု ဖြစ်ရပ်များတွင်လည်း အသက်အိုးအိမ်

ဆုံးရှုံးမှုများရှိခဲ့သည်ကိုလည်း ကြားသိခဲ့ရပါသည်။ သို့ဖြစ်ပါ၍ မော်ချီးသတ္တုမိုင်းသည် မြေပြိုမှု ဘေးအန္တရာယ်နှင့် နောင်အခါတွင် ကြုံတွေ့နိုင်မည့် အလားအလာ အခွင့်အလမ်း ပိုမိုလာမည် မှာ အမှန်ပင် ဖြစ်ပါသည်။

မော်ချီးသတ္တုမိုင်းတွင် ဘူမိနေထားပျက်ယွင်းမှုများကို သတ္တုတိုးဝင်ရာ သတ္တုအကြော စိုင်များ အနီးပတ်ဝန်းကျင်တွင် အများအားဖြင့် တွေ့ရှိရပါသည်။ သတ္တုကြောစိုင်များ ထုတ်ယူ ပြီးချိန်တွင် ကျောက်သားများကြားကွာဟမှု ဖြစ်ပေါ်လာခဲ့ပြီး ထိုနေရာများအတွင်းမြေအောက် ရေနှင့် မိုးရေများ စီးဆင်းဝင်ရောက်လာကာ ကျောက်သားအရည်အသွေး လျော့ကျမှုနှင့်မြေ မျက်နှာသွင်ပြင် မတည်ငြိမ်မှုများ ဆက်လက်ပေါ်ပေါက်လာမည်ဖြစ်ပါသည်။

လေ့လာတွေ့ရှိမှုများအရ မြေပြိုမှုများနှင့်မြေသား မတည်ငြိမ်မှုများသည် မော်ချီးသတ္တု မိုင်းအတွင်း ဆက်လက်ဖြစ်ပေါ်လျက်ရှိနေသည်ကို မျှော်မှန်းတွေ့မြင်ရပါသည်။ ယခုကဲ့သို မြေပြိုမှုများ များပြားလာခြင်းသည် အနာဂတ် မိုးရာသီကာလများတွင် သတ္တုမိုင်းတူးဖော်မှုနှင့် အနီးဝန်းကျင်ရှိ အခြေချနေထိုင်သော မိုင်းတွင်းနေ လုပ်သားပြည်သူများသာမက ဒေသခံများ အတွက်ပါ မြေပြိုနိုင်မှု ဘေးအန္တရာယ်အား စိုးရိမ်ပူပန် နေရပါသည်။

ယခုစာတမ်းသည် အဓိကအားဖြင့် မြေအောက်သတ္တုတူးဖော်မှုဆိုင်ရာ အကျိုးဆက် ဖြစ်သော မြေမျက်နှာသွင်ပြင် ထိခိုက်ပျက်စီးမှုများအပေါ် အလေးပေးဆွေးနွေး တင်ပြရခြင်း ဖြစ်ပါသည်။ အကျိုးရလဒ် အနေဖြင့် ယခုလေ့လာ တွေ့ရှိချက်များအပေါ်အခြေခံ၍လည်း မြေအောက် သတ္တုတူးဖော်မှုကြောင့် ဖြစ်ပေါ်လာသော သဘာဝပတ်ဝန်းကျင် ထိခိုက်ပျက်စီးမှု များနှင့် သတ္တုမိုင်းမြေပြိုမှုများကို လေ့လာဆန်းစစ် အကဲဖြတ်ရာတွင် အထောက်အပံ့ဖြစ်စေ မည်ဖြစ်ပါသည်။

Study on Wood Properties of Two Indigenous Species from Kachin State, Myanmar

1. Introduction

Myanmar has two geomorphological mountainous provinces: namely, the Western Ranges and the Eastern Highlands. These provinces are inherently unstable regions of the country. The steep slopes, unstable geologic conditions, and heavy monsoon rains combine to make the mountainous areas one of the most hazard-prone areas in Myanmar. Indisputably, the natural hazard and risk awareness have become an important issue by reaching to considerable magnitude in recent years.

Mawchi mine, Kayah State, Myanmar has been in the past a very successful mining operation. The geological formation at Mawchi is typical of tin and wolfram mine all over the world, an intrusion of igneous rock into the sedimentary rocks namely Mawchi Group. Mawchi is a lode mine where several parallel quartz veins accompanying minable scale of tin and tungsten occur both in the granite intrusive and in the intruded Mawchi sediments. The underground drifts follow the en echelon veins with high grade of tin and wolfram ores. The characteristic features of the Mawchi mineral deposits are its highly dissected topography on one hand, and decomposition of granites, affected by the tropical climate and disintegration of argillaceous slates on the other. All this leads to frequent landslides in rainy seasons and slumping of soil and rocks from the slopes. Sometimes, landslides result in dumping and silting of approaches to the portals of levels. Actually, some historical landslides events are recorded as fatal landslides. So, it goes without saying that the study area, Mawchi mine is familiar with landslide hazard.

In Mawchi mine, ore deposit has been developed by five mine levels with underground mining (Adit-cut) method. Vertical distances between them constitute 30-50 meters. At present mine workings of four levels No.2, 3, 4, and 5 are partially accessible. The majority of known ore veins No.1 level is worked out. The life of mine is estimated to be around over 100 years. This long-time consuming for exploitation of underground ore resources in Mawchi has strongly reflected the serious environmental impacts of mine area. The main impacts of underground mining activities on the surface inventory are surficial cracks, subsidence and slope deformation. A reliable prediction of the mining induced impacts are still a challenge, because the main reason is the existence of numerous interrelated factors, such as the rock masses characteristics, the ground surface topography, the natural precipitation, the method of excavation, which making the impact analysis becomes more complex.

Generally, the availability of more data and in-depth studies of a site, a deeper understanding on the mine stability and potential for ground failures can be determined. Ground failure is often related to prolonged rainfall events where failure mechanism will accelerate with the existence of cracks. The existence of cracks on slopes usually provides an easy pathway for rainfall infiltration into ground, allowing rain to infiltrate to deeper layers than in the absence of cracks. Results suggested that pore water pressure and slope stability were influenced by the existence of cracks. The influence of the crack on the infiltration and deformation of the ground decreased with increasing distance from the crack. Cracks are ubiquitous at the slope crests and strongly suggest that instability is imminent which are usually caused by differential activities. In mining activities, the original balance of rock stress within the study region had changed. The rock strata had been subjected to continuous movement, deformation, and discontinuous damage, resulting in stress redistribution and a new equilibrium.

When the area of the underground mining activities reaches a certain extent, the influence of the mining spreads to the ground surface, leading to subsidence, displacement, and deformation. The range and degree of ground surface deformations are comprehensively affected by various factors, such as mining depth, mining area, mining method, and geological condition. The process of mining-related subsidence is complex; the value and spatial distribution of ground surface displacement and deformation have certain regularities: surface subsidence at the top of the exploitation area is the largest, and the value of subsidence from the center to the edge of the subsidence basin gradually decreases. Furthermore, ground subsidence and deformation can be calculated using the corresponding method when the underground mining area and geological mining conditions are determined. The present study only spotlight that study of cracks and subsidence should be an importance issue of the influence of mining.

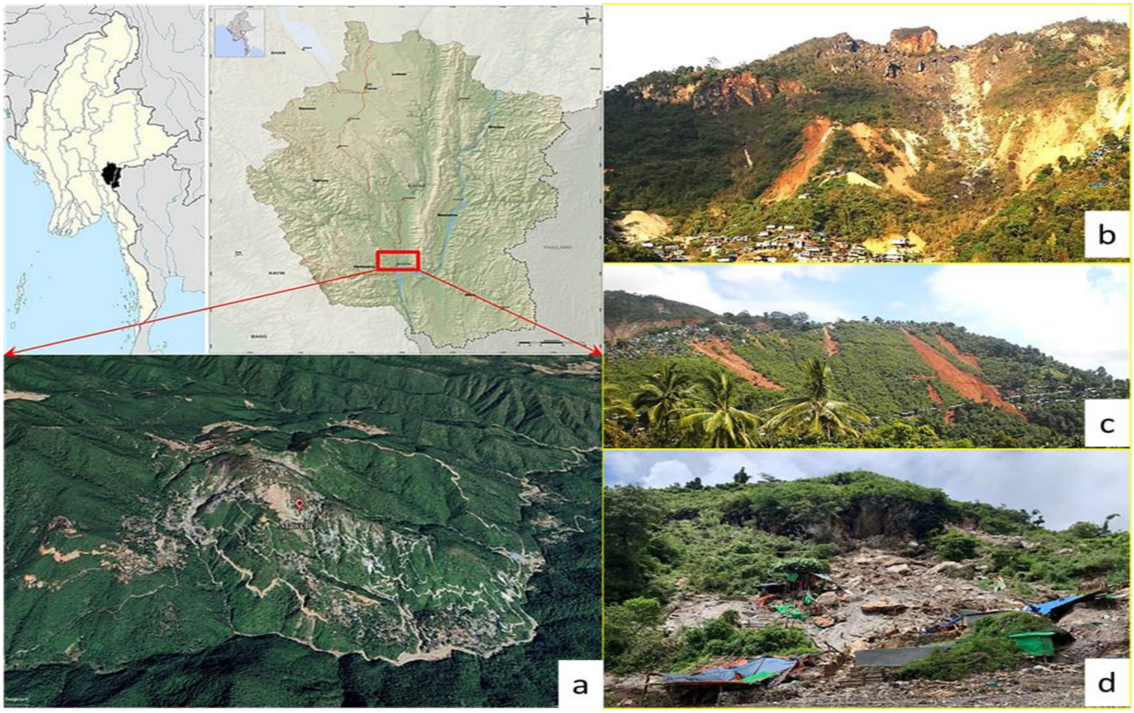

Figure 1. Mawchi mine and landslides (a) Location map of the Mawchi mine area, (b) Two times reported rock fall area 1985, 1988, (c) Shallow landslide occurrences, October 11, 2015 (d) Rock slope failure, October 25, 2019.

2. Objectives

Although the many of local and foreign researchers emphasized greatly on ore resources and ore reserves, actually landslide is a serious recurring geo-hazard in Mawchi mine area. Fragile events brought about medium to large scale landslides that have been chronologically recorded. It is hypothesized that Mawchi Mine Landslide is represented in two conditions, both soil and rock failure events. Admitting the true, this paper is shared only an item involving from the author’s doctoral research study for the analysis and assessment of Mawchi mine landslides. The principal objective of research study was to provide decision makers with the landslide hazards and spatial risk assessment methodology for proper management and planning of development in mine operation and surrounding area.

The main aim of this paper is to afford technical documentation of surficial impacts related to underground mining, to discuss significant impacts on the environment and land-use during or after underground mining projects. The upshots of this paper could provide guidance and reference for the assessment of surficial damage caused by underground mining in mountain areas.

3. Materials and Methods

The material used to desktop study is carried out prior to field investigation. All available data are collected to delineate the problem of study area (P.C. Mero et al, 2021). During this surficial impact assessment, all landslide occurrences and surface damage areas are thoroughly investigated. The planimetric locations of all inclusive ground damages were established and numbered using GPS, and their dimensions were measured using steel tape. To get direction and inclination of the failure conditions were measured with the aid of a Brunton compass.

The field investigation was allocated into two portions in this assessment, surface mapping and ground failures designation. In first study, all comprehensive surface morphological mapping is based on field investigation of existing landslides in area of known slope instability, which comprises of all visible existing and future slope failures, the possible locations of historical landslides and all current failures within research area such as subsidence, ground cracking, stripping area, dismantled area by landslide or erosions, human actions including new and illegal portals place for ore extracting. The second study is investigation of the extent of impacts and measurement of the surface damages. The method of investigation of the extent of ground damage involved on-site recording of each failure and the details of the damage condition, including the location, shape, number, width, the amount and direction of tilt of any ground failure (X.Diao et al, 2019).

4. Results and Discussions

When the extraction of some natural resources (coal, oil, shale and other minerals) or geological materials by surface mining is impossible, underground mining methods are used. In underground mining, geological materials completely enclose the working environment; this technique also differs greatly from surface mining techniques. Short-wall, Long-wall, Room and Pillar, Blast, etc. are the few methods in underground mining activity. Removal of the material by underground mining can create environmental problems and safety hazards (Aultun et al, 2010). Surficial impacts, ground subsidence and slope deformation due to underground mining activities is an old familiar problem, and the increase in use of long wall mining and further housing development into the abandoned mine lands in the suburban areas further accelerated the public concerns about surface subsidence and slope deformation due to underground mining. In this study, surficial impacts of Mawchi mine area based on the field surveying are slope failures, ground subsidence and tension cracks on upper slope. This consequence could constitute important reference material for future work on the technical assessment of mining related damage.

4.1 Surficial Cracks Analysis

Ten surficial crack sites on both soil and rock areas are recorded as shown in Figure-2 shows the location of crack sites. Cracks size, width and height are measured using a tape. Garmin GPSMAP 64s was used to locate the position of fracture formation and determine the distribution of cracks which are presented in Table 1.

The cracks at No.1, 2 and 7 are located in the Taung-paw village. In No.1, there are four parallel cracks with width of 3-5 cm, the length is more than 15m with 170˚alignment and the interval of parallel ranges is 0.3-1m. No.2 is located at the mining site by vertical shaft. The visible width of crack is 10cm and no step is seen. The length of crack is about more than 30m, its alignment is 110˚ and direction may be SW. No.7 crack is a step crack with the width of 5-7 cm, step height about 10cm, 40˚ alignment and SE direction. These crack sites are large noticeable relevant to the subsidence 1 and 2.

The crack at No.3 is located near KB-1 landslide site. The width of crack is 2m, 30m length and crack alignment is 310˚ with 40˚NE direction.

The cracks at No.4, 5, 6 are located at the Taung-paw Pagoda. It is a group of cracks and connected each other by offset, mainly distributed on the top of western part of Machihill. There is considerable close to the previous rock fall site, where large slope failure occurred since 1985 and 1988. It is indicated that dangerous level for rock fall site.

The cracks at No.8 are located at the Yadanar Aung Myay village, three cracks are recorded in which two are step cracks with the heights about 1-1.5m and another crack is about 15m length and width of range is 5-10cm. All cracks are SW direction alignment.

The cracks at No.9 are located at the head of Tin-Villa Bungalow landslide, east of Mawchi hill. There are three separate locations are noted. Two step cracks are with the heights of 1.5-3m with NE direction and another crack is 5-10cm height with SE direction.

The crack at No.10 is located at the Yukawkho village. It is a step crack with the width of 30 cm, the step height of 30cm and the crack length is 50m. It happened in residential area.

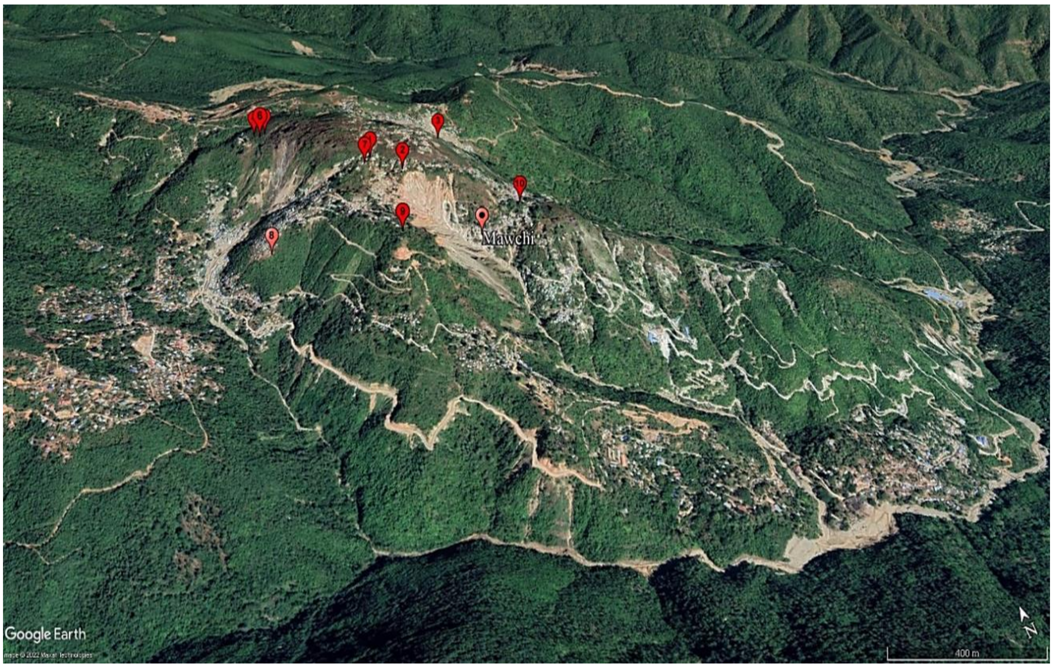

Figure 2. Locations of cracks occurrences in mine area

The rest of sites, cracks are formed in soil formations especially in colluvium deposit, the tensile cracks (No. 1, 2) are observed and some are found as step cracks (No. 3, 7, 8, 9, and 10). The formation of surface cracks exhibit both crack width and step height, the sizes of which are proportional to the magnitudes of the horizontal stretching (tensile) and vertical movement (shear), respectively. All these cracks are initial signs of slope failures. The application of ore processing mining method especially washing with water and improper mine design underground mining are the induced factors to initiate those crack signs and turn into instability of slope.

The sites No. 4, 5 and 6 are open cracks with the size 2-3m width and 10-50m length in limestone formation; mineralization is formed in the discontinuities as soft filling and the extraction of ore were observed in the current survey. The depth of cracks cannot identify. The two main adits, 2-west and 3-west are driving towards these cracks slope. Therefore, the main factors contributing to serious cracks can respectively be considered as both geometric condition of ore mineralization and its extraction. The steep slope is also a controlling factor to induce more serious damage.

This area is mostly controlled by geological structures where hydrothermal intrusion was taken place. After extraction of ores from those veins cause loss of filling in discontinuities and become open joints on the slope. Those open joints attract the running water /rain water that affect the stability of the slope. That fact also will reduce rating values of rock mass quality and again decrease slope mass stability.

Table 1. Cracks sites of the field data

Site	**Date**	**WGS 84**		**Elevation**	**Cracks**				**Location**
		Easting	Northing		Alignment	Direction	Width	Length	
1	2/3/2020	305838	2082513	1214.72	170			> 15m	Taung-paw village
2	1/3/2020	305930	2082404	1207.59	110	200 SW		> 30m	
3	1/6/2020	306158	2082592	1216.25	310	40 NE	2 m	30 m	Near KB1 landslide site
4	1/11/2020	305482	2082925	1224.46	350		3 m	30 m	Taung-paw Pagoda
					120		5 m	30 m	
5	1/11/2020	305520	2082895	1243.61	140		3 m	50 m	
					70		3 m	10 m	
					220	From 70	5 m	100 m	
6	1/11/2020	305499	2082896	1232.77	160		2 m	100 m	
					270		2 m	100 m	
7	12/28/2019	305810	2082500	1208.05	40 NE	SE	2-4 in	30 m	Taung-paw village
8	12/30/2019	305383	2082364	1034.93	120	210 SW	2-4 in	15 m	Yadanar Aung Myay village
8	12/30/2019	305435	2082423	1082.15	140	230SW	4 ft	30 m	
8	12/30/2019	305455	2082424	1095.57	140	SW	6 ft	30 m	
9	12/31/2019	305813	2082112	1157.34	20	110	4-6 in (4ft)	15 m	Tin-Villa Bungalow landslide
	12/31/2019	305882	2082027	1134.41	340	NE	D-5 ft	30 m	
	12/31/2019	305887	2082018	1132.09	320	50 NE	D-10 ft	30 m	
10	1/29/2020	306321	2082168	1106.86	110	SW 220	1 ft	50 m	Yukawkho village

Figure 3. Tensile cracks in site No.1 (left) and site No.2 (right)

Figure 4. Step crack in site No.3 (left) and open crack in site No.4 (right)

Figure 5. Open cracks in site No.5

Figure 6. Open crack in site No.6 (Left) and step crack in site No.7

Figure 7. Both tensile crack (left) and step crack (right) in site No.8

Figure 8. Step cracks in site No.9

Figure 9. Step cracks in site No.9 (left) and site No.10 (right)

4.2 Ground Subsidence Analysis

Subsidence or collapse can be defined as the vertical ground movement and have serious effects on environmental issues. Sinking and/or lowering of a land surface, which may occur gradually or suddenly, affects areas from few square meters to square kilometers. Collapse, subsidence and difficult engineering conditions sourced from underground mining activities constitute very important problems. Collapse and subsidence may occur in the course of time or suddenly and catastrophically. Planning and precautions in such hazardous areas are very important and has a priority.

The overlying strata gradually collapsed with the continuous progress of the work face. In the study area, three subsidence centers named S-1, S-2 and S-3 are observed. S-1 and S-2 were formed in Taung-paw village in 2017. S-3 is exited in 13-Gone hill. Subsidence S-1 developed rapidly and eventually sank to the depth of 5m depth in a few days and the S-2 also developed to the depth of 7m depth. The diameter of S-1 is about 30m and S-2 is about 25m in diameter. It is noticed that the rate of deformation slowed down and entered a slow progress in condition. The S-1 was happened on the sloping ground and S-2 is formed in flat area, where abundant underground mining work sites about more than 30 work sites (shaft, adit) around its environs are recorded. S-3 was occurred on slopping ground, near the 13-Gone old landslide. Its diameter is about 15m, the depth is 10m and happened in 2018. All the three sinking were occurred in overburden soil deposit overlie on sandstone and limestone. The following Table-2 shows the locations of those three subsidences.

Table 2. Descriptions of the three subsidence

No	Recorded Time	WGS 84		Myanmar Datum 2000		Elevation	Subsidence		Location
		Easting	Northing	Easting	Northing		Dimension width (m)	Depth (m)	
1	2/3/2020	305860	2082486	306228.43	2082181.62	1206.53	25	7	Taunpaw village
2	2/4/2020	306267	2082121	306635.13	2081816.51	1042.07	15	10	13-Gone Hill

No	Recorded Time	WGS 84		Myanmar Datum 2000		Elevation	Subsidence		Location
		Easting	Northing	Easting	Northing		Dimension width (m)	Depth (m)	
3	12/28/2019	305810	2082500	306178.71	2082195.42	1208.05	30	5	Taunpaw village

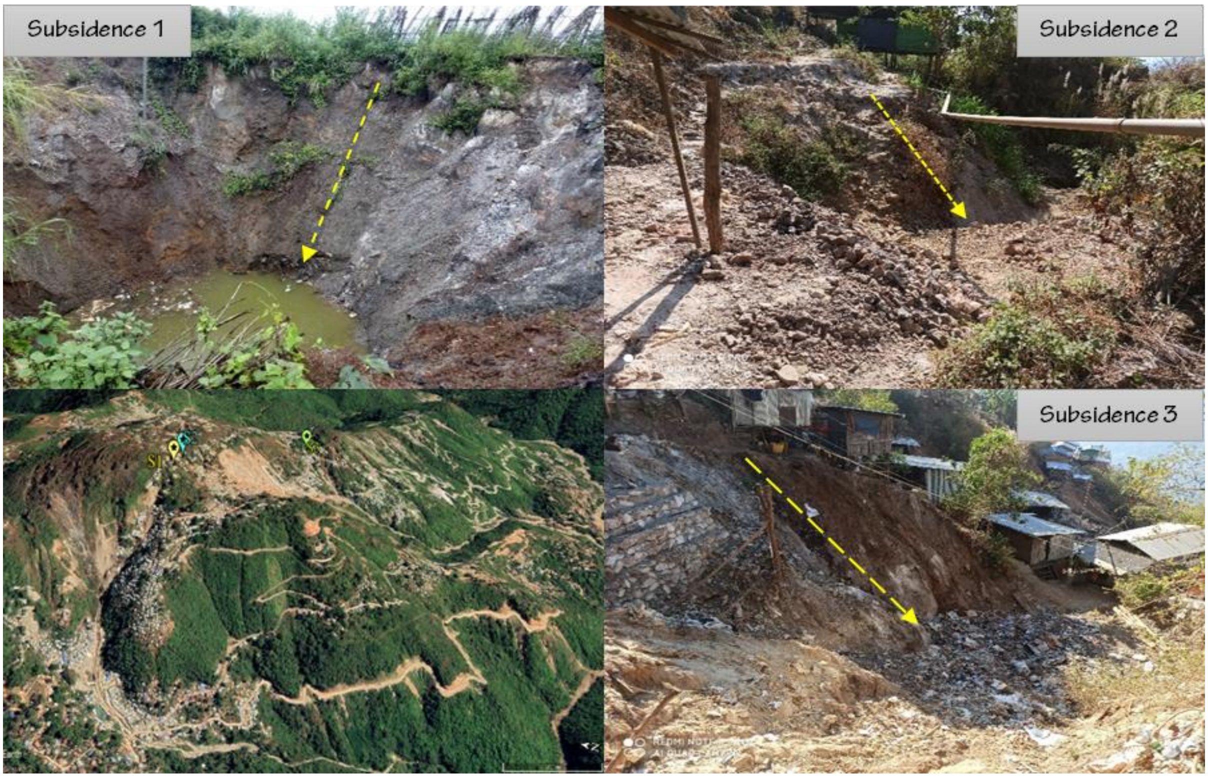

Figure 10	Three subsidence failure events of the study area

4.3 Slope Deformations Analysis

The underground mining process has a large negative influence on the environment of the whole undermined area. If after mining out of the seam, large depressions and reactivation of extensive slope deformations (blocks and landslides) on the surface occurs, several villages, highways and railways in endangered area may be affected.

That's why steps should be taken in modern mining operations to minimize impacts on all aspects of the environment. By carefully pre-planning projects, implementing subsidence and slope deformation control measures, monitoring the effects of mining and rehabilitating mined areas, the mine industry minimizes the impact of its activities on the neighboring community.

Many of slope deformations are occurred in study area. The previous and current slope deformations are listed in Table-3. There are two types of slope deformations, land sliding in soil formation and rock fall hazard favorable in structurally controlled rock slopes.

According to Figure-11, it is also clear that the directions of current adits are closely related and incubate to cracks, landslides and subsidence. Overburden deformation has a considerable influence on slope stability during underground mining works. Removal of the material by underground mining can create environmental problems and safety hazards.

This process consists of a series of operations that begins with "underground cutting" so that it will break easily when blasted with explosives. The overlying strata gradually collapsed with the continuous progress of the work face. Collapse, subsidence and difficult engineering conditions sourced from underground mining activities constitute very important problems in this Mawchi Mine. Collapse and subsidence may occur in the course of time or suddenly and catastrophically.

The result reveals that environmental impacts directly related to underground mining, which is a significant impact on the environment and land use during and/or after underground mining. This result will also be important in order to better understand the nature and magnitude of displacements of surficial impacts that can affect lives and infrastructures.

Table 3. Previous and current slope deformation of Mawchi mine area

No	Longitude	Latitude	Elv(m)	Way point	Deformation	Occurrences
1	97˚09' 23.8572"E	18˚49' 20.1288"N	1153	2MC01	Land slide	West of Bungalow
2	97˚09' 33.0156"E	18˚49' 26.5008"N	1203	3MC09	Land slide	East of Khedaung
3	97˚09' 37.335"E	18˚49' 35.058"N	1210	6MC02	Rock fall	KB1 work site
4	97˚09' 19.296"E	18˚49' 32.325"N	1149	8MC01	Localized	Western of mine
5	97˚09' 14.054"E	18˚49' 38.802"N	1138	11MC01	Rock fall	Western of mine
6	97˚09' 41.367"E	18˚49' 16.669"N	1085	28MC02	Land slide	13 Gone, Yukawko
7	97˚09' 11.775"E	18˚49' 30.180"N	1067	30MC01	Land slide	Yadanar Aungmyay
8	97˚09' 13.582"E	18˚49' 28.326"N	1095	30MC05	Land slide	Yadanar Aungmyay
9	97˚09' 21.279"E	18˚49' 28.117"N	1183	30MC08	Land slide	Taungpaw Chruch
10	97˚09' 27.741"E	18˚49' 20.002"N	1123	31MC01	Land slide	East of Bungalow
11	97˚09' 22.564"E	18˚49' 11.848"N	1047	31MC13	Land slide	Car road, 16 Gone
12	97˚09' 19.548"E	18˚49' 20.712"N	1089	31MC15	Land slide	Car road
13	97˚09' 44.240"E	18˚49' 15.218"N	1079	291MC03	Land slide	13 Gone
14	97˚09' 34.135"E	18˚49' 05.700"N	878	4201MC	Land slide	Near level-2, Ropeway station
15	97˚09' 33.188"E	18˚48' 59.356"N	870	4202MC	Local slide	16 Gone Car Road

5. Conclusions and Recommendations

The mine area has both unstable and actively failing that comprises surficial crack sites on both soil and rock areas are contributing to seriously stepped and opened nature. The formation of surface cracks exhibit both crack width and step height, the sizes of which are proportional to the magnitudes of the horizontal stretching (tensile) and vertical movement (shear), respectively. All these cracks are initial signs of slope failures. The application of ore processing mining method especially washing with water and improper mine design underground mining are the induced factors to initiate those crack signs and turn into instability of slope. Here, the western parts of cracks are great consuming to widening. If the west flank had to fail this would contribute a large volume of material and weight to the down sliding, likely triggering another rock falling events.

In the study area, some collapse and three subsidences were recorded. Collapse and subsidence conditions are sourced from underground mining activities constitute very important problems. It is noticed that the rate of deformation is slow and entered an active progress in failure condition.

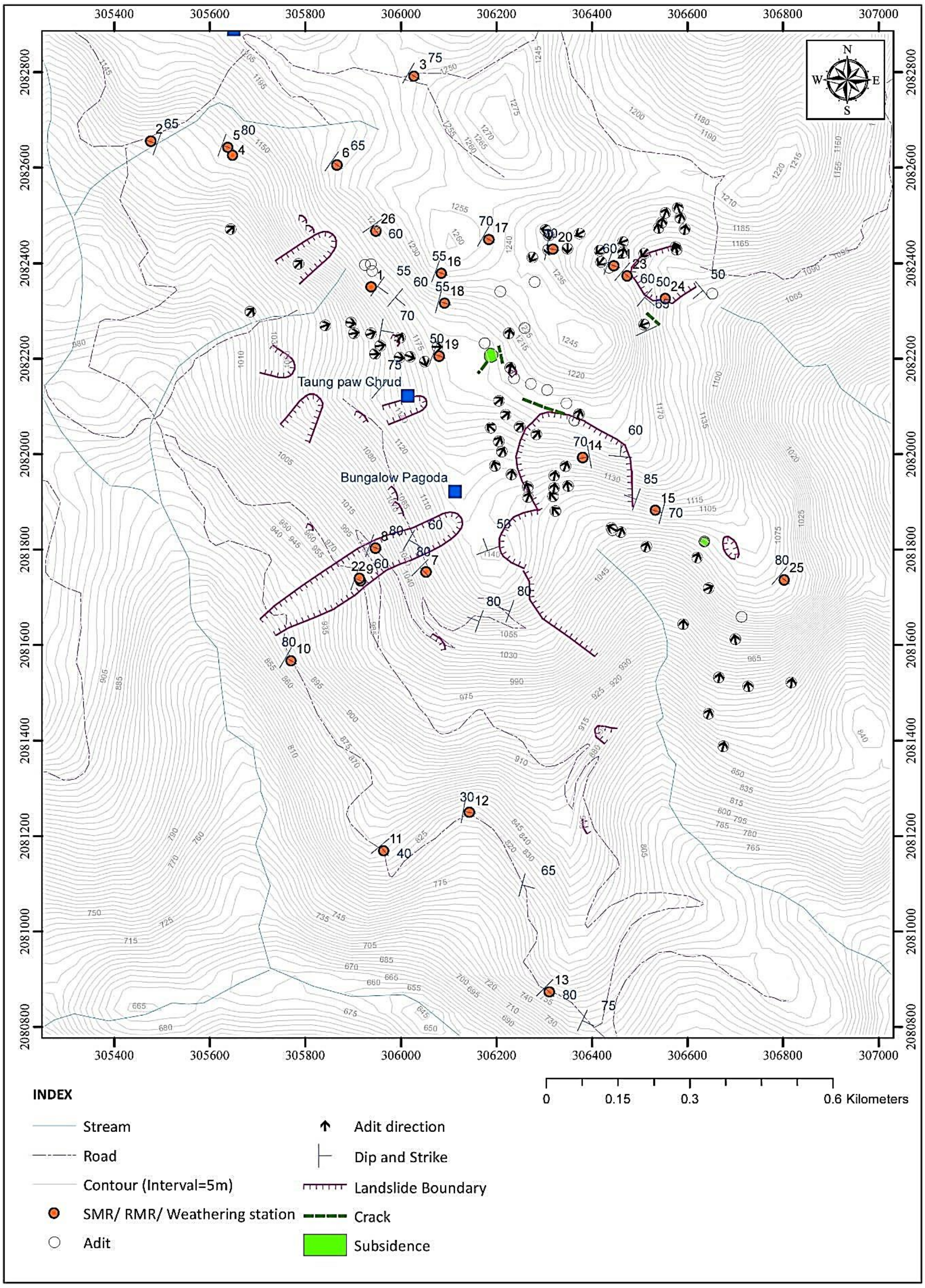

Figure 11. Slope deformations map of the study area

Many of slope deformations are related to the consequences of operation, drive and mining work that incubate to cracks, landslides and subsidence. Therefore, steps should be taken in safety mining operations to minimize impacts on all aspects of the environment. Periodic inspections of the mine site, training and review of the mining operations will all lead to a safer work environment. Further study, including a detail investigation, is recommended to be conducted by the professionals to assess this potential risk.

For a point being important issue can compel to recommend that there are direct connections between the developing area of cracks and subsidence caused by mining action. These areas can close at some failure degree which needs technical treatment to keep its safety and stable conditions. Moreover, a key factor in terms of future risk reduction is the necessity to engage with local people that continue living and working in areas at old landslide ground. Old landslides may be reactivated by striking at any moment, with little notice. In order to protect their home and family, it is important to be prepared. Because, mining activities that utilize blasting techniques contribute mightily to landslides. Vibrations emanating from the blasts can weaken ground and susceptible to landslides. The weakening of ground means a landslide can occur anytime.

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