Journal of Himalayan Earth Sciences Volume 51, No. 2A, 2018 pp. 87-93

Coal mining trends and future prospects: A case study of Eastern Salt Range, Punjab, Pakistan.

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Abstract

Coal is an organoclastic sedimentary rock, composed essentially of lithified plant debris. Coal is an important energy source and is available in all over the world. Pakistan possesses huge coal reserves across the country that can play a pivotal role in development of the country overcoming the energy crises prevalent in four seasons. Government of Pakistan is seriously looking for alternative resources other than hydro and thermal energy to meet the ongoing and growing energy requirements. Most of the world's lignite deposits are located in Asia. Pakistan is among the top most lignite coal-bearing countries in Asia possessing almost 97% of the coal reserves bearing lignite variety. The rest of the grades are of sub-bituminous to bituminous content. Amongst all the reserves in Asia, 3% are located in Pakistan. The major coal reserves in Punjab are found in Eastern & Central Salt Range and Trans-Indus Range. Most of the region's coal and carbonaceous coal deposits are located in the Paleocene Patala Formation, with a minor occurrence in the Tobra formation of the Permian age. Mining techniques are being pursued viz; room and pillar method and longwall system that are commonly applied in the areas. Supports are provided without geotechnical evaluation. Timbering is provided as supports in these coal mines. The analysis of accidents shows that roof collapse and fall of side walls are the most common and frequent type of fatal accidents making almost of total accidents.

Keywords: Coal mines; Mining techniques; Coal mines accidents; Eastern Salt Range.

1. Introduction

Coal is an important energy source (Lechner et al., 2016) and is available in all over the world (Hoek et al., 2010; Siepinska-Sawicz and Bak, 2016). Pakistan possesses huge coal reserves across the country (Ali and Khan, 2015) that can play a pivotal role in development of the country overcoming the energy crises prevalent in four seasons. In the wake of ever looming crises, Government of Pakistan is seriously looking for alternative resources other than hydro and thermal energy to meet the ongoing and growing energy requirements. An economically alternate solution is present in the form of coal in Pakistan. Being the second largest energy source, it provides for about 24 % of the total energy needs of the world. Besides its economic bearing, it is valued for its energy content, and hence is used widely for power generation. It has many uses including but not limited to manufacturing of steel, nylon, activated carbons, fertilizers, styrene, medicines and many drugs (Speight 1994). Chemically speaking, Coal is an organoclastic sedimentary rock, composed essentially of lithified plant debris. The initial sediment found in this process bears a moist, spongy material called 'peat', which later becomes compressed, dried and modified in both texture and composition due to high pressure and increased temperature associated with burial and tectonic activity (Speight 1994).

Mining of coal is carried out in two forms; either as surface mining or underground mining. The selection of mining methods depends on the coal seam thickness, angle of deposition, terrain and the rock mechanics of the surrounding rocks (Hartman and Mutmansky, 2002; Miller et.al., 1995). In general, it can be subdivided into two methods i.e. surface or open pit and underground mining and 40 % extracted from surface and 60 % from subsurface mining (Nersesian, 2016). Geological condition of deposits and mineable area specify which kind of mining technology can be used in which area as thickness of the coal seam and angle of inclination may vary, depending on the geology and topography of the area. Similarly on the basis of thickness, coal seam can be classified into different types. Coal seams having thickness less than 0.8 m are extremely thin coal seams; whereas thickness ranging from 0.8 to 1.3 m are termed as thin coal seam and thickness more than 1.3 m are called thick seam coal (Dong & Pan, 2008).

Pakistan faces the problem of low production which can mainly be attributed to lack of planned activities, surveys and proper geological and geotechnical evaluation of rocks. Moreover, support material for mining is not selected properly e.g. timber is commonly applied to support the roofs of coal mines which at times is not adequate to support the roof or walls of the coal mines resulting in fatal accidents/casualties.

2. Coal mining history

Mining can be declared as the second of mankind's most primitive activities – established that farming was the first one. The profession of mining is as old as history of civilization, as the man, since ages has been using metals and alloys in his daily life. Coal was source of fire and energy as was used for melting of metals. According to Lama (1988), in Australia, coal was initially discovered at Lake Macquarie in 1791 immediately after arrival of the first fleet. In the beginning, coal excavation procedure was done manually (refer Plate 1), however became advance with the passage of time and increase in demand. In 1890s the first coal cutting machine was introduced at Greta whereas electricity was introduced in 1893 (Elford and Mckeowan, 1947). According to Lama, up-till 1925, 20% of the coal was being mined with machines and in 1935 loading of the coal through machines was also introduced. By then, coal excavation methods had become reasonably advanced and the exploration was almost being done with machines in 1960s. Shuttle cars were later introduced in the mining in 1970 and contributed to about 90 % of coal production.

In 1748, at Ohio, coal was revealed by travelers and frontiersmen, who noted a coal mine on fire near Lamanshika creek, nowadays known as Sandy creek. In 1755 a map of the Middle British colonies in America was published, on which term "coals" was noted along the Hockhocking River presently known as Hocking River (Crowell 2005). In 1800 manual production of coal was estimated at one million tons per year. Transportation to the local market was carried through carts, canal boats and flat boats but with the passage of time, but with the introduction of new methods and technology, the volume of coal exploration increased gradually. At Ohio, the first coal fire plant titled as the Tiffin Electrical Illuminating Plant, was established in December 1883. With the increase in demand and consumption of coal the production of coal increased (Crowell, 2005). In Indiana State the bituminous coal was discovered in 1736, initially along the River Wabash. Systematic coal mining started in 1800s with underground coal mining method.

In South East Asia, the coal was explored along the river Damodar – a main river in eastern India. Eastern India hosts some villages and towns having very interesting names like Kalipahari (Black Mountain) and Angarpathra - meaning pot of burnt coal- indicating coal deposits. The naming of mountains- on the basis of physical appearance - thus substantiates the existence of coal. As evident from the nomenclature assigned by the locals, the coal was used as fuel in India but no historical evidence was available regarding coal industry until the mid of eighteenth century. However, some documentation shows that in 1774-75 shallow mines were in progress at Raniganj fields of West Bangal which showed the origin of coal mining in India. In the First World War period the augmented requirement of coal boosted the coal industry. Another half decade between 1937 to1942 is considered an important period in development of coal industry (Glimpse of Coal India, 2006). In 1945, the Singareni Collieries Company Limited (SCCL) was established as pioneer Government Company in India. The company in fact started the coal production from Yellandu area presently known as Andhra Pradesh and explored about 60,000 tons of coal, Coal Directory of Indian (2007-2008).

3. Coal mining in Pakistan

From Pre-Cambrian age to recent strata different kinds of rocks with various sedimentary and tectonometallic basins have been found in Pakistan. Pakistan has large coal reserves in almost all provinces but these reserves are not found in proper compressed forms that can play a key role in the development of this sector. The Salt Range coal deposits are the most substantial. In this region the carbonaceous coal and coal deposits are located in the Paleocene Patala Formation, with a minor occurrence in the Tobra formation of the Permian age (Wynne 1878; Gee 1938; Bhatti 1967; Shah 1980; Hassan 1985; Alam et. al., 1987; Warwick and Shakoor, 1988).

According to Paracha (1990) in 1948, just after the independence of Pakistan, the annual coal production was 200,000 tons. At that time the coal mining industry embarked upon the human labor only. The coal was cut with hand picks, packed and transported in bags by animals and humans. No equipment and machinery was used. The method of mining was in the ancient form i.e. room and pillar. Initially, production was low. But, with the passage of time and increase in demand of coal for different development projects, the coal production increased and reached up to 1.5 million tons in 1965-66 and touched the figures of 2.2 million tons by 1984-85.

Malkani (2012) evaluated that the demand of coal for energy generation projects of Pakistan will increase further as it was 6.5 percent in the year 2003-2004 and 7.6 percent in the year 2008-2009. In his study, he further pointed out that in spite of large demand and presence of coal in Pakistan, coal has to be imported to fulfill the demands of coal in different industries in Pakistan. Increase in coal exploration rate and discovery of new reserves are very significant in order to meet the required escalating demands of the industry. He describes that since the dependence on coal will increase in energy sector, therefore capacity to produce coal should also be enhanced as of today.

Pakistan has a great potential for power generation through coal but it remained underutilized (Khan et al., 1990). Most of the coal in Pakistan is Lignite and is ranked qualitatively at 7th in the world (Ali and Khan, 2015). In order to get more production, modern and well organized mining methods and facilities should be used (Pandit et al., 2012). Galloway and Hobday (1983), Ferm and Staub (1984), McCabe (1984) and Fielding (1987) have evaluated that for exploration of fossil fuel reserves, classification of coal bearing paleo-environment has regional and worldwide applications.

Pakistan is facing energy crisis since the last decade. In the present dismal scenario, utilization of coal resources in the sector of power generation has become crucial. Fortunately, Pakistan is blessed with the sufficient coal resources regarded as the “Black Treasure”. Coal fields and different resources of Pakistan are presented in figure 1. The estimated coal potential of Pakistan is 185.175 billion tons, approximately. The share of Sindh in the aforementioned deposits is 184.623 billion tons, including the 5th largest reserve of the world having lignite variety, known as the Thar coal deposit (175 billion tons). The coal potential of Punjab, Balochistan and KPK is 0.235 billion tons, 0.217 billion tons and 0.091 billion tons, respectively (Ahmad et al., 1992). The analytical data of approximately 450 coal samples from different mines of Pakistan deciphered the presence of lignite to sub bituminous variety from Sindh and bituminous variety form Baluchistan, Punjab and KPK. The trace element analysis of the coal ranges of Pakistan is comparable with coal rank of United States (Warwick & Javed, 1990).

The highest mean calorific values are obtained for the coal of Balochistan, Punjab and KPK. The major consumers of coal in Pakistan are WAPDA, cement industry and brick kilns etc. besides, households at minor level. So, there exists a genuine demand of coal in Pakistan but its demerits which primarily arise because of its low quality which prohibits its optimal use. Its quality is low because of the presence of high content of sulphur and nitrogen in the indigenous variety. Moreover, release of huge quantity of carbon dioxide after combustion, and the presence of the extremely fine particulate matter further aggravates the situation and environmental hazards. As a consequence, various techniques, for the utilization of clean coal are introduced in the country e.g. Fluidized Bed Combustion, Coal Beneficiation and Coal Gasification etc. (Warwick and Javed, 1990).

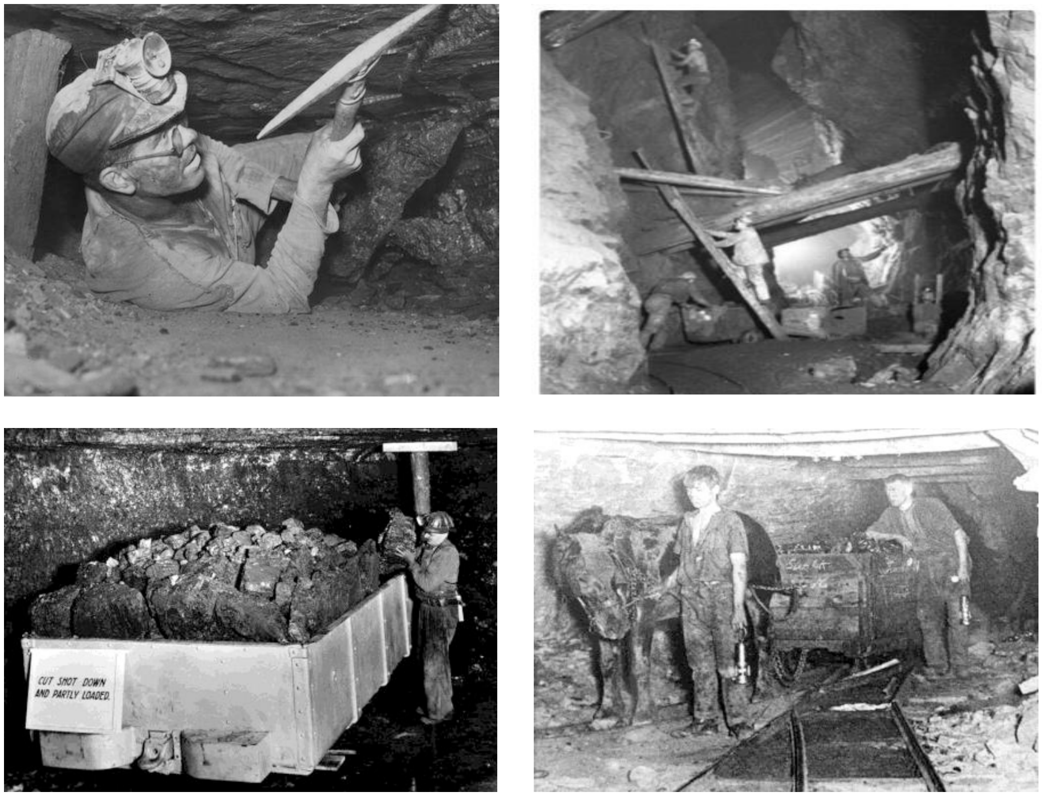

Plate 1. Coal exploration in ancient times was mainly carried out manually.

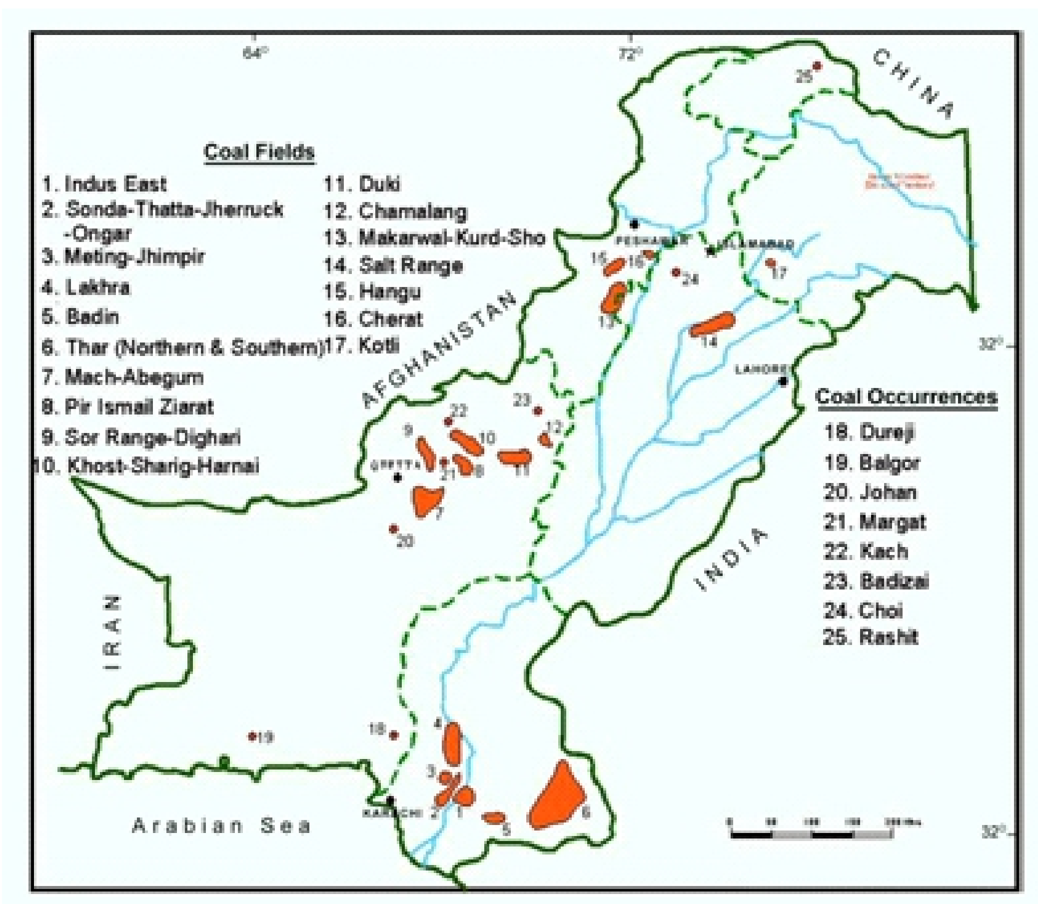

Fig. 1. Map showing coal reserves of Pakistan (Warwick and Wardlaw, 2007).

For coal exploration, different mining techniques are being pursued viz; room and pillar method and longwall system that are commonly applied in the areas of Balochistan, Punjab and Sindh. In KPK coal mining is less frequent (Paracha, 1990). The aforementioned statistics indicate that coal mining is of pivotal significance in Pakistan but the local coal mine support system does not meet the international standards (Plate 1 and 2). Timbering is commonly employed as the mine support technique in Pakistan, which causes frequent accidents in Pakistan and endangering the lives of labor. Poor roof supporting system i.e. wooden support caused a lot of collapses that certainly slowed down the production. These supports are designed without proper geotechnical evaluation and also without estimating the roof pressure of the overlying rock units, (Plate 3 and 4). Most of these accidents arise either from an insufficient number of support, or from improper placement, or after too great a lapse of time (Marck & Barczak, 2000). The rotting of the timber used for propping up the roof is also a frequent cause of the accidents, especially in poorly ventilated mines.

Coal grades in Pakistan generally range from lignite to high volatile bituminous. These varieties are friable with relatively high content of ash and sulphur. Most of the world's lignite deposits are located in Asia. Pakistan is among the top most lignite coal-bearing countries in Asia possessing almost 97% of the coal reserves bearing lignite variety. The rest of the grades are of sub-bituminous to bituminous content. Of all the reserves in Asia, 3% are located in Pakistan, (Malkani, 2012). Kazmi and Siddiqi (1990) evaluated that the main sources of coal in Punjab that are mainly distributed in Eastern & Central Salt Range, Trans-Indus Range and Makerwal area.

3.1. Accidents and fatalities in study area

During mining a number of accidents reported by Inspectorate of Mines from 2008-2013 are shown in figure 2 and presented in Table 1. The figures reported, shows that roof collapse and fall of side walls are the most common and frequent type of fatal accidents (Fig. 3) making almost 24 to 38% of total accidents from year 2008 to 2013.

Plate 2 and 3. Coal mines in progress in the Salt Range.

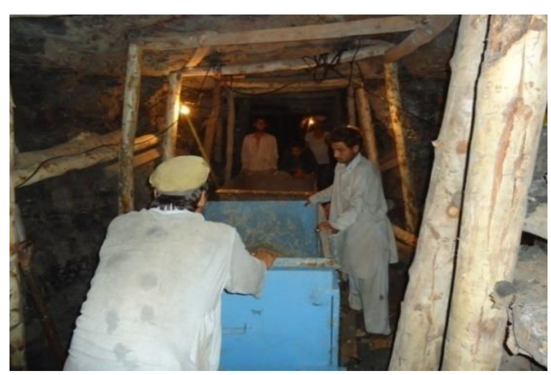

Plate 4 and 5. Field photograph representing use of Timber for support in Coal Mines.

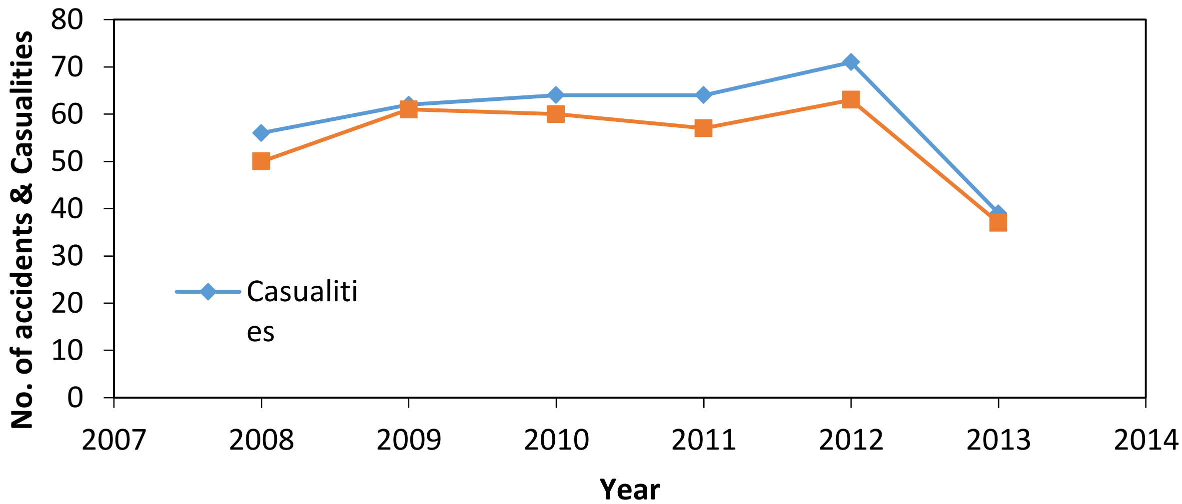

Fig. 2. Graph showing year wise causalities and accidents from 2008-2013.

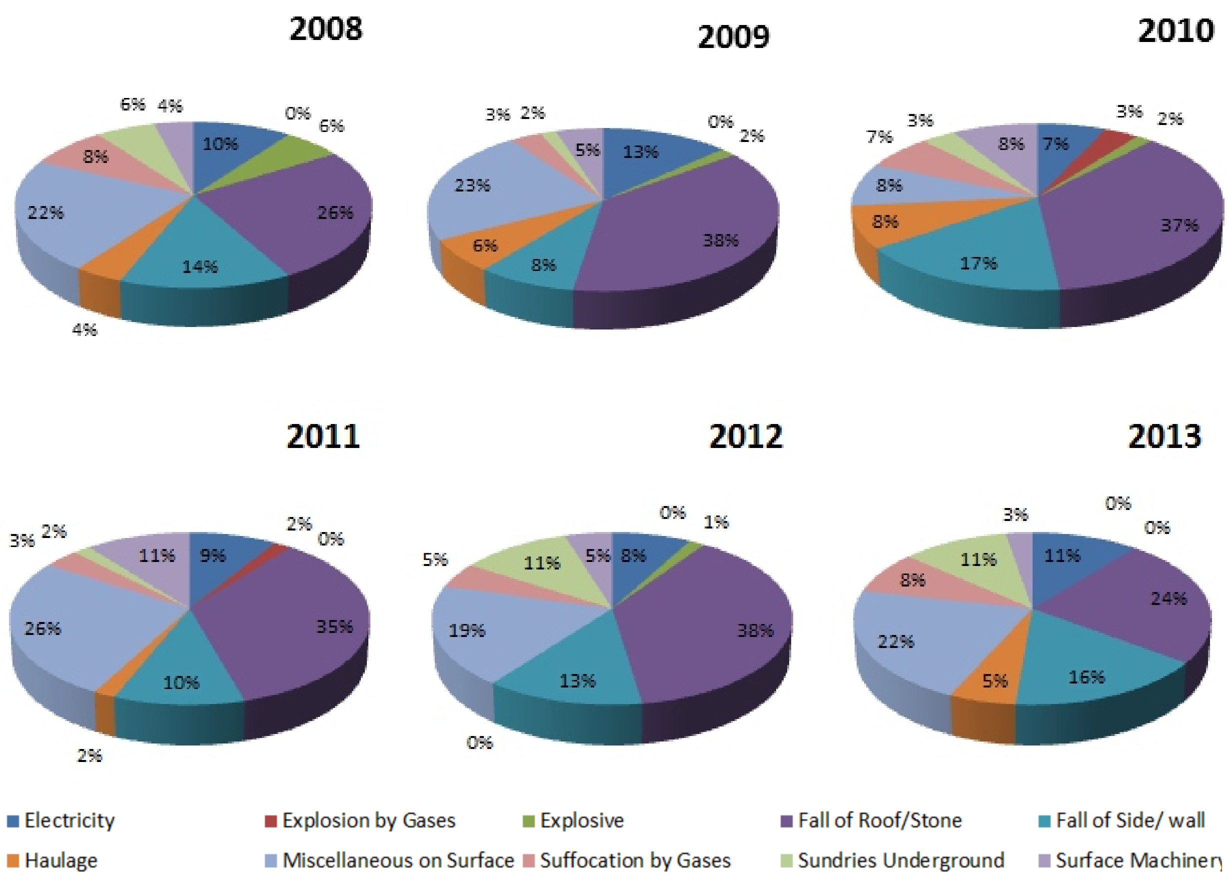

Fig. 3. Year wise (2008-2013) analysis of different accidents in mines, Salt Range.

Table 1. Classification Wise Fatal Accidents and Persons Died in Mines of Punjab From 2008 to 2013.

Clafication/Cause of Accident	2008		2009		2010		2011		2012		2013	
	Fatal Accidents	Persons Died	Fatal Accidents	Persons Died	Fatal Accidents	Persons Died	Fatal Accidents	Persons Died	Fatal Accidents	Persons Died	Fatal Accidents	Persons Died
Electricity	5	5	8	8	4	4	5	5	5	5	4	4
Explosion by Gases	-	-	-	-	2	3	1	4	-	-	-	-
Explosive	3	3	1	1	1	1	-	-	1	1	-	-
Fall of Roof/Stone	13	13	23	24	22	22	20	22	24	27	9	9
Fall of Side	7	8	5	5	10	10	6	6	8	11	6	8
Haulage	2	3	4	4	5	8	1	1	-	-	2	2
Miscellaneous on Surface	11	12	14	14	5	5	15	15	12	13	8	8
Suffocation by Gases	4	7	2	2	4	4	2	3	3	3	3	3
Sundries Underground	3	3	1	1	2	2	1	1	7	7	4	4
Surface Machinery	2	2	3	3	5	5	6	7	3	4	1	1
Total:	**50**	**56**	**61**	**62**	**60**	**64**	**57**	**64**	**63**	**71**	**37**	**39**

4. Coal mining in eastern salt range

Extraction of coal in the area started in the beginning of nineteenth century. Some of these mines are well developed nowadays and the coal is extracted from different sections of the eastern salt range. Coal is mined more protuberant in Ara and Basharat areas. During the field excursions, it has been perceived that mostly there is only one layer of coal but at some places the sand and clay partings divides the coal layer in two parts or layers.

A detailed engineering geological evaluation of the coal mines, in the area has been carried out. The mines that were identified on the satellite images have been verified through ground survey of the study area with the help of Global positioning systems (GPS) and visited during the field studies. A detailed survey has been carried out in the area and a summary of the selective coal mines in progress and closed has been compiled and presented in Table 2 and 3 and also marked on satellite image (Fig. 5 & 6).

A total number of 416 mines have been visited amongst these 63 are in progress while the rest have been closed. The main reasons found in abandoned mines are low production, low quality, water problems and the stability problems that causes roof or wall collapse in the coal mines.

Coal mining in the study area is being carried out with old techniques i.e. manually (Plate 6) and the coal excavated is transported to the surface or mine mouth by the old haulage system (Plate 7) or by the help of animals (Plate 8). In some mines of the study area both systems of transportation is used. Donkeys are trained to carry the coal to the mine mouth. The supporting system used in the mines have also not been found appropriate to support the mine roof and walls (Plate 9).

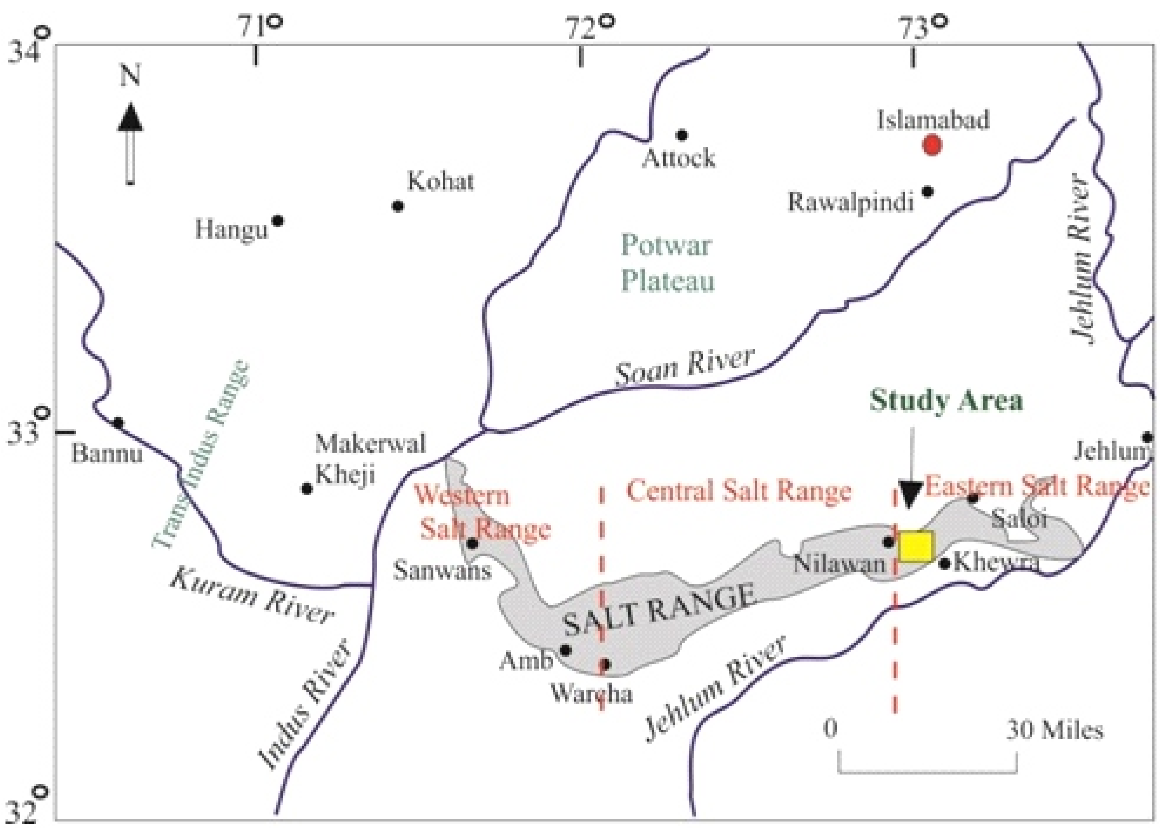

Fig. 4. Map showing the Eastern Salt Range (Study area).

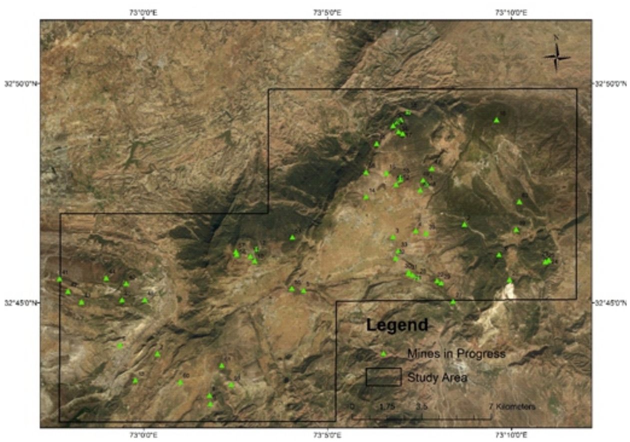

Fig. 5. Coal Mines in Progress in Eastern Salt Range.

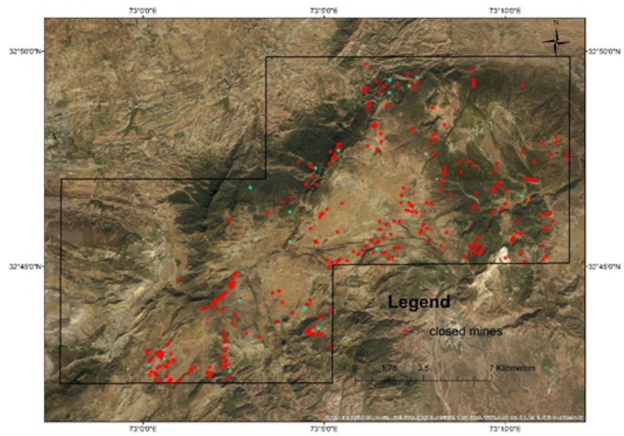

Fig. 6. Closed coal mines in Eastern Salt Range.

Table 2. Details of selective closed mines in the Eastern Salt Range.

Sr. No.	Mine No.	Location of mine		Mine Name	Reason of Closure
		Easting (m)	Northing (m)		
1.	1	3216645	955176	Mine No.6	Due to end of pocket seam & water problem
2.	5	3221709	958902	Mine No.6	The mine is closed due to heavy water problem.
3.	10	3220711	960539	Mine No.6-B	Due to water problem & explosive issue
4.	20	3221426	961275	Mine No.13	The mine is closed due to shortage of labour and explosive issue.
5.	30	3221414	956106	Mine No.1	The mine closed due to heavy water seepage.
6.	50	3214409.195	948169.2942	Tunnel No.2 Nali	Closed due to ending of coal seam.
7.	69	3211363	947656	Mine NO. 786	Closed due to Faulted area and Explosive issue.
8.	78	3218872	955653	Mine No. 5	Thin Seam, not economical.
9.	84	3222496	955836	Ali Mine	Roof fall in the mine.
10.	90	3221614	960703	Mine NO. 786-A	Due to Collapse of mine mouth
11.	93	3221527	960919	Mine NO. 786-D	Collapse of mine.
12.	111	3218586	958019	mine no.5	Collapse of mine.
13.	165	3211851	947781	Ratucha 7-B	Collapse of mine.
14.	149	3211931	948622	Dher No. 23	Seam thickness is not economical.
15.	200	3219623	960594	Mine No. 3	Extensive Water Seepage.
16.	230	3218560	951049	Qadir Mine	Explosive issue & Shortage of Labour
17.	255	3223208	957385	Mine No. 02	Fault line is passing through the mine. Difficult to stabilize the shear zone area.
18.	319	3227620	955569	Mine # 03 Jadeed	Closed due to low quality of coal seam.
19.	333	3227918	958679	Mine # 12	Due to fault problem and water
20.	349	3218432	952907	Mine No. 7	Collapse in Mine

Table 3. Detail of selective mines in progress, Eastern Salt Range.

Sr. No	Mine No	Northing	Easting	Mine Length (m)	Mine Diameter (m)	Mine Height (m)	Mine Inclination (o)	Overburden on Mine	Excavation Method	Lithology in Mine (m)	Coal Quality	Coal Seam Thickness (m)	Water Condition in mine	Support Type	Incident or Collapse reported
1	1	32°47'42. 6"	73° 07' 42.1"	153	2.5	2.6	30	1-2	Manual	0-120 Limestone, 120-130 shale, 130-143 Limestone, 143 -153 Coal	Good Quality	0.45	No	Timber	No
2	5	32 45 17.5	73 4 21.8	186	2.3	2.13	36	2 - 3	Manual	0-86 Limestone, 86-103 Shale, 103-112 Claystone, 112-165 Carbonaceous Shale, 165- 186 Coal	Low Quality	0.152	Water Seepage	Timber and Masonry Wall	No
3	10	32 45 58.9	73 3 3	353.	1.5	1.8	10	65-70	Manual	0-97 Limestone, 97 -143 Shale, 143-200 Carbonaceous Shale, 200 – 353 Coal	Lignite	0.30	Water Seepage	Timber	No
4	15	3629710	322197	109	1.5	1.8	30-35	10-12	Manual	0-15 Shale, 15-60 Limestone, 60-76 Shale, 76 -92 Limestone, 92-109 Coal	Low Quality	0.28	Water Seepage	Timber	No
5	20	3627093	327778	187	1.2	1.8	22	8-10	Manual	0-36 Limestone, 36-51 Shale, 51-76 Limestone, 76-143 Sandstone, 143-187 Coal	Good Quality	0.35	Water Seepage	Timber and Masonry Wall	2 Injuries
6	25	32º 45'56 .5"	73º 10'55 .7"	80	1.82	1.7	25	25-28	Manual	0-29 Shale, 29-61 Carbonaceous shale, 61-80 Coal	Good Quality	0.34	Minor Water Seepage	Timber	4 Injuries
7	30	73º 07'12 .6"	32º 45'42 .2"	197	1.76	2.4	33	2 -5	Manual	0-136 Limestone, 136-150 Shale, 150-180 Carbonaceous Shale, 180-197 Coal	Medium Quality	0.61	Minor Water Seepage	Timber	NO
8	35	32º 49'02 .0"	73º 6'48. 2"	354	1.4	1.4	36	50-55	Manual and Blasting	0-53 Limestone, 53-97 Claystone, 97-190 Shale, 190-320 Carbonaceous Shale, 320-354 Coal.	Low Quality	0.29	NO	Timber	NO
9	40	32º 45' 26.7"	72º 59' 23.2"	61	1.7	2.1	11	15-18	Manual and Blasting	0-43 Limestone, 43-52 Shale, 52-61 Coal	Good Quality	0.38	NO	Timber	2 Injuries
10	45	32º 45´34 .3″		92	2.2	1.9	26	8-10	Manual	0-64 Limestone, 64-81 Shale, 81-92 Coal	Low Quality	0.32	NO	Timber	NO
11	50	32º 47'48 "	73º 07'36 "	118	3.3	2.2	20	No	Manual and blasting in Lime stone	0-14 Shale, 14-45 Silica Sand, 45-100 Shale, 100-118 Coal	Good Quality	0.36	NO	Timber	2 Injuries
12	55	32º 45'27 .9"	73º 04'02 .9"	95	1.8	2.1	25	15-17	Manual	0-5 Over burden, 5-20 Limestone, 20-60 Shale, 60-64 Sandstone, 64-95 Coal	Medium Quality	0.29	NO	Timber	3 Injuries
13	60	32º 43' 8.3"	73º 02' 23.1"	158	1.3	1.6	15	1	Manual	0-10 Overburden, 10-30 Shale, 30-41 Carbonaceous Shale, 41-69 Sandstone, 69-97 Carbonaceous Shale, 97-103 Limestone, 103-136 14Claystone, 136-139 Shale, 139-15158 Coal	Good Quality	0.31	Water Seepage	Timber	No
14	63	32º 43' 34.5"	73º 02' 07.7"	152	2.1	2.1	27	1-2	Manual	0-5 Overburden, 5-71 Limestone, 71-78 Shale, 78-126 Claystone, 126-134 Carbonaceous Shale, 134-152 Coal	Medium Quality	0.37	No	Timber and Masonry Wall	No

Plate 6. Manual excavation in coal mines of study area.

Plate 7. Transportation of coal to the surface by mechanical haulage.

Plate 8. Coal transportation by animals from mine to the mine entrance.

Plate 9. Poor roof supporting system in coal mines.

4.1. Geological evaluation

The study area lies in the eastern segment of Salt Range (Fig. 2). In the study area the formations exposed are from Pre-Cambrian to late Miocene. Salt range formation of late Pre-Cambrian to early Cambrian is the oldest one and the Nagri formation of Pliocene is the youngest one (Sameeni, 2009; Ghazi et al., 2015). The main lithology/rock units of different formations are limestone, sandstone, shale, marl and clay stone. In the study area i.e. Eastern Salt Range the coal is being mined from the Patala Formation of the Paleocene age. The Permian strata (Nilawahan Group) are relatively thin and its thickness increases towards Central Salt Range. Mesozoic strata (Triassic, Jurassic and Cretaceous) are totally missing in the area due to erosion however it is thick in the Western Salt Range. As a whole, the Cenozoic succession (Paleocene, Eocene and Miocene-Pliocene) is well developed in the study area, however the Paleocene rocks are not so much exposed. The Nammal formation & Sakesar limestone of the Eocene have wide distribution throughout the Salt Range but Chorgali formation is present at few places. Kamlial formation of Miocene is well exposed in the study area but Murree formation is absent. Among the Pliocene Siwaliks, the Chinji and Nagri formations are well exposed. The rock units exposed in the study are presented in Table 4.

In the eastern and central Salt Range, coal and carbonaceous shale deposits are present as single beds, which are frequently split by dark grey shale or thin beds of quartzose sandstone. There exists a minor difference in the average thickness of coal and carbonaceous shale deposits of the eastern and central Salt Range. In the extreme eastern Salt Range, there are strikingly thick pockets of coal. In the areas where mining from the escarpment has been conducted for a long span of time, shafts into the hill side exceed 60 m. Limited borehole data indicates that the thickness of coal beds and the carbonaceous shale diminishes NW, toward a northeast striking void area in the central Salt Range (Warwick and Shakoor, 1988). The plateau areas of the Salt Range have been generally covered by Eocene limestone. Exploratory drilling has revealed the average depth of the local coal bearing zone to be approximately 130m (Warwick and Husain 1990). Moreover, the preliminary total coal resource for the Salt Range is about 235 million metric tons as estimated by (Warwick and Shakoor, 1988).

The Patala Formation is about 5 to 9 m in thickness and is comprised of dark gray fossiliferous shale interbedded with white quartose sandstone, siltstone, marl, limestone, carbonaceous shale and coal (Alam et al. 1987; Warwick and Shakoor 1988) in the eastern and central Salt Range. The Patala Formation is present above this and grades toward the west into the Lockhart limestone and Hangu Formation. The Patala Formation underlies the Nammal Formation, Sakesar limestone and Chor Gali Formation. This succession disconformably underlies the Kamlial Formation of the Miocene age.

a) Tectonic setting of the study area

The Salt Range has been divided into three parts, from Tilla Jogian to Khewra Gorge is known as Eastern Salt Range, Khewra Gorge to Sakesar Peak is Central Salt Range and from Sakesar peak to Kala Bagh Strikeslip fault in known as Western Salt Range (Gee,1989). In the eastern part, the Salt Range thrust is obscured whereas, in the central and western part it is prominent (Morely, 1986) with obvious folding (Lillie et al., 1987).

In Eastern Salt Range, the size and height of the Salt Range is decreased in the East and splits into two ridges having north-east trend, Dil Jabba and Chambal-JogiTilla, The hills of DilJabba comprises of upright anticline and crossed by the Diljabba-Domeli Thrust, whereas in Chambal-JogiTilla, the axial surface of fault propagating fold embraces steep dips (Qayyum, 1991) along with multiple thrust and split faults (Kazmi and Jan, 1997).

Gee (1980) stated that the Salt Range in the eastern part is marked by two back thrusted faults that are oriented NE-SW and are named as Dil Jabba fault in the northern part and Chail fault in the southern part. Dil Jabba fault has a prominent extension further in north-east wards, at a number of exposures it brings Salt Range Formation over the Nagri Formation and Chinji Formations at some places in the

Salt Range (study area). Whereas, Chail Fault, is not so much persistent and disappears in north-east and south-west directions.

DilJabbad fault when enters in the north-northwestern part of the study area, north of Basharat is named as DilJabba-Karangal thrust and comes to an end near Choa Saidan Shah. The Salt Range thrust is an emergent thrust front and a large low-angle detachement along which the Potwar Plateau has been translated southward (Jaume et al., 1988). Domeli fault splits to the southwest and named this the DilJabba thrust (Lillie et. al., 1987; Pennock et al., 1989). The DilJabba thrust is interpreted as a back thrust of the well-known Salt Range Thrust (Fig. 7).

Table 4. Stratigraphic Succession observed in the Eastern Salt Range.

AGE	GROUP	FORMATION	Rock Units
Pliocene, Late Miocene	Siwalik Group	Nagri Formation	Sandstone, shale
		Chinji Formation.	Clays, shale Sandstone
Early Miocene	Rawalpindi Group	Kamlial Formation.	Limestone, shale
Disconformity			
Early Eocene	Chharat Group	Sakesar Limestone	Limestone (nodular), chert
		Nammal Formation	Limestone, shale, marl
Paleocene	Makarwal Group	Patala Formation.	Shale (fissile, calcareous, carbonaceous)
		Hangu Formation.	Sandstone, shale, laterites
Disconformity			
Early Permian	Nilawahan Group	Warchha Sandstone	Sandstone
		Dandot Formation.	Sandstone(at places pebbly), claystone, shale
		Tobra Formation.	Sandstone, siltstone, shale
Disconformity			
Middle & Early Cambrian	Jhelum Group	Baghanwala Formation.	Sandstone, shale, clay
		Jutana Formation.	Dolomite, sandstone, siltstone, claystone
		Kussak Formation.	Sandstone, siltstone and shale
		Khewra Sandstone.	Sandstone and shale
Disconformity			
Late Pre - Cambrian to Early Cambrian		Salt Range Formation	Marl, gypsum, shale, dolomite

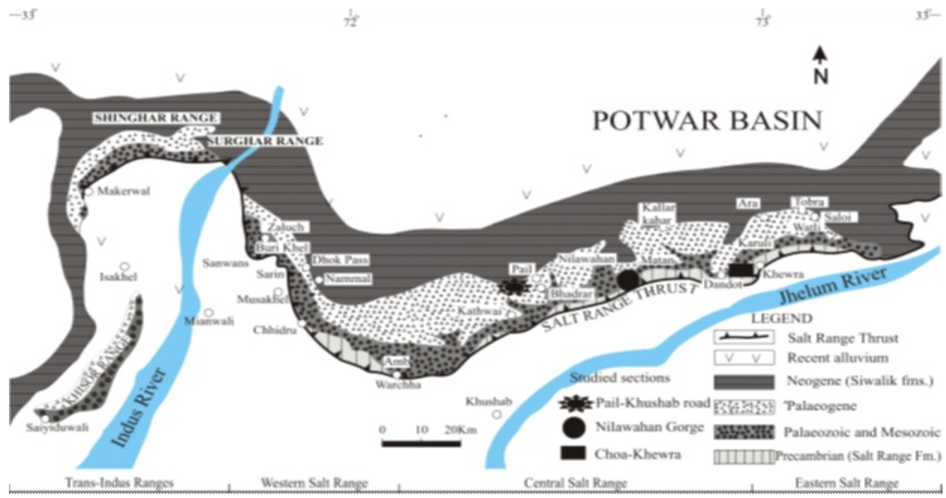

Table 4. Stratigraphic Succession observed in the Eastern Salt Range.

The Karangal Ridge is comprised of Precambrian-Cambrian sequence thrust over the Kamlial Formation of Miocene age belongs to Dulmial anticlinal feature. In the hanging wall, Khrewra, Kussak, Jutana and Bahaganwala formations are present. The transport direction along the Karangal back thrust is towards northwest. The structural geometry of hanging wall of Diljabba Thrust seen from valley present in NW of Wahali Zerin village. The rocks were observed dipping NE in direction and the strike of the Karangal Ridge was NNW. The Permian and Paleocene strata were noticed in the NE of Karangal Ridge.

The deformation along Diljabba-Karangal and Domeli thrusts show reversal of structural dips of uplifted sheets. The structural dip of Diljadda-Karangal Thrust sheet is dipping SE with a NE-SW strike. The Domali ridge was far in the back ground and showing regional dip opposite to DilJabba-Karangal stratigraphy.

4.2. Supporting system in coal mines

The supports provided in the coal mines are wood timbers, masonry walls and occasionally horse shoe. The masonry walls have been provided in the parts of coal mine where shale is exposed as the shale has very high swelling and slaking properties the miners are using a masonry wall technique to stabilize the shale. Cement of Dandot cement factory is used as cementing material (Plate 10). In mine no. 5, the iron horse shoe is being used along with timber to support the moderately to highly fractured limestone and sandstone (Plate 11).

Eucalyptus camaldulensis is being used as support in the coal mines of the study area (Plate 12). The fast growing quality, proper diameter to the breast height, easy availability in the eastern salt range, short time to grow as well as low cost of the Eucalyptus wood are the main reasons of most frequent use as support. It is adapted to a diversity of ecological conditions and consequently has been planted frequently and is especially favored on farmlands (Ashraf et al., 2012).

The timber of Eucalyptus is provided along the walls as well as on the roof to protect the roof fall (Plate 9). Weight of wood, related to its unit mass is known as wood density. This is an essential lineament of timber, as it controls the strength characteristics. The strength of wood depends upon its density and the strength increases with the increase in its density. The denseness is therefore generally used to estimate the strength characteristics of wood. Moisture contents of the wood are directly affected by the density of the wood. Most commonly the density of wood is given as dry air density, whereby the mass and volume of the wood are measured with its level of moisture at 15% (or 12%). Density is often also given as a dry-fresh density, whereby the mass of the wood is measured dry, and the volume saturation point (about 30%) at a high level of moisture. The wood density of Eucalyptus camaldulensis increases along the longitudinal direction and decreases along radial position from the pith to the bark (Sonderegger et al. 2008).

The durability of the heartwood depends on a high resin content, which increases its resistance to decay and pests. The resin contents of the Eucalyptus are relative low as compared to other species. During the studies it has been observed that at many places the effect of air, temperature and moisture has affected the timber and the supports are bended (Plate 13) and even broken at some places (Plate 14).

Plate 10. Brick wall in coal mines to support the shale.

Plate 11. Iron horse shoe shaped support in coal mine no.5 to support the shale

Plate 12. Eucalyptus is being used as Timber support in coal mines.

Plate 13: Timber bended due to weathering and ressure

Plate 14: Timber support provided at roof has been broken due to pressure.

5. Conclusion

Coal is one of the most important energy resources in the world. It can play an important role in development of the country. As Pakistan is facing shortage in energy resources, coal can be utilized to overcome the shortage in a number of industries and can also be utilized for power generation. In Pakistan, salt range has conspicuous coal deposits. These deposits are extracted by old and manual techniques that results low production with a high number of risk as the supports are provided without geological and geotechnical evaluations. The analysis of accidents in coal mines data represents that roof collapse, roof fall and side walls failures are the most prominent accidents in coal mines and continuous threat to labour life and also slows down the coal production. As the coal is extracted from the Patala formation in the Salt range and the roof of mines generally comprise shale that has swelling and slacking properties. On exposure, the rock pieces or coal falls from the roof of the mine on the men frequently, whilst they are at work and in a majority of cases are either instantly or ultimately fatal; whilst those who escape from being killed, are generally disabled for life by broken limbs.

In order to enhance the coal production, proper systematic and scientific approach is essential to analyze the mining technique as well as the support required that will certainly provide the safety to the life of labour and also will increase the production rate.

Acknowledgement

The authors are obliged for the services rendered by the Department of Earth Sciences, University of Sargodha, Pakistan regarding research work, Dr. Faisal Rehman, Mr, Saeed Hassan for Field work support and anonymous reviewers for their constructive comments. The manuscript is part of Ph.D thesis of Mr. Muhammad Fahad Ullah.

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