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Surface Coal Mining Methods in Australia

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1. Introduction

Minerals are one element of Australia's natural resource base. Other key natural resources include forestry and fisheries, and together with agriculture, they make a significant contribution to the Australian economy and Australia's Gross Domestic Product (GDP). Mining contributed 7.7% Gross Value Added in 2008-2009, up from 4.9% in 2005-2006 (University of Technology Sydney [UTS] and Monash University, 2010; Australian Bureau of Agricultural and Resource Economics [ABARE], 2010).

Australia's export earnings from energy and mineral commodities in 2010 were \$A165 billion, 25 per cent higher than in 2009 (ABARE, 2010). Australia's black coal exports were worth almost \$A43 billion in 2010, second only to iron ore (\$A49 billion) which was Australia's biggest export earner for that year. The total production of raw black coal in Australia in financial year 2010 - 2011 was 405 million tonnes (Mt). Black coal occurs in all States of Australia and the Northern Territory, but New South Wales (NSW) with 46% and Queensland (QLD) with 38% have the largest share of Australia's total identified resources. Queensland (55%) and NSW (42%) produce the most black coal with locally significant operations in Western Australia, South Australia and Tasmania. Figure 1 shows the black coal locations in Australia.

Figure 2 indicates the Australian electricity generation by fuel in 2008/2009. The major uses of Australian coal are

- electricity generation - thermal or steaming coal
- steel industry - coking coal.

In Australia, the major coal mining methods are as follows:

- Underground mining operations:
 - Longwall mining, and
 - Bord and pillar mining (also known as room and pillar mining).
- Surface mining operations
 - Open cut mining (strip mining)
 - Using draglines,
 - Using truck and shovels, and
 - Using a combination of above (integrated mining systems).

- Highwall mining
 - Continuous highwall mining, and
 - Auger mining.

This chapter will only focus on surface mining operations in the Australian coal industry.

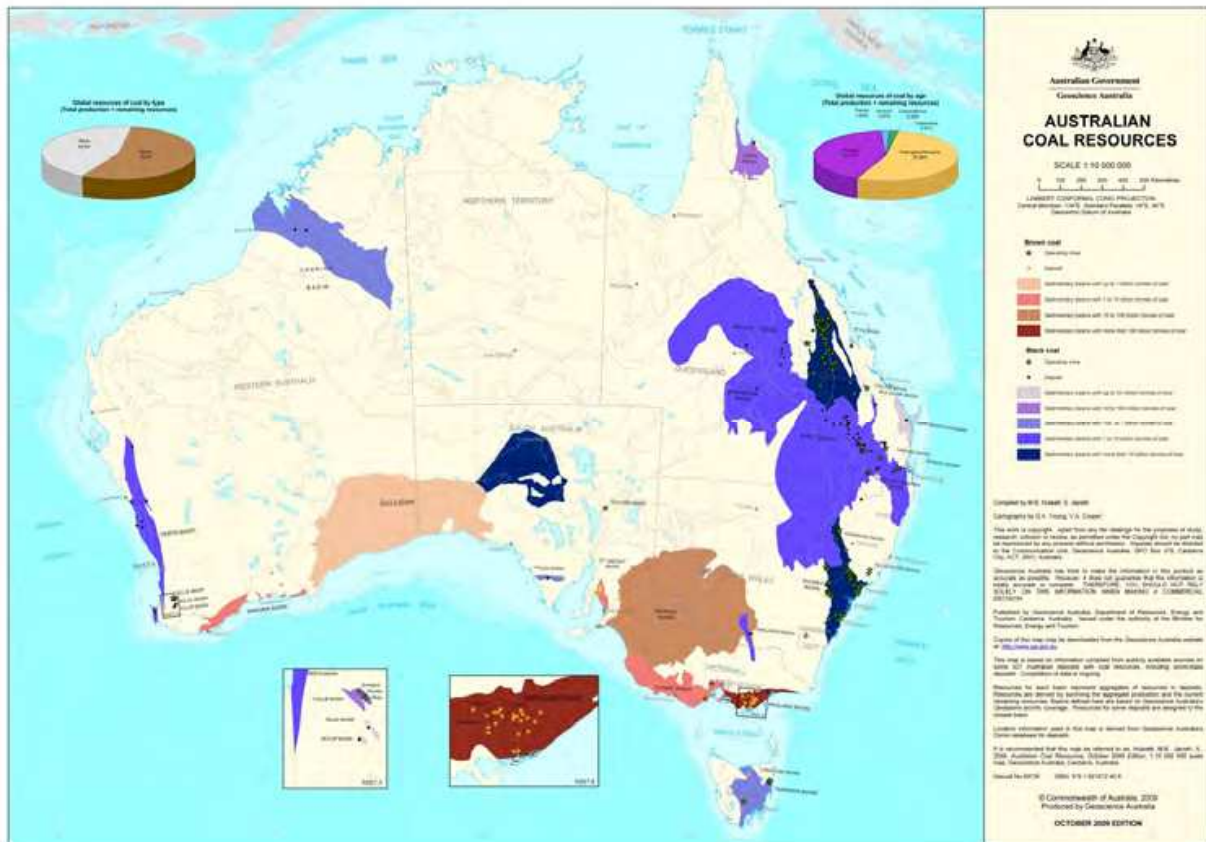


Fig. 1. Australian coal resource map (Geoscience Australia, 2009).

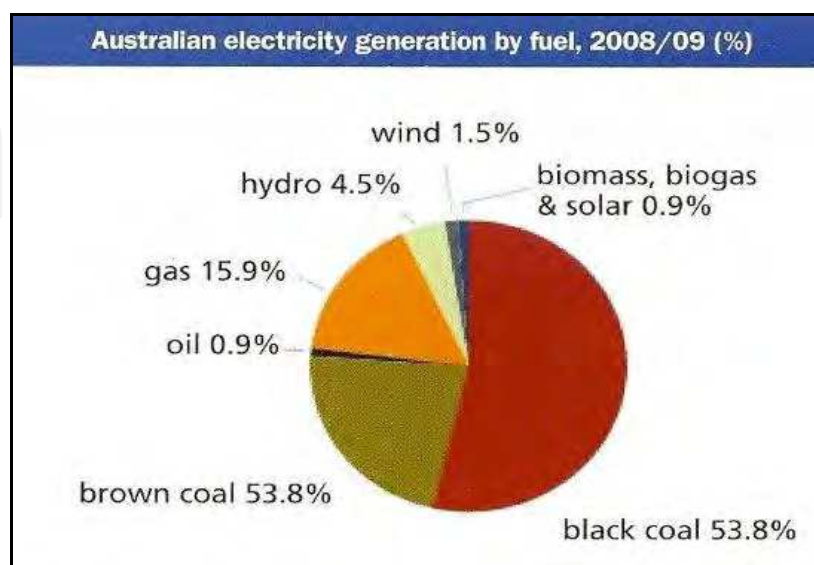


Fig. 2. Electricity generation by fuel (ABARE, 2010).

2. Open cut mining methods – strip mining

Large-scale open cut coal mining operations commenced in Australia in mid 1960s and since then there has been significant developments in this method of mining. The mines are now operating at significantly higher annual tonnages, growing deeper, more complex and operating at higher stripping ratios (Westcott et al., 2009).

The following major equipments are used in Australian coal mines:

- Draglines,
- Trucks,
- Shovels
- Bucket wheel excavators,
- Crushers and conveyors,
- Scrapers,
- Dozers,
- Slushers and dragline hoppers, and
- Surface continuous miners.

Initially open cut mines in coal mining was classified as strip mines where draglines were used, and open cut mines where truck and shovels were used. Currently a lot of mines use both equipment as integrated systems in Australia. Strip mining is ideally applied where the surface of the ground and the ore body itself are relatively horizontal and shallow and where a wide area is available to be mined in a series of strips (Westcott, 2004). Table 2 provides some examples of the Australian surface coal mines. Figure 3 illustrates a typical overall mining sequence of strip mine operation.

Mining method description	Example mines
Multiple seam, steep dip, truck and loader, strike cut haulback mine with truck and loader coal mining.	Mt. Owen (NSW), Leigh Creek (South Australia), Duralie (NSW), Ravensworth East (NSW)
Several seam, moderate dip, dragline, down dip strip mine with throw blast, dozer assist and truck and loader prestrip.	Peak Downs (QLD), Norwich Park (QLD), Hail Creek (QLD), Curragh (QLD), Moura (QLD), Hunter Valley - Riverside (NSW)
Multiple seam, moderate dip, truck and loader, block cut, haulback mine.	Liddell (NSW), Wambo (NSW), Camberwell (NSW), Hunter Valley - Cheshunt (NSW)
Multiple seam, moderate dip, truck and loader, down dip strip, haulback mine.	Mt Arthur North (NSW), Muswellbrook Coal (NSW)
Thick, single seam, moderate dip, dragline - down dip - strip mine with throw blast, dozer assist and truck and loader prestrip.	Blair Athol (NSW), Newlands (QLD), Gregory (QLD), Goonyella/Riverside (QLD), Saraji (QLD)
Thick, single seam, moderate dip, bucketwheel excavator, block, cutback mine.	Yallourn (Victoria), Yoy Lang (Victoria), Hazlewood (Victoria)
Multiple seam, moderate dip, dragline down dip, strip mine with throw blast, dozer assist and truck and loader prestrip	Bengalla, Drayton, Bulga, Warkworth, Hunter Valley - Howick

Table 1. Examples of Australian surface coal mines (adopted from Westcott et al., 2009).

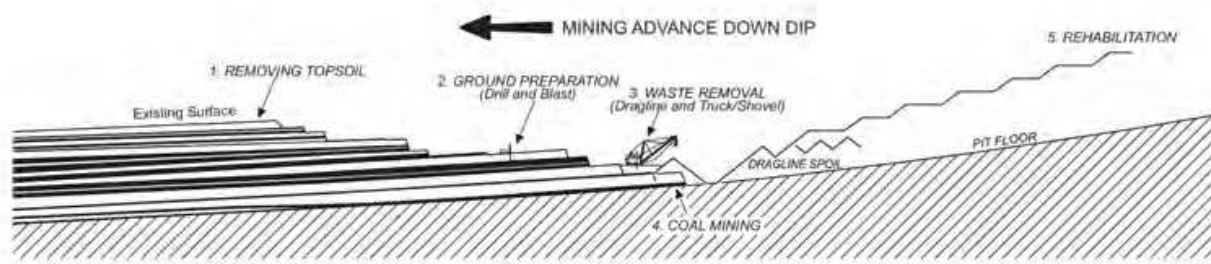


Fig. 3. Overall mining sequence of a typical surface coal mine in Australia (after Westcott et al., 2009).

2.1 Dragline method

Dragline is the predominant machine which is used to remove the overburden and expose the coal when the deposit's characteristics match the draglines' physical capabilities. Once the characteristics of the deposit alter from the physical limitations of the dragline, the overburden removal becomes costly as the machines' rehandle increases (Scott et al., 2010). In this situation, typically in multi-seam mines, truck and shovels are introduced to create an integrated mining sequence, which operates in tandem to generate a cost effective and efficient mining system (Fox, 2011).

Draglines are the lowest cost overburden removal equipment in common use. However, they are generally restricted to (Westcott et al., 2009):

1. Large deposits to ensure adequate strip length and sufficient reserves to justify the capital expenditure.
2. Gently dipping deposits, due to spoil instability on steep dips.
3. Shallow deposits, as draglines can only excavate a maximum of 50 to 80 m of overburden due to reach and dump height limitations. At greater overburden thicknesses draglines may be supported by pre-strip with alternative equipment, but the compromises this entails usually adversely affects the cost effectiveness of the pre-strip.

There were 68 draglines operating in QLD and NSW in 1992, with additional draglines either being built or ordered (Baafi and Mirabediny, 1998). While the most common machines average a 46m³ bucket size, there has been a trend in favour of larger machines. These draglines feature much larger bucket sizes (up to 115m³) and dimensions allowing the draglines to operate at greater depths and widths without needing pre-stripping and reducing rehandle (Aspinall et al., 1993; Gianazza, 2010). A typical dragline section is shown in Figure 4.

Draglines work in strips, which are typically 40 to 90 m wide and few kilometres long and the overburden is excavated by the dragline and dumped on the surface for the initial strip (box cut) and subsequently in adjacent mined out strips as illustrated in Figure 5.

Strips are generally aligned along strike with each subsequent strip down dip from the previous strip. The dragline starts at one end (or the middle) of the strip and advances along the strip to the other end. At the completion of each strip the dragline relocates to the start of the strip and commences the next strip, this is referred to as deadheading. Ramps for coal

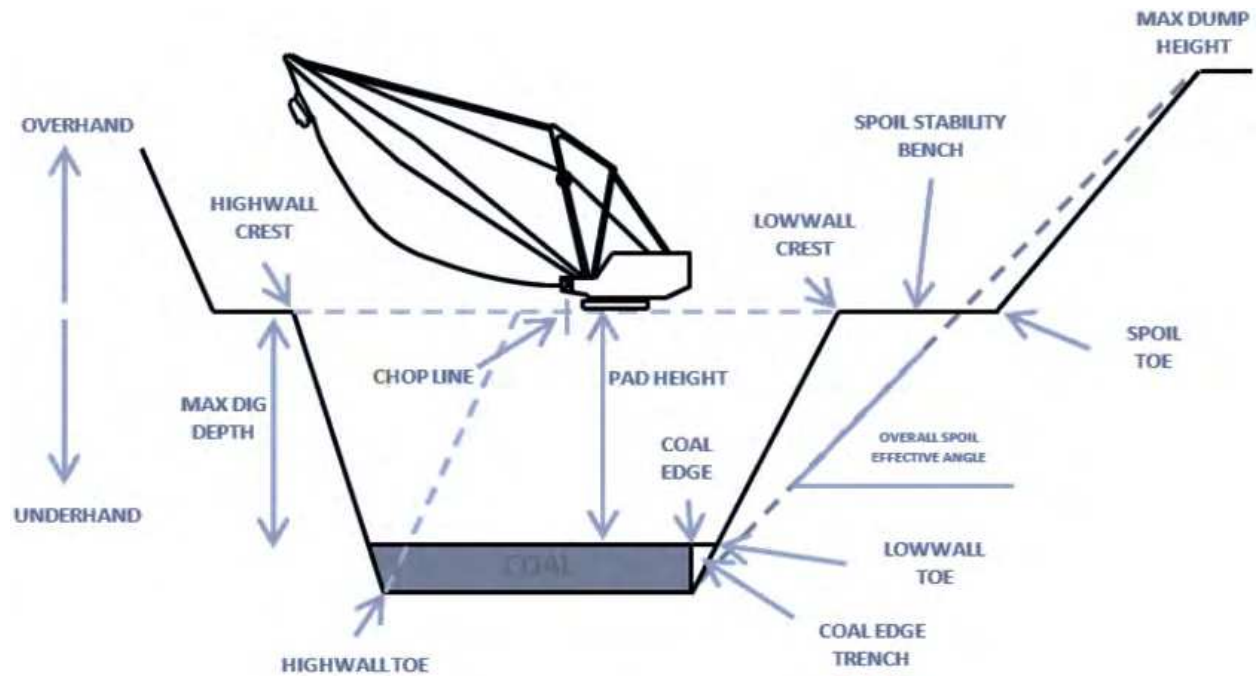


Fig. 4. Dragline Working Section (Gianazza, 2010).

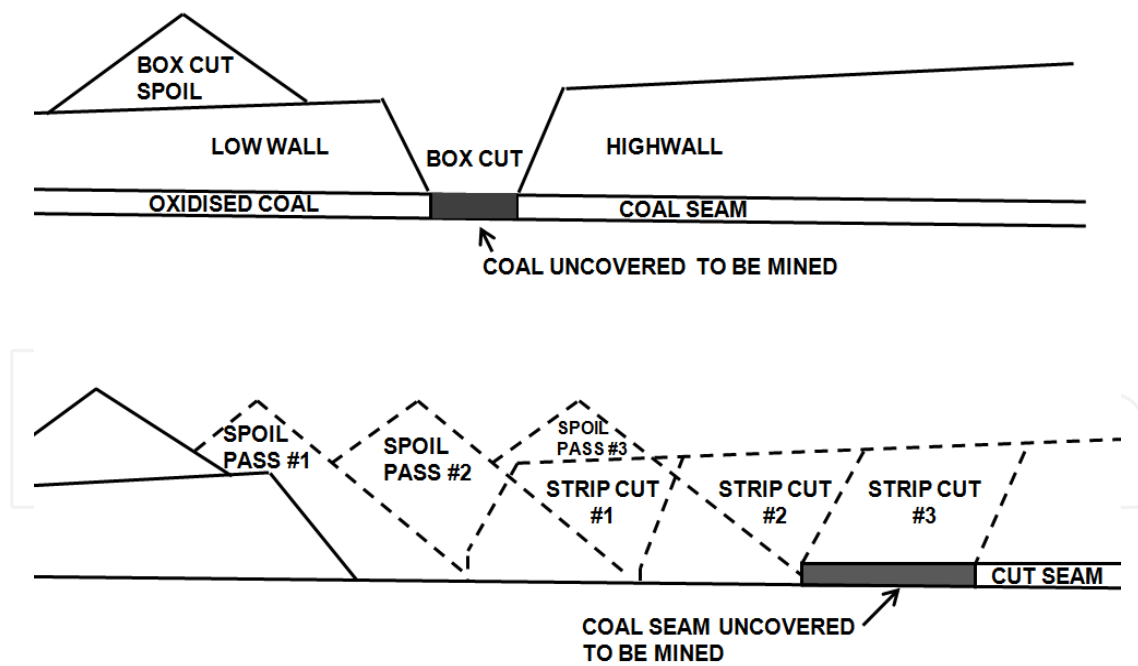


Fig. 5. Box cut, strip cuts and spoil piles (Humphrey, 1984).

mining access are either taken through the overburden dump as a valley, dozed through the spoil pile parallel to the strip, created in the highwall either parallel or at right angles to the strip, or by a combination of these alternatives. Draglines are often supplemented by throw blasting and/or dozer assistance to increase overburden removal capacity (Westcott et al.,

2009). Figure 6 illustrates a typical dragline while removing the material in one of the NSW mines.

The following are some of the advantages of using a dragline:

- Direct cast (excavate and transport),
- Low operating cost, and
- Handles hard digging.

The following are some of the disadvantages of a dragline:

- Constraints on dig depth and dump height,
- Relatively inflexible,
- Requires detailed planning, and
- High capital cost.

The rigging on a conventional dragline weighs 20 tonnes and this has not changed in design in 100 years. This conventional rigging system limits the flexibility of the dragline operation and makes bucket control difficult. Along with high productivity costs when a dragline is out of action for rigging maintenance, there is also substantial safety hazards associated with replacing heavy pieces of equipment.



Fig. 6. A typical dragline in operation in Hunter Valley Region in NSW.

A new technology was developed by the Cooperative Research Centre for Mining (CRCMining) Australia called the Universal Dig and Dump system (UDD). This replaces conventional rigging with a lighter, innovative configuration, improving operational flexibility. A medium sized UDD can move up to 13 tonnes more dirt in each pass and a

specially designed computer system provides precise control over the bucket, enabling the dragline to dig and dump anywhere under the boom (Mining Technology Australia, 2011). This was developed in conjunction with BHP Billiton Mitsubishi Alliance (BMA). This has resulted in a significant improvement in productivity and is being installed on many draglines operating in Australia. Figure 7 shows one of these buckets in operation.

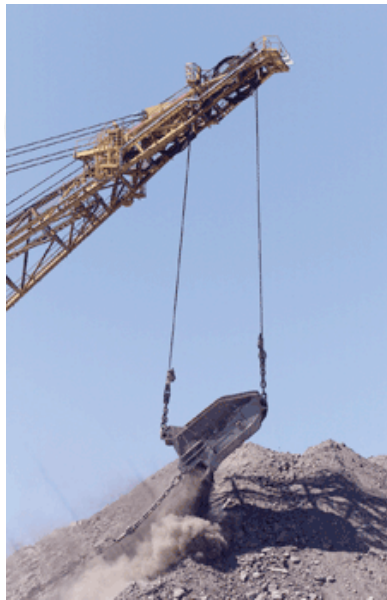


Fig. 7. A UDD bucket in use (Mining Technology Australia, 2011).

2.2 Truck and shovel method

Truck and shovel mining method is the most flexible mining method and therefore better suited to geological complex deposits, varying overburden depths and thicknesses, and smaller deposits (Westcott, 2004). They offer cheaper capital investments than draglines, however they cost more to operate on a bcm (bank cubic metre) per hour removal rate. Another major benefit with the system is the ability to haul material long distance to ensure rehandle will not become an issue in the present time and future of the operation (Fox, 2011).

Truck and shovel method is inherently more flexible than dragline methods which makes them better suited in the following applications (Westcott et al., 2009):

1. Geologically complex deposits with resultant irregular pit shapes, which could not be efficiently mined by a dragline.
2. Steeply dipping deposits, where the equipment cannot operate on the seam roof and floor. Mining commences at one end of the deposit and advances along strike with strips laid out down dip. Overburden is initially dumped expit and then inpit when sufficient dump room is available. The pit is excavated as a series of horizontal benches (terraces) and coal and waste are exposed on every bench. Each bench extends from the floor of the lowest seam to the down dip economic pit limit.
3. Basin deposits that combine the problems of steep dips at the margins with short strike length and varying overburden depth along the strip.
4. Small deposits, which do not require the high productivities gained through use of a dragline.

'Haulback' mining is a particular application of a loader and truck operation. It refers to the fact that the waste is 'hailed' (transported) and dumped 'back' into the previously mined out area. Where the advance is down dip the configuration is not that different from a dragline strip mine and techniques such as throw blast and doze assist can also be incorporated. A good example of this design is Mount Arthur North of BHP Billiton in the Hunter Valley, NSW. To keep haul distances as short as possible, many operations make use of rehandle bridges across the strip to transport waste from lower benches to the dump. As mining depth increases, a greater proportion of waste is long hauled around pit endwalls to the upper dump levels. 'Terrace mining' also dumps in pit but mines along the strike so the waste dump is keyed into a highwall. Multiple waste haulroads link the mining terraces to waste benches. This minimises haul cycle times for waste removal by reducing the vertical component of the haul. For the technique to work successfully both the mining terraces and the dump benches must be offset from adjacent benches to allow operational scheduling of mining activities. The method relies on the highwall being planned in its final position because once the mine is backfilled it would be a big economic hurdle to rehandle the waste to add another down dip increment. 'Cutback' open pit mining is where the waste is not dumped in pit but the waste is hauled to an external dump. Reasons for not dumping in pit could be that the floor is too steep for stable dumps or else the option of coming back later to either deepen the pit or extend the highwall down dip are part of the long-term plan. Panel shapes and sizes are dictated by production requirements, available equipment fleet and deposit geometry, rather than by parallel strips. Cutback mining may be used equally well in steeply or shallowly dipping deposits (Westcott et al., 2009).

The versatility of the system and ability to haul large distance makes this system extremely favourable in nearly all mining situations (Hays, 1990). Once equipment has been selected and the four main issues of cycle time are targeted and managed as best as possible to the conditions, will the system perform and achieve high production rates (Fox, 2011). A typical truck and shovel operation can be seen in Figure 8.



Fig. 8. A view of a truck and shovel operation in Hunter Valley Region in NSW.

2.3 Integrated mining system – combination of truck & shovel and dragline

The integrated mining system where truck and shovel is combined with the use of a dragline for overburden removal, provides a system with many benefits. Generally, the truck and shovel system is used to remove the upper and thinner overburdens found within a deposit and the draglines remove the much deeper overburdens, which would be out of the working range of a shovel operation (Aiken and Gunnett, 1990), as shown in Figure 9.

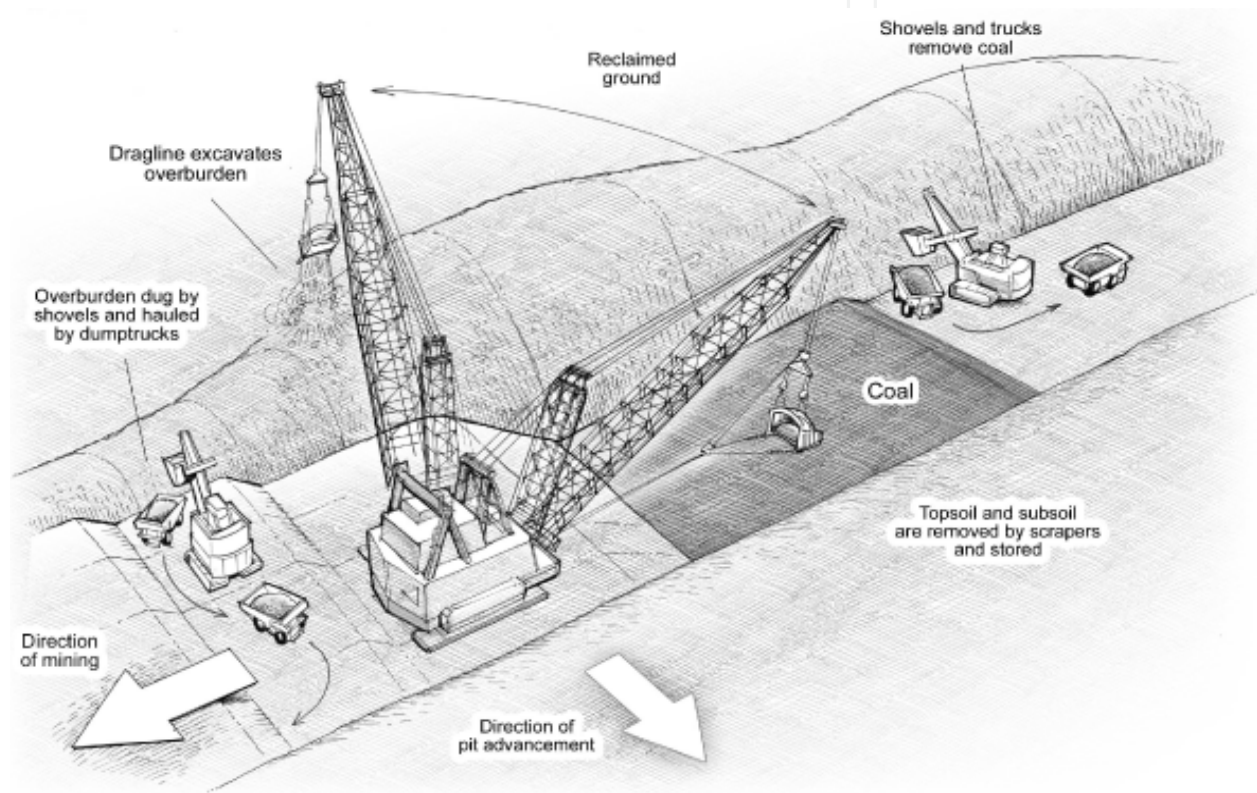


Fig. 9. Integrated Mining System – combination of Truck & Shovel and Dragline methods (after Fox, 2011).

3. Case studies

3.1 Mount Thorley Warkworth mine, NSW

Mount (Mt.) Thorley Warkworth is an open cut coal strip mine located in the Hunter Valley, approximately 15km south of Singleton, NSW. The mine is owned by Coal & Allied and is operated by Rio Tinto Coal Australia, which is one of the largest mining companies in the world. Mt. Thorley Warkworth is a joint venture between Coal & Allied Industries Limited (80%) and Posco Australia Pty Ltd (20%). Coal & Allied has been around for 150 years and along with Mt. Thorley Warkworth. Figure 10 shows the location of Mt. Thorley Warkworth mine in the Hunter Valley Region.



Fig. 10. Mt. Thorley Warkworth locality map (after Fox, 2011).

Mt. Thorley Warkworth Mine currently produces around 12mtpa (million tonne per annum) of thermal export coal with the possibility of ramping up to 15mtpa in the future. The mine has operated an integrated mining system since the site's commencement in 1981. The site has two processing plants on site, due to the merger of the pits, and the coal type and quality depend on which plant the coal is delivered to. Once the coal is washed, it is then transported with the help of a conveyor to the coal loading unit for transport to Newcastle Port for exportation. Currently, the fleet system has 76 trucks ranging from 190t to 240t trucks, with the purchase of 330t trucks scheduled for 2012 (Corrigan, 2011).

The draglines operate in the lower portion of the seams where the interburden are the greatest and the pre-strip shovels and excavators are used on the upper portion of the deposit, where the interburden average is around 15-20m. The highwalls are 70 degrees, lowwalls are 45 degrees and the spoil and dump angles are 37 degrees. These angles allow the pit to operate safely as the geotechnical conditions are extremely favourable (Fox, 2011).

Mt. Thorley Warkworth Mine has a life of mine until 2050 and with the current coal processing capacities, the site has the ability to achieve a much higher production rate and increase the revenue generated. Figure 11 illustrates the aerial view of the mine and Figure 12 shows the truck and shovel system currently operating and removing the pre-strip material.



Fig. 11. Mt. Thorley Warkworth Mine aerial view (Fox, 2011).



Fig. 12. Mining sections in Mt. Thorley Warkworth Mine (Fox, 2011).

3.2 Curragh mine, QLD

Curragh Mine is located in the Central Queensland's Bowen Basin coal fields near Blackwater and operated by Wesfarmers Curragh Pty Ltd. The first successful extraction of coal occurred during the 1960's in the area. In 1984, Curragh Mine began export of hard coking coal, mostly to Japanese and Korean smelters. Since then, the mine has undergone two major expansions: developing the Curragh East deposit on the eastern side of Blackwater Creek and the Curragh North deposit, which more than doubled the recoverable reserves available in 2005 (Gianazza, 2010). Figure 13 shows the location of the mine.

Curragh Mine currently has a mine life up to 2025, with over 220 million tonnes of coal reserve within the mine plan and produces three different coal products: export metallurgical, domestic thermal and pulverised coal injection coals, each with varying specifications and parameters. The mine has a unique combination of complex geological settings and equipment compared with other mines in the Bowen Basin, QLD. Mining operations in Curragh Mine have five major seams with four of these seams mined in a single pit. The average seam thicknesses for each of the coal seams mined vary between 1 and 2.5m at the mine. Due to the geological complexity of the mine, the process differs significantly from pit to pit. Developed over a strike length of approximately 16 km, mining at Curragh Mine commenced at the line of oxidation (LOX) and has progressed down dip to the east. There is also a general trend in the topography sloping towards the east, limiting the increase in prime stripping ratio. Prior to removal of overburden, vegetation is removed, the land is assessed for indigenous significance in the area, and the topsoil stripped and stockpiled for later use in rehabilitating previously mined areas. With the exception of the first top 20m at Curragh North, all overburden and interburden are drilled and blasted for removal through either truck and shovel or dragline operations (Gianazza, 2010).



Fig. 13. Location map of Curragh Mine (Gianazza, 2010).

Curragh Mine operates four large capacity walking draglines as primary stripping machines, including one of the world’s largest, with a 114m³ bucket. Depending on the pits

and faulted areas, the draglines generally operate a multi-pass digging method, with strip widths usually in the range of 60-70 m range and highwalls designed at 63 degrees. The mine also operates a unique fifth dragline which provides significant operational flexibility, performing specific tasks more efficiently and effectively than a truck and shovel operation. This significantly facilitates overburden removal around highly faulted areas, due to its small size and high mobility. The coal removal process is undertaken by multiple fleets of hydraulic excavators, belly-dump coal haulers (204t) and rear dump trucks (180t). Coal is transported to the Coal Handling and Processing Plant (CHPP) and discharged at two 500t hoppers. The CHPP is dual line in design, with total crushing capacity of 2,400t of raw coal per hour. The plant allows flexibility by running coal to the preparation plant feed stockpiles through one line, and running bypass steam coal through another. Simultaneously processing two different coal types, the plant handles more than 1,400t of coal per hour through three modules. Product coal is stacked onto two stockpiles, each capable of holding 150,000t of coal. A bucket-wheel reclaimer loads the 7,000t coal trains at a rate of 3,000t per hour (Gianazza, 2010).

A total of 7 truck and shovel circuits combined with the operation of 5 draglines and the largest single span conveyor in the Southern Hemisphere, makes Curragh Mine both unique and successful at being one of QLD's leading producers of metallurgical and thermal coal (Brown, 2007). A monitoring system was placed in all 5 draglines in 2009, which provides production monitoring, high-precision GPS (Global Positioning System) and bucket depth control information back to operators.

3.3 Mount Arthur Coal mine, NSW

Mt. Arthur Coal Pty Ltd, fully-owned by BHP Billiton, operates the Mt. Arthur Coal open cut mine situated 5km south of Muswellbrook in the upper Hunter Valley of NSW (Figure 14). The mine produces thermal coal used for power generation. The coal is sold to both domestic and export markets. Production capacity of the mine is 20mtpa of raw energy coal and the operation shares the area with rural properties and other industries such as horse studs, vineyards, olive groves and residential suburbs.

Current mining activities are focused on 21 unique seams which were identified during the exploration stage. Mining is conducted using truck and shovel mining fleet. Mining equipment consists some of the largest and quietest trucks engineered in the world. The overburden mining fleet consists of rear dump trucks and rope shovels, while the coal mining fleet consists of trucks and a combination of excavators. Mining activities occur 24 hours per day, 7 days per week, on 12 hour shifts supported by approximately 1,000 full time equivalent personnel.

Mt. Arthur Coal currently operates under separate planning approvals for the Bayswater No. 3 Mine, Rail Loading Facility, Mt. Arthur North Mine, South Pit Extension, Exploration Adit and the Mt. Arthur Underground (Figure 15). Open cut mining is conducted via a multi-bench, multi-strip shovel and excavator operations, which provide for the greatest operational flexibility and efficiency in the staged recovery of the coal resource at Mt. Arthur Coal. The extraction of coal via open cut methods is currently undertaken from the Mt. Arthur North and South Pit Extension area, as well as the Bayswater No 3 area, in which Saddlers Pit is mined using a contract fleet. To date only a limited amount of underground

coal has been extracted from the Woodlands Hill seam via the Exploration Adit (Bailey, 2009).

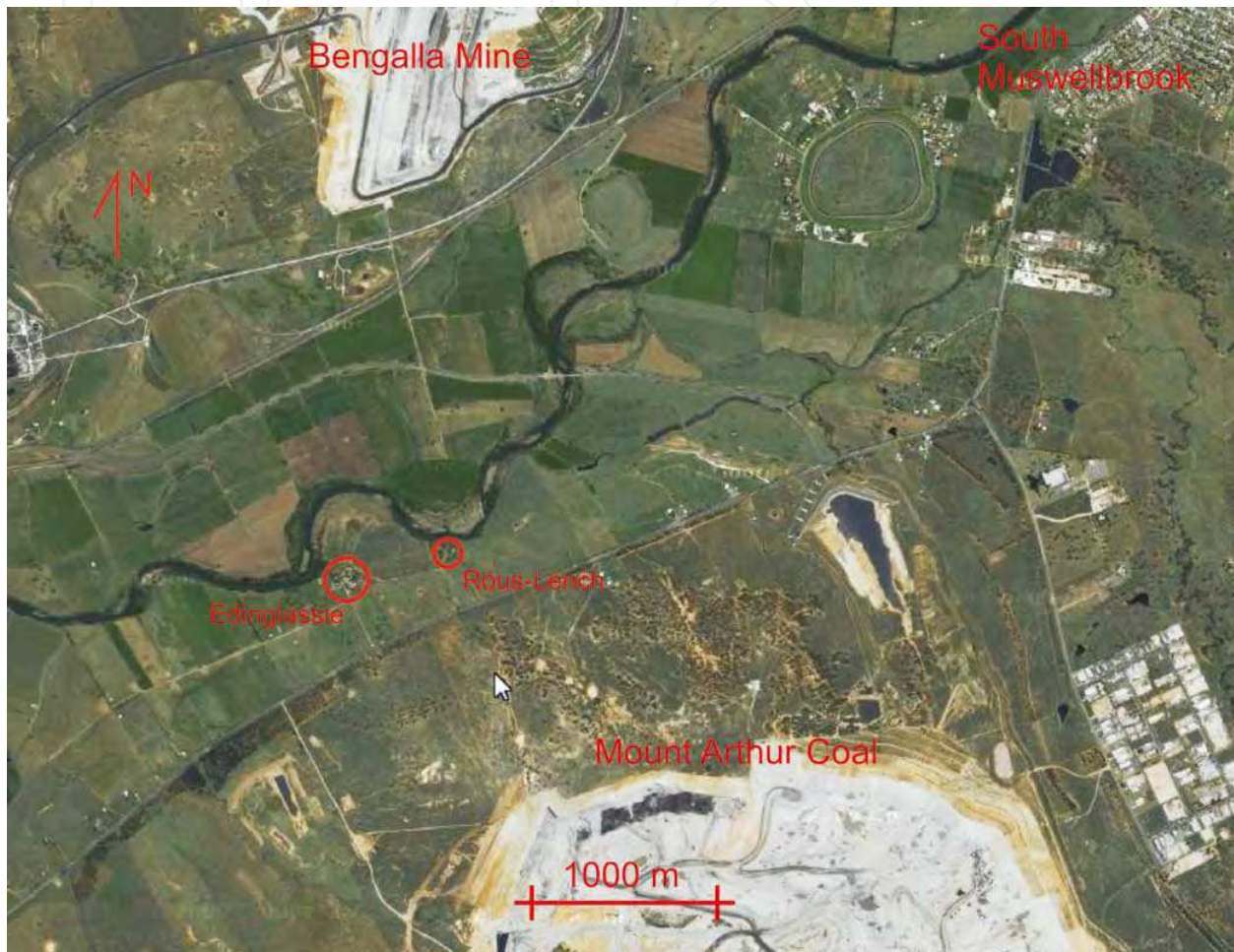


Fig. 14. The location map of Mt. Arthur Coal (Bill Jordan & Associates, 2009).

Large electric shovels are used to remove overburden and excavators are used to load coal into large capacity haul trucks for transportation to the CHPP and it is located adjacent to the mine. Figure 15 shows an example of an excavator dumping onto trucks. Preliminary crushing takes place at the base of the hoppers before a conveyor transports the coal to the crushing station. Up to 2,000t of raw coal is fed through the crusher and 1,200t through the preparation plant per hour. The CHPP is where the coal is crushed, screened, cleaned and sorted according to market requirements. After the coal has been removed, rehabilitation is a priority at the mine. The overburden is replaced, shaped, covered with topsoil and replanted to resemble the original landscape (Umwelt, 2006).



Fig. 15. Excavator removing the overburden and dumping onto trucks at Mt. Arthur Coal Mine (after Tredinnick, 2005).

Once crushed, the coal is transported to one of three locations:

- The domestic coal stockpile and then transported by conveyor to the local power station. Approximately 1.7 million tonnes of coal is used for domestic energy generation each year.
- The coal preparation plant where any impurities are removed, and then transported by conveyor to the export coal stockpile.
- Directly to the export coal stockpile and then to the export coal rail load-out facility for transportation to the Port of Newcastle. Approximately 10.7 million tonnes of coal was transported by rail to Newcastle in 2010.

The coal mining industry is concerned to minimise its impact on all aspects of the environment - visual landform, air and water quality, noise levels, native flora and fauna, soil conditions, and historic, indigenous and archeological sites (Australian Coal Association, 2011). One of the best examples of an environmental management of mining activities is Mt. Arthur Coal Mine. In 2010, approximately 12.3 million tonnes of coal was transported from Mt. Arthur Coal. From initial mine planning through to final site rehabilitation, the mine aims to minimise the impact of the operations on the natural environment and nearby residents.

A range of environmental issues and social impacts need to be managed at the mine site. The degree to which these are involved with the mine planning and operations department is determined by the location of the site and the inherent characteristics of the deposit and

surrounding environment. Mt. Arthur Coal has a large number of statutory approvals relating to environmental management that cover the different activities on site. In total the operation must comply with more than 1,500 approval constraints, in addition to the requirements of government policies and legislation (Tredinnick, 2005).

The proximity of the Mt. Arthur Coal operations to the community of Muswellbrook exacerbates certain facets of the operation (Figure 16).

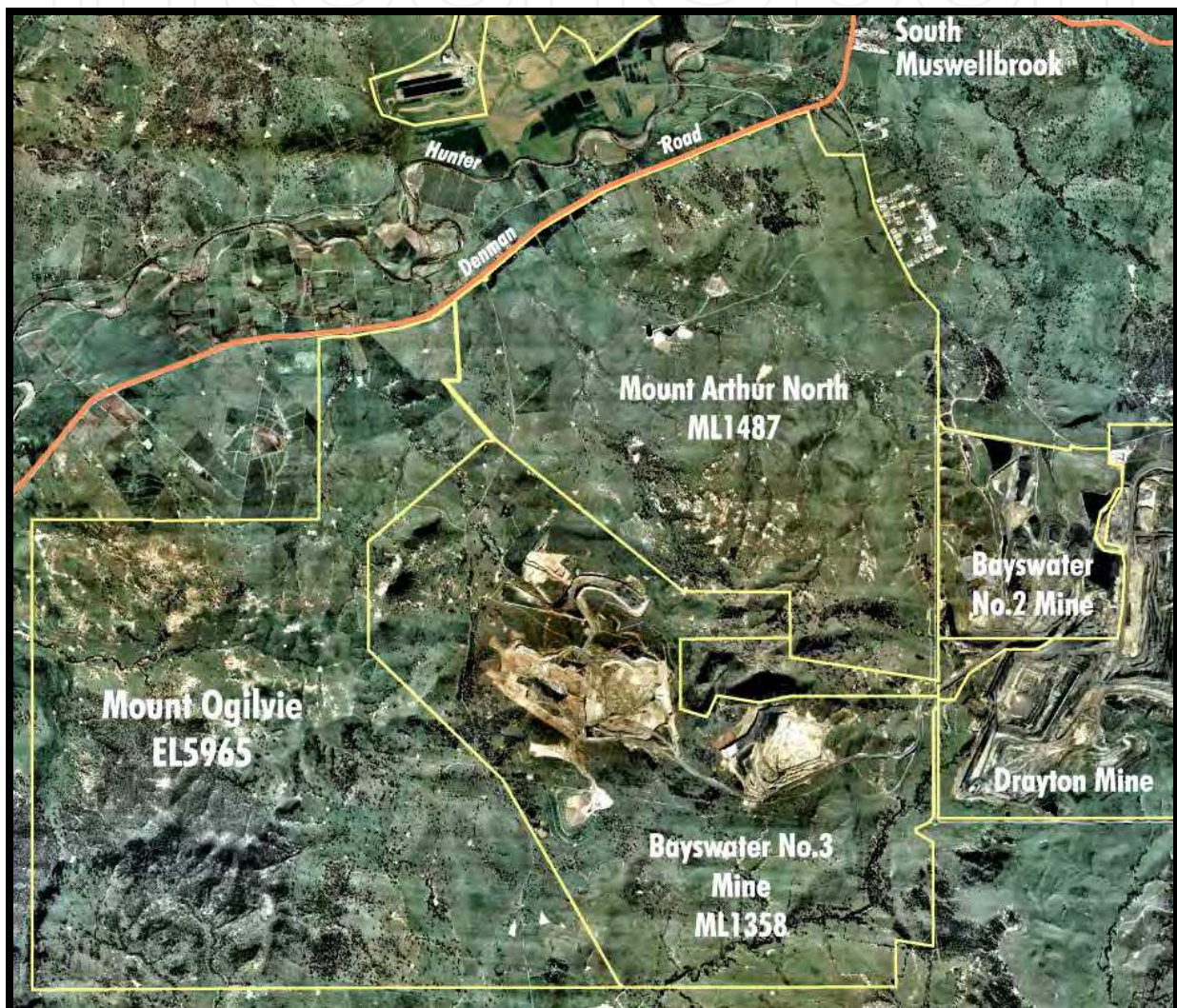


Fig. 16. Mt. Arthur Coal Mine mining lease (after Tredinnick, 2005).

Effective management of these facets involves detailed mine planning. Some key facets of the operation, from a community perspective, that need to be addressed include (Tredinnick, 2005):

- Noise: Mt. Arthur Coal is required to meet some of Australia's most stringent noise limits for mining operations. These limits are set by government and are based on noise levels considered acceptable to the surrounding community. Haul trucks, dozers and

excavation equipment are the most significant source of ongoing noise. The coal handling and preparation plant, and workshop areas are further sources of operational noise, although they have been located to minimise noise impact. From the first stages of mine design a noise model was developed to allow various mine designs and fleet configurations to be evaluated. Mt. Arthur Coal purchased a fleet of trucks that are the quietest trucks in the world. These trucks produce 16 times less noise output than a standard truck.

- **Visual Amenity:** The mine has an extensive visual impact management by doing progressive rehabilitation. To ensure safe working on night shift there is a requirement to illuminate working faces and overburden dumps. This use of lighting plants in turn has the potential to impact on nearby residents. There is an operational requirement to plan the location of all lighting plants to ensure that safe working conditions are maintained while at the same time minimising impacts on the local community.
- **Blasting:** The ground vibration and over pressure from blasting is strictly regulated. The 100% limits for Mt. Arthur Coal are a ground vibration of 10mm/s and an over pressure of 120 dBL. In addition, blasting is not allowed if the wind speed exceeds 10m/s. Actual ground vibration and over pressure results, as averaged across all monitoring sites, are approximately 0.3mm/s and 100dBL. In addition to ground vibration and over pressure NO_x and dust generated by blasting are issues of concern to the local community.
- **Spontaneous Combustion:** Mt. Arthur Coal has committed considerable truck resources to long hauling clay rich overburden to the east pit to cap off areas of spontaneous combustion. This has seen over 95% of the spontaneous combustion eliminated.

4. Conclusions

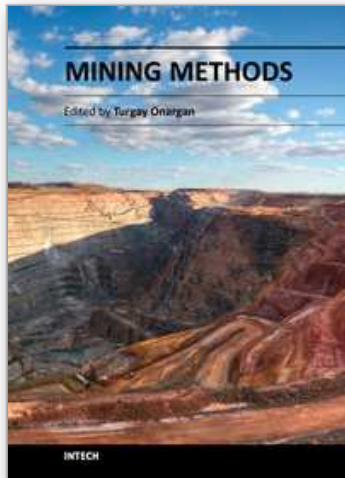
Robertson et al. (2009) stated that the inexorable growth in world population and living standards places demands on coal resources for energy and metallurgical coke production. Within one more generation the global demand for food and energy will double. Coal is abundant and has many advantages: globally distributed, price is affordable and stable and readily converted to other valuable products. There is enough coal reserves for approximately next 120 years, which is almost 2 times more than gas and 3 times more than oil reserves. Coal provides 27% of global primary energy needs and generates 41% of the world's electricity. Australia has abundant high quality coal reserves and its geographical location close to the Asia-Pacific market has stimulated the development and expansion of the coal industry to become Australia's highest export earner. Geology, freight distances, political stability, established infrastructure and maturity enhance Australia's role in the supply of coal to world markets and Australia has vast resources of economically recoverable black coal reserves, capable of supplying demand for decades (Robertson et al., 2009). Australia is a world leader in surface mining technologies. In Australia, approximately 77% of black coal is produced from open-cut mines and surface mining equipment has increased dramatically in size over recent years. Recent developments are being made across various areas of the mining industry. With latest research and development achievements in automation, the surface coal mining productivity in Australia will continue to grow with lower cost and more environmental friendly.

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An economic viability of a modern day mine is highly dependent upon careful planning and management. Declining trends in average ore grades, increasing mining costs and environmental considerations will ensure that this situation will remain in the foreseeable future. This book describes mining methods for the surface and underground mineral deposits. The methods are generalized and focus on typical applications from different mining areas around the world, keeping in mind, however, that every mineral deposit, with its geology, grade, shape, and volume, is unique. The book will serve as a useful resource for researchers, engineers and managers working in the mining industry, as well as for universities, non-governmental organizations, legal organizations, financial institutions and students and lecturers in mining engineering.

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