Challenges associated with further development of the Waterberg Coalfield

by L. Jeffrey*

Synopsis

The Waterberg Coalfield has vast potential to become a significant mining and industrial centre in South Africa. Its future development hinges on a number of critical decisions that must be made jointly by government, power utilities and industry, and on some technical and economic challenges that must initially be overcome.

Sufficient water is the primary key to enabling exploitation, together with an adequate market for the large volumes of low-grade coal. As the most likely consumer of this coal will be either a power station or a petrochemical complex, the need for additional energy will be a driving force in the development of this coalfield.

Conventional mining methods can exploit the shallow coal resources in both the Grootegeluk and the Vryheid formations, but alternative technologies such as coalbed methane extraction and underground coal gasification are the only currently known technologies that may be able to exploit the deep Grootegeluk Formation resources. However, extensive research is still required into these procedures, particularly with respect to the Waterberg coals.

Transport infrastructure to the region is currently not sufficiently well developed to support large-scale exploitation of the region's coal resources. In particular, the railway line would have to be extensively upgraded to allow the increased export of coal. Alternative transport methods such as pipelines would also have to be pursued to serve a large Sasol-type petrochemical complex or coal gas extraction. The road network would also require improvement, as only the roads between the main commercial centres are currently tarred. Dr Con Fauconnier, Kumba CEO, concluded his presentation to the Investing in African Mining Conference 2004 with the words: Again, it's all about infrastructure – when it's there, it enables the development of bulk mining projects which attract the resultant economic benefits for the region and country as a whole. These words aptly sum up one of the stumbling blocks to the future development of the Waterberg Coalfield.

Introduction

The Waterberg Coalfield (Figure 1) is seen by many to be the replacement coalfield for the Central Basin (Witbank, Highveld and Ermelo coalfields). Many believe the vast resources are suitable to replace future dwindling coal exports from other coalfields, as well as to supply additional energy requirements. Others, however, believe the technical challenges imposed by the fine mudstone intercalations of the Volksrust Formation, combined with depths of up to 400 m, are not economically surmountable in today's energy and export coal climates. What is not disputable, however, is that innovative ways of extracting and utilizing the coal will be needed to further successfully develop this coalfield, South Africa's largest remaining coal resource.

The Waterberg Coalfield is characterized by an upper 60 m thick sequence of intercalated mudstone and coal bands (the Grootegeluk Formation), with a lower 55 m thick portion of discrete seams (the Vryheid Formation) more similar in character to the seams occurring in the Central Basin. Recoverable reserves are shown in Table I.

Present development

Grootegeluk Coal Mine (GCM), an open-pit colliery owned by Kumba Resources (Pty) Ltd (Kumba), is located west of Ellisras/Lephalale in the shallow portion of the coalfield and is the only colliery currently operating (Figure 1). The mine has reserves of 442 Mt and a total resource of 3 000 Mt. Mining utilizes the truck and shovel method, with benches fixed to geological horizons, resulting in bench heights ranging from four to twenty metres. This allows selective mining of the various coal qualities, and with the appropriate beneficiation, a range of coal products are produced (Table II). The yield of saleable coal, after beneficiation, is usually very low and typically less than 50%. The yield of blend coking coal from the upper mining benches is only about 10%. A further 40% yield is obtained by producing a relatively high-ash (35% ash) middlings coal for Matimba power station.

The bulk of the prepared coal product is a low-quality power generating coal. The lower Vryheid Formation coal could also be suitable

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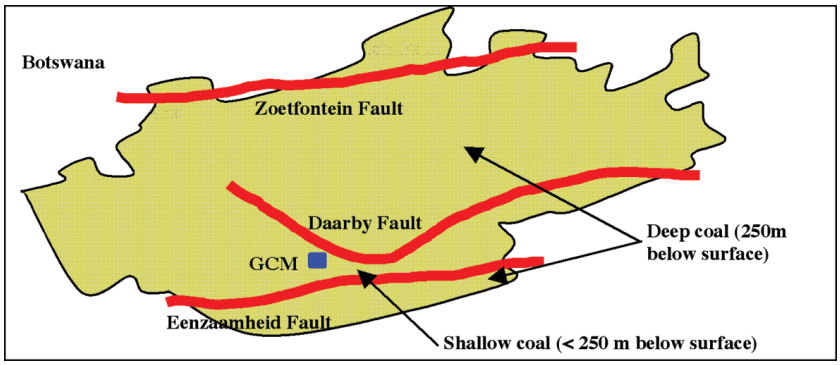

Figure 1—Deep and shallow coal areas (modified after Venter[1])

Table I

Waterberg Coalfield recoverable reserves (Mt)*

Waterberg Coalfield recoverable reserves (Mt)			
Total	**Low grade bituminous (CV# = 25.5 MJ/kg)**	**High grade bituminous (CV > 25.5 MJ/kg)**	**Coking coal**
15 487	13 111	1 697	679

*After Bredell[2]

Table II

Current saleable GCM production (Mtpa)*

Current saleable production (Mtpa)					
Semi-soft coking coal	**High ash steam coal (Eskom)**	**Corex coal**	**Medium phosphorus PCI coal**	**Sized steam coal**	**Total**
1.850	13.300	0.490	0.200	0.400	16.240

*After Venter[1]

as a feed coal for a Sasol-type operation. A small percentage of the coal can be processed to a high quality product (blend coking coal or pulverized coal injection (PCI) coal) that can possibly be considered for export or use in remote areas.

Due to the nature of the Waterberg Coalfield, all the Grootegeluk Formation coal requires beneficiation prior to utilization as the ash content from the run of mine (ROM) coal is between 55 and 60%.

The majority (14.2 Mt) of GCM's coal is sent by conveyor to Eskom's 3 990 MW Matimba power station (Ruffini[3]), the largest direct dry-cooled power station in the world (Kendal power station is the only other fully dry-cooled station in South Africa). One 665 MW set is used solely to run the power station and its fans. Without Matimba to consume the high-ash coal, GCM would not be economically viable. A similar scenario would apply to any other mining operation in the Waterberg that produces a low-ash (6–15% ash) product from the Grootegeluk Formation. The 1.8 Mtpa of semi-soft coking coal and the PCI product supply the Iscor steelworks at Vanderbyl Park, while the metallurgical products supply Saldanha Steel, the local smelting market (Samancor and Xstrata) and Suprachem. One million tons of the semi-soft coking coal and the PCI product are currently exported via the Matola Coal Terminal in Mozambique and the Bluff Mechanical Appliance in Durban each year. Kumba is to receive a share of the 82 Mtpa Phase 5 expansion of the Richard's Bay Coal Terminal (RBCT), which will not be able to be met by the existing shareholders in 12–16 years (Spicer[4]), thus freeing up space for coal from the Waterberg. However, any increase in the production of export coal would have to be matched by an increase in the market for other products to make the operational financially feasible.

Challenges for further development

Market for low-grade coal

The low-grade Waterberg coals with their high ash content and low yields are a significant stumbling block to further development of the coalfield. Any new exploitation will only be financially feasible if a market can be found for the vast quantities of low-grade coal that will be produced. To make the Waterberg coal viable, the yield of saleable coal needs to be maximized, which can only be done by producing multiple products.

Power generation

According to Spicer[4], with present power generation installations at current capacities, the demand for electricity will outstrip supply in the next four years. Both Eskom and Kumba believe it is feasible to construct a new power station in the GCM vicinity consuming upwards of 12 Mt per annum. Economics and government policy will determine the placement of a new power station, and any one of the following options may be used:

- Expansion to existing power stations, including Matimba
- Construction of a new power station, not necessarily in the Waterberg
- Transport coal (by rail or road) to current mothballed stations in the Central Basin.

Gas production

Underground coal gasification (UCG) converts coal into combustible gas *in situ* that can be used for power generation (as low to medium heating value gas for simple or combined cycle turbines or for co-firing in existing power conversion systems), hydrogen production, conversion to synthetic natural gas (syngas) and chemicals manufacture. The CO_2 can be removed, thus providing a source of clean energy with very low greenhouse gas emissions. In addition, there is no mining, transport, reclamation nor coal or ash handling on surface; UCG is thus a clean coal technology. Potential customers would be Eskom, Sasol and industrial and domestic users in Gauteng, although pipelines would have to be installed.

Coalbed methane (CBM) can be used for power generation, transportation fuel, petrochemical feedstock and residential heating and cooking; water is produced as a by-product.

Steel production

The steel industry is currently booming, especially in Brazil, China and India. Brazil and India in particular are looking for additional coking coal supplies; Brazil's CVRD is currently doing a feasibility study on Mozambique's Moatize deposit, while many Indian companies are visiting South Africa with the intention of investing in local deposits, particularly those with coking potential. The export potential for South African semi-soft coking coal is thus improving. South Africa has very limited supplies of hard coking coal (found only at Tshikondeni Colliery, another Kumba colliery). It is possible that some of our present imports of around 450 kt per annum from China could be substituted by the semi-soft coking coals from the Waterberg (Spicer[4]). Provided a market was found for the large amounts of low-grade coal, sufficient higher-grade coal, in particular the semi-soft coking coal and PCI coal would be available for export. A low-ash coal suitable for export can also be produced from the Vryheid Formation. The constraint on coal exports from the Waterberg, however, is the lack of suitable infrastructure and the long distance from the coal terminals, which adds considerable cost to the product.

Chemicals production

According to van Dyk, Coertzen and Potgieter[5], Sasol's area of interest in the Waterberg contains sufficient coal to supply a Secunda-sized petrochemical complex using the Sasol-Lurgi Fixed Bed gasification process for 25 years. This would require a mining operation of 47 Mtpa, similar to that at Secunda and Sasolburg. Their research has shown that direct liquefaction, pyrolysis, and high temperature Sasol-Lurgi gasification with Fischer-Tropsch processes for fuels and chemicals production would be the most economic flow scheme for this deposit. Electricity co-generation would be desirable as a strategic advantage. Saleable products would be transported to Johannesburg for inland distribution, into Africa and/or exported through Durban. Pipelines may be required to overcome the lengthy transport distances; fortunately, Sasol is already an experienced manager of product distribution by long distance pipelines.

There is some potential to produce activated carbon for use in the South African water treatment activated carbon market; however, this is not economically feasible at present when compared with activated carbon produced from other Sasol sources. Kumba believes it is possible to produce benzene, toluene and xylene (BTX), although petrochemical companies are reputedly not so optimistic. The extraction of CBM to produce H_4 for use in a BTX process would be an attractive scenario. A 1991 study proved the technical viability of this technique, but new technologies will need to be used to remove the sulphur.

Extraction

Before extraction of any sort commences away from GCM, the geological structure needs to be clearly understood. Only the major faults have been mapped to date, but it is known that numerous smaller faults subdivide the deposit into distinct blocks. There is thus potentially a moderate risk in extracting this coal economically. Any Waterberg mining operation, in the near future is likely to be a surface operation not only due to the size and extent of the mineable shallow reserves, but also due to the ability to cross-subsidize the overall operation from multi-product offerings. The use of new machinery can substantially reduce costs from current levels.

Conventional extraction is unsuitable for the deep Grootegeluk Formation coal and most unconventional technologies are not yet proven, particularly in a South African context. The finely interbedded nature of the Grootegeluk Formation, together with its thickness (± 60 m), precludes selective conventional underground mining and poses currently insurmountable problems regarding roof support and spontaneous combustion of the remaining strata. The large depths (250–400 m) in most parts of the basin also militate against underground extraction for the Grootegeluk Formation, but not necessarily for the Vryheid Formation where Kumba has already started initial underground extraction.

Xaba and Jeffrey[6] briefly investigated potential unconventional extraction methods to release the energy and carbon content of coal (Table III). Some techniques, like UCG, are not new but still face some major technical difficulties. UCG is not fully established yet due to the complexity of reaction kinetics, heat transfer and gas flow in the reservoir model. The problems are further complicated by the fact that these technical difficulties are site specific and will vary in each coal basin depending on the coal characteristics. UCG could play a role in the harnessing of energy from the Vryheid Formation, if the coal is not utilized for other goods such as low-ash export coal or metallurgical products.

Like UCG, CBM drainage may allow possible development in areas where traditional mining methods are unsuitable—the deep coal areas (no less than 400 m deep) with seams of high vitrinite content (which the Grootegeluk Formation coals do have) of at least 20 m thickness. However, major geotechnical barriers such as low permeability of coal, variable or low quality gas and variation in gas supply hinder

the development of CBM drainage. The coal needs to be gassy and cleated with high permeability in order to release the gas. Unfortunately, South African coals tend not to be gassy, although there is often free gas, and are described as 'tight' i.e. the gas is not easily released. In addition, the hydrogeology of the deposit needs to be clearly understood to ensure sufficient gas flow. CBM drainage is only feasible from the Grootegeluk Formation, not from the Vryheid Formation.

Other processes, such as the biotechnology process in coal, are promising but extensive research is still required. Borehole mining has not been proven in the coal industry and appears to be inapplicable to South African coal, which is shallow, and not steeply dipping, an optimal configuration. Table III describes the status of some unconventional extraction methods.

Beneficiation

Beneficiation will play an important role in the future utilization of the Waterberg coal. Specific beneficiation strategies may need to be developed for specific product requirements. The low yield of saleable coal from the Grootegeluk Formation implies a large tonnage of discard that will need to be stored in an environmentally acceptable fashion. It further suggests that beneficiation plants will need to be high-capacity plants. It is more viable to use the coal close to the source of mining and then transport the products to their markets. Extensive research by Sasol into different beneficiation technologies has shown that barrel washing, dense medium washing, flotation and dry coal beneficiation are suitable for producing a coal product for gasification.

Water

Large volumes of water would be needed for mining, beneficiation and processing purposes. However, both surface and groundwater are very scarce in the Waterberg. The suggestion of utilizing groundwater to increase the existing supply is thus highly unlikely. Three possibilities for providing sufficient water for further development are the raising of the Moloko Dam, pumping water from the Crocodile River to the Moloko Dam and importing water from the Zambezi River. A CBM by-product is water and this should be of at least a high enough quality for industrial purposes.

Environmental impact

Any future development in the Waterberg will have to ensure that the scarce groundwater resource is well protected and that pollution of aquifers does not occur, as has formerly occurred. This is of particular concern in coalmining and beneficiation, but may also be important with less conventional extractive technologies. Waste coal dumps are often subject to self-heating, with the resultant release of toxic gases into the atmosphere. The high carbon content of the Waterberg discards promotes spontaneous combustion; this has previously been a problem at GCM and great care will have to be taken in managing the dumps to prevent further atmospheric pollution. The Waterberg has become an important ecotourism area and care will have to be taken not to impact negatively on this when exploiting the coal. Currently the majority of game farms are in the eastern part of the area, while the largest part of the coalfield is to the west.

Infrastructure

The planned expansion of RBCT will allow for an additional 10 Mt of coal to be exported annually, thus allowing for increased production of export steam and blend coking coal. Since the current RBCT coal suppliers are unlikely to be able to supply the terminal to capacity within the next 16 years, increased production and expansion in the Waterberg Coalfield has the potential to make up the difference.

Critical to the upgrading of the coalfield is the upgrading of necessary infrastructure like water supply and rail networks. There is not sufficient railway coverage in the region at present to allow for major expansion. If large tonnages of coal are to be exported, the railway network will

Table III

Unconventional extraction methods

Technology	Status	Benefits	Major potential barriers	Status in South Africa
Underground coal gasification	Mature—researched for over 50 years.Commercially applied in Australia, USA, CIS. and UK	Extraction of otherwise unmineable coal	Complexity of UCG technical model esp. reaction kinetics, heat transfer and gas flow are site specific	Conceptual study to apply UCG locally by Eskom is ongoing
Coal mine methane (degasification)	Mature—applied commercially in the USA, UK, Australia, China, CIS and Germany	Extraction of gas in otherwise unmineable coal. Increases safety in mining environment	Very low quality gas-enrichment might be necessary. Very low gas concentration in coal	Currently not applied locally; attemptedat Majuba Colliery before closure
Coal bed methane	Applied commercially in Belgium, CIS, Australia, USA and China	Extraction of gas in otherwise unmineable coal. No surface subsidence	Technical barriers: low permeability of coal, variable/low quality gas, variation in gas supply. Lack of infrastructure and anchor customer	Feasibility study in the Springbok Flats Coalfield. Current exploration and testing in the Waterberg Coalfield
Biotechnology	Research in early stages (Brookhaven National Laboratory)	Utilization of very low rank coal (often discarded)	Reaction kinetics and mechanism not yet fully understood	Still far from implementation stages
Borehole mining	Currently applied in mining salt, uranium ore and phosphate. Successfully applied in mining of frozen gold placers in Alaska	Potentially low mining costs. Highly automated and not labour intensive	Efficiency and economics unproven in coal. Large diameter holes might be expensive in some areas	Not tested locally especially in coal mining

*Modified after Xaba and Jeffrey[6]

require extensive and expensive upgrading, thereby increasing production costs as well as the sale price of the final product(s). Two possible solutions are the extension of the COALlink railway line to the Waterberg or the construction of a new railway line via Polokwane and Burgersfort.

Pipelines for gas distribution would be required if CBM or UCG becomes viable or if Sasol sets up a petrochemical complex.

Socio-economic impacts

The greater Waterberg area is an area of low rainfall, vast areas of natural bush and numerous game farms; ecotourism, agriculture and GCM are the main income generators for the local communities. However, a significant portion of the population is unskilled and unemployed; consequently any economic development will have considerable socio-economic impact.

A Secunda-type petrochemicals complex could provide between 20 000 and 30 000 jobs, with the additional benefits of education and training, infrastructure and communications development and water reticulation. In addition, capital investment in mining, power generation, and infrastructure will occur; taxes, levies, royalties and other economic contributions will flow and secondary industries will develop.

Kumba has had consultation with the NER, Eskom, DWAF and other governmental institutions, as well as with potential consortium and investment partners. Kumba believes that there are massive value adding opportunities in the Waterberg for the Limpopo Province and its stakeholders. In 15–20 years the Waterberg will become the coal hub for South Africa due to the vast reserves and the gradual depletion of the Witbank and Mpumalanga coal reserves. Waterberg coal production could be increased from 15 Mtpa to 45 Mtpa over 15 years (Spicer[4]).

Suggested steps for the future

A decision must be made whether expansion of existing generating capacity or a new power station is the most suitable way to provide the country with its immediate future energy needs. Eskom, the DME, IPPs and coal producers would need to be engaged on this study. Once a decision is reached, the next step is to decide where such expansion or construction should take place. Initially, the expansion of the Central Basin power stations, where possible, is likely to be the most favourable scenario, as there are still coal resources of suitable quality in the area to exploit. Although these deposits are not large, this would promote the involvement of small enterprises in the power industry and would assist in democratizing the coal-producing industry. Matimba power station could also be expanded in this stage, thus dovetailing with Kumba's development plans.

However, if the decision is for new generating capacity (as must happen if the country continues with current economic growth levels), the DME needs to finally decide whether an IPP or Eskom would build it—and where. In this scenario, it is probable that the Waterberg is the most suitable site for a large power station, ideally close to Matimba. The advantage of this location is the proximity of Lephalale town and distribution power lines. The relative closeness to the West African Power Pool may make a new Waterberg station more attractive if power can be sold into this market. Conversely, the pool may pose a challenge to the profitability of a new station in this location. The disadvantage of a Waterberg site compared with other potential sites is the distance from the markets; significant losses are incurred when electricity is transported over long distances.

A new power station in the Waterberg would act as a catalyst for further development as there would be an assured market for the low-grade coal, thus making the extraction of the more desirable higher-grade coals economic. Provided sufficient water is available for mining and beneficiation and the infrastructure is upgraded significantly, the export and metallurgical coal products could be more fully exploited.

The Council of Geoscience should undertake exploration aimed at mapping the smaller faults to better understand the geological structure; some geologists have expressed the opinion that reflective seismic techniques should be used to fully delineate the structure. However, the technique did not prove economically viable at depths less than approximately 150 m in the Witbank Coalfield. In particular, coal-mudstone contacts were impossible to resolve, although coal-sandstone contacts were clearly discernable. Although processing of seismic data is difficult and there are few people in South Africa with the necessary skills, the technique can be crucial in understanding multi-zone coals; two-ton Vibro machines have worked well in other parts of the world, notably Colombia, and experiments with different buried energy sources would enhance the usefulness of the procedure.

The possibility of acquiring government assistance in building the railway, as a job creation strategy, should be investigated.

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