RECLAMATION AND ENVIRONMENTAL MANAGEMENT IN DIMENSION STONE MINING

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ABSTRACT

From the point of view of the environmental impact created, dimension stone mining is a relatively benign industry. There are no emissions besides those of the diesel powered earthmoving equipment utilised in its extraction and a small amount of blasting gases. Contamination of water resources is only likely in the event of petrochemical spillages from storage facilities and equipment, and these can largely be either prevented or cleaned up effectively. The major environmental impacts are of a visual nature, while in sensitive areas, habitat destruction and the destruction of archaeological heritage may become significant impacts.

The dimension stone industry has grown at an average rate of over 7% per annum since 1986, and is forecast to continue growing at this rate for the foreseeable future. The cumulative environmental impact of the industry will thus become more significant over time.

This paper discusses the environmental impacts of dimension stone mining and recommends effective means for dealing with the practical aspects of reclamation and mine closure in dimension stone mining within the context of environmentally responsible business practices. The discussion focuses mainly on the operations of the Finstone Group in Southern Africa, which are considered to be world leaders in the application of environmental management within the dimension stone mining industry, although reference is also made to other situations which the authors have encountered at dimension stone quarries around the world.

1 INTRODUCTION

Dimension stone is a collective term for various natural stones used for structural or decorative purposes in construction and monumental applications [1]. As discussed in the accompanying paper at this conference on dimension stone prospecting and mining methods, dimension stone has exhibited annualised growth of 4.9% over the last 75 years and has in fact accelerated in recent years, with annualised growth of 7.6% since 1986. This rapid growth in production and demand has resulted in rapidly increasing environmental impact of the industry, especially in terms of the disposal significant volume of fines generated by dimension stone processing [1], but also in terms of the increased number of quarries disturbing the natural environment.

The defining feature of dimension stone is that unlike other mineral commodities which have value mainly as a result of their physical properties, the physical properties of a rock are merely the minimum qualification in determining whether it is fit for use in dimension stone applications. The ultimate success in marketing a natural stone as a dimension stone lies firstly in its appearance, and secondly in the possibility of producing rectangular blocks of suitable dimensions [2] (hence the term dimension stone) to allow for successful production of the final product in the required sizes. Indeed, the USBM defines dimension stone as "naturally occurring rock material cut, shaped or selected for use in blocks, slabs, sheets or other construction units of specialised shapes and sizes"[3]. A dimension stone block thus has value as a result of its dimensions and appearance, underlain by a set of minimum physical properties (among these are various strength parameters, workability, ability to take a polish, and resistance to physical and chemical weathering).

This defining feature, together with the set of minimum physical properties required has important implications in terms of the environmental impacts of dimension stone mining, as well as the management thereof. Indeed, when it is the intention to merely blast and remove stone for its physical properties (such as in crushed aggregate or ore mining), recovery can be almost 100% of the volume removed, while when the same stone is quarried with the intention of producing dimension stone blocks, recovery of saleable blocks is typically between 3% and 60%. This results in large quantities of waste rock which need to be disposed of, with resulting environmental implications.

The physical properties required of a successful dimension stone also have significant environmental implications – due to the requirement for inert materials which are not affected by weathering (and in today's context, the effect of severe chemically polluted atmospheric environments), dimension stone residues are typically benign from a pollution point of view. Like natural aggregates, dimension stone is used in its natural state, and does not require concentration and extraction from an ore. It is these latter two processes that result in significant environmental impacts such as acid mines drainage and other toxic effects associated with many of the metal extraction industries [4].

Similarly, mining methods themselves generally have a low impact on the surrounding environment due to the need to carefully extract large blocks or slabs without damage to the stone [1]. Recent advances in dimension stone mining technology have also had the effect of reducing environmental impacts [5]. Particularly in granites, improvement in diamond wire sawing efficiency has significantly reduced the use of explosives in the extraction of blocks. This has resulted in higher recovery of saleable blocks [6] and therefore less waste to be disposed of, as well as reducing the emissions of blasting gases (SO2 and NOX), noise and ground vibration. Diamond wire sawing has also largely replaced jet flame cutting for loosening benches in hard stone deposits. This has resulted in significant reduction in noise (jet flame cutters operate at over 130dB), as well as reduced energy requirements and thus lower contribution to greenhouse gases.

In the past, the environmental damage caused by mining was accepted by society because of the economic benefits that derived from mineral extraction [7]. However, the past few decades have seen a growing awareness among the general public of environmental impacts, and the impacts of mining in particular have come under significant scrutiny. Indeed, "the immediate image of mining is of a dirty, hazardous and environmentally damaging industry" [8], while the public is generally are unaware of the important role which mineral resources and the finished products made from them play in daily life, especially since most of these products are derived and thus not readily recognisable as materials of mineral origin [9]. Much of this negative perception has resulted from negative press coverage of mine closures and accidents, while mining is often highly visible in comparison with the environmental impacts of other industries. In this regard, while a study in Australia suggested that mining was responsible for 1.1% of presumed extinctions of endangered plant species, compared with 38.2% attributed to grazing and 49.4% to agriculture [10], we would suggest that public perception sees mining as a far greater threat to biodiversity than agricultural uses of the land. Indeed, it has been written that the attitude of the general public to mining is based on the erroneous assumption that adverse visual impact is the same as severe environmental impact

[9], and that the impact exerted by mining on our environment is wrongly exaggerated. This is often the case with dimension stone quarries, which are often located in places easily seen by the public, over long durations, and which have high visual impacts during their operating lifetimes. In addition, the NIMBY (not in my back yard) syndrome has worked adversely against mineral production in many European countries as well as the USA [4],[11]. This syndrome, aggravated by poor management of the situation from the Department of Minerals and Energy (DME) (ignoring illegal mining operations, issuing mining authorisations without proper public consultation, lack of policing of adherence to environmental requirements and ignoring complaints from the public) has resulted in significant conflict between landowners, quarries and the DME over granite quarries the Brits area in South Africa. This conflict has been highlighted several times on national television, further reinforcing the public's negative perceptions of mining in general and of granite quarrying in particular. As a result of this conflict and ignorance in the DME with regards to the dimension stone industry, granite and slate mines have been classified as medium risk operations in terms of the DME guideline for the financial evaluation of financial provision for rehabilitation [12], the same risk category as large gold, silver and uranium mines, and a higher risk than anything other than coal, metal sulphide, asbestos and antimony mines. However, all other dimension stone sources (including norite, which is the rock type of the quarries that caused all the trouble!) are classified as low risk operations.

However the environmental impacts of dimension stone are generally not significant, are mainly of temporary duration, and can be effectively managed [1]. While there is an economic cost to limiting environmental impacts [4], these costs are not significant in dimension stone mining if proper planning and consideration is applied from the exploration stage through to mine closure. In fact, it has been noted that truly environmentally conscious operation requires that activities be conducted with the future in mind [7], and that this will not only minimize the environmental effects of each activity, but will also result in significant cost savings [12]. In the context of the dimension stone industry, these cost savings are not limited to costs of restoration, but may also be real cost savings in operating costs when proper planning over the lifecycle of a deposit is applied.

Unfortunately, however most dimension stone operators are relatively small scale operators [2], and smaller operators tend to be less well equipped to respond to the increasing environmental demands because of a general lack of staff with appropriate environmental awareness and training [14]. In addition, small operations tend not to be characterized by the planning required to achieve the cost-effective environmental management of resource extraction that is best achieved by whole-of-life mine planning [14].

2 ENVIRONMENTAL IMPACTS OF DIMENSION STONE MINING

Environmental impacts should ideally be identified and mitigated according to the phase in the mining life cycle. This is a more practical way of dealing with environmental impacts since the scale of impact differs according to phase (e.g. impacts made during the exploration phase are much less than those made in the operational phase). In addition, the environmental monitoring and management varies with each phase of the mining life cycle and hence the total project costs. The environmental impacts of dimension stone will therefore be discussed according to phase in the mining life cycle. The life cycle of a mining operation goes through the following phases [15]:

- Exploration: Economic deposits are identified and their characteristics are determined to allow recovery.
- Development: Preparations are made for mining.

- Extraction: Valuable material is removed for sale or processing.
- Reclamation: Disturbances caused by any of the preceding activities are corrected or ameliorated.

2.1 Environmental Impacts during the Exploration phase

The first stage of management of environmental impacts of quarrying operations comes with the exploration for a new dimension stone deposit. Exploration activity usually impacts the least on the environment in comparison to other phases of mining. However, in the past, prospecting and exploration for dimension stone was the domain of non-professional prospectors, who because of lack of knowledge of the market and industrial requirements of the processing industry, coupled with the absence of professional exploration skills seldom conducted formal investigations or evaluations prior to opening quarries [15],[17]. This has lead to many ugly scars on the landscape, not only in South Africa, but around the world, as full scale quarrying commenced without any knowledge of the underlying geology, and in these circumstances is often unsuccessful. Finstone has developed an approach to exploration whereby exploration is carried out in phases (these are discussed in more detail in the accompanying paper) - completion of each phase prior to test quarrying does not guarantee a successful quarry, but provides sufficient information to make an informed decision as to whether or not to proceed to the next stage taking the risks of a negative outcome into account. At each step of this sequence, the environmental impacts are taken into account, and the minimum possible footprint is disturbed. From an environmental point of view this phased approach has the benefit that environmental disturbances are minimised considering the possibility of a negative outcome. Thus if an exploration project is abandoned after drilling, the environmental impact is orders of magnitude lower than if the “boots and all” approach had been used. The phases of exploration utilised by Finstone are listed below:

- Desktop Study
- Field evaluation
- Detailed mapping
- Geophysical methods
- Drilling
- Bulk Sampling
- Test Quarrying

The field evaluation stage of exploration has minimal impact on the environment; impact is caused mainly by the exploration team’s vehicles when they clear existing flora for pathways. Should the team choose to establish exploration camps close to the site then further environmental impacts will be caused by fires, sanitation and domestic waste disposal. This also has a minimal impact.

At the detailed mapping stage environmental impacts may start to intensify, particularly if it is necessary to mechanically clean mapping traverses. This may result in removal of vegetation and soil. Fortunately in the case of dimension stone it is not often necessary to clear paths for mapping as fairly large solid outcrops of stone are often the exploration target and these have minimal cover if at all. Where mapping traverses need to be cleaned, these should be limited 2 metres in width, and are generally spaced at around 20 metres. In most cases removal of soil to expose the rock outcrop would be to a depth of less than a metre. The small samples (generally a maximum size of 30cm x 30cm x 30cm) which may be extracted at this stage do not have significant impact, and the extraction sites can be concealed by replacing topsoil, or by rockshading. If after detailed mapping is completed it is decided not to pursue the project further, it is relatively easy to replace the removed soil and seed with appropriate vegetation. If it is considered to use geophysical methods such as ground penetrating radar to further evaluate discontinuities in the stone, the cleaned mapping traverses are generally used for GPR traverses, and so additional environmental impact is minimal.

From the drilling stage the environmental impact begin to become more significant, but can still be limited. The most severe environmental impact is land clearance caused by road construction for easier access for vehicles and air compressors resulting in damage to natural resource base, possible damage to sites of archaeological, religious or historical importance and health and safety risks to community members, livestock and wildlife. If the distance to actual drilling site is not extreme, environmental damage may be limited by constructing pipelines for the supply of air and water to the drill rig, thus minimising disturbance of the site, as the rig itself can be carried by hand to the drilling site.

At the bulk sampling stage the impacts are not considerably more than during the drilling phase, as a relatively small area is disturbed to extract the one or two blocks required. The exception to this would be in the case of a relatively mountainous area where drilling can be accomplished by carrying the relatively lightweight drill to the site by hand and supplying compressed air and water by pipeline, while bulk sampling requires the construction of an access road to the sample site. The impacts of bilk sampling are however limited by the relatively small area disturbed, and can be ameliorated by replacement of off cuts positioned so that the naturally weathered surface is exposed, by replacement of topsoil, reseeding and if necessary rockshading. Figure 1 below show one of Finstone's bulk sampling sites after reclamation.

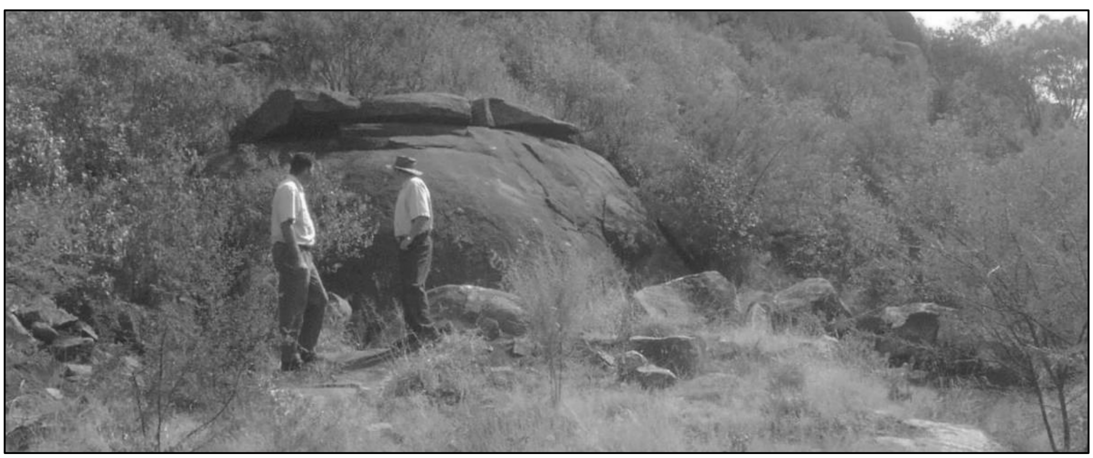

Figure 1 Bulk sampling site after reclamation

Should a decision be made to proceed from bulk sampling to test mining, the environmental impacts are not significantly different from full scale mining, with the exception that at this stage no permanent infrastructure such as offices, workshops and compressor houses would be constructed.

Impacts on the natural resource base during the exploration phase may include impacts on soil, agricultural land, forest or woodland resources and surface and groundwater resources. Impacts on soil may result from vehicle traffic, drilling and materials storage resulting in soil erosion; impacts on soil structure (mainly compaction) and soil chemistry (as a result of petrochemical spills). Impacts on agricultural land may result in short term destruction of crops or grazing land or long term impacts due to disturbance of soil or vegetation which may affect long term agricultural viability. Forest or woodland resources may be impacted by clearance for exploration purposes; wood gathering by exploration crews; fires resulting from spontaneous combustion of fuel sources or exploration teams; access provided by exploration tracks for illegal loggers and charcoal burners into areas that were previously inaccessible. The quality and quantity of surface or groundwater resources may be impacted by poor storage of chemicals and fuels resulting in spillage; inappropriate waste disposal practices; stream damming or diversion; land clearance in the upstream catchment and soil erosion.

Impacts on biodiversity may include loss of habitat, fatalities resulting from direct contact with exploration equipment and supplies (vehicles, bulldozers, chemicals, waste); introduction of alien species; disturbance of behaviours (e.g. breeding) and hunting or bush meat trade. Damage to or impacts on access to sites of archaeological, religious or historical significance can be incredibly emotive and inflict major damage on the relationship with the local community. Exploration poses a risk to the health and safety of community members, livestock and wildlife through contact with machinery and vehicles; excavations and contact with chemicals and fuels.

2.2 Environmental Impacts during the Development Phase

Development is the preparation the facilities, equipment, and infrastructure required for extraction of the valuable mineral material, and the phase includes land acquisition, equipment selection and specification, infrastructure and surface facilities design and construction, environmental planning and permitting, and initial mine planning [15]. During this phase of many mining projects, there may also be a need for involuntary relocation of communities located in proximity to the proposed mining area. This can be a fatal flaw of a project and should be facilitated by qualified and experienced consultants. In the case of dimension stone however, given the scale and margins of the average quarry, it is likely that any requirement for significant relocations will render the project unviable. However, given the nature of the mining methods employed (especially if fully non-explosive methods are used) it is possible to mine safely much closer to human settlements than with most other surface mines and quarries [1].

In equipment selection, it is necessary to consider the sources of power to be used for the equipment. In dimension stone extraction, drilling is a major part of the production process. Consideration should be given to hydraulic drill rigs, as the energy conversion cycle is far more efficient than with pneumatic drilling. However, due to technical and labour considerations, drilling may be conducted by pneumatic drills, and consideration should be given to using electrical compressors if infrastructure is available. If the project is situated at high altitude, consideration must also be given to the fact that the engines of diesel powered earthmoving equipment may require modification in order to operate efficiently and cleanly [7]. In addition, in granite, consideration should be given to using diamond wires saws rather than jet flame cutting, as these have a positive impact on recovery of saleable material and reduction in noise [5]. Roads should be designed in such a way as to avoid soil erosion and to cause as little disturbance to flora as possible. Maintenance workshops should be designed to avoid contamination of soil and water by spilled fuel and lubricants. An important factor at this stage in dimension stone quarries is the choice of location of the waste dumps, and these should be sited in such a way as to minimise the visual impact where possible.

The construction phase is associated with a number of environmental impacts resulting from excessive site clearance, poor waste management, poor site water management and socio-economic impacts. Impacts that may be caused by excessive site clearance during the construction phase, in addition to those mentioned in the exploration phase, are excessive dust problems, increased soil erosion and increased noise due to vehicle traffic and the use of explosives. The buffer (mainly vegetation) that limited noise and dust to local communities may also be removed.

Poor waste management practices at this stage are particularly extensive due to a lack of established waste disposal facilities, ignorance of how to dispose of certain waste streams and failure to train the construction workforce in appropriate waste disposal. The types of waste that need to be disposed of at this point are construction waste, packaging material, oils and greases from construction fleet, tyres and domestic refuse (should there be camps around the site).

The main environmental impact resulting from poor site water management is associated with storm water management; especially in high intensity rainfall areas. Poor site water management can undermine or destroy structures, limit or even suspend site access, cause major soil erosion and lead to widespread contamination if flood events wash away poorly contained hydrocarbons or chemicals.

Impacts of quarry construction on the social environment have to also be taken into consideration, especially if there is a pre-existing community near the proposed mining project. These impacts include public health risk caused by increased vehicle traffic (dust, hydrocarbon spillage, greenhouse gas emissions) and access to unsecured infrastructure under construction; nuisance factors such as noise, dust and vibration; adverse impact on traditional lifestyle of local communities for example alcohol abuse, prostitution, introduction of a cash economy, in-migration and breakdown of traditional tribal culture.

2.3 Environmental Impacts during the Extraction Phase

The major impact of dimension stone mining on the environment is the aesthetic visual impact of quarrying upon the landscape. Any mining activity which disturbs the surface of the earth will have a visual impact for its duration, and dimension stone quarries commonly have a high degree of visual impact due to the fact that they are often located in areas of positive relief, and thus visible from large distances and often from many directions. In addition, the geometry of the dimension stone quarry with its regular squared faces stand out within the natural environment, particularly when the faces are created by diamond wire sawing, and thus smooth with much higher reflectivity than the natural surroundings. Visual impact for the duration of mining operations is unavoidable, but is likely to be temporary and restricted to the duration of mining and perhaps some time thereafter, depending on climate and the degree of effort put into reclamation of the quarry and its waste dumps (in Brazil for instance, a dimension stone quarry can hardly be seen after just a few years even without reclamation due to the rapid rate of plant growth and blackening of the fresh rock surface).

Disturbance of the earth’s surface by any from of mining will result in complete removal of existing vegetation and ecosystems within the disturbed area, and dimension stone mining is no exception. The impacts are significant, but localised to the disturbed area, and the overall extent of the impact is determined by the concentration of mining and the sensitivity of the disturbed ecosystems. A proper environmental impact assessment (EIA) process will however identify areas where mining would cause irreparable damage, and mining should be excluded from such areas.

In South Africa, many early settlements were built in elevated areas which offered good defensive positions. As stone suitable for dimension stone is often found in elevated areas, it is necessary to conduct a thorough archaeological heritage survey over the proposed mining area as part of the EIA process in order to identify the extent of any archaeological sites which may exist. Mining would generally destroy such sites, and sites of exceptional significance may dictate the no mining option, whilst in the case of lesser sites the impact would need to be managed as discussed below.

The impact on of dimension stone mining on air quality is limited to the generation of dust from mine haul roads, and within the quarry itself as a result of drilling and diamond wire sawing. While some authors ascribe the significant amount of fines produced in granite quarrying to the cutting processes [18], in the dry climates of Southern Africa, fines generated by the action of the tyres of earthmoving equipment on the road surface materials and gravels imported into the quarry to aid working processes are generally the most significant contributor. Given the nature of the quarry operations, and the significant amount of fine materials produced, these are not absorbed by vegetative land cover, as would happen in a natural catchment [18]. These fines, lacking cohesion, are washed away by rainfall and may be transported by either suspension or saltation, from the higher lying areas of the quarry to discharge points into the river system. However a study in the Porriño quarrying and processing area in Spain, where an estimated 350 000m^3 of granite fines are generated per annum (mainly from processing) has shown that granite fines do not embrace significant risks for the environment [19], while a study specifically related to an intensive granite quarrying area of approximately 200Ha in Porriño concluded that suspended solids with associated increase in Chemical Oxygen Demand constituted the only significant pollutant on runoff waters, particularly when associated with increased flow caused by rainfall events [18].

Infrastructure found on most small to medium sized dimension stone quarries includes offices, power lines, stockyards, workshops, and dressing yards and waste dumps. Offices usually generate domestic waste, power lines have negligible environmental impacts, stockyards and dressing yards may impact on soil structure in the form of compaction, while the release of granite/stone fines is a significant impact of dressyards, although as discussed above this is in most cases not harmful. Workshops may be prone to hydrocarbon spillages that change the soil chemistry and may affect groundwater quality (only in severe cases). If fuel is stored on site, there is a possibility of spontaneous combustion that may lead to uncontrollable fires, groundwater and soil contamination.

Environmental impacts not associated with infrastructure include impacts to groundwater, surface water and communities. Groundwater inflow in surface mining operations can flood the lower sections of the pit – provided that the pit has surpassed the depth to the water table. High pore pressures in side walls can trigger collapse, leading to catastrophic events. However, most rocks mined for dimension stone are acquitards and this situation is therefore highly unlikely.

3 ENVIRONMENTAL IMPACTS OF DIMENSION STONE MINING IN SOUTH AFRICA

Mining of the Rustenburg dimension stone deposits commenced in the Bon-Accord area in the late 1930s, and there is evidence of small scale quarrying of the Wonderkop layer east of Brits using techniques common to the pre-1960s era. The first quarry in the Rustenburg area was established on the farm Nooitgedacht 287JQ in 1947, and was closely followed by further operations on the nearby farms of Boschpoort and Tweedepoort. Mining of the Belfast Black material commenced at Kwaggaskop in 1961. Mining was conducted on a very small scale, producing blocks for the domestic tombstone market, and often conducted by the monumental masons themselves. The technology employed was simple. Splitting was accomplished by means of drilling a line of coplanar holes, and inserting steel wedges which were then hit with a hammer to produce a splitting force, or for larger splits within the boulders, by means of a single hole drilled in the plane of the cleavage direction, and charged with blasting gunpowder and initiated with a length of fuse. Because this type of splitting requires that the split material be free to move in order to get a clean split, the loose boulder horizons were initially worked. Blocks and waste material were handled by jib cranes. Because the high recovery pockets were initially mined, and the production volumes required were small, the areas disturbed by mining were limited. The quarrying companies were generally small owner operated concerns, and they attempted to maximise profits by making the most of the available stone resources – dimension stone quarrying was still an art. In addition, economic block sizes were smaller than required by today's processing equipment, and waste material that could not produce economic block sizes was often cut in the quarry to produce curb stones and other products (anyone who has walked Pretoria's streets will have seen the curbing of Rustenburg material which lines them, and which dates back to this era). As a result, the environmental impact of the quarrying was minimal, with only small waste dumps located alongside the relatively small quarries.

During the 1960s, the export market for Rustenburg and Belfast material was established, and there was some consolidation in the companies involved dimension stone mining. Production volumes grew, but remained largely for the monumental market. Larger jib cranes were introduced, and quarries operated deeper into the semi-solid horizon, as moving of these cranes was laborious and costly, and it made sense to remain within the high recovery pocket. Jet flame cutting technology was developed, which enabled quarry operators to loosen material in the solid horizon for further splitting by blasting gunpowder, and the advent of electric detonators and fuse heads allowed for multiple holes to be blasted simultaneously, which allowed larger primary splits to be made. The quarries advanced deep into the solid formation horizon with the only limitation on depth being the reducing size of the excavation at depth due to the dip of the major jointing. Environmental impact remained very limited due to the small areas disturbed, and on the 1975 government orthophotos of the Rustenburg area can be seen to be limited to around a dozen pits, each disturbing not much more than one or two hectares. The situation in Belfast was much the same.

During the late 1970s and early 1980s, front end loaders were introduced to the industry in South Africa for handling of blocks and removal of waste. This change meant that it was much easier to move a quarry when recovery dropped, or when the loose boulders were worked out at one location, and thus keep unit production costs at a minimum. This coincided with the increase in world demand for granite for construction purposes, and production volumes expanded rapidly. The result

was total devastation of the Rustenburg and (to a lesser extent) Belfast dimension stone districts from a visual impact point of view, with hardly a kopje left untouched, and waste dumps and gravel pits being developed at random, often as close as possible to the quarrying site (see Figure 2).

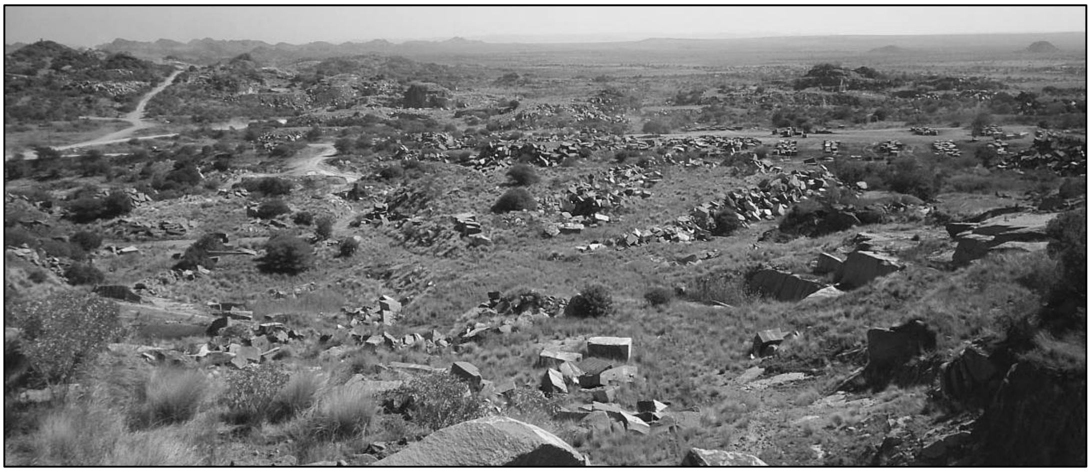

Figure 2 An area in Kelgran's Rustenburg quarries devastated by poor mining practice

This style of mining was equally devastating from a sustainable mining point of view. As time went by, the recoveries achieved dropped progressively as higher recovery boulders were selectively mined out, until the recovery in the remaining boulders was no longer economic. In addition, waste dumps were often made on top of potential future reserves for the sake of keeping the cost of transporting waste to a minimum, while desperation to mine at higher recoveries lead to non-viable blasting of semi-solid and solid formations without sufficient loosening of these prior to blasting, resulting in serious blasting damage to the stone. The result was that large areas of reserves were no longer accessible without redevelopment at high cost (see Figure 3). By the mid 1990s, many companies in the Rustenburg area were in serious financial difficulty as a result of these mining practices, and many smaller operators closed their doors. It is worth noting that many of these companies made windfall profits during their early days as a result of raping the ore reserves, but left substantial reclamation liabilities when they closed their doors.

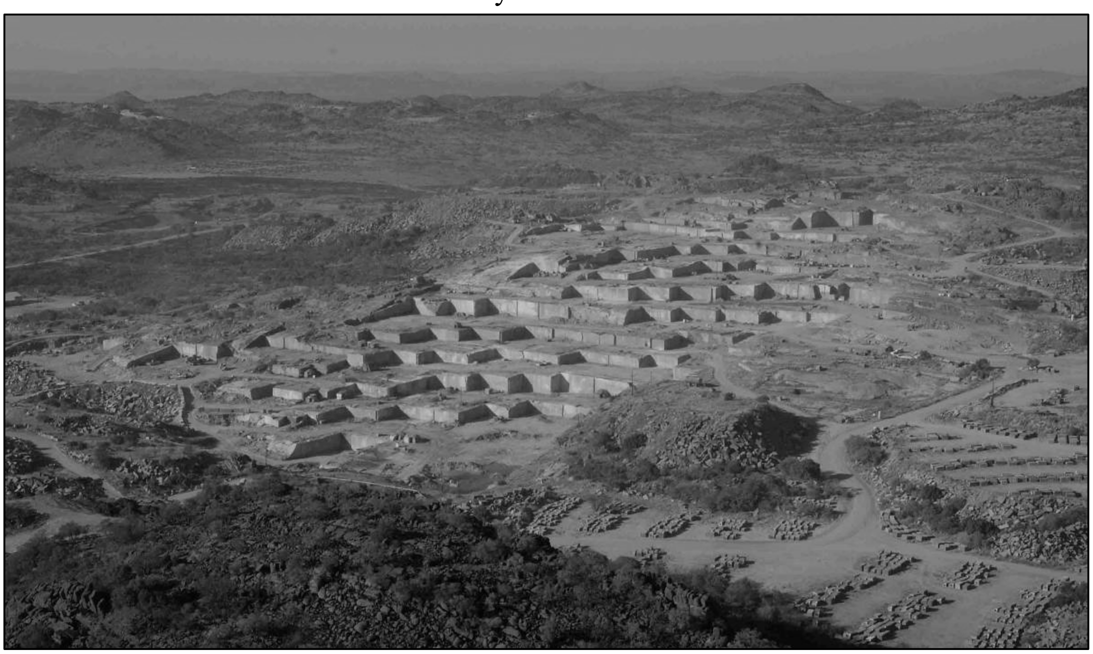

Figure 3 An example of poorly planned selective mining and indiscriminate waste dumping

At Kudu Granite, which today comprises the bulk of Finstone's current Rustenburg division, it was decided in 1994 that in order to survive it was necessary to implement formal mining disciplines in order to redevelop its quarries for sustainable profitability. As a result, extensive geological exploration and modelling (involving over 8000m of diamond core drilling, geophysical techniques, advanced mineralogical work and field mapping) was conducted, and formal mine planning was implemented based on the results of this work. In addition, new mining technologies were implemented, in particular the use of diamond wire and expansive mortar (Kudu was a world leader in the implementation of both these methods in the granite industry), in order to increase recovery of saleable material and contribute to the sustainable utilisation of the mineral resource.

Redevelopment of the quarries was not cheap however, and was also time consuming. The E Reef quarry at Springbok mine (see Figure 4) which is now one of the largest producing granite quarries in the world took over three years and in the order of US$ 8 million (in 1996 terms) worth of development costs before it became profitable.

Figure 4 Springbok Quarry, E Reef

It can be seen that mining is conducted to the average grade of the ore reserve, as it is necessary to remove both good and bad recovery areas simultaneously with this type of mining, as it is not possible to leave pillars of poor material at random locations. Recovery is lower overall than with selective boulder mining, and hence costs are higher, but the operation still makes comfortable profits, and has reserves at current mining rates in excess of 60 years. Had the old style of mining continued here, the operation would have long been closed down. The environmental impact of this type of mining is also substantially lower, as a much smaller area is disturbed at any one time (the entire reserve base of this quarry covers only around 40 Ha), and it is also possible to plan the mining and waste dumping operations in such a way as to minimise future reclamation costs as discussed below.

4 MANAGEMENT OF ENVIRONMENTAL IMPACTS

During the operational phase of a quarry's life, the impact on the environmental can be lessened by planning with future closure in mind. Thus it can be seen in Figure 5 below that the area cleared for mining and associated facilities has been kept to the minimum to that absolutely necessary for the safe and efficient operation of the mine. Further, topsoil beneath the infrastructure areas has been removed and stockpiled, while topsoil ahead of the advancing waste dump is also removed and stockpiled. The waste dump has been sited to the north of the quarry, taking visual impacts into account – the southern side of the hill will remain unmined due to expected low recoveries, and is highly visible from the Magaliesberg mountain range, a major tourist area. Siting of the waste dump to the north of the quarry ensures that there is no visual impact seen from the Magaliesberg, both during mining and after closure.

Contrast Figure 5 with the mining that has taken place in Figure 2 (this is an area within Kelgran's Rustenburg quarries, and was quarried at intervals over a period of approximately 20 - 25 years prior to Finstone and RED Graniti acquiring an interest in Kelgran).

Figure 5 The W2 quarry at Wonderkop showing orderly quarry development, stockpiling of topsoil removed from areas required for infrastructure, and removal of topsoil ahead of waste dumping.

It is also good practice to plan mining where possible in such a way as to be able to utilise waste from operational quarries to fill the voids of worked out quarries. By planning properly, many voids from quarries and gravel borrow pits can be filled up during the course of mining at very little extra cost (see Figure 6 and Figure 7). Comparatively, given the situation in Figure 2 above, it would not be economically feasible to fill the worked out voids at the end of the life of the quarry. Similarly, the correct location and construction of waste dumps can significantly assist in lowering the final reclamation cost for the quarry. Waste dumps that are constructed on flat areas should be built up in layers of 6-10 metres in height, with a terrace of at least 6 metres wide between the crest of one layer and the foot of the succeeding layer. In this way, the outside perimeter of a completed layer can be reclaimed concurrently with the dumping of the next layer. Further, if the waste dump is planned in such a way that the final perimeter is constructed first, and then filled back towards the quarry, it is possible to reclaim the outside perimeters at a very early stage, thus reducing the visual impact during the operating phase of the quarry.

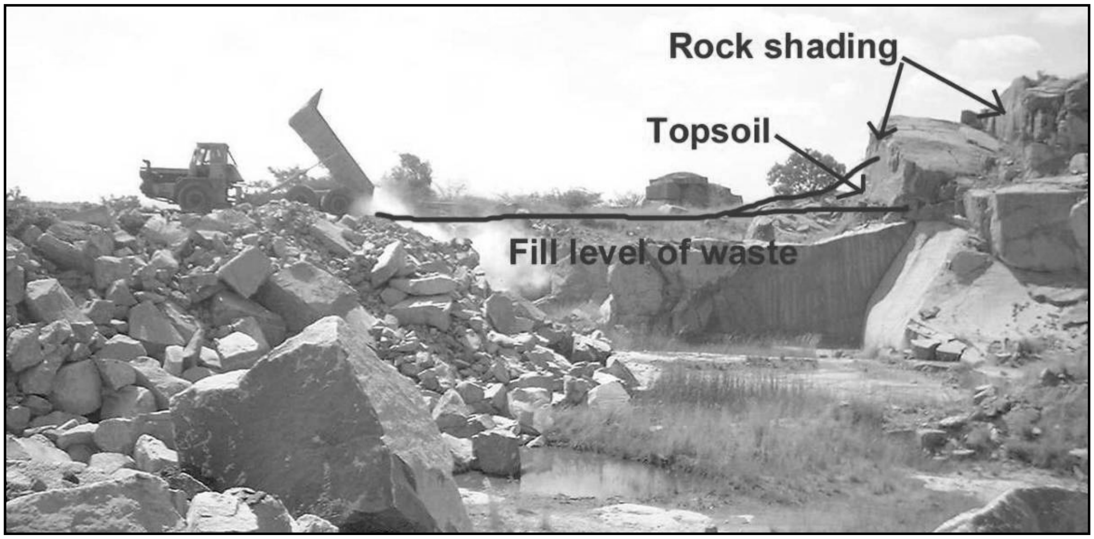

Figure 6 Backfilling of the worked out B7 quarry at Finstone's Marikana Mine

Figure 7 B7 quarry after backfilling and topsoil placement

Topsoil should be removed in advance of mining and waste dumping and where possible, utilised as soon as possible for reclamation to ensure minimal loss due to erosion and reduced fertility of stockpiled soils as a result of the decrease in nitrogen-fixation organisms and leaching of calcium and potassium from the soils. Where this is not possible, topsoil stockpiles are kept to a height of 2 m in order to limit run-off rate and, in this way, reduce erosion, or where this is not feasible, water control structures are utilised to control run-off and thus minimise erosion of the stockpile. If necessary (this is seldom the case, as it generally contains a fertile seed bank), the stockpile is seeded with seeds of grasses and shrubs to keep organic activity alive, as well as ensure a fertile seed bank in the topsoil when it is finally used. While the regulations of the now defunct Minerals Act regarded the top 0.5m as being topsoil, Finstone's quarries have always removed the entire topsoil layer down to the subsoil, even where this is significantly thicker than 0.5m, as topsoil is always a scarce resource, and even if this lower material does not contain seed and is poorer in soil organisms, it has been found to be useful in reclamation. Some authors recommend that where topsoil is less than 150mm thick the unconsolidated material beneath this should also be removed and treated as topsoil [7]. We would agree with this recommendation, as we have had good results in such circumstances from mixing this layer with the topsoil and treating the mixture with animal manure or fertiliser. In the case of dimension stone quarries located in formations with a lot of small loose boulder cover, these too are removed and stockpiled (often with the soil) as they are useful in final landscaping to give a more natural appearance.

As noted above, the dimension stone mining industry is a clean industry from a pollution point of view. The environmental impact assessments conducted by Finstone during the compilation of its EMPRs identified petrochemical pollution as the most serious threat in this regard, and in order to maintain our record as a clean industry, this threat is taken very seriously. Consequently, all petrochemical storage areas are situated on concrete slabs surrounded by bund walling with a containment capacity of 150% of the fuel or oil stored (see Figure 8). Wash bays are constructed so that oil and grease is retained by means of a three stage separator, which is cleaned regularly. All runoff water from within workshops also passes through this separator. Oil spillages within workshops is soaked up by means of saw dust, which together with used oil filters and soiled rags are collected by a waste disposal company for disposal at a licensed hazardous material waste disposal site.

Figure 8 Bunded diesel storage facility (Nells Quarry)

Old oil is collected and stored, and is sold for recycling. All quarry sites are equipped with emergency petrochemical spillage kits which are used such events as hydraulic pipes bursting in service and spilling oil. Any contaminated soil is bio-remediated using proprietary products kept on all sites for the purpose. The process involves loosening the contaminated soil to allow for oxygen penetration (the soil is usually transported to a specific impervious site for treatment to avoid compaction during the process), and adding agricultural fertiliser and the proprietary products containing appropriate microbes to break down the hydrocarbons. The soil is kept damp and is turned periodically over a period of several weeks as the microbes break down the hydrocarbons. Technically, this is a contravention of Regulation 70(5) of the MPRDA, which requires that "*Oils, grease and hydraulic fluid spills must be cleaned up by removing all contaminated soil and disposing such soil in a waste disposal receptacle or at a licensed facility*".

We however believe that it is a better solution than that prescribed by regulation, as it effectively treats the problem rather than just moving it to another location. Extensive attention has been given in the maintenance programs of all equipment to replacement of hydraulic pipes which show signs of potential failure before this happens, as well as to ensuring that chafing of these pipes does not take place.

All industrial waste is collected for recycling, and at the larger sites domestic and office refuse is also sorted for recycling. All non-recyclable industrial waste is collected by Waste-Tech for disposal at a registered hazardous material disposal site, while non-recyclable domestic and office waste is disposed of at the nearest municipal waste dumping site.

All gravel roads in quarry areas have a speed limit of 60km/h for light vehicles and 30km/h for heavy vehicles in order to minimise the amount of dust generated by vehicles. In addition, where available water allows, roads are sprayed with water on a regular basis in order to prevent dust creation. In the quarry, it is not practical for various reasons to use wet drilling, and all drilling in the quarry (with exception of diamond core drilling) is done with air flushing. Dust collectors are used to catch the dust created from drilling. On the dressing yards, wet drilling is possible, and here water is universally used as the flushing medium in Finstone's quarries.

Various exotic invaders establish themselves on disturbed areas and freshly reclaimed waste dumps. Where these are pioneer species such as khakibos (Tagetes minuta), they are left alone, as they provide initial soil stability, and are ultimately displaced by the grasses within a few seasons. However, Wild Tobacco (Nicotania glauca) and Castor Oil plant (Ricinus communis) are removed on a regular basis. Larger plants are cut down, and the stumps treated with herbicide to prevent coppicing, while smaller plants are removed using a tree popper. The material is burnt after it has dried. Fountain grass (Pennisetum setaceum) is a perennial invader grass which it is compulsory to remove in terms of the Conservation of Agricultural Resources Act, and this grass is sprayed with herbicides during the growing season before seed is set.

During the operational phase of a quarry, attention is also given to removing trees and shrubs where possible, and replanting these either in a nursery, in areas where reclamation is in progress or outside the mining area, thus lessening the impact on floral biodiversity.

5 RECLAMATION OF DIMENSION STONE QUARRIES

In South Africa, the term rehabilitation has traditionally been used for the range of activities relating to the remediation of environmental damage to the surface of a mine after extraction is completed. The Minerals and Petroleum Resources Development Act (MPRDA) refers at Section 41(*Financial provision for remediation of environmental damage*) to "*rehabilitation or management of negative environmental impacts*" and at Section 107 (1)(a)(iii) to "*the rehabilitation of disturbances of the surface of land where such disturbances are connected to prospecting or mining operations*". Nowhere however is the term rehabilitation defined in the law. Regulation 57(e) of the MPRDA requires that "*the land is rehabilitated, as far as is practicable, to its natural state, or to a predetermined and agreed standard or land use which conforms with the concept of sustainable development*". The term used within the literature surveyed for returning the land to the exact conditions that existed before the disturbance is restoration [7], however it is in fact often neither possible nor desirable to return disturbed land to its previous condition or use [7]. Rehabilitation in the literature surveyed indicates that the disturbed land is returned to conditions that conform to a prior use plan (often agricultural) [7], which accords with second part of Regulation 57(e).

We prefer the term reclamation, defined as “a response to any disturbances to the earth and its environment caused by mining activity” [15] as it is wider in scope and includes all aspects of management of negative environmental impacts caused by mining..

As dimension stone mining is a clean operation, the main aims of reclamation are as follows:

- Ensure that worked-out areas are safe for future uses;
- Minimise visual impact of disturbed areas;
- Revegetate worked-out areas with suitable plant species;
- Achieve long-term stabilisation of all worked out areas to minimise ongoing erosion; and
- Monitor and manage reclaimed areas until the vegetation is self-sustaining.

Reclamation practice varies widely, depending on the type of mine, its location, and the applicable legal requirements [7] (we would suggest that the legal requirements should not implement on reclamation practice, and that responsible companies should operate to the highest environmental standards of environmental management within the context of sustainable development, irrespective of the fact the local legal requirements may be lower than these). Similarly, even within the field of dimension stone mining, there is no unique method that can be prescribed for all situations. Each quarry requires a particular solution depending on the region where it is situated, the type of quarry (hillside or pit), and the mining methods applied [20]. Nevertheless, we will discuss some general principles which have been successfully applied in Finstone’s quarries.

5.1 Landscaping

While most dimension stone operators in South Africa consider rockshading (discussed below) as the only form of visual impact mitigation required, this alone is insufficient to meet the standards which Finstone aspires to achieve in its rehabilitation. This was considered especially important in view of the fact that the main road to Sun City passes within a few kilometres of most of Finstone’s Rustenburg operations. However, in view of the fact that the natural kopjes consist of rocky outcrops interspersed with trees and grassland, and the limited topsoil available, it was decided that contouring of the shape of the waste dumps, together with limited topsoil application and rockshading and revegetation would provide a solution. The conceptual waste dump design to achieve this is shown in Figure 9 below, while Figure 12 shows an area that has been reclaimed in this way, approximately 18 months after topsoil was placed. Figure 10 below shows the same waste dump from a distance. The top two terraces have been rock shaded and topsoil has been deposited, while the bottom terrace still requires rockshading. The straight lines of the tops of the waste dumps are still very prominent, although as can be seen in the foreground, there are some straight terraces that occur naturally. These straight lines will be broken up to an extent as trees grow. The dump shown in Figure 10 was an existing waste dump, which was already far advanced in its development. Consequently any radical landscaping would not have been economic. With new dumps however, it is planned that the edges will be broken up by landscaping work as part of ongoing waste dumping. In practice, waste dumps on the sides of kopjes, which have large slopes will be terraced once the dump has reached its final profile at the top level, by dumping additional material along the sides at progressively lower levels, and developing these terraces at differing angles. Final reclamation will thus only occur toward the end of the life of the quarry. In the case of waste dumps in the valleys, these will be developed from the bottom up, by initially dumping at an appropriate height (around 6-10m), until the final designed perimeter is reached.

Thereafter, dumping will proceed on the top of this dump at successive heights, leaving terraces of 6m wide, and working from the perimeter toward the centre. This will allow for reclamation of the outside profiles at a much earlier stage, resulting in very little outstanding reclamation toward the end of the life of the dump.

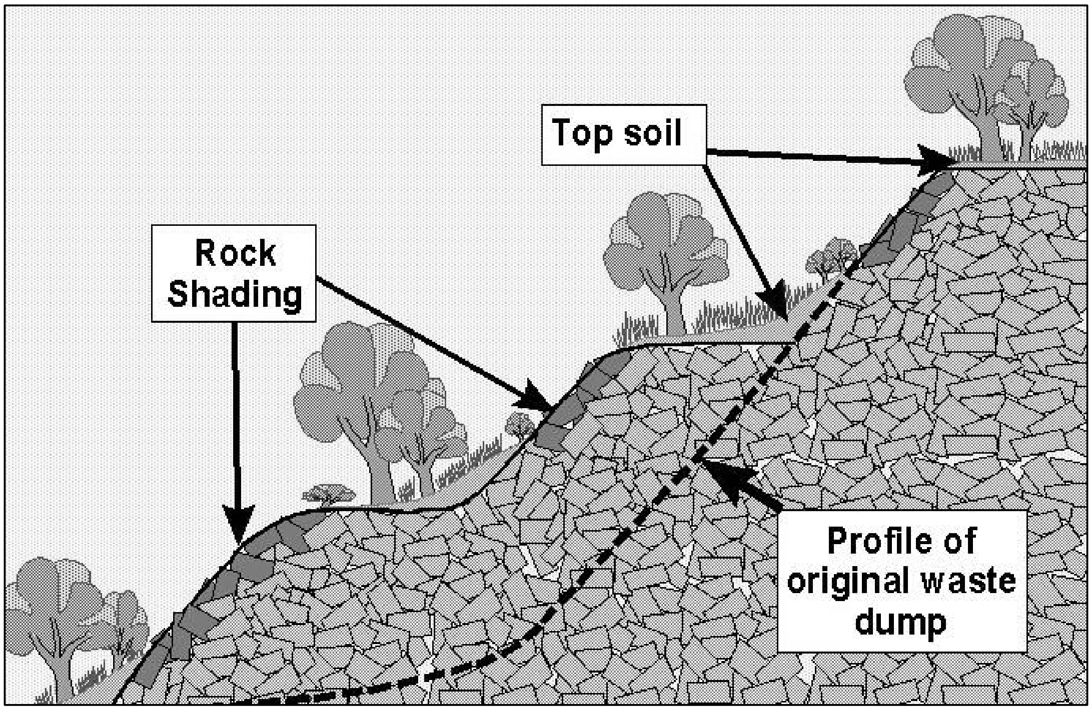

Figure 9 Mitigation of visual impact of dimension stone waste dump

Figure 10 Terraced, topsoiled and rock shaded waste dump (Marikana Quarry)

While many historical voids are filled during the course of mining as discussed above, there are several old quarries which have become perennial water holes, and ecosystems have established themselves around these holes as discussed below. Filling all of these would be environmentally detrimental, but they do pose a risk to human and animal life in terms of their steep sides, and if left as is pose a long term safety risk for the mine owner. The solution being applied to these is to landscape the approaches to these water holes where possible in order to provide for safe access for humans and animals, and to pack waste blocks along highwalls which cannot be so landscaped in order to prevent inadvertent access.

Another important part of final landscaping work is the construction of berm walls to control rainwater runoff and prevent erosion of the topsoil. These are either hand packed with stone in kopje areas, or constructed with topsoil on waste dumps and other large flat areas. Deep ripping of compacted surfaces is practiced in order to encourage infiltration and allow plant root growth. It is important to note that the limited topsoil used on the sides of waste dumps is initially subject to some erosion due to the steepness of the natural angle of repose (37°). However, observations show that where excessive amounts of topsoil are not used, the topsoil stabilises in individual pockets with negligible slope between the large waste blocks.

It must be pointed out that Regulation 72 of the MPRDA requires that "*Granite off-cuts and related waste must be broken into manageable units to be either recycled, crushed or disposed of and the applicable land must be rehabilitated* ...". No clarity is provided as to what size constitutes "*manageable units*", and it is thus unclear whether the principles described above are legally compliant. In any case, it is not economically feasible to break the large blocks of waste into small pieces, and doing this would further destroy what may be a valuable potential resource in the future, as technology may allow for some of this waste to be used (remember, in dimension stone, size counts!).

5.2 Rock shading

The major source of visual impact from Finstone's South African quarrying operations is due to the grey-blue (Rustenburg), black (Belfast) or light green (Olive Green) colour of freshly cut stone, compared to the red-brown or brown colour of weathered boulders in the natural state, as well as the light colour of the gravel used on roads and working surfaces. This could be ameliorated by covering the waste dumps with topsoil, and re-establishing vegetation. Topsoil resources in most quarrying areas are however scarce, and the amount of topsoil removed in advance of waste dumping is insufficient to cover the waste dumps satisfactorily, particularly when waste is dumped down the kopje sides. Topsoil must therefore often be removed from undisturbed areas in order to reclaim these dumps, which is environmentally undesirable, as well as costly. In addition the final appearance achieved (see Figure 11), while preferable to barren waste dumps does not blend into the natural kopje environment (this can be seen in the background of Figure 12 or the foreground of Figure 4). In addition, the natural habitat for many animals such as dassies and owls is substantially altered in that there are no longer crevices and cavelets found in the natural kopjes for them to escape predators or for breeding.

Work was consequently done on developing an economic alternative method of ameliorating the visual impact without the negative effects of utilising topsoil from undisturbed areas, with a focus on developing an economic method of shading the broken rock surface to a more natural colour. Research uncovered products available from the USA, which essentially used an epoxy resin based glue to stick sand particles to the rock face.

Figure 11 Waste dump covered with topsoil

While the results are aesthetically very pleasing, the process in 1994 cost in the order of R10-15 per square metre covered, and was thus not economically viable. In addition, the life of the epoxy resin was not guaranteed beyond 20 years. However, studies by the company's geology department showed that the natural red-brown colour was a result of weathering of the outer 1-2mm of the rock surface, with the iron content in the pyroxenes being converted to mainly to haematite (Fe_2O_3) with some limonite (Hydr. Fe_2O_3 & FeO(OH)) and magnetite (Fe_3O_4). Attempts were thus made to find a chemical which would mimic the natural process by coating the rock surface with iron oxides. As iron oxides are insoluble, various soluble iron salts (mainly sulphates and chlorides) were tested. The sulphates gave pleasing results, but ferric chloride (FeCl3) was just as acceptable, and is available commercially in large quantities at a reasonable price, as it is extensively used in sewage treatment. It was decided to pursue this route, and testing was done at various concentrations to establish which would give the best results. It was found that at low concentrations (less than 20% contained FeCl3) the coverage was poor, and insufficient to sufficiently alter the grey-blue appearance. At slightly higher concentrations, coverage was acceptable, but the surplus water lead to the development of limonite preferentially to haematite, with the result that the colour achieved tended toward yellow or orange, and did not blend in with the natural rock colour. Concentrations of around 40% gave the best results. This was ideal, as one of the products supplied by NCP for sewage treatment is a 43% concentration of contained FeCl3. There was however a worry that introducing even relatively small quantities of chemicals into the reclamation process could have potential pollution effects, in an industry which as noted above is essentially pollution free. Initial trials were thus conducted on a small scale in order to determine whether there would be any effects on surface or ground water before large scale spraying commenced. Results showed slight decreases in pH and slight increases in dissolved salts in rainwater runoff from freshly sprayed areas. While these were within acceptable limits, areas which had had several days to dry before rain had negligible changes in the quality of runoff water. It was also found that high humidity during drying caused a tendency for preferential formation of limonite, while rain within the first 24-48 hours after spraying caused much of the ferric chloride to be washed off, requiring that the work be repeated. Due to these factors, it is preferential that spraying of rock surfaces with ferric chloride be conducted during the winter months. However, care must be taken, as experience has shown that where there is excessive dust collection on the rock surfaces, such as is the case with dumps close to haul roads, haematite tends to from around the dust particles rather than on the rock surface, resulting in substantial loss of coverage when the rains wash off the dust. This can be overcome by washing down these surfaces with water several days prior to spraying, or by treating these areas during dry window periods within the rainy season. An example of a waste dump treated with ferric chloride is shown in Figure 12 below.

While rockshading with ferric chloride provides reasonable amelioration of the visual impact, especially at a distance (>5-10km), this alone is insufficient in achieving Finstone's goal of restoring disturbed areas as far as possible to their previous appearance so as to blend in with the natural kopjes. These standards of reclamation, while not excessively expensive for new quarries which are properly planned from the beginning are very difficult to attain economically in old areas without integration of mine planning and reclamation planning.

It is also important to consider how the colour achieved by rock shading blends in with the existing natural environment, as the method described above works well in Finstone's Rustenburg, Belfast and Northern Cape operations, as well as in Zimbabwe, as the colour of the existing natural boulders is very similar to that that can be achieved by careful application of ferric chloride. However, the method does not perform well in test applications at quarries in the Parys area, as the natural weathering of the rock is a much lighter brown, and the freshly cut surface in fact is less visually intrusive than when treated with ferric chloride. Even in the Belfast area, more soil and vegetation are required to achieve a natural look, as although the colour is close to the natural weathered colour, the natural hills have far less rocky outcrops than Rustenburg. In the Northern Cape, the quarries are situated in huge rocky outcrops, with occasional piles of loose boulder scree, and rockshading can give satisfactory results without topsoil and revegetation, as there is little or no topsoil and vegetation in the natural state. In Zimbabwe, rock shading gives good results, but may be unnecessary, as the quarries are situated in remote areas which are fairly hilly, and consequently the quarries are not observable to large numbers of people.

Figure 12 Waste dump treated with ferric chloride

In addition, the topsoil is rich and rainfall relatively high, and so vegetation fully mitigates long term visual impact within a few years. At Finstone's Namibian quarries, situated in the Namib Desert, rock shading is inappropriate, as it would totally contrast to the existing landscape. Further, most topography surrounding the quarries is fairly flat, and so here the strategy is to keep waste dumps as low as possible, to have flatter slopes than the natural angle of repose on the final perimeter, and to cover the perimeter as far as possible with the sandy gravels stripped in advance of mining and dumping.

5.3 Revegetation

Revegetation is an integral part of Finstone's reclamation activities. The reasons for this are that revegetation is the most effective and economic method of stabilising the soil against erosion assists in re-establishing biodiversity in the reclaimed area and helps ameliorate visual impacts.

Topsoil reclaimed in advance of waste dumping has a high seed content, particularly of grasses and Acacia species, and where possible is used directly from stripping for reclamation. In this way, rapid revegetation is obtained at minimal cost. The grass development seen in Figure 12 above was the result of this process, only 18 months after topsoil was deposited. In some areas where topsoil is in short supply, it is necessary to mix topsoil with norite gravel in order to obtain the coverage required. In these cases the mixture is fertilised with cattle and goat manure purchased from local communities, or else fertiliser in the form of limestone ammonium nitrate is added. Technically, this is a contravention of Regulation 70(7) of the MPRDA which requires that "*the chemical and physical properties of top soil to be used for the purposes of rehabilitation must not be changed by introducing foreign material, gravel, rock, rubble or mine residue to such soil*". A seed mixture of Oulandsgras (Eragrostis curvula), Smutsvinger (Digitaria eriantha), Rhodes grass (Chloris gayana) and Kweekgras (Cynodon Dactylon) is distributed at the start of the rainy season. Seed of the common fast growing acacia species (Acacia caffra, A. karoo, A. nilotica and A. tortilis), and Sekelbos (Dichrostchys cinerea) are collected on the properties, and are also spread on the sides of topsoiled waste dumps.

A nursery is maintained on one of the mines in the Rustenburg area, and trees such as Marula (Sclerocarya birrea), Rooi Ivoor (Berchemia zeyheri), the bushwillows (Combretum erythrophyllum, C. apiculatum and C. molle), and the wild fig species (Ficus ingens, F. natalensis, F. glumosa and F. soldanella) are cultivated from seed or cuttings collected on site. Other trees such as Acacia species and the Karee species (Rhus lancea, R. leptodictya and R.pyroides) are purchased from various municipal and private indigenous nurseries in the area. Trees are planted on topsoiled areas, and watered at weekly intervals for the first season, where after they are left to survive on their own. The focus is on the fast growing Acacia and Karees, as well as fruit bearing trees such as the wild figs, Marula and Rooi ivoor. The latter ultimately attract bird life and baboons, which in turn bring other seeds into the area with their droppings. Wild fig is especially useful in old quarry areas where topsoil thickness on top of solid rock is limited.

In worked out quarries, a bench is left below each highwall, both for stability and safety, as well as to facilitate reclamation (see Figure 13). A mixture of waste rock and soil (the waste rock helps provide stability to the soil and allow steeper slopes, which in turn allow for a thicker deposit within the available space, but is again technically a contravention of Reg 70(7) of the MPRDA) is placed against the foot of the highwall (which itself may be rockshaded) and seeded with grasses, shrubs and small trees. The bench surfaces are covered with soil, and it is attempted to slope this away from the highwall crest to prevent erosion. In many cases, waste blocks are packed along the highwall crest to form a permanent safety barrier, and these in combination with manually packed stone berms these may also assist in preventing erosion of the soil. Where the width of the bench and highwall safety allow, pockets may be blasted into the footwall and filled with soil to assist growth of larger trees. In areas where suitable indigenous creepers or trailing plans occur, these may also be established so as to trail over the highwall.

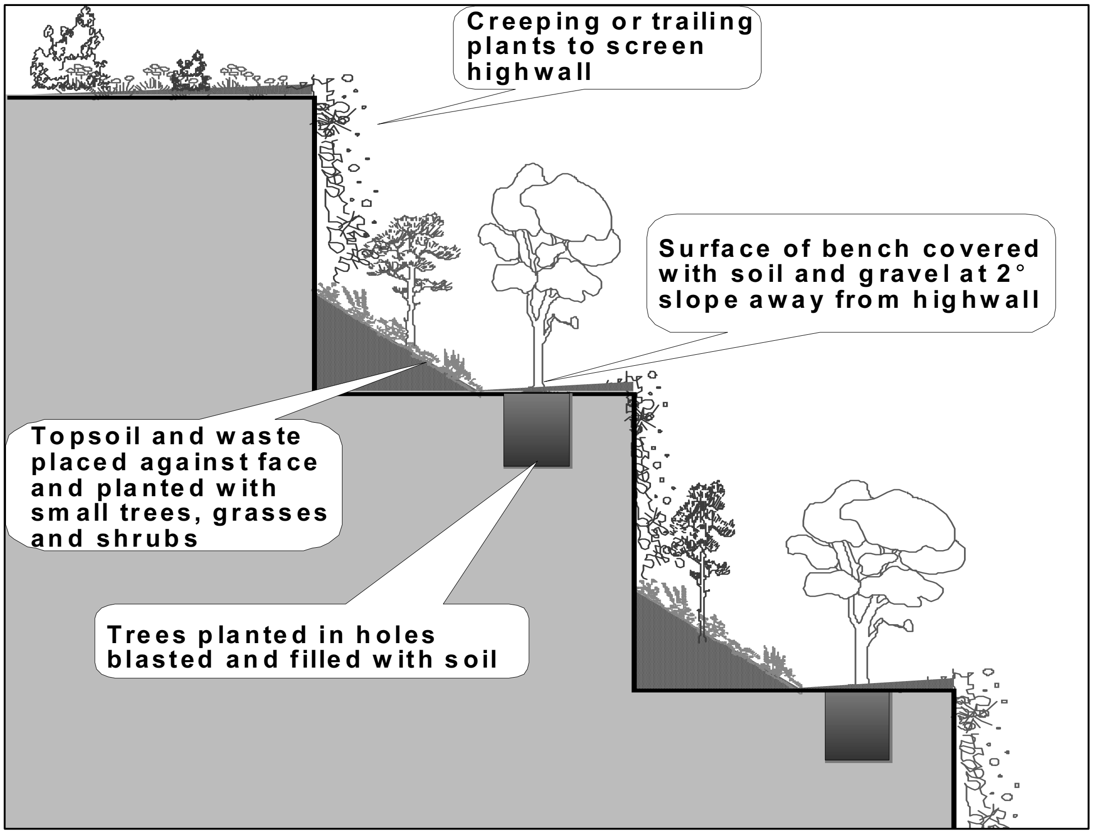

Figure 13 Conceptual layout of reclamation of solid formation quarry (after Dunda[20])

6 CONCLUSIONS

While the environmental impacts of mining are often largely exaggerated in the eyes of the public, it cannot be escaped that mining has an appalling public image. While the industry can take some of the blame for this given a historical track record of contempt or ignorance of its impacts, much of this has to do with the fact that the impacts of mining are often far more visible than those of other industries. In fact, it is ironic that the visual impacts which inflame public opinion against mining are often the least significant impacts of metalliferous and coal mining operations – the potential for severe pollution from these operations is far more significant than their visual impacts or local destruction of ecosystems by extensive surface mining.

Dimension stone mining, by the very nature of the requirements for the final product is a clean industry from a polluting point of view. However, the visual impacts are often significant, given that many deposits are situated in hills or mountains. In South Africa, the Department of Minerals and Energy has taken a view that the environmental impacts of dimension stone quarrying are severe. This view has been informed by the significant negative television coverage of quarries in the Brits area as a result of poor handling of conflicts surrounding these quarries by the DME themselves, as well as the erroneous assumption that adverse visual impact equates to severe environmental impact. It does not help however, that the dimension stone quarrying industry in the past conducted quarrying on an unsustainable basis, literally picking the eyes out of the reserves with no forward planning or respect for the environment, leaving large areas of disturbance in the public eye.

Since the mid 1990s however, today's two largest operators in the dimension stone industry (Finstone and RED Graniti) have however adopted a far more professional approach to all phases of the dimension stone project lifestyle. By following this approach, environmental impacts are minimised. Further, reclamation techniques have been developed which adequately address the long term impacts of dimension stone quarrying operations.

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