QUARRY RECLAMATION IN ENGLAND: A REVIEW OF TECHNIQUES[1]

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Abstract. This article reviews different techniques for reclaiming quarries in England. They can be used to reclaim abandoned quarries as well as those that are still operating. A number of reclamation techniques have been developed to revert land that has been quarried for minerals to some productive state. The techniques discussed in this paper include rollover slopes, backfilling, bench-planting, and restoration blasting. These techniques are mainly used to prepare quarry landform to support vegetation, ensure safety at site, as well as accommodate different after-uses. A less conventional method of natural recovery or spontaneous succession is also discussed. Whether applied solely or in combination, the use of these techniques has a potential to enhance the environmental qualities of land degraded by quarrying.

Additional Keywords: daleside; limestone; rollover; after-use; post-mine land-use; environmental design.

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Introduction

Quarrying is an ancient practice, dating back at least to the Stone Age. Although stone was needed to create tools such knifes, axes, hammers, and arrows, as well as for construction (Tandy 1975), extraction was on a relatively small scale. The uses of stone for present-day industrial applications such as in the construction of roads and manufacture of cement means that exploitation is now undertaken on a much larger scale. Quarrying continues to be carried out because of the economic importance of the minerals extracted from below the earth surface. In turn, this extraction has the potential to have a devastating impact upon the environment.

Quarrying nowadays takes place under strict rules and regulations as well as through self-policing by mineral extraction companies. This control on the industry has helped to reduce the disturbance of land as well as ensuring that disturbed land is reclaimed. Reclamation is a process of returning a disturbed piece of land to a productive state (Down and Stocks, 1978). The land could be reclaimed in order to accommodate its original use or any other type of use suitable for the existing conditions (economic, socio-cultural and physical). Hackett (1977) identified the following objectives of quarry reclamation:

1. To restore the chemical and structural health of the soils. Before reclamation, soils in quarries could have chemical and structural composition that can inhibit plant growth.
2. To restore the health of vegetation in order to enhance biodiversity.
3. To create a safe environment in and around the quarry in order to create opportunities for human activity.
4. To improve the visual and environmental qualities of the quarry landscape.
5. To preserve aspects of interest such as geological features, wildlife, and plant habitats.
6. To create habitats for wildlife and plants.

Even though quarrying is an ancient activity, reclamation of quarries in England dates back only to the late 18th Century. Examples of these include coal and iron works in the North east and Midlands, Attingham Park in Shropshire, and waste tips on the Duke of Northumberland's estates (Tandy, 1975). In this era, reclamation was done as a voluntary activity until 1948 when legislation was enacted to ensure that all mineral extraction sites are reclaimed after closure (Tandy, 1975).

This necessitated development of different methods of reclaiming different extraction sites with a potential of obtaining many different outcomes.

This paper reviews selected, commonly used, hard-rock quarry reclamation techniques. Even though the techniques can be applied anywhere and on any rock type they may need to be adjusted depending upon the environment and regulations in those places.

Five different techniques including, rollover slopes, backfilling, bench planting restoration, blasting, and natural recovery are reviewed. The paper discusses what the techniques are, how they are applied, what it takes to apply them, as well as the advantages and disadvantages of applying each of the techniques in a reclamation scheme.

Reclamation

Reclamation is a process that involves creation of appropriate landform to support any envisaged post mineral extraction after-use, and creation of appropriate surfaces for the establishment of vegetation. The success of any reclamation scheme is aided by proper implementation of these two processes. The importance of adequate planning for both the extraction and reclamation processes during the planning stages of a quarry cannot be overemphasized (Darmer, 1992). Well planned sites can lead to fine landscapes, examples of which include the Norfolk Broads, Eden project in Cornwall, the National Water Sports Centre at Holme Pierrepont, Nottingham, Grays quarry in Essex, and many other magnificent sites across the England (Bradshaw, 1984; Cilek, 2006).

Planning for reclamation takes into account a number of factors. They include the public's preference for the type of after-use, the intended final grade of the site, depth of the extraction pit, whether extraction was wet or dry, availability of fill material, soil characteristics, availability of top soil, quarry setting, cost, availability of technical expertise, character of the surrounding landscape, and land ownership. These have an influence on the type and choice of reclamation techniques that can be applied as well as the final appearance of the reclaimed quarry landscape.

When designing new landscapes, reclamation schemes should follow applied theories and principles of landscape design. More importantly, designs must also follow theories and principles specifically relevant to the intended after-use of a site for reclamation to be successful. All this has to be done within the sphere of acceptable and recommended technical requirements for the intended after-use (Department of Environment, 1989; Hibberd, 1986; Land Use Consultants, 1992b; Moffat and McNeill, 1994; Allington and Jarvis, 2008; Jarvis and Pile, 2008; Legwaila and Lange, 2010).

The techniques described in this article have been developed and refined over time to better achieve functional, aesthetically pleasing (Lange and Legwaila, 2012), and sustainable post mineral extraction landscapes. They can be used independently or in combination to prevent monotony in the landform of the final landscape. The success of these techniques lies partly, but more importantly, on the proper management of all processes that precede reclamation (Wolf, 1980). These include site clearing (vegetation removal), stripping of topsoil and subsoil, and the removal of overburden and its storage on or off site. The mitigation of visual impacts during operation is also an important aspect, which can be tailored to build up to the final reclamation scheme. The extraction of the mineral will need to follow a predetermined layout from which a landscape reclamation scheme was based. However, because of the long life span of quarries, it is not always possible to ascertain that the post extraction land use and the reclamation scheme that was envisioned during the initial stages of quarry planning will be implemented. Sometimes change is unavoidable, and in most situations it has resulted in outstanding reclamation schemes. The need for change could be caused by a number of factors, including improvements in reclamation technologies, improvement in technical knowledge, changes in extraction technologies, change in planning policy, and sociological factors (Department of Environment, 1995). Any diversion in any of these processes from a pre-planned path and design will have to be reconciled with the reclamation scheme. This might necessitate updating of the scheme to align it with the new strategies. For this reason, legislation in England allows and encourages operators to periodically review their reclamation schemes throughout the operation to ensure relevance (Department of Environment, 1995).

Quarry Landscape Elements

There are two major elements that are of importance in quarry reclamation: landform and vegetation (Cripps et al., 2004). They are the most important aspects that drive the success of quarry reclamation. Figure 1 illustrates how different aspects of landform and vegetation can contribute to this success. It is important that attention is given to the design of the landform at the onset as a foundation for all other elements that will make up the reclaimed landscape (Nicolau, 2003). Expansive as landform design undertaking might be, it is crucial, because besides being the foundation, it is what people will be seeing in the period before vegetation establishes and matures (Downing and Pagan, 1972; Nicolau, 2003).

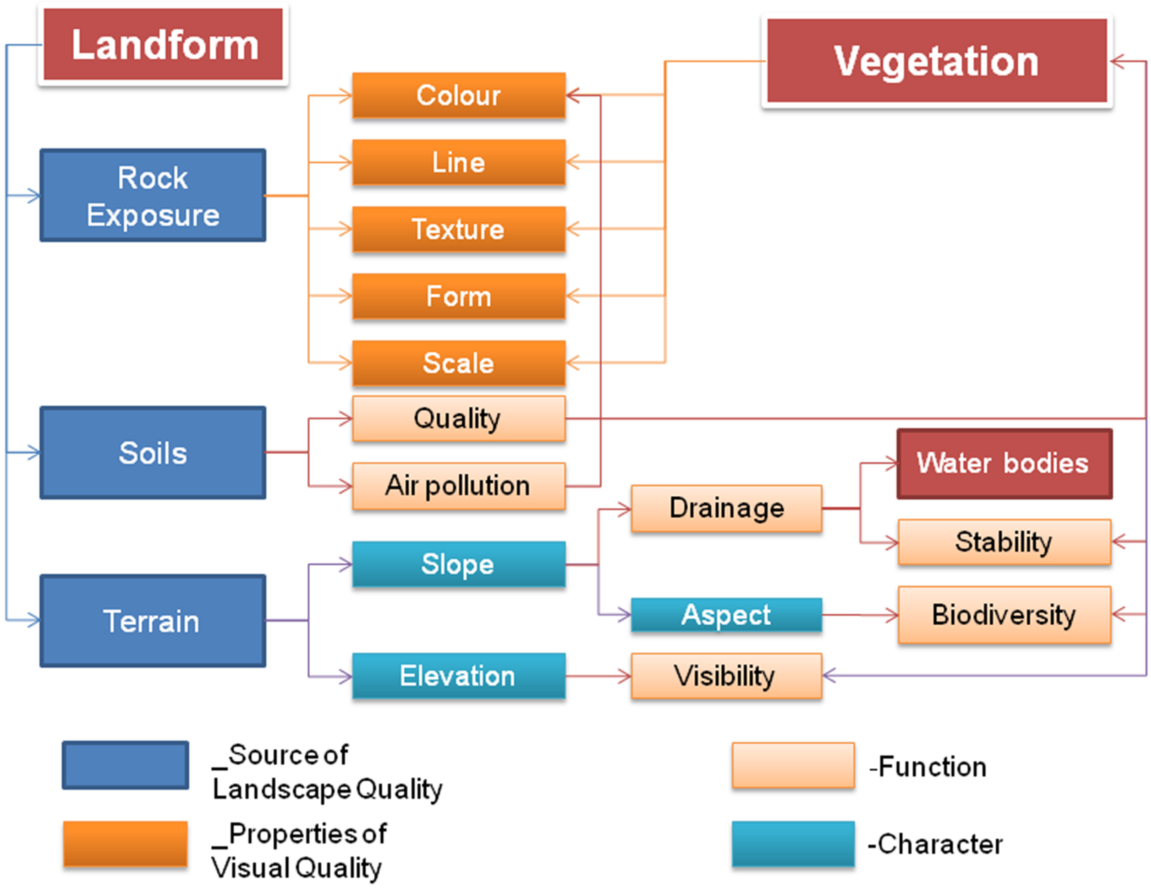

Figure 1. An illustration of how landform and vegetation contribute to environmental quality in quarry reclamation.

<u>Quarry Landform</u>

Most quarries have three main components that make up a quarry landform. They all require different treatments during reclamation. These are the quarry floor, face, and bench. In many situations, the quarry floor becomes the focus for any intended after-use. It can either be flooded or dry depending on the depth of the water table and depth of extraction (Department of Environment, 1989). It can also be ripped to develop a suitable planting surface for vegetation establishment. Quarry faces have crevices that attract a variety of plant and animal species and can present an invaluable ecosystem with the least disturbed plant and wildlife habitats (Yundt et al., 2002). Because of their heights and steep slopes (Table 1), quarry faces also attract activities such as rock climbing (Land Use Consultants, 1992a). Benches on the other hand can be used to provide access to different parts of the quarry for reclamation management, as well as for recreational purposes where public access is allowed.

Overall, there is a great potential for treating all these sections of a quarry to attain a wide range of landscapes and facilities for both environmental and social benefits. In a spectrum of after-uses of quarries worldwide, there is on one end, landscapes that are purely natural with very little or no human activity like Miller's Dale Quarry (Fig. 2) in the Peak District, England, to highly urban, high-tech, and highly used human centred areas, such as the Songjiang hotel in China (Fig. 3).

Table 1. A range of dimensions of quarry components cited from different articles (Land Use Consultants, 1992a; Walton et al., 2004; Cripps et al., 2004).

Components	**Dimensions**
Face Slope	70-90^{o}
Overall Slope	45-60^{o}
Quarry Face height	10-20m
Bench Width	7-15m

Figure 2. Millers dale quarry (Thwaites, 2008). Figure 3. Songjiang hotel (Welch, 2015.

Of the three main components of a quarry landform, benches and faces, which make up the quarry wall, present the most challenge in the reclamation process. This is so because of the safety and visual quality challenges they present. They also cause contrast in form and colour between the quarry landform and the undisturbed landscape around quarries. The earth surface of a natural landscape is usually dominated by vertical structure in the form of vegetation, whereas horizontal lines caused by the edges of quarry faces dominate the quarry wall. This causes the quarry landscape to fall out of place with its context (Cripps et al., 2004). Different authors have provided guidelines on the application of different techniques that can minimize these differences and help blend the quarry landscape with its surroundings (Allington and Jarvis, 2008; Cripps et al., 2004; Jarvis and Pile, 2008; Walton et al., 2004).

Vegetation

Quarries are "hostile environments" for plant establishment (Wheater and Cullen, 1997). This is mainly because of poor soils, unavailability of topsoil, steep slopes, and size of the quarries. Even though it might be available in small amounts at the end of mineral extraction (Escalante-Montanez et al., 2005), topsoil is a very important factor in the success of vegetation establishment in any reclamation schemes (Mouflis et al., 2008; Defra, 2009). Because of its importance, sometimes it has to be imported from outside the reclamation area (Land Use Consultants, 1992a), or engineered onsite from soil forming substances. Although they come at a cost, these soils do not always produce desired character of vegetation at their new sites because of their quality (Bradshaw, 1984). This is especially so for limestone quarry sites. Soils that lie above limestone mineral are alkaline and are referred to as calcareous soils. They support calcareous vegetation, which is characterized by grassland with sparse woodlands. The use of highly nutritious soils on these sites may therefore produce vegetation that is out of place with that in its surroundings (Riley and Rimmer, 2003). One of the techniques applied in the industry is to mix the topsoil with limestone dust to mimic the highly alkaline calcareous soils.

Techniques of Rreclamation

There are several techniques that may be applied to reduce the visual impact of quarries and provide potential for the creation of biodiversity, including the creation of rollover slopes, backfilling, bench planting, and restoration blasting (Gunn and Bailey, 1993; Land Use Consultants, 1992a; Walton et al., 2004). The option of allowing natural recovery or spontaneous succession may sometimes yield desired result. Before reclamation became a mandatory part of quarrying operations, this was the norm, and although because the growth of vegetation, a lack of benching, and the effects of weathering on the colour of the rock reduce the visual impact of former quarries, it would not be appropriate for dealing with modern quarries, which tend to be on a much larger scale. However, by assisting natural recovery, it might form part of a scheme and could be applicable for certain smaller quarries and parts of a large quarry (Bradshaw, 1984; Wheater and Cullen, 1997).

The success of both natural recovery and other schemes, benefit from the use of local soil. The re-establishment of sustainable vegetation is likely to be more successful if locally derived roots and seeds are already present in the soil. Obtaining suitable soil from the quarry site itself requires careful planning, so that the soils are used soon after they are excavated. Obviously this is difficult if the quarry is present for 10 years or more and reclamation is carried out at the end of this period, which is typical for hard-rock quarries.

Often the success of reclamation schemes can be greatly enhanced by the use of combinations of techniques, sometimes selectively, to address different challenges and achieve an intended outcome. The choice of any one or a combination of the techniques is dependent on the following factors:

1. The intended after use of the site,
2. The character of the surrounding landscape,
3. Availability of topsoil,
4. Availability of fill material,
5. The cost of using any particular technique,
6. The significance and character of the regional landscape,
7. The intended final grade of the site,
8. Availability of technical expertise.

Rollover slopes

This method involves tipping and pushing material over the top edge of the quarry and spreading it on the underlying benches creating gentle slopes over quarry faces (Fig. 4). In a study based on a survey of 45 quarries, Walton et al., (2004), observed that in about half the cases, rollover slopes proved to be a successful technique. It is often used in highly visible parts of a quarry, although because of the smoothness of the surfaces the landform may not look or behave like the natural landforms (Wheater and Cullen, 1997). Natural topography tends to have uneven slopes with depressions and knolls which create different microclimatic conditions and soil moisture conditions throughout the landform (Cripps et al., 2007; Water-front-Trail, 2010). This provides an opportunity for a number of different plant species to establish naturally in the different portions of the reclaimed quarry (Moffat and McNeill, 1994; Nicolau, 2003).

Advantages. 1. The presence of fill material provides an opportunity for vegetation establishment. The type of vegetation that establishes will however be limited by the amount of material deposited and its chemical and structural composition.

2. The covering of quarry walls reduces the potential for rock falls which provide safe conditions and opportunities for public access.

Disadvantages. 1. The techniques could require a lot of soil or other fill materials which might need to be sourced externally. Some planning authorities for example, do not allow materials to be imported from sources outside the area which can limit the extent to which reclamation can be undertaken.

2. This technique may result in the presence of steep slopes which may limit the options for after-uses of the site. The slopes could also make access to the upper parts of a quarry for planting and maintenance very difficult (Down and Stocks, 1978).

3. The covering of rock faces reduces establishment of biodiversity on rock crevices. It also removes industrial archaeological interests of a site.

4. There is a high potential for soil erosion and mudslides especially during rainy seasons and before vegetation is established. Care has to be taken to ensure that the fill material has suitable structure to withstand erosion as well as being suitable for plant growth.

Figure 4. An example of rollover slopes being formed at the Hope Cement Works, Hope, Derbyshire, England. The technique was used in a progressive reclamation scheme to cover a number of benches where extraction has ceased.

Backfilling

Backfilling is the process of partly or completely filling a quarry void with soil, soil forming materials, and/or waste rock in order to restore the original grade (Haywood, 1979) or create a new landform (Fig. 5). It has been used widely to restore sites where coal has been extracted using open-casting methods. Unfortunately it is not usually suitable for restoring limestone quarries as the amount of overburden material is low compared with the amount of mineral extracted.

Figure 5. An example of a backfilled Permian limestone quarry. Holme Hall Quarry, Stainton, Maltby, Rotherham. The site was designed and developed to accommodate an agricultural after-use.

This method is dependent on the availability of a significant amount of backfill material either onsite or from external sources, and the cost of acquisition and transportation could become limiting factors. However, such schemes have been used in other locations where the void has been used to dispose of domestic and other wastes. Depending upon the nature of the waste, a lining and leachate capturing system might be required to prevent pollution to local surface and groundwater resources. In coal mining areas, colliery spoil may be available to backfill limestone quarries and surplus waste ash produced in coal fired power stations may also be used for this purpose.

Advantages. 1. This technique covers rock faces and as such removes any potential for rock falls.

2. Where the amount of fill material is sufficient, the original topography can be recreated providing an opportunity to revert the site to its original functions.

3. Vegetation can be established anywhere on the site after the landform has been crafted.

4. Selective backfilling can be used to expose rock faces with geological or archaeological interest or to expose areas with potential to be wildlife and plant habitats (Fig. 5) (Cerver, 1995).

Disadvantages. 1. Depending on the slopes created, materials used and environmental conditions, there is potential for soil erosion and other forms of instabilities to occur.

2. Very large volumes of fill material are required. As generally the material may need to be sourced externally, it is likely to be costly to implement. Some quarry operators have employed what can be called 'fill material transfer strategy' to undertake backfilling. By extracting mineral from two or more adjacent sites, overburden, waste, and topsoil from two sites can be used to restore one pit, while rock extraction occurs in the other (Fig. 7). This can also be beneficial in preventing double handling of materials.

3. The high likelihood of settlement due to the self-weight and moisture induced densification that occurs after tipping of fill material which would limit the options for after-uses. This possibility can be minimised by compacting the fill as it is placed.

4. The creation of smooth soil slopes lacks the unevenness of natural ground, where this contributes a diverse and robust ecology.

5. When backfilling a wet excavation (those below the water table), there is a potential of contaminating underground water. It is therefore very important that materials used in such situations are not contaminated or toxic, (Down and Stocks, 1978).

Figure 6. A small section of a quarry face was left exposed to display a piece of industrial archaeology after backfilling a limestone quarry at Dirt Low rake, Hope, Derbyshire, England.

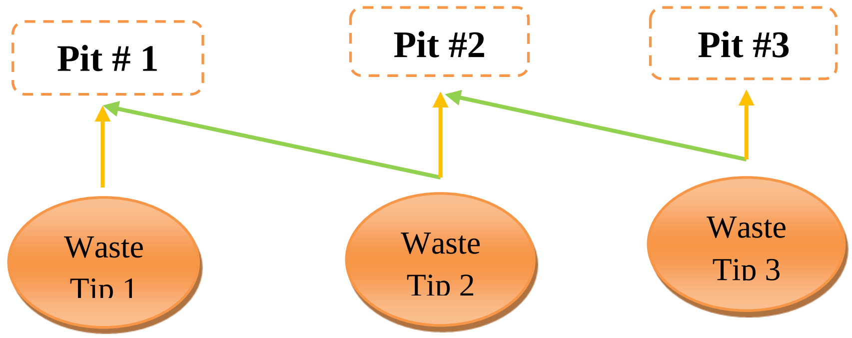

Figure 7. An illustration of the fill transfer strategy. This enables Pit #1 to be reclaimed using fill material from Pit #1 and Pit #2, Pit #2 to be reclaimed using fill material from Pit #2 and Pit #3. The reclamation options for Pit #3 are more limited because of the small amount of fill material left over. Material may have to be sourced externally to back-fill Pit #3.

Bench Planting

This involves placing soil and waste material on benches to create a planting surface (Land Use Consultants, 1992a) (Fig.8). The material covers only a small portion of the rock face. The main purpose is to enable establishment of vegetation on the benches which could eventually conceal the rock faces. In view of the limited space usually available on benches and the stability of the soil, the soil thickness is liable to be insufficient to establish a significant amount of vegetation. Normally large deep rooted trees cannot be use but with the right type of plants, this technique can minimize the amount of exposed rock face.

When soil or soil forming materials are tipped over the quarry edge on to the benches, some finds its way into the crevices of the rock faces. This creates an opportunity for vegetation to establish on the rock faces, which helps to soften and conceal the rock faces thus improving the biodiversity and visual quality of the site. The technique could be appropriate to use where there is very limited amount of soil and it works best if natural soil containing locally derived seeds and roots is used.

Figure 8. An example of bench planting at Dene quarry, Cromford, Derbyshire, England. The shallow soil can only support grass, other groundcover and shrubs.

Advantage. 1. A relatively small amount of fill material is required for this technique.

2. When a diverse variety of vegetation of different sizes is established on the benches, rock faces could be hidden from view thus improving the visual qualities of the site.

3. Important plant and wildlife habitats within the quarry can be preserved. The crevices on quarry wall creates different microclimatic conditions that could be suitable for different species. Where soil is available, plants could grow and further diversify the microclimate on the quarry face which could increase its suitability for other species.

Disadvantages. 1. Depending on the depth of the soil material placed on the benches, some deep rooting plants may be precluded.

2. There is a high possibility of rock falls from the exposed rock faces which could render a site unsafe for public use. Such problems may require use of rock fall preventative or protective measures.

3. Access to benches might be difficult and specialized equipment might be required for placing and spreading the soil on the upper benches. This might add to the cost of reclamation and also make it difficult to maintain certain areas of the quarry.

Restoration Blasting

Restoration blasting is a technique that was developed and tested by a group of researchers from the Limestone Research Group (Cullen et al., 1998; Gunn et al., 1992; Yundt et al., 2002). The intention was to use the final phase of blasting of the quarry faces to simulate landforms found in a locality. It was first explored experimentally in 1988 in the quarries at Hope Valley Cement Works and Tunstead Limestone Quarry in Derbyshire, England to create landforms typical of the limestone valleys of the area such as that at the Great Rock Dale (Fig 9). Figure 10 shows the landform characterized by screes, grassy slopes and rock buttresses and headwalls. The technique was developed after studying the evolution of landforms in natural dales as well as in disused or abandoned limestone quarries (Wheater and Cullen, 1997; Cullen et al., 1998).

Despite the fact that this technique was tested on limestone quarries, it also has potential to be used in the reclamation of other types of hard-rock quarries (Cripps et al., 2007), although modifications may be required for the technique to be applied to areas with different landforms and geology (Yundt et al., 2002). It should also be appreciated that the blasting has to be carefully designed as the objectives are very different from normal quarry operations (Gunn et al., 1992). This decision requires thorough analysis of the physical, geological, geotechnical, and biological characteristics of the site and the surrounding landscape.

This technique is best applied on the visually intrusive sections of the quarry, where screening is either impossible or intrusive (Walton et al., 2004). It has the advantage of blending the quarry landform into its surroundings. It creates a layer of loose material on the bench surfaces (scree) which can be soiled and planted (Gunn and Bailey, 1993; Gunn et al., 1992; Cripps et al., 2007; Land Use Consultants, 1992a; Wheater and Cullen, 1997). However, it is usually less successful at reducing the visual impact of edges of benches (Cilek, 2006).

Figure 9. An example of a natural Daleside. Great Rocks dale, Buxton, Derbyshire, England (Gunn et al., 1992). Note the presence of rock headwalls and buttresses, grassy slopes, screes, and trees.

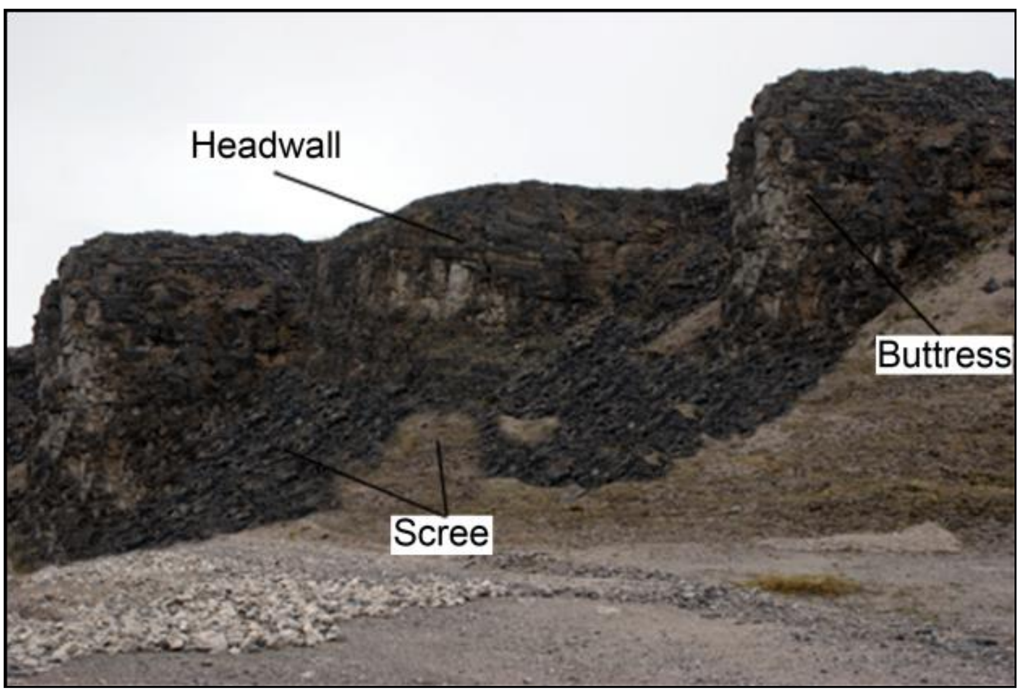

Figure 10**.** An example of a quarry wall that has been reclaimed using restoration blasting at Tunstead quarry, Buxton, Derbyshire. The landform was created to simulate the natural Daleside landscape which is made up of headwalls, buttresses, and scree piles (Cripps et al., 2007; Gunn et al., 1992).

Advantages. 1. Blasting design can be tailored to replicate existing landforms, in order to blend the quarry with the surrounding landscape.

2. The scree blast piles created as part of the restoration blasting process can be used as substrate for vegetation establishment. This may require the application of soils or the installation of soil pockets in the scree specifically for planting (Gunn et al., 1992). The vegetation can help conceal the amount of exposed rock. The plants and the scree piles could also act as rock fall barriers and cushions respectively, thus improving safety.

3. The technique reduces the overall slope of the quarry walls where it has been applied. This helps with blending the quarry to the surrounding landscape especially in areas where the surrounding landscape has shallow slopes.

Disadvantages. 1. This is a highly technical undertaking which requires specialized blasting and geotechnical expertise. Sourcing the necessary experts and the equipment could be costly and would have a bearing on the total cost of reclamation. Selective application of the technique could help reduce such costs. It can be focused on the most visually intrusive parts of the quarry (Gunn et al., 1992).

2. The quarry wall and buttresses are liable to be unstable, posing safety risks for land-users. It may be necessary to remove potentially unstable material from faces and undertake other rock stabilization and protection measures, at additional cost.

3. Soil erosion might occur on the scree blast slopes especially when they have been top dressed with soil for vegetation establishment. This could be minimized by establishing groundcover.

4. Scree blast piles alone may not be sufficient for the establishment of vegetation, especially shallow rooting grasses. In such cases, soil, organic matter, sludge, or other soil forming materials may have to be brought in. This could have an impact on the overall cost of the reclamation project.

5. The material blasted to create scree piles and the rock underneath it could be valuable material that has been sacrificed for reclamation purposes. This

means that a certain amount of revenue will be lost from not using these materials as production material (Gunn et al., 1992), however, the social and environmental benefits of such undertaking could over weigh the economic benefits.

Natural Recovery

Natural recovery is a process in which re-vegetation relies on the presence of seeds and roots in the soils or are transported from adjacent land by natural processes. It happens through different stages referred to as primary and secondary succession. These stages occur through processes of species colonization, spreading, and replacement over time (Davis et al., 1985). It has been concluded in previous studies that disturbed sites that were left to nature, produced landscapes with higher biodiversity and higher aesthetic value (Fig. 11) than those reclaimed through human intervention (Cilek, 2006; Cullen et al., 1998; Hands and Brown, 2002; Hendrychová, 2008; Wheater and Cullen, 1997). The use of natural succession has been recommended as a cheap alternative for the reclamation of abandoned quarries (Novák and Konvicka, 2006). It could also be applied on quarries that went through normal closure requirements. Contention and therefore avoidance of such an undertaking is caused by the duration with which this process produces acceptable landscapes (Fig. 12). In most cases, the site characteristics, especially the soil conditions, slows down growth and sometimes "maintains the site in arrested successional stages" (Novák and Konvicka, 2006).

Because of limitations in the amount of soils in quarries, most parts of the quarry could remain exposed due to lack of vegetation cover. These could provide important habitats for a variety of wildlife as well as create opportunities for exhibition of industrial archaeology (Bradshaw, 1984; Moffat and McNeill, 1994; Ursic et al., 1997).

Figure 11. An example of a quarry site that underwent natural recovery. The site exhibits high biodiversity (Hope cement Works, Hope, Derbyshire).

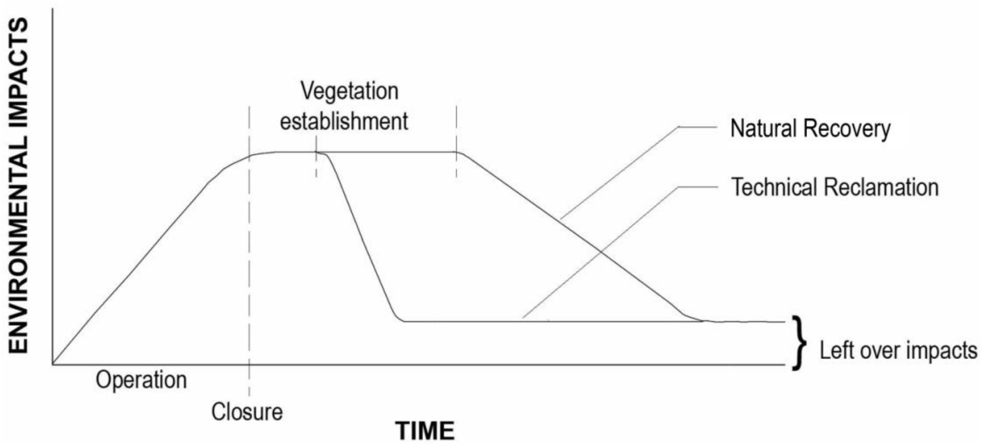

Figure 12. An illustration of the extent of environmental impacts over time after different reclamation interventions. Generally it takes longer for environmental impacts to decrease under natural recovery than it does under technical reclamation. It also shows that there will always be left-over impacts regardless of the type of reclamation interventions

<u>Advantages.</u> 1. There is a high possibility of establishing highly diverse sustainable ecosystems that is adapted to the adverse conditions of the quarry landscape over time.

2. It has a low cost of implementation. This is despite the fact that cost might be incurred reshaping the landform and making the site safe. This could involve activities such as grading and removal of loose rocks from the quarry faces.

3. There is no specialized expertise such as blasting, plants selection and planting, landscape design, and management required.

Disadvantages. 1. Depending on the availability of a seed bank and quality soils, it may take a long time for the vegetation to become established. Until vegetation becomes established, there could be problems with soil gullying and instability if slopes are not stabilized.

Conclusion

Reclamation of quarries is important not only for the sustained functioning of the environment but also for their aesthetic qualities. Most quarry activities in England occur in or near areas of public interest with high aesthetic value attached to them. These include Site of Special Scientific Interest (SSSI's) and Areas of Outstanding Natural Beauty (AONB's). It is therefore in the best interest of the public and the areas to enhance the aesthetic quality of quarried land.

The different techniques discussed here have been developed for the reclamation of hard-rock quarries and are essential in creating safe, sustainable, ecologically rich, and aesthetically pleasing post quarrying landscapes. Each of the techniques discussed vary in the type of landscape that they can produce. To create interest through diversity of form and character, it can therefore be beneficial to use the techniques in combination. This can be achieved through selective treatment of different parts of the quarry landscape. This can help with judicious use of the scarce materials used in reclamation. When a combination of different after-uses is implemented within a site, e.g. recreational lake and agriculture, different slopes could be applied to different portions of the quarry to accommodate the different uses. Therefore a limited amount of fill material could be used to create the required landform in just one part of the quarry (Land Use Consultants, 1992a). Care must be taken to ensure that where combined after-uses are developed, they are compatible with each other, to ensure the sustainability of the scheme.

There are a number of challenges in reclamation of quarries including limited availability of topsoil as well as fill material. This can affect the level to which land can be reclaimed. It influences the amount and type of vegetation that can be established as well as the form of the ground surface. These have a high impact on the visual qualities as well as the functional capabilities of the land. Another common challenge involves rock stability on reclaimed quarries which has a bearing on the safety of the site hence its availability for public use.

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