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QUARRY REHABILITATION - CLIFFS, LANDFORMS AND ECOLOGY

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ABSTRACT

Over the last fifteen years major progress has been made to provide acceptable rehabilitation of quarries in various countries. Many stone quarries are located in scenic areas of natural beauty and this necessitates the best possible rehabilitation. After the stone has been extracted efforts are made to **simulate natural landforms** to blend the quarry faces into the surrounding landscape. The resulting **naturalized cliffs** and the quarry floors offer scenic value and also provide excellent habitats for a variety of vegetation and wildlife, including birds, snakes, butterflies and amphibians.

In the U.K., the landform replication research conducted by the Limestone Research Group, with trial sites at the Hope and Tunstead quarries, was found to result in some faces that are unstable. This is primarily the result of limestone that is fragmented to start with. More recent research by ECUS Ltd. indicates that the ideal rehabilitated quarry uses the Rollover Concept. Several quarry operators in the U.K. are trying the Rollover Concept. At a super quarry in Scotland, the upper benches that may be visible will be sloped to the natural mountain grade and restored using peat and grass seed and the Rollover Concept. In Ontario, Canada legislation has required rehabilitation of stone faces to be sloped at 2:1 and completely revegetated. In the early 1990's Ontario quarry operators began looking at creating a landform that blends with the landscape and recognizes the ecological value of cliffs.

The most critical factors in quarry rehabilitation are **planning ahead** so the most suitable landform and ecosystems are completed and **staving at the leading edge of research and techniques.** The examples outlined above recognize the value of cliffs in terms of visual interest and the ecological value of the rehabilitated landscape.

INTRODUCTION

As the stone is being extracted from a quarry a decision must be made as to how the site will be rehabilitated. Around the world, many stone quarries are located in scenic areas of natural beauty and this necessitates the best possible rehabilitation after the stone is extracted. The rehabilitation of stone quarry faces should resemble the natural, unquarried landforms as much as possible. The final landform created must be visually, ecologically and structurally acceptable and blend with the surrounding landscape.

LANDFORM SIMULATION/REPLICATION IN THE U. K. PEAK DISTRICT

The concept of Landform Simulation/Replication* in the Peak District got started in the United Kingdom in 1988 and involves the construction by *Restoration Blasting* of varied slope sequences consisting of rock screes (talus), buttresses and headwalls, which could be selectively vegetated *(Habitat Reconstruction)* to produce landform/vegetation assemblages similar to those on 'natural' limestone dalesides (valley sides) (Gunn, Bailey & Gagen, 1992).

In 1988 the United Kingdom Department of the Environment (now DTLR) commissioned the Limestone Research Group at the University of Huddersfield and two quarry companies to create trial sites on selected faces at the Hope Quarry (Blue Circle Industries pic) and the Tunstead Quarry (Tilcon (South) Ltd). These trial sites had certain practical constraints and in 1998 ECUS Ltd. commenced a three-year research project to assess the success of the trial sites in terms of their stability, visual appearance and vegetation establishment, and to make recommendations for the future application of the technique (Brashaw, Cripps, et al, 2001)

Landform Replication aims to construct a landform that resembles that in the unexcavated natural landscape around the quarry. The objective is to render the rehabilitated site as compatible and visually unobtrusive as possible. The U.K. landform replication concept has been developed for hilly and very scenic landscapes and would have to be modified and tailored to be applied or partially applied to quarries in other locations with different landforms and geology. Most quarries in the Peak District Park are visible in the landscape because the quarrying is removing sections of hills and dales. Carboniferous Limestone of the White Peak contain shales, sandstones, deposits of volcanic rock and volcanic ash, as well as local mineralization of the limestones which are host to a variety of vein minerals. This causes the limestones to be fragmented resulting in some faces that are unstable (Gunn, Bailey & Handley, 1997).

Further ECUS Ltd. found that the landform replication sites:

> "had a number of shortcomings that would render them unacceptable landforms to leave in most disused quarry environments. Perhaps most significantly the landforms were not found to be acceptably stable. However, the technique has many positive attributes and many valuable lessons have been learnt from the experiment which can be used or developed in the restoration of limestone quarries". (Brashaw, Cripps, et al, 2001)

* In the U.K. research work the term "landform replication" is used and this connotes "a copy or reproduction" or "exactly the same". We think that it would be more appropriate to use "landform simulation" which connotes "a surface resemblance" or "similar". We believe it is impossible to replicate a landform but it is possible to simulate one. Therefore, we will use "landform simulation" except when specifically referring to the U.K. technical papers that refer to "landform replication".

For more detail on Landform Simulation in the U.K. see the following articles and reports:

- Yundt & Lowe, "Landform Replication/Simulation in the United Kingdom" Aggregates and Roadbuilding magazine, May - June 1999.
- Brashaw, Cripps, Czerewko, Ellson and Bradley, "Limestone Landform Simulation in Quarry Restoration" Quarry Management, December 2001.
- Ecus Ltd., Reclamation of Limestone Quarries by Landform Simulation Summary of Lessons Learnt from Trial Sites. June 2002.

THE ROLLOVER CONCEPT, UNITED KINGDOM

The Rollover Concept is a different rehabilitation approach, and involves efforts to hide part of the cliff face by backfilling or sloping thus making the top one or two lifts disappear or blend in with the landscape when viewed from far away (landscape view). Aesthetics in the landscape is the key factor. The final rehabilitation should not look like a quarry with regular faces. In the Rollover Concept the greened skyline helps the quarry face blend with the surrounding rolling topography. Significant views from outside the quarry must be examined to get the landscape context correct.

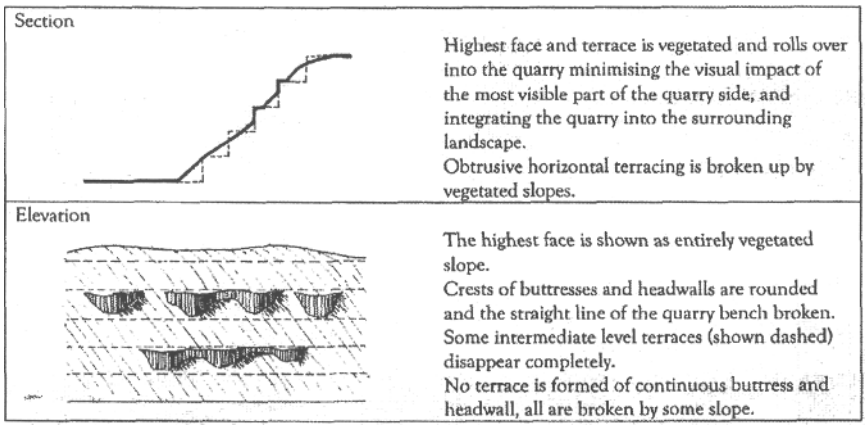
Two quarries that are using the Rollover Concept are **RMC (Goddards Quarry)** and **Tarmac (Darlton Quarry)** at Stoney Middleton in Derbyshire. The quarries are in or adjacent to the Peak District Park and the objective is to hide the quarry from the view of surrounding road and significant views in the Park (Yundt & Lowe, 1999).

The 6000 acre **YEOMAN (MOVERN) LIMITED (Glensanda Estate)** lies within the Strontian granite complex, on the northern shore of Loch Linnhe, near Oban, Scotland. The quarry when fully extracted will resemble a "crater" with only the uppermost benches visible from a distance. In terms of restoration, under legislation, Yeoman established a £3/4 million restoration assurance bond. The operation plan includes 20 metre benches and 15 benches in total. The upper 5 benches, which may be visible, have to be sloped to the natural mountain grade and restored using peat and grass seed. This is another example of the use of the rollover concept of blending in the upper faces and hiding the quarry from view. (Larson, 1992 and 1998).

The ECUS Ltd. study (Brashaw, Cripps, et al, 2001) indicates that the ideal restored quarry side is the rollover approach.

> The "...highest face and terrace is vegetated and rolls over into the quarry minimizing the visual impact of the most visible part of the quarry side, and integrating the quarry into the surrounding landscape. Obtrusive horizontal terracing is broken up by vegetated slopes" (Brashaw, Cripps, et al, 2001).

Figurel. Illustrates the Rollover Concept (the Ideal Restored Quarry Face) (ECUS Ltd., 2002)



The Rollover Concept of viewing the quarry in the landscape from a distance is just starting to be used in the United Kingdom and its progress should be followed closely to see how applicable it might be to other geographic locations.

ONTARIO CANADA SITES USING LANDFORM SIMULATION AND NATURALIZATION

The Aggregate Resources Act of Ontario (1990) under the "Provincial Standards" requires,

> "When the site is finally rehabilitated, all excavation faces...of a quarry have a slope that is at least two horizontal metres for every vertical metre;"

Most of the quarries in Ontario extract limestone or dolostone. Historically, all stone faces were sloped at 2:1 and revegetated. This produced some stable and safe but very unimaginative slopes with little ecological diversity. Safety was the key factor. There are two excellent examples of vertical quarry faces being filled and sloped from top to bottom to create a 2:1 grade -- the Walker Brothers, Thorold Quarry and the Nelson Aggregate Co., Burlington Quarry.

In the early 1990's, the concept of landform simulation and naturalized quarry faces started to be discussed and implemented for sites in the vicinity of the Niagara Escarpment, a scenic geological landform that includes forests, wetlands, cliffs and the Bruce Trail for hiking. The aggregate industry and their consultants have been working with the Ontario government to change these requirements to be more suitable to current thinking including landform simulation, leaving aesthetic vertical faces above and below the watertable, etcetera.

The emphasis is on creating an interesting landform that recognizes the landscape and ecological value of cliffs. Several quarries in Ontario have approved site plans that are similar to what is described above. An exemption from the regulations and standards under the Aggregate Resources Act that states that the face has to be sloped to 2:1 must be obtained from the Ministry of Natural Resources.

It has been recognized by the Ministry of Natural Resources that,

> "rehabilitated extraction sites can provide the necessary habitats for unique plant and animal communities and may act as havens for rare or threatened species. In some cases extraction has led to the expansion of a species' range and the industry is one of the few that is creating new valuable wetland and cliff habitats." (Browning, 1993)

MNR believe it is not acceptable to wait 30 years for a site to become a valuable wildlife area. Information from abandoned sites is being used to develop relatively inexpensive techniques that will enhance biodiversity at current extractive operations. With a carefully planned progressive rehabilitation program a pit or quarry can support a wide variety of species even while extraction is on going (Browning, 1993). MNR are trying to determine what factors and processes are involved in naturalization and what procedures can be developed to facilitate or speed natural regeneration (Browning, 1998).

DUFFERIN AGGREGATES MILTON QUARRY ONTARIO CANADA

The quarry opened in 1962 and rehabilitation started in the mid 1970's. The initial focus was to hide the quarry operations from view. This was done by moving the plant site from a position that was clearly visible in front of the highly valued scenery of the Niagara Escarpment. The next focus was to rehabilitate the quarry itself with the traditional 3:1 and 2:1 slopes. The quarry face, which was extracted in a single bench, was completely backfilled using overburden from the site or imported.

Since 1990, rehabilitation emphasizes a landform more characteristic of the surrounding escarpment, which includes cliffs of dolostone. The rehabilitation vision is a naturalized landscape with conservation, water management, recreation, education, and economic benefits. The design promotes a diversity of habitats with

many plant and animal communities encouraged by extensive tree and shrub planting of native species. The final landscape will feature extensive naturalized water bodies and wetlands with irregular shorelines, islands, wooded upland margins and slopes, open space and over 10 km of cliff faces.

Quarry faces leave a single bench ranging from 10 m to over 30 m in height depending on the topography of the land and the depth of the dolostone. Stretches of the cliff face are left exposed to mimic the natural escarpment landscape and in most areas only the lower portion is backfilled, using pond lines, overburden and forest soils. Other areas are completely backfilled to provide linkages to the top of the face and adjacent lands.

Photograph 1. Cliff Face Rehabilitation at Dufferin Aggregates Milton Quarry Simulates the Natural Niagara Escarpment Landscape

Rehabilitated cliff faces range from 2 - 10m in height. Slopes range from 2:1 to almost 10:1 in the most southern corner of the quarry. This new approach has enhanced the quarry rehabilitation. The cliff faces and slopes are more diverse, attractive and a better fit with the surrounding Niagara Escarpment landscape. The faces also provide cliff habitat and microclimate variations.

The quarry edges and floor are already used by many species of birds and other wildlife. A rehabilitation monitoring program records survival and growth of planted species, natural regeneration, aquatic and soil conditions and bird, herptile, dragonfly and butterfly inventories. Various community types are beginning to develop including old field, successional woodland and wetlands. Interesting findings include 40 breeding bird species, over 100 pairs of cliff swallows and mourning warblers in the closed canopy, and Virginia rail in the developing wetland on the quarry floor. There are also six herptile species including spotted newt and 34 species of butterflies. The public can view the cliffs and developing wetland from a lookout point accessible

from the Bruce Trail, a 725 km trail that runs from Niagara Falls to Tobermory. (Zimmerman and Lowe, 2001). When fully extracted in 10 - 20 years, the site will offer significant conservation and recreation benefits.

MILTON LIMESTONE (LAC PROPERTIES INC.) - MILTON ONTARIO CANADA

Aggregate extraction at this limestone quarry finished in 2001 and Milton Limestone is preparing the site for donation to Conservation Ilalton, as a public recreation area. Traditional backfilling of faces has been completed except for one rock face that was to remain vertical and rough and craggy to promote plant growth and simulate natural escarpment faces,

Photograph 2. Cliff Face being Rehabilitated at Milton Limestone with Face Scaled and Bottom Third Soil Sloped

Conservation Halton expressed concerns for public safety with a vertical 30-metre face. A restoration blast was used to produce an 8 metre wide rock ledge 8 metres down from the top of the face. The restoration blast could have been more successful if the distance between the face and the property boundary had been greater. The Bruce Trail is located along the property boundary and all the usual blasting controls have to be met including no fly rock, A standard blast pattern was used to maximize the blast cast of the stone to clear as much rock as possible off the ledge. The blasted material did not fall away from the ledge as was anticipated. It became evident through the ensuing freeze-thaw cycles that the ledge area contained sufficient loose rocks to create a falling rock hazard. A long reach excavator was utilized to scale both the ledge and the vertical face. The culled rock assists in promoting a natural talus slope at the bottom of the face. The bottom third was soil sloped. A 45-acre lake has been built into the quarry floor and a 300-metre long by 100-metre wide

wading-swimming-beach area has been created. The remaining land area will incorporate picnic-park features. When completed during 2002 this former quarry site will probably be linked to the adjoining Kelso recreational area (Scott, 2002).

KERNCLIFF PARK BURLINGTON ONTARIO CANADA

Several aggregate companies operated this quarry, located on the brow of the Niagara Escarpment, over the years and eventually it was abandoned in the late 1950's. Natural regeneration occurred since the 1960's with good positive results. The City of Burlington is currently upgrading the site for public use as part of the city park system. As much as possible, the City wants to minimize the rock scaling of the cliff face to help maintain its natural appearance and to minimize disturbance of vegetation occurring on the quarry floor area. The City has budgeted $1 million over six years with final completion in 2006. The following work has been completed at the site,

- over 200 m of face was scaled by hand by repelling down from the top;
- a railing has been constructed along the top of the face (safety issue);
- the entrance, a parking lot and a path system have been paved;
- rock piles have been left in place to provide snake habitat;
- a prairie garden has been planted;
- an interpretative area has been started by placing armour stone at the entrance for landscaping and to create a small terraced amphitheatre (the Management of Abandoned Aggregate Properties Program (MAAP) helped with this aspect of rehabilitation);
- a wall of fame has been completed to recognize the partners in the project; and
- a boardwalk has been built through the wetland.

This site is one of the best examples of natural regeneration in Ontario. The trail system in the park links to the Bruce Trail at the top of the cliff. This link to the Bruce Trail provides another opportunity to demonstrate the potential for rehabilitated quarries including, cliff and vegetated faces, wetlands, diversity of plants and habitats, tall grass prairie and the interpretative potential (MAAP, 2001). From an ecological viewpoint, the site consists of two vegetation units, a series of wetlands and successional old field/shrub communities.

The wetlands consist of a permanent pool of open water surrounded by robust emergents such as cattails. Willow shrubs and red osier dogwood are present along the base of the quarry wall. The wet meadow community is dominated by variegated horsetail, sedges and rushes and provides habitat for the following regionally rare plant species: variegated horsetail, spike rush and obedient plant. The large wetland in the west corner of the quarry provides breeding and foraging habitat for species such as red-winged blackbird, common yellowthroat and spotted sandpiper. Bank swallows actively forage over the open water portion of the wetland

and nest on the adjacent cliffs. The presence of the relatively secretive Virginia rail and sora is indicative of the high quality of the wetland. The wetlands provide year-round habitat for painted turtle and green frog as well as breeding habitat for American toad, northern leopard frog and gray tree frog.

Old field species and successional shrubs and trees have colonized the quarry floor in areas where thin layers of topsoil have accumulated. A successional woodland is developing on the rock piles along the base of the quarry. Kerncliff Park supports a wide variety of herpetofauna; particularly eastern garter snake, brown snake, eastern milk snake, northern ringneck snake, northern water snake, northern ribbon snake and northern ringneck snake have been observed within, and adjacent to, these areas. White-tailed deer regularly move through the quarry area and red fox have been observed denning in the vicinity of the rock piles (Featherstone, 2002).

CLIFF ECOLOGY RESEARCH GROUP UNIVERSITY OF GUELPH ONTARIO CANADA

The Cliff Ecology Research Group was formed in 1985 within the Department of Botany at the University of Guelph. The Group is an interdisciplinary team that analyses the structure and function of cliff systems. The Group review information about the geology, geomorphology, microclimate, flora and fauna of cliffs. They provide evidence to suggest that cliffs worldwide may represent an invaluable type of ecosystem, consisting of some of the least disturbed habitats on earth and contributing more to the biodiversity of a region than their surface coverage would indicate (Larson, Matthes and Kelly, 2000).

For the past ten years the Cliff Ecology Research Group has focused research on the Niagara Escarpment, a band of limestone cliffs that extends over 740 km through southern Ontario. They have raised the awareness of the ecological values of cliffs, particularly with the discovery of the old growth forests.

In the mid 1990's, with support from the Aggregate Producers' Association of Ontario, Ursic, Kenkel and Larson studied plant communities in 18 limestone quarries in southern Ontario that had been abandoned for between 18 and 100 years. Species composition is highly variable at recently abandoned sites, but becomes predictable in quarries abandoned for 70 years or more. The resulting community on these man-made cliffs resembles that of the nearby natural cliffs of the Niagara Escarpment in both species richness and composition (Larson, Matthes and Kelly, 2000 and Ursic, Kenkel and Larson, 1997).

Ursic, Kenkel and Larson provide three implications of their results for the management and restoration of vertical rock faces in abandoned limestone quarries, as follows:

> "1. Unlike the vegetation communities that result from rehabilitation strategies involving backfilling, the community that results from natural recolonization is sufficiently similar to natural escarpments to suggest that quarry walls will support stable assemblages of native species, that will not require future maintenance.
>
> 2. As long as the 100-year timeframe for recolonization is considered acceptable, no monetary expenses are incurred during the rehabilitation process. In contrast, the cost of backfilling exposed quarry walls and landscaping slopes can be substantial.
>
> 3. It may be possible to accelerate succession on quarry walls by direct planting, or by the creation of suitable tree canopies on quarry floors and tops. These plantings will shade the wall and facilitate the recruitment of stress tolerators found later in the natural successional sequence." (Ursic, Kenkel and Larson, 1997)

Ursic, Kenkel and Larson recommend that the rehabilitation practice of backfilling exposed cliff faces in abandoned limestone quarries be reconsidered in favour of the more effective and less expensive alternative of natural regeneration suggested in their paper.

CONCLUSIONS

These case studies demonstrate that **rehabilitated quarries have landscape, recreational and ecological values** and in many cases around the world, they are located in scenic areas of natural beauty. The specific value of quarry faces as future cliffs must be recognized in terms of visual landscape interest and ecological value. Ecological value includes significant bird and wildlife habitat.

Innovative approaches between industry and government at all levels are necessary to produce high quality rehabilitation of quarries. It can take years to research and evaluate approaches to cliff or quarry face rehabilitation.

If you have a quarry face to rehabilitate, it is essential to **plan carefully and try different techniques** to get the rehabilitation objectives and design correct or appropriate to the area. Safety and stability are a challenge that must be dealt with when rehabilitating a quarry face. The measures taken in regard to safety and stability are very dependent on the final land uses near the quarry face and these final land uses are likely to include recreation in scenic areas.

Critical evaluation and monitoring are needed for both aesthetics and ecological values to assess the success of the rehabilitation. It is essential to pass on to other quarry operators, both the successes and the failures. Cliff and quarry face rehabilitation must be explained to the public so there is a better understanding of the objectives and the results.

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