# Field Guide

## Application of Engineering Geology to Surface Mine Design, British Gypsum, Newark Nottinghamshire

Sunday 1st April 2007

## Engineering Geology through the Centuries

**A Joint Meeting of the Yorkshire Geological Society and the Engineering Group of the Geological Society: (Part of the celebration of the bicentenary of the Geological Society of London, under the Society's "Local Heroes" initiative for the bicentenary)**

YORKSHIRE GEOLOGICAL SOCIETY

British Gypsum

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

200 YEARS serving science & profession

# Application of Engineering Geology to Surface Mine Design, British Gypsum, Newark Nottinghamshire
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Leaders Noel Worley *British Gypsum Ltd* and Helen Reeves *British Geological Survey*

Field Trip Safety Issues

1. The YGS takes the safety of its members extremely seriously. However, attendees of field meetings must also take responsibility for their own and other participants' safety. In order to ensure the safety of all participants the YGS reserves the right to limit or refuse attendance at field meetings.

2. You must declare to the field trip leader, at the start of the field trip, any disabilities or medical conditions that may affect your ability to safely attend a field meeting.

3. Inform the leader if you leave the meeting early.

4. The Leader is not expected to provide First Aid – ensure that you have adequate supplies for your own needs.

5. Wear appropriate clothing and footwear for the locality and time of year. Anticipate potential changes in weather conditions.

6. Children must be accompanied and supervised by a responsible adult at all times.

7. The Leader's decision is final on any matters relating to each field meeting.

**Introduction**

Gypsum has been commercially exploited in the Newark and Vale of Belvoir Districts of Nottinghamshire and north Leicestershire, since the 16$^{th}$ century when it was being mined to make plaster. However it was not until the middle of the 19$^{th}$ century that the extraction of gypsum commenced on an industrial scale from surface mining operations.

The gypsum, the Newark Evaporite, occurs in the highest strata of the Triassic Age Norian Mercia Mudstone Group Cropwell Bishop Formation. The outcrop of this formation follows the alignment of the Trent valley to the north of Newark and lies beneath a large part of the Vale of Belvoir to the south. The gypsum in these evaporites is often of exceptionally high quality and has been exploited for the manufacture of plasters for industrial uses including pottery, ceramic, dental and surgical applications as well as building plasters.

The trip will include visits to the Kilvington and Bantycock Opencast Mines. The former is reaching the end of its operational life and the latter re-starting and is following a period of care and maintenance. The purpose of the visit will be to observe how modern engineering geological methods have been used in the sequence of steps involved in the design of the excavation and mining processes through to final restoration. This will include the opportunity to examine dewatering operations, overburden management, mine transport, mineral processing, and restoration methods.

Meet at 10am at the Kilvington Opencast Mine located approximately 22 kms east of Nottingham, SK800430 and can be accessed by road from Nottingham by following the A52 toward Grantham. At Elton on the Hill turn left (north) towards Orston and continue for some 5 kms and the Kilvington Opencast Mine is situated on the western side of the road. Meet in the mine car park. Please note that hard hats, high visibility clothing, and protective foot-ware are mandatory.

## References

**P R N Hobbs, J R Hallam, a Forster, D C Entwistle, L D Jones. A C Cripps, K J Northmore, S J Self and J L Meakin, 2002.** Engineering geology of British rocks and soils- Mudstones of the Mercia Mudstone Group. *British Geological Survey Research Report, RR/01/02* 106p.

**Anon 2006**. Mineral Planning Factsheet, 'Gypsum'. British Geological Survey for the Office of the Deputy Prime Minister 7p.
http://www.mineralsuk.com/britmin/mpfgypsum.pdf

First Grade alabastrine gypsum from the Newark Evaporite

# ITINERARY

## Sunday 1st April 2007

### Morning Arrive Kilvington Opencast Mine SK800430 - 10am mine office car park

The Kilvington Opencast Mine represents a post-war mining development that was commenced originally by the Associated Portland Cement Manufacturing Company who later became Blue Circle, to provide a source of gypsum for the manufacture of Portland Cement. In this respect its location in central England and close proximity to a railway were crucial because the some product needed to be exported to support cement-manufacturing plants distributed throughout the country.

The site was worked more or less continuously until the late 1970's when competition from other sources of supply and closure of the railway forced cessation of mining operations and the site was left in a partly restored condition with approximately half of the 142 ha permitted area being worked. In 1995 British Gypsum Limited acquired the interests and operations recommenced the following year. These have continued to recover the remaining gypsum reserves to provide a supply of high purity white gypsum to the nearby Jericho Factory and also support the Company's building plaster-manufacturing operations elsewhere in the midlands.

The mine is designed as an opencast strip operation to recover multiple gypsum seams from a simple layered sequence in the Newark Evaporite. The Evaporite comprises some 13 separate beds of gypsum that vary in thickness from over 0.75 m to 0.2 m, the aggregate thickness of seams being some 2.15m. The overburden is typically 7 m thick comprising grey-green dolomitic mudstone of the Blue Anchor Formation and forms the rockhead for most of the site. In the southern part of the site overburden thicknesses were greater and included the black shales of the Westbury Formation (Penarth Group). A 2–3 m layer of alluvium covers the northern part of the site and was probably deposited by the River Devon that also forms the northern boundary.

### Locality 1 Mine Access Road

The mine access road affords an extensive view showing the sequence of opencast mining operations. The mine is worked in a series of rectangular shaped cuts that are excavated through the overburden layers to access the first gypsum seam. These cuts are typically 50 m wide and contain a series of benches that accords with each of the gypsum seams and inter-burden. Transport within the excavation is effected by a series of ramps constructed to allow the movement of materials; these are designed at gradients of 1 in 10 for main haul roads and up to 1:6 for inter-seam working areas. Slope angles of the excavation are constructed at overall 1 in 1.

Overburden, comprising the Blue Anchor Formation and Alluvium layer is currently being stripped down to the first seam, the 'Grey Rock', using excavators and dumper trucks. This material is then back-cast behind the working area. At this site the

sequence of tipping generally follows the original geological sequence. The *circa* 20% bulking of these loose tipped materials is evident in the filled area.

The upper two gypsum seams are too strong to be broken out using hydraulic excavators and therefore these are subject to drilling and blasting prior to being recovered. Each of the remaining 10 seams is thinner and is mined using hydraulic excavators. Both gypsum and inter-burden are transported using dump trucks on haul roads constructed from compacted Cropwell Bishop Formation Mudstone.

The current working area is adjacent to the River Devon and the outcrop of the saturated zone of the Cropwell Bishop Formation is evident in the south facing side-wall of the excavation. Karstification of the highest gypsum seam has occurred and water flows through these cavities into the excavation.

**Locality 2 Mining Area**

The descent into the excavation allows close examination of the Blue Anchor Formation overburden in the main haul road and gypsum beds within the Cropwell Bishop Formation. The majority of the excavation is located in the saturated zone and groundwater inflow is evident in the excavation. In the Cropwell Bishop formation water issues from fissures formed by dissolution of satin spar veins.

The Blue Anchor formation comprises some 4 – 5m of weak grey green thinly bedded dolomitic mudstone. Stronger beds of siltstone are evident as more prominent layers. Gypsum is present within the lower parts as discontinues nodular masses and satin spars. The Blue Anchor formation is weathered at the rock head to stiff clay.

The Cropwell Bishop Formation comprises red-brown mudstone beds with continuous nodular beds of very white fine-grained gypsum. The mudstone is typically a weak and jointed rock mass whereas the gypsum beds are significantly stronger by virtue of their continuity and crystallinity with UCS values up to 30 Mpa, and tensile strengths up to 2.5 Mpa. The Cropwell Bishop Formation mudstones are further affected by the development of relatively close-spaced steeply inclined joints some of which are filled with satin spar gypsum. Sub-horizontal satin spar veins are conspicuous and may extend for several metres in length.

**Locality 3 Final Restoration**

To the south of the working area are south facing views showing the mined areas that are undergoing restoration. The restoration scheme comprises a combination of low level wetland and lake features linked by mixed marginal woodland and meadows. The choice of restoration scheme was constrained by:

- Recharge from the Devon and its tributary
- Shortage of soils from old opencast working
- Extraction of + 2m of gypsum
- Proximity to settlements at Kilvington & Alverton

- Nature conservation interests on the old railway
- Footpaths and proposed Sustrans Cycle Track

Over 120 ha have been restored most of which are already back in productive agricultural use. The first lake was formed in 2006 and the base of this was lined with reworked Blue Anchor Formation Mudstone to improve water retention. The lake has risen over 12 months almost to final level despite pumping continuing to the north.

**Lunch approx 12.30**

**Bantycock Opencast Mine 1pm**

The Bantycock Mine opened in 1982 and originally permitted reserves amounted to over 10 M tonnes from a 100 M cu m excavation. Output was and typically 0.6 M tonnes pa of gypsum. In 1993 the mine closed when supplies of gypsum produced from the desulphurisation of the flue gases from coal-fired power stations became widely available (FGD). The subsequent growth in demand for gypsum-based building materials, expected decline in availability of FGD gypsum, and exhaustion of the reserves at Kilvington has led to the re-opening of the mine this year.

The mine works in a similar geological sequence as Kilvington but seam thickness is greater at over 3 m, however overburden thickness is generally 25 m and the overall excavation depth attains 50 m. The overburden comprises, Blue Anchor Formation, overlain by Penarth Group strata including, the Westbury Formation overlain by the Cotham Member of the Penarth Group and limestone and shales strata belonging to the Lower Jurassic.

**Locality 1**

The large scale of the Bantycock Mine is evident from locality 1 where east rfacing views of the mine are obtained. Pumping of water from the open cut has been taking place for some 2 years and levels have been reduced by over 10 metres during this interval. Piezometers are installed to the north of the excavation in the filled areas and also into the undisturbed Cropwell Bishop Formation. The hydrographs of each of these shows how the groundwater stored within the replaced overburden is being drawn down at a slower rate than within the excavation. A similar delayed response is also evident within the bedrock.

The sidewalls of the excavation were not originally designed as long-term features but nevertheless have performed reasonably well have been standing for almost 15 years. Progressive degradation is however evident on both the shorter eastern and western faces.

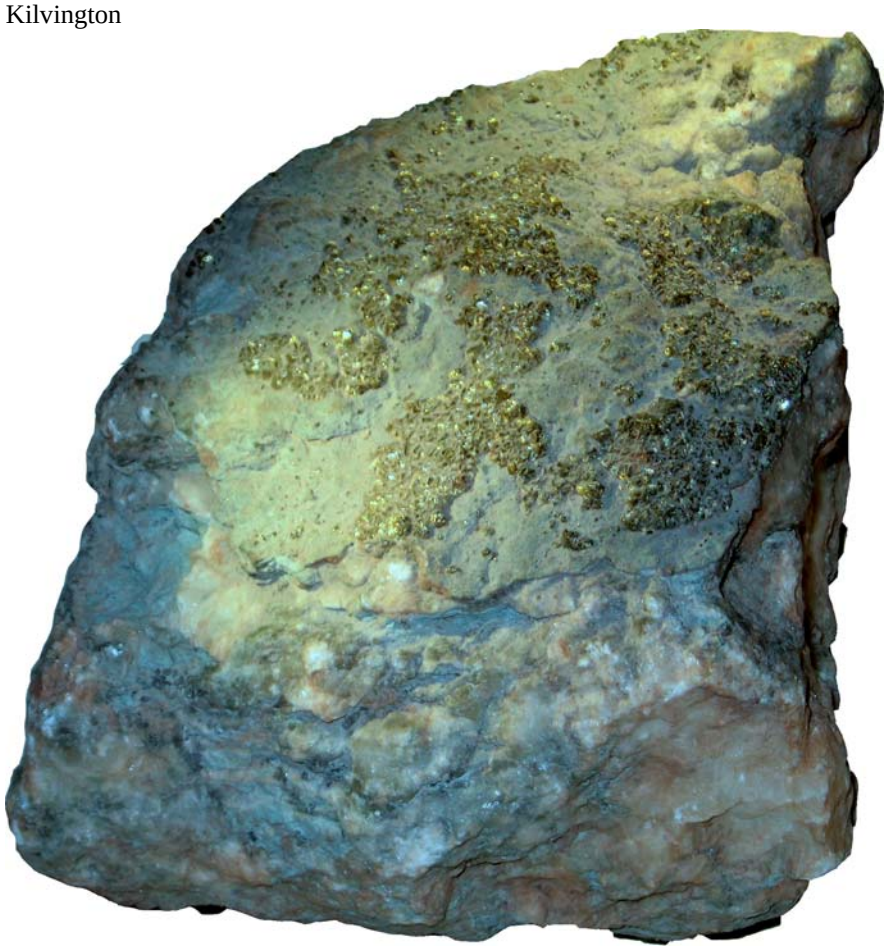
Excavation of overburden in the new cut at Bantycock Mine has been underway for approximately 2 months and a new 50 m wide cut is approaching the base of the Westbury Formation at the time of writing.

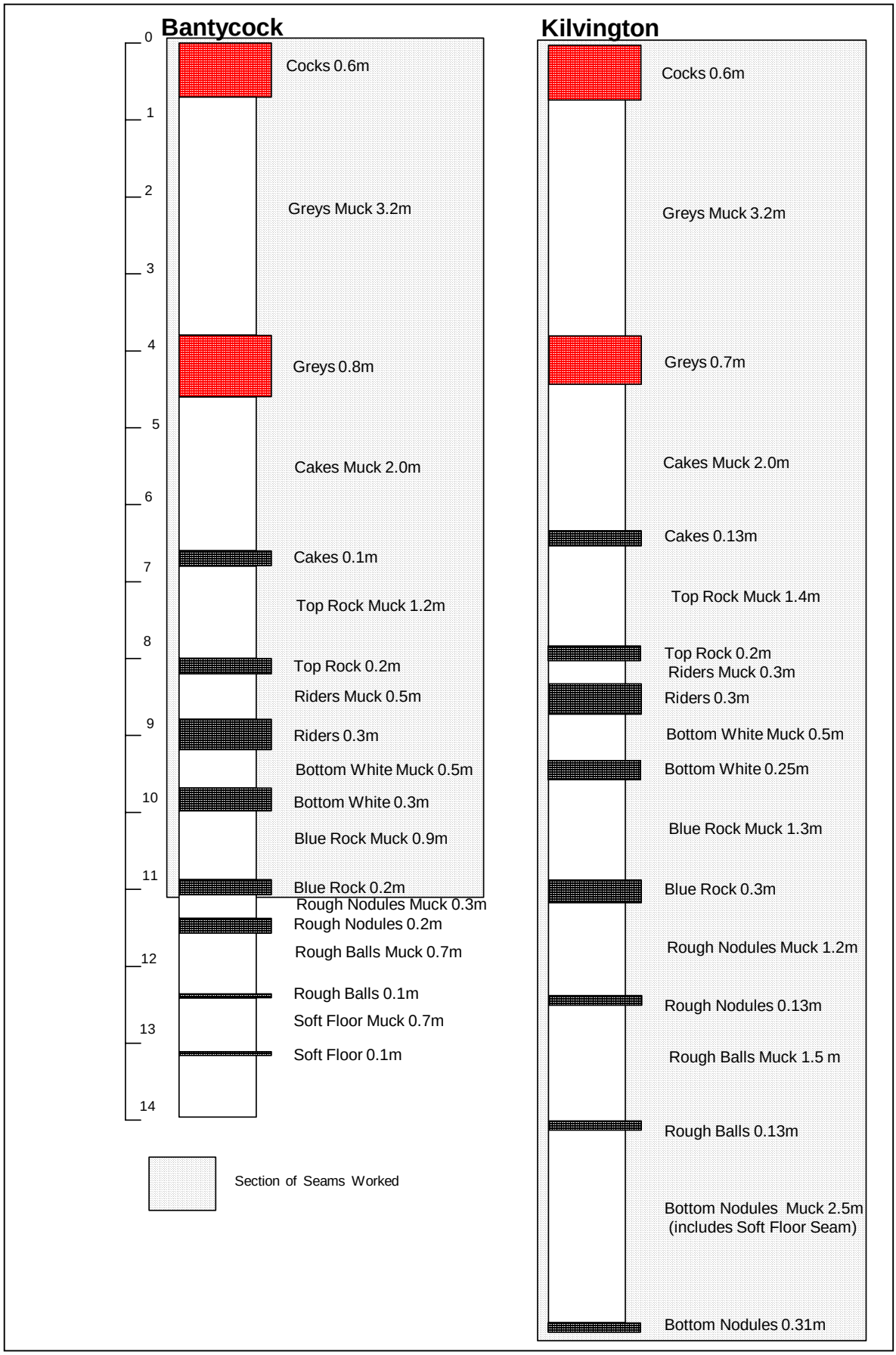
Overburden is currently being placed within part of the opencut and will soon be filled. It is planned to surcharge the area to the north to establish an overburden store this will be used to fill in the void space that will accommodate the mineral processing plant.

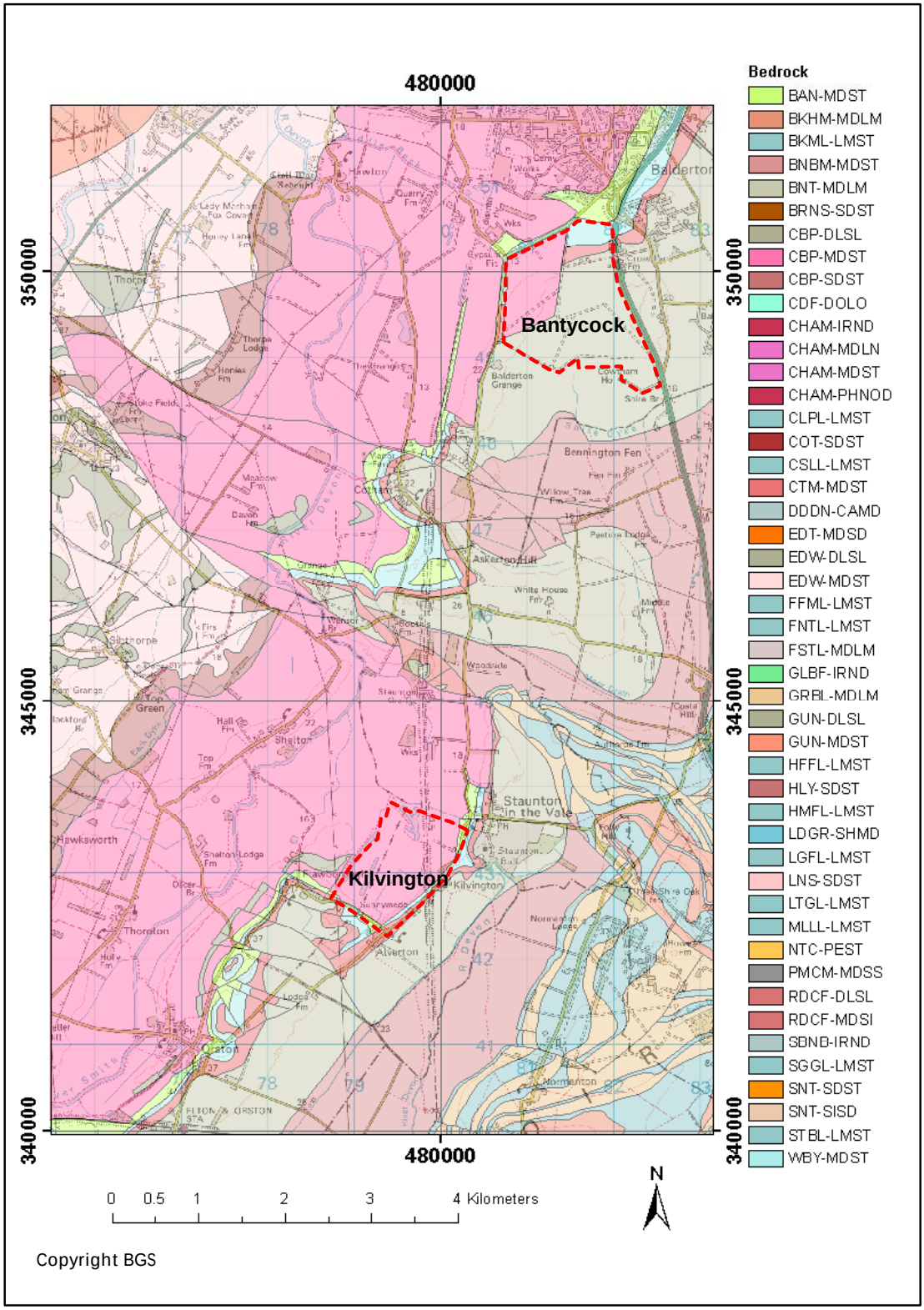
**Locality 2**

If time permits and weather conditions are favourable there will be the opportunity to enter the workings, which afford some of the best exposures of the Westbury Formation and overlying Cotham Member in the UK.

Pyrite mineralisation of dolomitic mudstone plaster on gypsum from Grey Rock, Kilvington




Bantycock
Kilvington
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Cocks 0.6m
Greys Muck 3.2m
Greys 0.8m
Cakes Muck 2.0m
Cakes 0.1m
Top Rock Muck 1.2m
Top Rock 0.2m
Riders Muck 0.5m
Riders 0.3m
Bottom White Muck 0.5m
Bottom White 0.3m
Blue Rock Muck 0.9m
Blue Rock 0.2m
Rough Nodules Muck 0.3m
Rough Nodules 0.2m
Rough Balls Muck 0.7m
Rough Balls 0.1m
Soft Floor Muck 0.7m
Soft Floor 0.1m
Section of Seams Worked
Cocks 0.6m
Greys Muck 3.2m
Greys 0.7m
Cakes Muck 2.0m
Cakes 0.13m
Top Rock Muck 1.4m
Top Rock 0.2m
Riders Muck 0.3m
Riders 0.3m
Bottom White Muck 0.5m
Bottom White 0.25m
Blue Rock Muck 1.3m
Blue Rock 0.3m
Rough Nodules Muck 1.2m
Rough Nodules 0.13m
Rough Balls Muck 1.5 m
Rough Balls 0.13m
Bottom Nodules Muck 2.5m
(includes Soft Floor Seam)
Bottom Nodules 0.31m




Geological Map of the area south of Newark Nottinghamshire

British Geological Survey
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Kilvington Mine looking westwards. The overburden layers comprising alluvium (tan coloured), Blue Anchor Mudstone (grey) and Cropwell Bishop Formation (red brown). The first gypsum seam, the 'Grey Rock' is prominent and represents a thick but discontinuous layer and deposited sub-aerially in a sabkha setting.

Bantycock Mine stripping operations for the new cut in the Westbury Formation. The Cotham Member (brown) is evident in the mid ground.

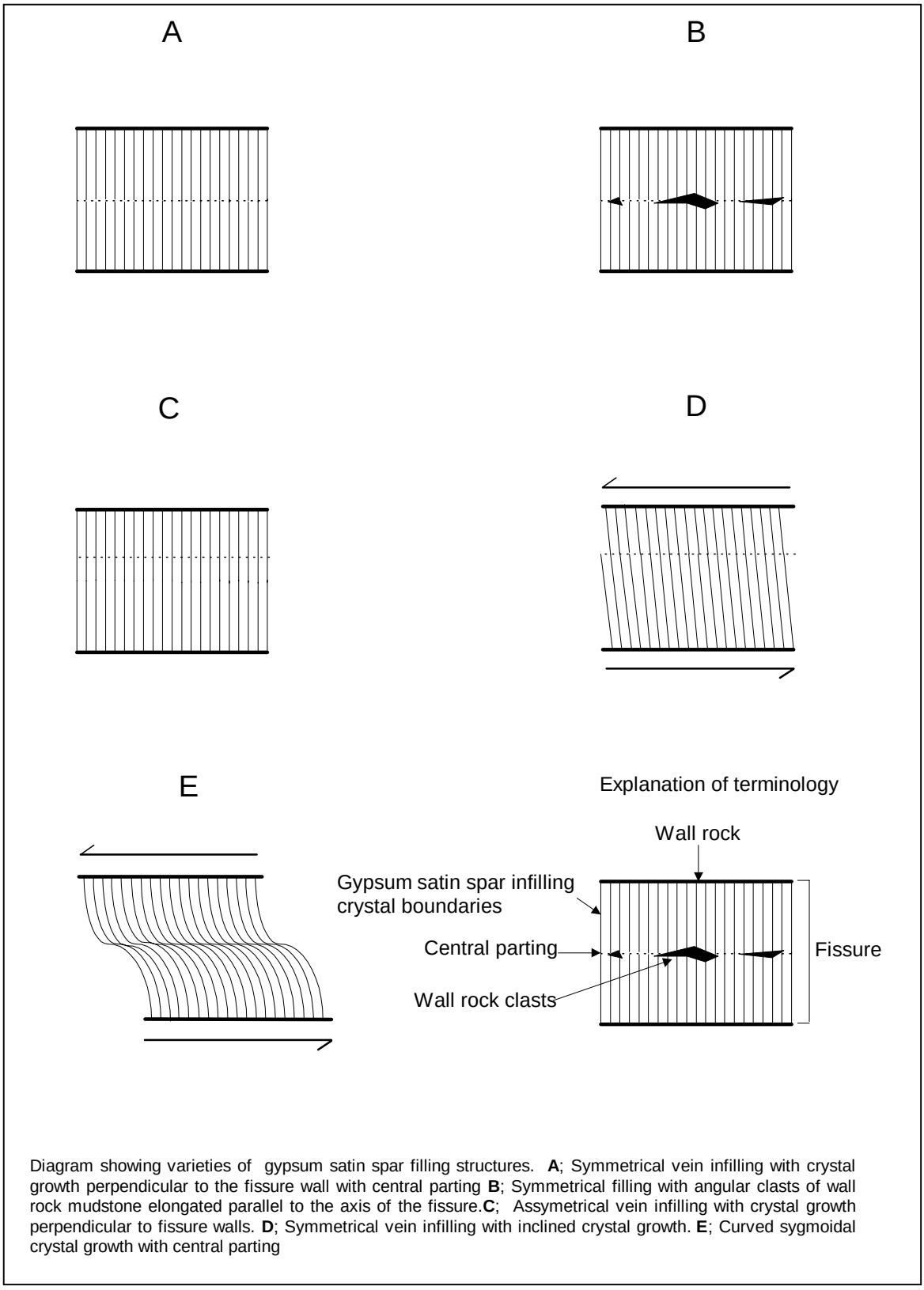
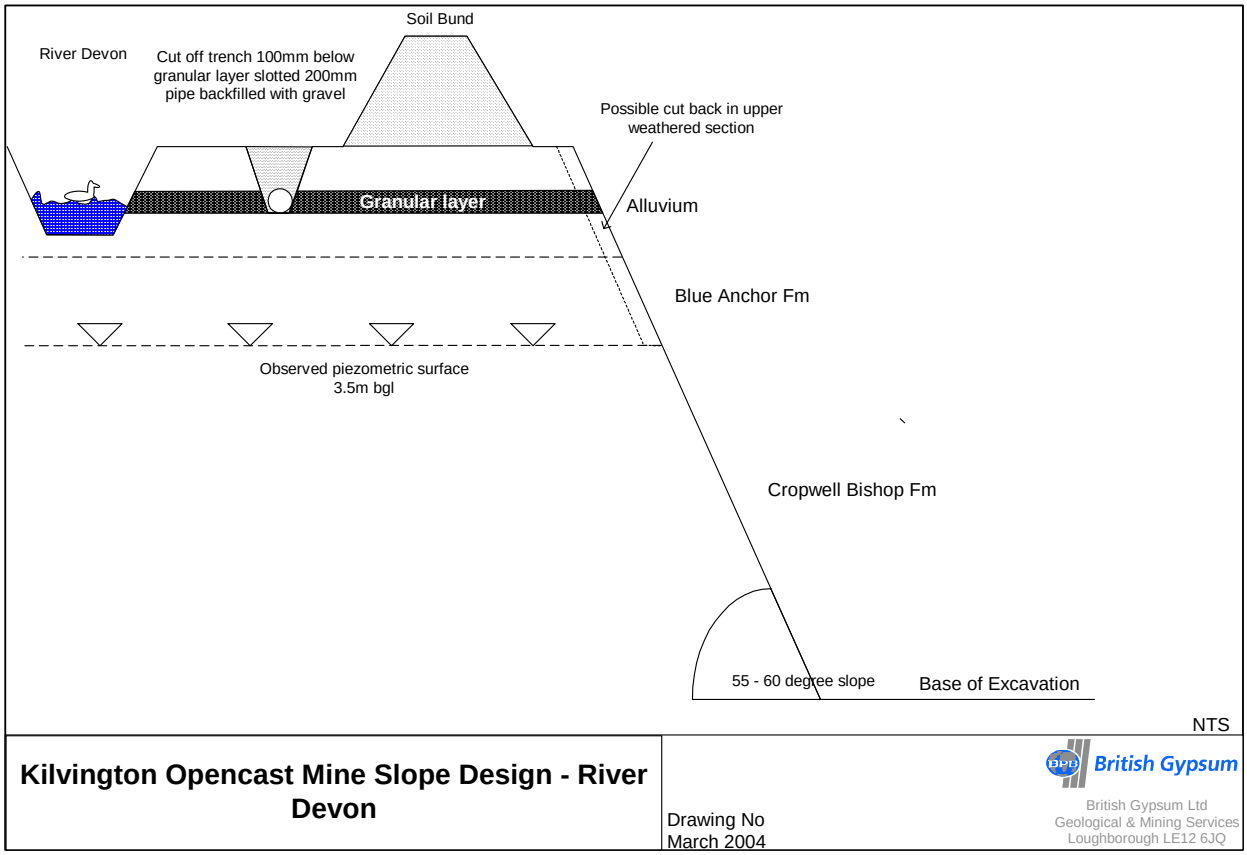
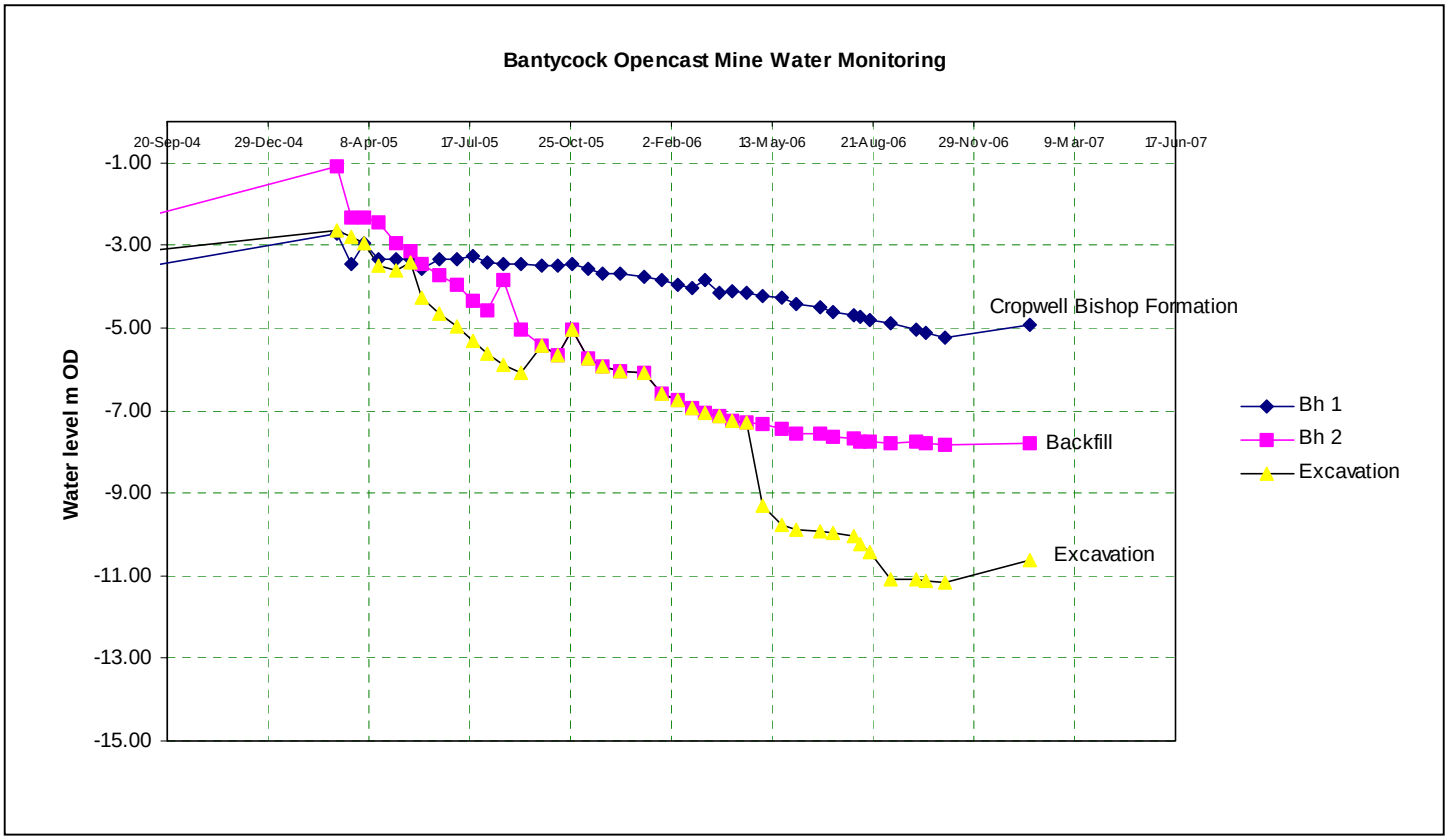



Diagram showing varieties of gypsum satin spar filling structures. **A**; Symmetrical vein infilling with crystal growth perpendicular to the fissure wall with central parting **B**; Symmetrical filling with angular clasts of wall rock mudstone elongated parallel to the axis of the fissure.**C**; Assymetrical vein infilling with crystal growth perpendicular to fissure walls. **D**; Symmetrical vein infilling with inclined crystal growth. **E**; Curved sygmoidal crystal growth with central parting




Hydrograph showing the differential effects on draw down of pumping from the excavation

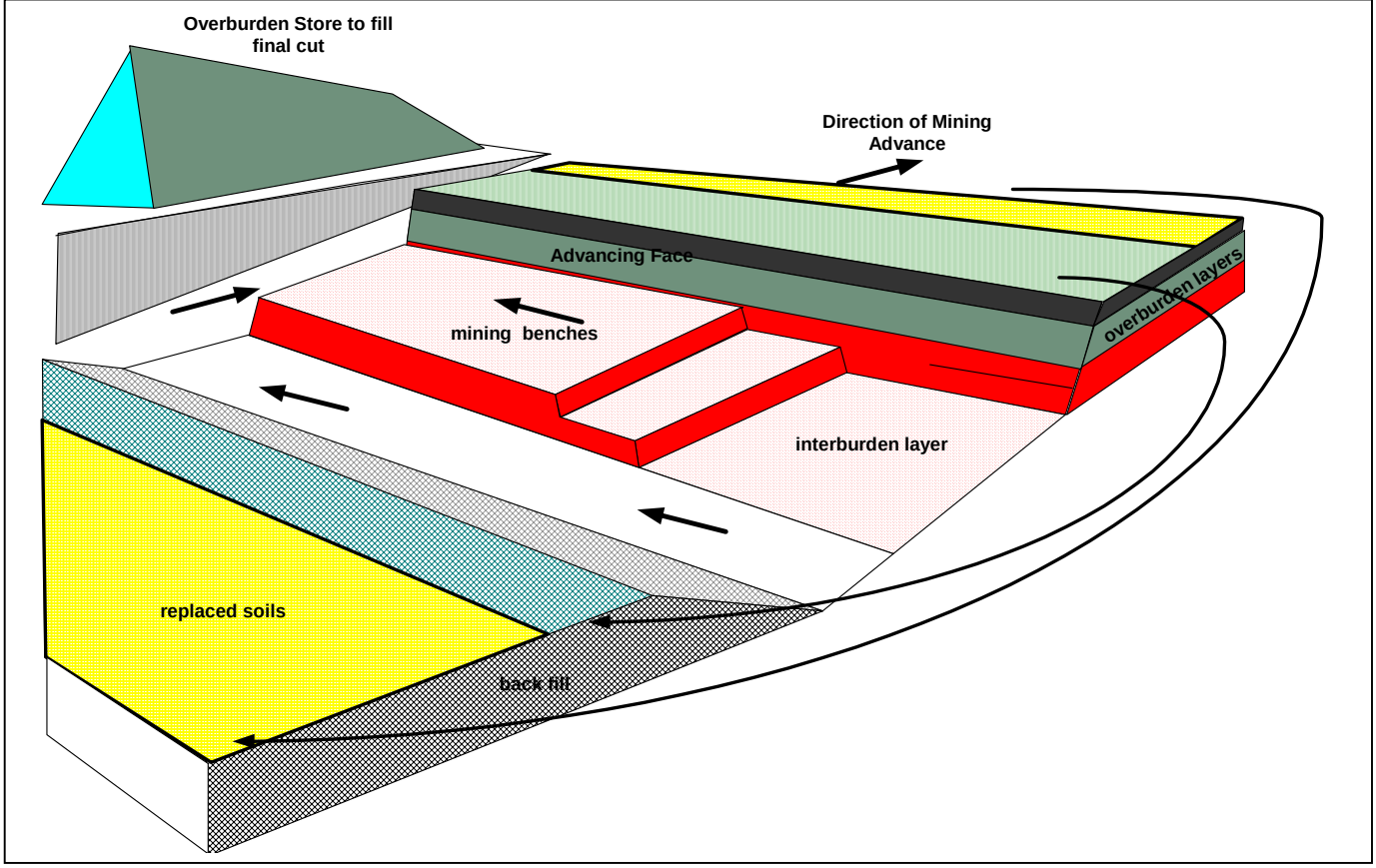



Diagram showing the operating sequence of a gypsum opencast mine

Bantycock Mine undergoing dewatering. The geological layering comprising from the base, Cropwell Bishop Fm with gypsum beds, Blue Anchor Formation, Westbury Formation, Cotham Member, and Lower Lias.


River Devon
Disused railway
Field 3
Lake 3
wl 15m
Lake 2
wl15m
Field 2
Field 4
Field 1
Field 5
Reed bed to lake shallows
Island for nesting birds
Proposed farm track
Lake 1
wl 15m
Limit of shallows
Wetland
Car Park
Forever Wood
Field 6
Kilvington
Field 7
Wetland/reed beds
Alverton
Legend
Existing hedgerow
Proposed woodland
Proposed hedgerow
Proposed hedgerow tree
Restored agricultural land
Grassland
Restoration contour
Reed bed
SUSTRANS cycleway
SUSTRANS diversion

# Tip Appraisal Form

The Quarries Regulations 1999

| | | | |
|---|---|---|---|
| **Site** | | **Tip No / Name** | |
| **Location** | | **Grid Ref** | |
| **Was tip previously classified under M & Q (Tips) Regs?** | | **Date of last inspection** | |

| **AUTOMATIC SIGNIFICANT HAZARD TRIGGER ISSUES** | | |
|---|---|---|
| Is tip more than 15m high | | If answer to any of these questions is 'yes' the tip must be regarded as a **significant hazard** and a Regulation 33 geotechnical assessment obtained.<br>If answer to all questions is no, proceed to carry out appraisal using criteria below to assist. |
| Does tip cover more than 10,000 $m^2$ | | |
| Is tip built on ground with gradient greater than 1:2 | | |

| **FACTORS AFFECTING SECURITY** | | | | | | **APPRAISAL SCORES** |
|---|---|---|---|---|---|---|
| What is tip constructed on? | Unknown ground conditions | Lagoon or filled area | Topsoil or peaty subsoil | Firm/stiff clays, sand, or mudstone | Rock or engineered foundation | |
| | 50 | 30 | 20 | 10 | 0 | |
| What is tip or stockpile made of? | Wet fines | DSG | Overburden WF | Overburden CBF/BA | Gypsum anhydrite mineral | |
| | 50 | 30 | 20 | 10 | 0 | |
| How was the tip or stockpile constructed? | Back-tipped | Placed with shovel, dozer, or dumper | Compacted with rubber tyred plant | Compacted with roller | Placed in enclosure | |
| | 30 | 25 | 15 | 5 | 0 | |
| What are the drainage conditions like? | Springs beneath tip | Boggy ground beneath tip | Standing or flowing water above tip | Firm land no drains | Free draining or engineered drains | |
| | 50 | 40 | 30 | 10 | 0 | |
| What features are visible on tip? | Tension cracks | Slumping of side slopes | Undercutting of slopes | Erosion of slope | Soil creep | |
| | 40 | 30 | 25 | 15 | 10 | |
| Is design being followed? | Design has not been followed | | | Design is being followed | | |
| | 30 | | | 0 | | |
| **TOTAL TIP APPRAISAL SCORE** | | | | | | |

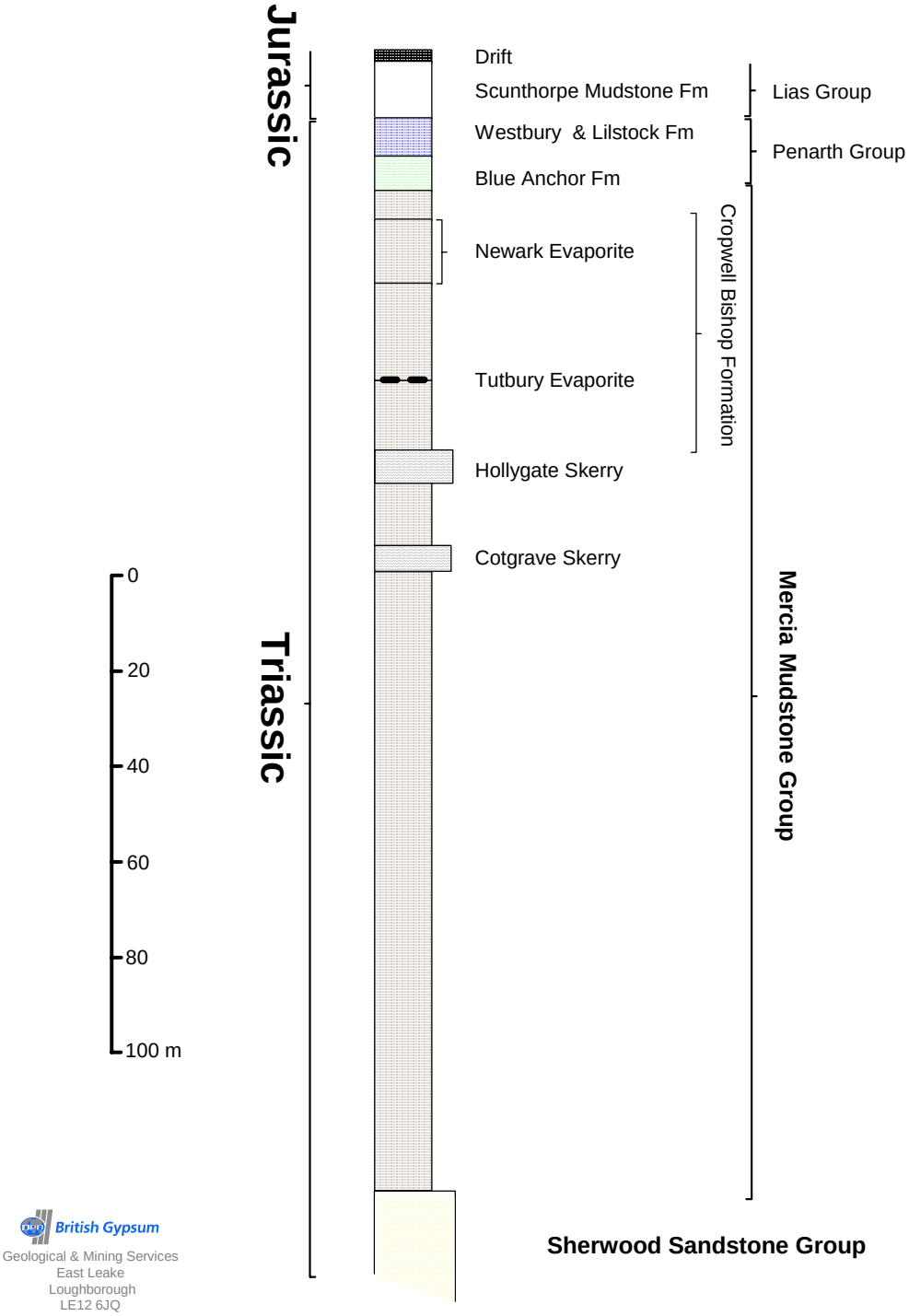
| | | | |
|---|---|---|---|
| Appraised by | | Date of Appraisal | |
| Signed | | Checked by | |

| | | | |
|---|---|---|---|
| **Site** | | **Face No./Name** | |
| **Location within site** | | **Grid Reference** | |
| | | **Date of last Appraisal** | |

| **DEFINE STRENGTH OF MATERIAL** | | |
|---|---|---|
| Can lumps of face material be broken by hand? | | If answer is "yes" it should be assumed that the face is evacuated in weak or very weak rock or engineering soil. If material cannot be broken by hand it is moderately weak rock. Or stronger. |

| **AUTOMATIC SIGNIFICANT HAZARD TRIGGER ISSUES** | | | | |
|---|---|---|---|---|
| **Soil, very weak or weak rock** | | **Moderately weak or strong rock** | | If answer to any of these questions is "yes" the face must be regarded as a **significant hazard** and a regulation 33 geotechnical assessment obtained from a specialist.<br><br>If answer to all questions is no. proceed to carry out appraisal using criteria below to assist. |
| Is vertical depth of excavation more than 7.5 metres with overall face angle of greater than 1V:2H (27°) | | Is vertical height of individual face more than 15m (50feet)? | | |
| | | Is overall face height between 15 and 30 metres and steeper than 45°? | | |
| Is any part of quarry floor more than 30 metres below ground within 30 metres of site parameter? | | | | |

| **FACTORS AFFECTING FACE SECURITY** | | | | | | **APPRAISAL SCORES** |
|---|---|---|---|---|---|---|
| What is face geology? | Weak overburden | Soft clay | Stiff clay | Mudstone | Shale slate | |
| | 40 | 30 | 20 | 10 | 0 | |
| Which way do beds dip? | Out of face by more than 30° | Out of face by more than 10° | By less than 10° | Into face at less than 30° | Into face at more than 30° | |
| | 40 | 20 | 0 | 10 | 20 | |
| How variable are geological conditions? | Variable within metres | | Vary over 100's of metres | | Consistent across site | |
| | 30 | | 15 | | 0 | |
| What are the drainage conditions like? | Springs flowing from face | Seepages from joints/cracks | Standing or flowing water above face | Erosion by gullying | Free draining or engineered drains | |
| | 40 | 30 | 20 | 10 | 0 | |
| What features are visable in or behind face? | Tension cracks | Slumping of overburden | Slumping mineral | Under-cutting of slopes | Soil creep | |
| | 40 | 30 | 25 | 15 | 10 | |
| Is design being followed? | Design has not been followed | | | Design is being followed | | |
| | 30 | | | 0 | | |
| **TOTAL EXCAVATION APPRAISAL SCORE** | | | | | | |

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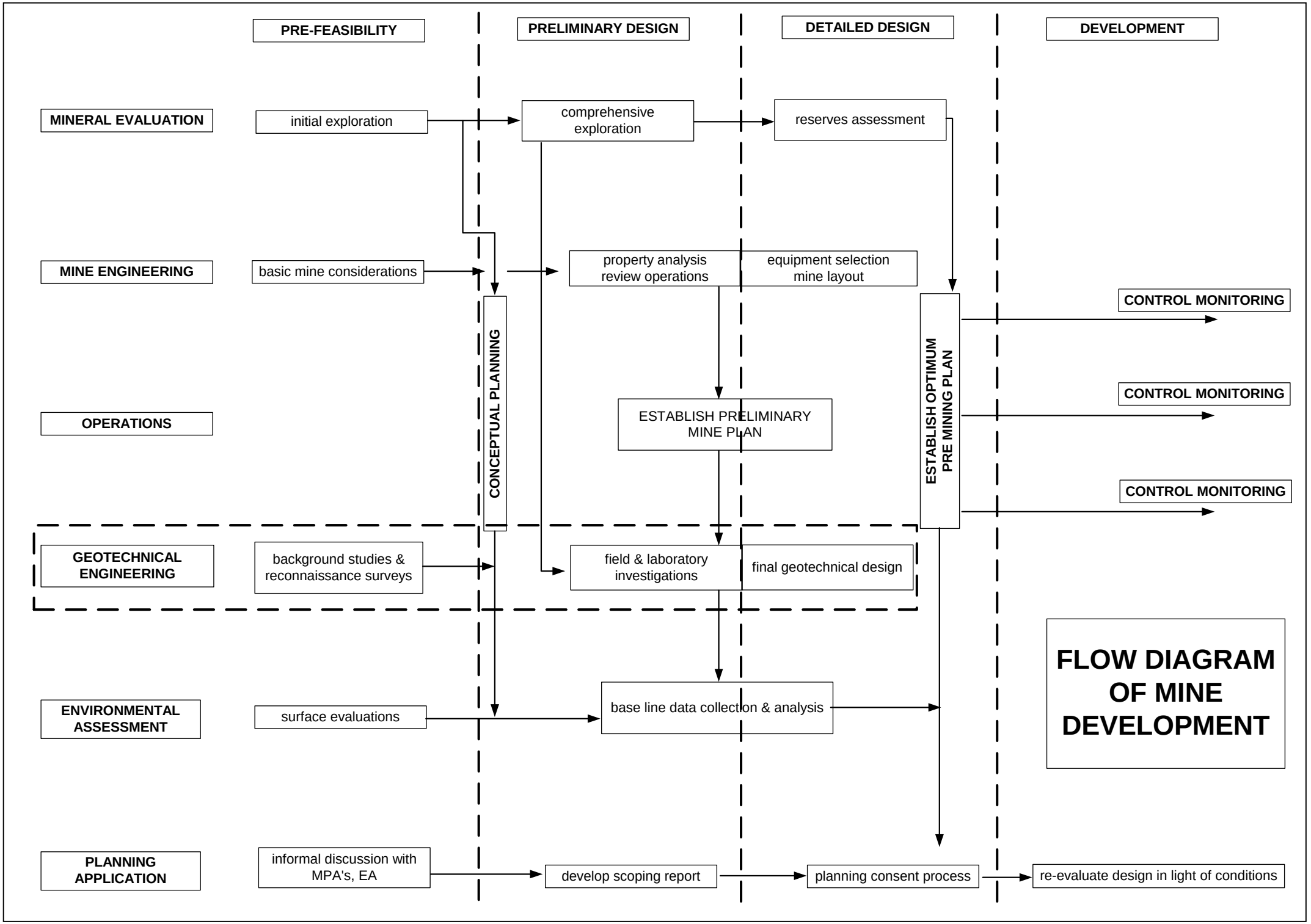
PRE-FEASIBILITY
PRELIMINARY DESIGN
DETAILED DESIGN
DEVELOPMENT
MINERAL EVALUATION
initial exploration
comprehensive exploration
reserves assessment
MINE ENGINEERING
basic mine considerations
property analysis review operations
equipment selection mine layout
CONTROL MONITORING
CONCEPTUAL PLANNING
ESTABLISH OPTIMUM PRE MINING PLAN
OPERATIONS
ESTABLISH PRELIMINARY MINE PLAN
CONTROL MONITORING
CONTROL MONITORING
GEOTECHNICAL ENGINEERING
background studies & reconnaissance surveys
field & laboratory investigations
final geotechnical design
FLOW DIAGRAM OF MINE DEVELOPMENT
ENVIRONMENTAL ASSESSMENT
surface evaluations
base line data collection & analysis
PLANNING APPLICATION
informal discussion with MPA's, EA
develop scoping report
planning consent process
re-evaluate design in light of conditions

Notes