Stabilisation of Penstrowed Quarry, Newtown

by Partial Backfilling

Report in Support of Planning Application Rev-B

G F Grigg Ltd

GroundSolve Ltd

Consulting Geotechnical, Engineering Geology and Environmental Engineers

CONTENTS

1.0 INTRODUCTION

G F Grigg Ltd (GFG) proposes to stabilise part of their dis used quarry at Penstrowed near Newtown by partial backfilling with site won materials.

The quarry is classed as a Site of Special Scientific Interest (SSSI) and Planning Permission will be required for the proposed work. In addition, the Countryside Council for Wales (CCW) will be statutory consultees for any such application.

At present GFG allow geological field trips onto their site to inspect the geological formation and it is considered essential as part of the SSSI classification that access to these formations is maintained.

The geology of the site comprises the Penstrowed Grits, which are Silurian in age and are the youngest and most easterly sandstones deposited in the southern and central parts of the Welsh Basin. Most of this section comprises beds of sandstone reaching several metres in thickness, interlayered with thinner bedded siltstone and mudstone. The quarry is particularly well known for its Flute casts, see photograph 1 below.

To enable the quarry to be stabilised and allow continued access for field studies a way of undertaking the backfilling of the quarry needs to be agreed with all relevant parties. The quarry will be backfilled by using material processed on site under the current license and permit held by G F Grigg. This allows the treatment of waste to produce soil and aggregates.

Consequently, GFG have appointed GroundSolve Ltd (GSL) a firm of Chartered Engineering Geologists and Geotechnical Engineers to carry out a stability analysis of the quarry face and present ways of stabilising the cliffs by backfilling the quarry, but also allowing continued access.

The other parties concerned are as follows:

- David Ladd, Planning Consultant appointed by Shearer and Morris on behalf of GFG,
- Claire Walters Environmental consultant.

A meeting was held on the 27th January 2012 to discuss draft proposals. Those present were, as follows:

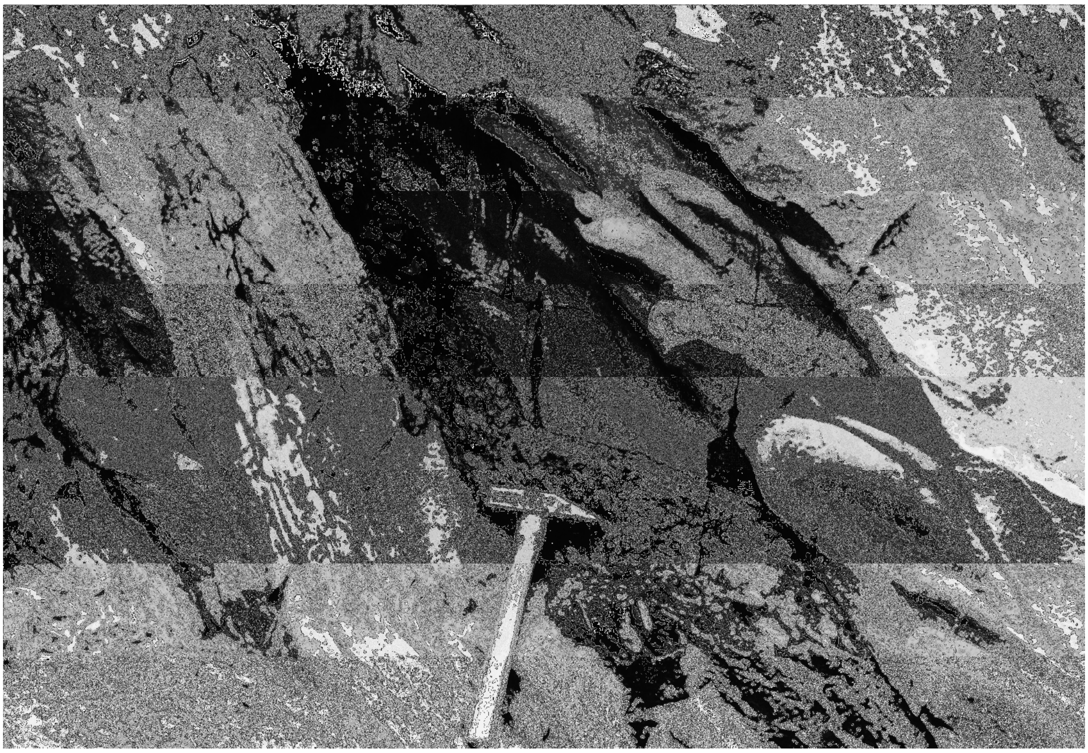
- Gareth Owen (CCW),
- Mike Green (CCW),
- Claire Walters (Ceri Environmental),
- Graham Grigg and Phil Davies (GFG),
- Mike Woosnam (Shearer and Morris),
- Mike Scott (GSL).

Following this meeting CCW provided a Site Management Report for the quarry, Reference 1, which was produced in 1994, and which is attached in Appendix A.

Preliminary design drawings were then produced, which presented a way of achieving the brief. Subsequent to submission of the drawing and accompanying report further comments were received from CCW and another site meeting held on the 15th August 2012 with Dr Bob Mathews the author of the 1994 report and Mike Green, both of CCW.

The design drawings have been updated to incorporate the comments from CCW, which are presented in this report, which also presents a review of all existing information and surveys of the quarry. In addition, risk assessments, specifications and methods of working are presented.

This report has been produced in support of the planning application for the proposed scheme.



Photograph 1: Flute Casts

2.0 THE SITE

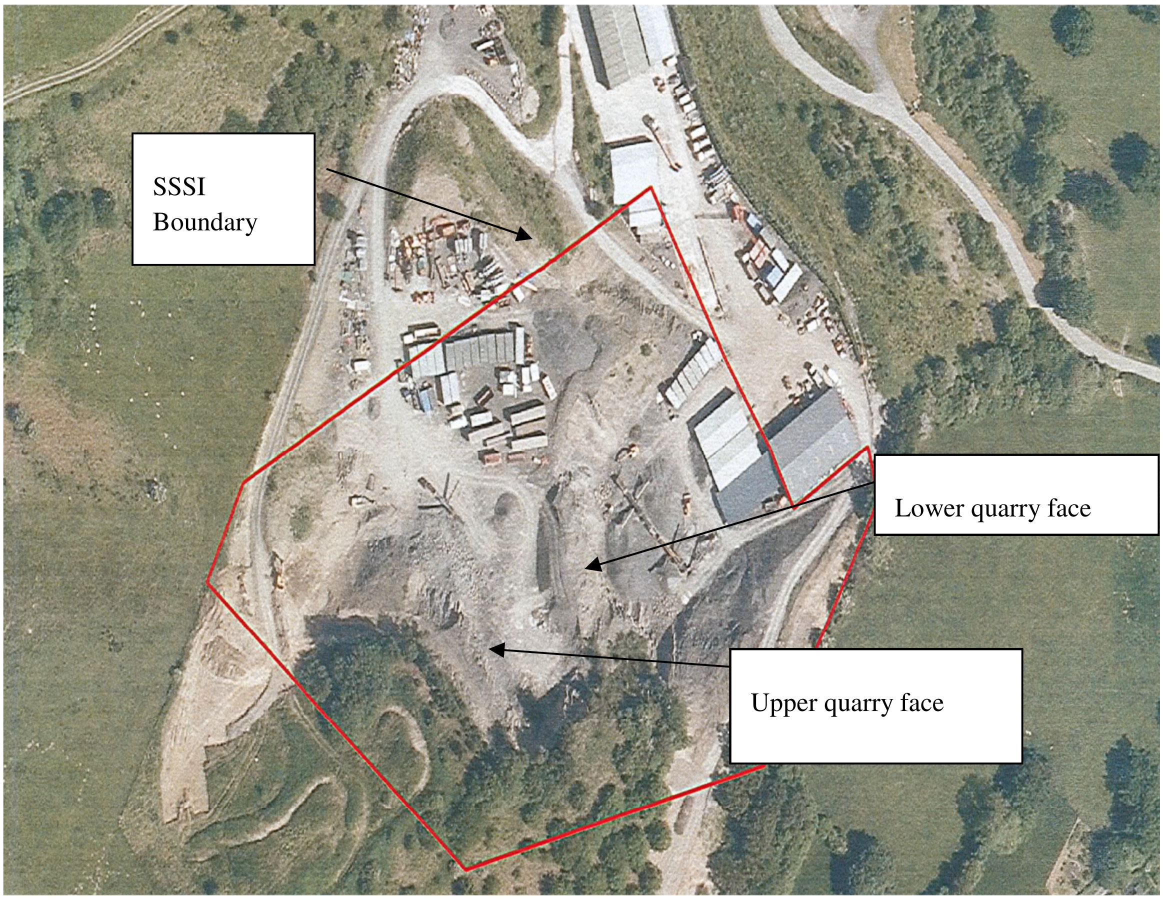
2.1 Site Location and Quarry Description

The quarry is located some 4km west of Newtown in the hills to the south of the A489T at National Grid Reference SJ 068 910, see Figure 1.

The site comprises a dis used quarry cut into the north eastern flank of a hill known as Maesmawr. It is split into two levels, representing former quarry benches; see Drawing CG 01 and Photograph 2.

The top quarry face is at an elevation of around 239mOD, falling to an elevation of 212mOD, some 27m high. A wide bench separates the upper and lower benches and the lower bench extends to an elevation of 195mOD, a height of some 17m. The quarry faces at present range from near vertical/vertical rock faces to faces with aggregate stored against the face.

The quarry faces trend in a south east to north west direction and the boundary of the SSSI is shown on photograph 2 in red.



Photograph 2: Aerial photograph of the site

2.2 Geology

The site lies within the, "Welsh Basin", a marine depression surrounded by land, which was largely infilled during Lower Paleozoic times. It was filled with fine to coarse grained sediments from surrounding land masses, which comprise rhythmic alterations of mudstones (fine grained) and greywacke (coarse grained sandstone) of the Penstrowed Grits, which are Silurian in age.

These rocks outcrop in an extensive north to south trending belt running east of Newtown. They represent a classic turbidite sequence, which was deposited from sediment laden density currents (turbidity currents), which flowed north into deeper parts of the basin. These produced graded bedding shown by upward fining in grain size, along with an abundance of sedimentary structures, such as flute casts, seen on the underside of some coarse grained units in the Penstrowed Grits, confirming the high energy depositional environment.

The Penstrowed Grits in the quarry consist of a rhythmic alternating sequence of cream coloured greywacke sandstones, and dark grey siltstones and shaley mudstones, see Photograph 3.

Photograph 3: Alternating sequence, lower quarry face

However, the reason the site was originally notified lies in the wide range of sedimentary structures found in the rocks on site, these include;

- Graded bedding, where coarse grained basal units pass up into a fine grained laminated sandstone,
- The base of many of the sandstone beds are characterised by abundant sole structures, including flute casts and tool marks,
- Ripple marks on the top of sandstone beds.

The flute casts are formed when hollows were eroded into the top of the underlying bed and later infilled with coarser sediment. The tool marks appear as linear grooves and were produced by an object (tool) such as a pebble being dragged along the sea floor.

Turbidity currents transfer large quantities of sediment from shallow to deep marine environmental at high speed, with the coarser fragments settling out of suspension first followed by the finer grained silty material. The fine grained shaley mudstones overlying the sandstones representing the background sedimentation in the deep water immediately preceding the arrival of the next turbidity current.

2.3 Hydrogeology and Hydrology

Due to the general topography, i.e. sloping steeply to the north east and the presence of sandstone bedrock the groundwater is anticipated to be at significant depth beneath the site, with any groundwater flows being in the same direction as the slope towards the valley floor, which contains the River Severn.

The only other watercourse in the vicinity of the site is a small stream, which is to the north of the site offices and which flows in a south west to north east direction down slope towards the River Severn.

2.4 Structural Geology

Following deposition of the Penstrowed Grits they were deformed at the end of the Silurian/beginning of the Devonian by the Caledonian Orogeny (period of mountain building).

This deformation being characterised by a single set of folds on upright, mainly NE to SW trending, axial planes, which are accompanied by a cleavage.

The quarry itself is located close to the core of the Central Wales Syncline (bowl shaped feature) and on the north western limb of a smaller scale anticline (dome shaped structure).

Due to these historic earth movements the alternating beds dip steeply to the north west at angles of up to 60º, reflecting their position on the north west limb of a tight anticlinal fold.

The fine grained mudstones are cut by a finely spaced cleavage, which is orientated sub parallel to the bedding. The succession is also transected by several north to south striking faults which have a downthrow on the eastern side.

Some sandstone beds are cut at high angles by well defined system of joints, which are infilled, either by quartz or by iron rich dolomite.

2.5 History

Reference 1 records that prior to 1946 the quarry was owned and worked by the Local Council, which exploited the hard sandstone layers for use as building and road stone.

The quarry was connected by a short rail link to the main Shrewsbury-Aberystwyth railway some 600m to the north east of the site. However, this link was closed in 1937.

The previous owners purchased the site in 1946 and continued to work the quarry until 1984 approximately, when it was abandoned.

GFG purchased the quarry in March 2001 and it is currently used for the processing and storage of aggregates.

3.0 CONSERVATION PRINCIPLES

3.1 CCW Report

According to Reference 1, the main objective at Penstrowed quarry is to maintain the integrity of, and access to the rock faces particularly those which are located on the upper level, since it is in this area that the best examples of sedimentary structures can be found, see Photograph 4.

Photograph 4: sedimentary structures exposed on upper face

This exposure represents a combination of the clear rhythmic alterations, sedimentary deposition and the well developed sole markings.

At the time of the inspection in 1994 the quarry still had planning permission to continue quarrying operations and CCW were keen to ensure that worked faces were left in a condition, which would allow continued access by geologists to the rhythmic sequence of sediments and sedimentary structures. (This is no longer the case and the quarry does not have planning permission to continue quarrying).

Reference 1 also identified the following potential threats to the concealment of the rock faces at Penstrowed quarry.

The process of natural degradation, which is ongoing, could lead to the concealment of some rock faces at Penstrowed quarry, particularly those on the upper level. At the time of inspection by CCW the friable nature of the turbidite sequence had resulted in the accumulation of a considerable quantity of debris at the base of the cliff, see Appendix A.

It also noted that rock falls in this area are a major hazard when approaching the cliff faces.

The report also considered the possibility of the quarry being used for, "other purposes", which could lead to the grading or battering back of the cliff face to improve stability. An activity, which could severely damage or result in the loss of the geological interest at the site.

It was concluded that should quarrying recommence then a similar face providing an accessible cross section through the turbidite sequence could be left. Liaison with the quarry operator was recommended to ensure any remaining faces would be left in a safe condition and not covered by quarry waste materials.

3.2 Other Correspondence

Correspondence with interested parties has been supplied and these are summarised below with the issues that need to be addressed.

Letter from CCW to David Ladd, dated 4th August 2011.
Reply from CCW regarding enquiry about infilling quarry.

Such activity falls under two Potentially Damaging Operations (PDO) listed for this SSSI, as follows:

- PDO 7, Dumping, spreading or discharge of any materials,
- PDO 15 infilling of pits.

Under Section 28E (3) of the Wildlife and Countryside Act 1981, consent is needed from CCW for all activities listed as PDO's for this SSSI.

CCW would not object in principle to the proposed works. Indeed, consent may be given for the works provided that they could be demonstrated to have no adverse impact on the important features of the SSSI. CCW welcomes comments that the sedimentary structure, which is special feature of the SSSI, would be left exposed and the proposed works would be designed to improve access for researchers and students.

CCW's response would therefore be dependent on the details of the proposed scheme and as much information as possible should be provided. This information should include,

- A series of plans and cross sections detailing the proposed area and thickness of the fill and its interaction with the areas of exposed rock strata,
- If it is proposed to bury any rock exposures this would need to be supported by detailed geological appraisal as to the value of the lost exposure and the potential for creation of replacement exposures elsewhere,
- It would also be useful if a method statement was provided detailing the infilling works, including provision or the continued protection of the geological features as works progresses.

CCW may also require an assessment of the potential impact on other natural heritage interests such as landscape and European Protected Species.

E-mail from Tom Evans (Flintshire CC-on behalf of North Wales Minerals and Waste Planning Officer) to David Ladd, Dated 31st August 2011.

The following should be supplied as part of your submission:

- Full planning application forms,
- A proposed plan showing finished levels,
- A topographic survey,
- Cross sections of the quarry to show existing levels and proposed levels,
- A working plan,
- Landscaping scheme,
- Ecological survey,
- Highway suitability survey,
- If required an EIA.

However, it may turn out that not all of the above will be required.

The issued considered potentially problematic were:

- Highways,
- Visual impact,
- Possible impact on species.

E-mail from Tom Evans (Flintshire CC-on behalf of North Wales Minerals and Waste Planning Officer) to David Ladd, Dated 21st September 2011.

In terms of the requirement for an EIA, this is dependent on whether the input of waste would exceed 50,000 tons per annum, whether the site exceeds 0.5 of a hectare and whether the site is situated within 100m of any controlled waters.

E-mail from Tom Evans (Flintshire CC-on behalf of North Wales Minerals and Waste Planning Officer) to David Ladd, Dated 7th October 2011.

In terms of dust generation and mitigation, I accept that the landscaping aspect of the proposal is unlikely to cause problems, especially if conducted in damp conditions. The use of plant for the recycling of inerts is more likely to generate dust, especially if operated in dry conditions.

While there are no residents nearby, for the benefit of the workforce and in order to prevent a visual impact, it would be wise to include some form of basic dust suppression scheme, such as the use of a bowser to dampen material and stockpiles to prevent visual dust from leaving the site.

I do not expect that noise generated would be significantly more that that which is currently being produced on site by way of its day to day workings.

In relation to surface water drainage, I would suggest a basic drainage scheme incorporating bunds and gullies at the upper part of the site in order to prevent the direct flow of surface water down to the lower areas. The diversion of surface water to a small alleviation pond may be appropriate to contain large amounts of surface water, which may be generated by severe weather conditions.

From the information you have provided so far, I do not think an EIA will be required, however, if you want formal confirmation it would be necessary to provide a formal screening request with exact details.

An indication of proposed landscaping, restoration and planting would be required

4.0 EXISTING QUARRY FACE STABILITY

4.1 General

Reference 1 has already highlighted the dangerous nature of the rock faces for close inspection at the base of the cliffs. This is also shown by damage to one of the existing buildings on site; see Photograph 5, which also has a small fallen block nearby.

Photograph 5: Damage to existing building from rock fall

At present the quarry owners allow unrestricted access to the exposures on site, which as detailed above have been recorded as dangerous by CCW. While the onus is on the visiting parties to provide suitable insurance, a grey area exists in law as to whether the quarry owner could be held liable for allowing access to land that is dangerous should an incident occur. As far as we are aware the quarry owner does not ask to see the wording of the visiting parties insurance. This therefore leads to a risk for both parties, which at present is considered to be significant and should be reduced.

It is therefore important to understand the potential for further failures, in terms of their size, location and frequency.

4.2 Rock Face Stability

When considering the rock face stability, two issues need to be considered, as follows:

- Potential for large scale failures,
- Possibility of small to medium sized rocks falling from the quarry face.

The overall quarry face stability is determined by the orientation of the major discontinuities in the rock mass, i.e. the bedding, jointing and any major faults.

To understand the stability of the rock face and the likelihood of further instability, which may affect the site, it is important to understand the varying types of failure mechanism in rock.

There are several recognised mechanisms for rock slope instability to occur, which are generally based on the orientation and spacing of the discontinuities within the rock mass.

General failure mechanisms are listed and explained below.

- Planar failure,
- Wedge failure,
- Circular failure,
- Toppling failure,
- Raveling and weathering.

The main failure mechanisms are presented in diagrammatic form in Appendix B.

Planar Failure

For planar failure to occur the following conditions must be satisfied:

- The plane on which the sliding occurs must strike parallel or nearly parallel (within approximately ±20º) to the slope face,
- The sliding plane must "daylight" in the slope face, which means that the dip of the plane must be less than the dip of the slope face,
- The dip of the sliding plane must be greater than the angle of friction of this plane,
- The upper end of the sliding surface either intersects the upper slope, or terminates in a tension crack,
- Release surfaces that provide negligible resistance to sliding must be present in the rock mass to define the lateral boundaries of the slide.

Wedge Failure

This occurs when discontinuities striking obliquely to the slope face allow a wedge of rock to fail along the intersection of two such planes.

Circular Failure
Circular failure relates to closely fractured/weathered slopes that fail in a similar manner to soil slopes.

Toppling Failure
Several types of toppling failure have been identified and these are listed below:

Block Failure, where individual columns are formed by discontinuities dipping steeply into the face, with a second set of widely spaced orthogonal joints defining the column height. The columns are forced to topple by weight pressing behind from other columns and weathering action.

Flexural Toppling, where continuous columns of rock, separated by well developed, steeply dipping discontinuities, break in flexure as they bend forward. This type of failure is typical in thinly bedded shale's and slate in which the orthogonal jointing is not well developed.

Secondary Toppling, whereby erosion of a weaker band allows the stronger upper band to be undercut and fail.

Raveling and Weathering
These are slow time dependent processes largely controlled by continued freeze thaw activity on the slope, which may cause loosening of small blocks that may fall with time. These activities can also be exasperated by root action if vegetation is present on the face.

4.3 Discussion on Failure Mechanisms

Both the upper and lower quarry faces discontinuities have been mapped by a chartered engineering geologist from GSL. The readings are summarised in the table below.

Face	**Bedding**	**Joints**	**Comments**
Upper	45° to 338°		
		75° to 196°	Impersistent
	60° to 316		
		60° to 058°	Joint in sandstone
Face	Trends	135° to 315°	
		76° to 072°	Joint in sandstone
Lower			
		Vertical Strike 150°	Joint in sandstone
	58° to 320°		
		Vertical strike 155°	Joint in sandstone

As can be seen from the above data the faces are largely defined by the joint set in the sandstone bands, with the dip of the beds at right angles to the face. The joints were only observed to be only in the sandstone bands and were not persistent across the varying horizons.

A bedding shear zone was observed on the upper face, which comprised a thin layer of quartz veining with striations underlain by around 5mm of soft, grey clay. This would have formed during the movement of the rocks over each other during the orogeny and represent a very weak zone within the rock mass.

In addition, the cleavage was observed to be very well developed in the mudstone bands, see Photograph 6.

Photograph 6: Well developed cleavage in the mudstone

A large fault was also observed in the quarry face on the lower section which trends in a south west to north east direction, see Photograph 7.

Photograph 7: Fault in quarry face showing change in geology across the fault

The main discontinuity affecting face stability is the bedding, which was observed to be steeply dipping in a north westerly direction, i.e. directly along the orientation of the quarry faces. Consequently, planar failure along the bedding planes is not possible.

The only joint set observed was confined to the sandstone layers and was not persistent across any of the mudstone horizons. Consequently, no obvious joint sets were observed, which could lead to large scale wedge failures. In fact, this joint set has largely defined the orientation of both rock faces and has lead to a fairly stable configuration from the discontinuities.

The main risk of failures were related to the potential for small to medium sized blocks of rock to fall from the slope and several examples of this mechanism can be observed on site, especially where one of the buildings has been slightly damaged by falling rocks.

Blocks are loosened by several mechanisms and these are discussed below.

During quarrying the rock would have been quarried by blasting with explosives, which in itself can cause significant blast damages to faces left behind, caused by gasses from the blast being forced into existing discontinuities and causing them to open up. These will then weather with time leading to failures.

In addition, the act of removing large volumes of rock can lead to stress relief, whereby discontinuities open as the load applied on the rock is removed.

Both the above mechanisms then lend themselves to active weathering of the face by such mechanisms as freeze thaw, whereby water flows into the open discontinuities, freezes and then forces the cracks open further.

Finally vegetation growth with roots forcing themselves into discontinuities can dislodge large blocks.

Once the potential for rocks to fall has been identified, it becomes important to determine how far they can fall and the gradient of the rock face. The survey has shown that rocks falling from the top of the quarry faces have the potential to generate large momentum due to the heights involved. In addition, any slight gradient of the rock face will lead to falling rocks bouncing off the face and potentially travelling some distance from the face.

4.4 Risk Assessment

From the above discussion it can be concluded that the risk of large scale failures is very low, however, as with any rock face small to medium size blocks will always fall sporadically. This leads to the general degradation of the faces mentioned in Reference 1 (Appendix A).

This is not a problem for operational quarries, or for companies such as GFG who work within quarries, and can protect their work force.

However, as soon as other people are allowed onto site and in particular are intent on standing at the base of a high rock face a risk to these people is presented. While this can be negated by visitors carrying relevant insurance, it does not necessarily protect GFG from spurious claims by people injured by falling rock while on site. It is also considered prudent in any circumstances to provide as safe as possible environment for students to take advantage of the rock outcrops.

There are several options to address this risk and these are discussed below:

The most cost effective way of reducing the risk would be to carry out regular scaling of loose rocks from the face. However, the faces are high and this would involve bring specialist plant to site at GFG expense. However this would be a unacceptable cost to protect site users not employed by GFG.

The base of the quarry could be fenced off to prevent access, although this also incurs expense for GFG and also restricts use of the existing working floor space. However, this also limits the accessibility for geological inspections.

Slope stabilization measures such as rock netting and bolting could be installed on the face, although this would have considerable expense and would also detract from the geological features.

The most appropriate way of addressing both issues would be by constructing the proposed works, as follows:

Backfill quarry face with inert material and leave the top 6m of face exposed for inspection, on the upper quarry face to comply with CCW's requirements. During the works the exposed quarry should be scaled to remove all of the loose rock and the faces battered back slightly to a more stable gradient. The area of face left exposed being those selected areas agreed with CCW, which are presented on the Drawing CG 01 – Rev B. Should any further locations of interest be found during the works, such as on removal of stockpiles then the landform can be adjusted to accommodate these structures.

It is also proposed to backfill the lower quarry face, however, several features have been identified by CCW and the proposed landform has been adjusted according, so that they remain open for inspection, see Drawing CG 01 Rev B. Again the rock faces should be scaled during the works to remove existing loose blocks.

Access tracks could also be created to the top for maintenance plant and geology students, see Drawing CG 01 –Rev B. In addition, the most valuable outcrops could be left at ground level with easy access. Detailed construction details are presented in section 5.

4.5 Other Issues

Should the quarry face be backfilled the drainage of the site will need to be considered, mainly to prevent surface run off containing silt flowing downslope and having any detrimental environmental impact.

At present the site is subjected to significant rainfall run off from the hillside above and rainfall falling on the site itself. At present there is no active drainage to cater for these flows. Therefore development of the site during backfilling would be able to address this issue.

5.0 PROPOSED WORKS

5.1 Site Preparation and Drainage

The proposed development areas are currently covered with aggregate stockpiles, which will need to be moved.

The formation will then need to be prepared prior to the commencement of tipping. This will involve ensuring the quarry has a back fall of around 1 in 100 towards the quarry face to ensure drainage away from the edge of the quarry. This can best be achieved by using a fine quarry dust to provide a level formation of low permeability.

The drainage for water percolating through the deposited material will then flow in a south easterly direction towards the quarry faces.

A granular drainage blanket should be constructed at the base of the proposed infilling. This should comprise a 300mm thick layer of single size stone (40mm), which can be processed/obtained from materials already on site. The drainage blanket should then be covered with a geotextile separator before placing the inert material.

At the base of the quarry face a trench/soakaway should be constructed in the sandstone bedrock, which should be some 1m deep and some 600mm wide. It will be necessary to excavate this trench using hydraulic/pneumatic excavators. This trench should also be backfilled with single size stone.

A granular drain should also be provided adjacent to the quarry face to intercept surface run off from above and also divert rainfall back into the drains.

The above drainage design should ensure that all water falling/flowing onto the deposited material is captured and taken to soakaway.

5.2 Slope Stability

In addition, the stability of the deposited material will have to be considered, for such items as:

- Side slope stability,
- Drainage,
- Stability of any rock slopes below the deposited material.

The above drainage measures should ensure that water does not build up in the deposited material that could lead to the potential for slope instability of the placed material.

During placing of the materials it is recommended that they be lightly compacted using the tracked machines used for placing the fill material. Side slopes for the inert material shall not exceed 1 in 2 (26.5º) to ensure side slope stability.

5.3 Proposed Work

Upper Rock face – Phase I

It is proposed to backfill this section first to enable the existing facility in the lower quarry to continue in operation for the foreseeable future.

CCW have requested that the top 6m of the upper face be left exposed, along with the outcrops at ground level at the southern end of the quarry. In addition, CCW have requested that an area where graptolite fossils have been found is left exposed, see Photograph 8.

This will involve backfilling against the face shown below to approximately half way up the slope to an elevation of around 120mOD. A 3m wide access track will then be constructed at the base of the slope to comply with CCW requirements for inspections and to also enable plant access. The southern end of the deposited material will be battered back to ground level to secure access to the ground level outcrops, see Drawing CG 01 – Rev B.

Behind the access path a slope at a gradient of 1 on 2 (26.5°) will be constructed to the main level plateau of 224mOD. This will allow the quarry face to be largely hidden once the site has been landscaped. To the north east of the level plateau a 1 on 2 slope will fall towards the top of the lower quarry face.

At the base of the slope the 3m wide access track will be constructed with an earth berm constructed between the access track and the top of the quarry face. This earth bund will be some 3m wide and around 1m high and will act as a safety barrier for plant and personal visiting the quarry. It has also been agreed with CCW that all of the boulders on site in the lower quarry containing features of interest would be placed on this berm to allow students safe access to feel the structures, removing the need for climbing on the quarry faces.

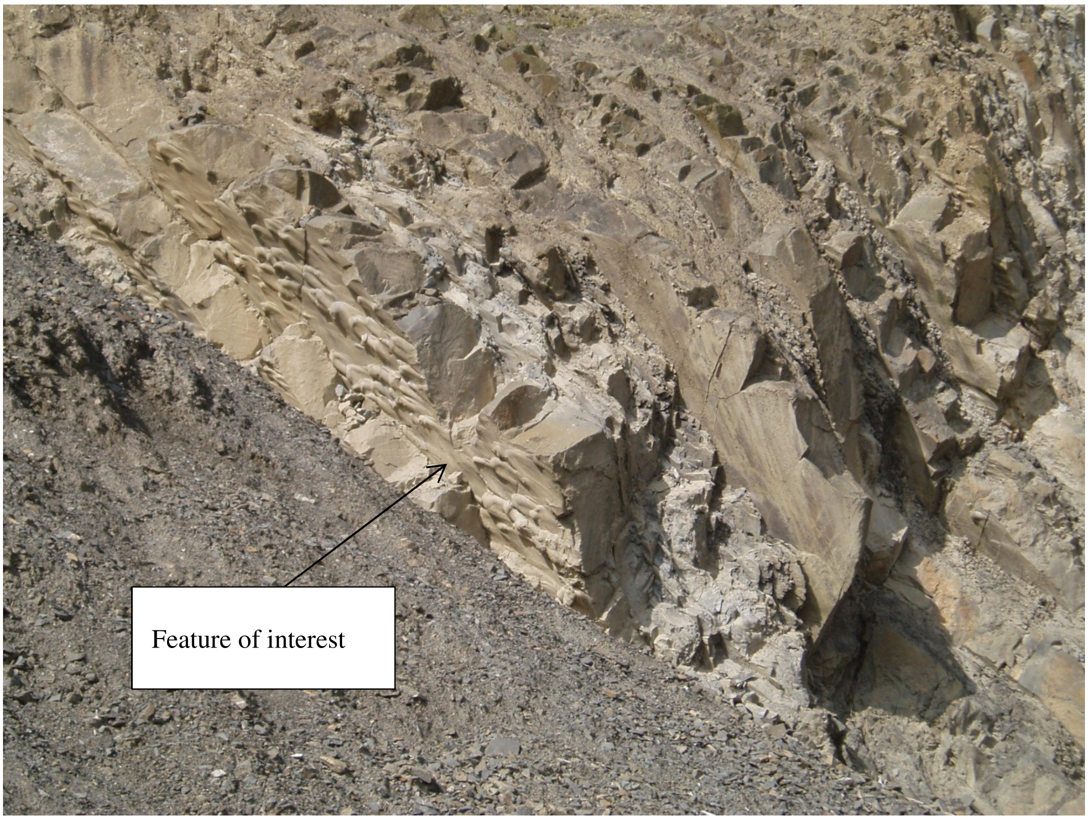
To help ensure long term stability of the exposed rock face and reduce the risk during inspections it is recommended that the face be battered back to a gradient of around 75 to 80º and the face scaled of any loose blocks. This can be carried out by scraping the teeth of the excavator bucket across the face.

Photograph 8: Upper quarry face

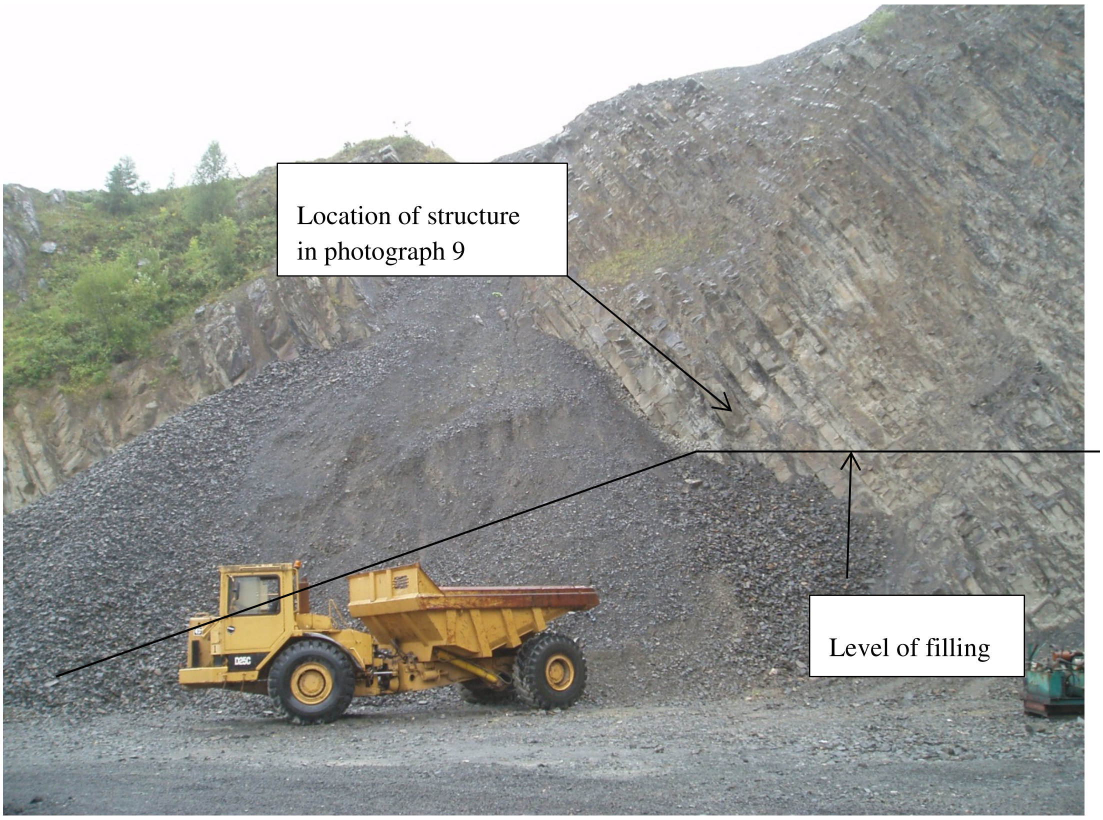
Lower Quarry Face – Phase II

Recent removal of a stockpile against the quarry face has revealed a feature of interest that CCW want to keep open for inspection, see Photograph 9 below, with its location shown in Photograph 10.

It is estimated that this feature is at an elevation of around 195mOD and this should determine the plateau level. It is also required to keep several in situ features available for inspection on the southern corner of the Phase II works. Consequently, access will be formed by lowering the levels locally to these structures. The level of filling in this area is indicated in Photograph 10. A 3m wide access track will be constructed to allow access to both sets of structures.



Photograph 9: Showing feature of interest.



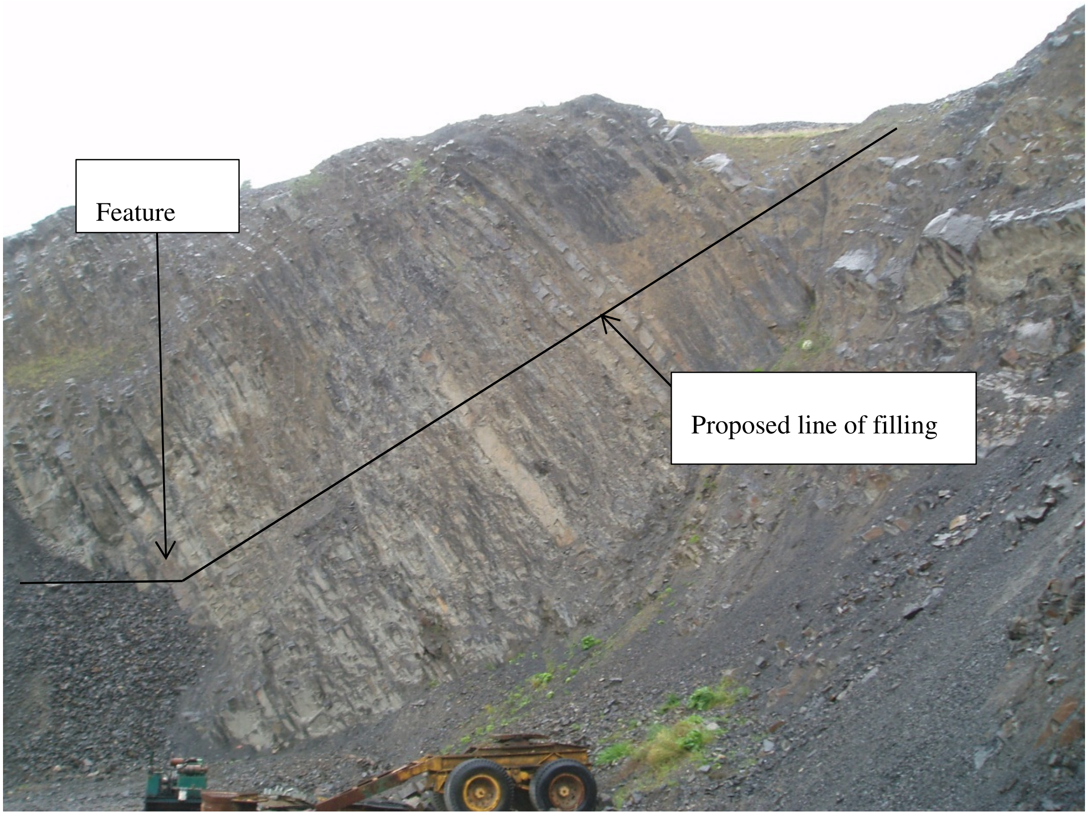
Photograph 10: Showing location of structure

The northern face of the lower quarry, which has the fault is considered to be the most unstable on site and CCW have no objections to this face being completely backfilled, see Photograph 11.

Photograph 11 Lower quarry face

The approximate line of filling is shown below on photograph 12.

The constructed plateau will then extend in a north east direction where a 1 on 2 slope will be formed to tie it into the existing quarry slopes, see Drawing CG 01 – Rev B.



Photograph 13: Showing line of filling

5.4 Quantities

It has been calculated that the upper quarry will contain 43,564m³ of deposited material, with the lower quarry containing 23,228m³.

Based on a unit weight of around 1.8 T/m³, this would give a total tonnage of 120,225 tons.

5.5 Slope Landscaping and Reinstatement

On completion of the work the side slopes can either be topsoiled and planted. Alternatively they can be hydroseeded with a suitable mix that is similar to the land either side of the quarry.

Once the work has been landscaped it will reduce the visual impact of the quarry from the lower valley floor.

The actual landscaping proposals will have to be submitted and agreed with the Planning Authority.

5.6 Risk Assessment

The main risk during the works will be as follows:

- Rock falls when machinery/men are working below the rock face,
- Working close to the top of lower rock face.

The first issue can be addressed by scaling of the rock faces as the work progresses and especially before any man access is required. In addition, any machinery working at the base of the rock face should be fitted with suitable protection bars to the cabs to protect from rock fall.

The second issue is easily catered for by providing a 1m high and 3m wide earth bund at the top of the lower face; see Drawing CG 01 – Rev B. This could be further supplemented by adding some of the numerous boulders on site that contain the sedimentary structures of interest.

5.7 Brief Requirements

The above work will have the affect of stabilising the face, so it can be inspected in a safer manner. However, there will still be a risk to site visitors. To protect GF Grigg from any liability it is recommended that visitors should sign a suitably worded disclaimer before being allowed on site.

To achieve easy inspection it is recommended that an access ramp be constructed up the side of the deposited material to allow access for students. It is recommended that this access ramp at the top of the deposited material be at least 3m wide. This will then allow access for machinery at a later date should any maintenance be required on the exposed rock face.

It is also recommended that the outcrops mentioned above be left clear for inspection with an access road left at the base of the slope on the upper face extending round to the outcrop; see Drawing CG01 – Rev B.

The outcrops to be left open for inspection are presented in Photographs 14 to 17, with examples of some of the sedimentary structures visible.

Photograph 14: Location of outcrops on upper face to be left exposed

Photograph 15: Tool marks

Photograph 16: Surface ripple marks

Photograph 17: Outcrops to be left exposed on Lower face

5.8 Conclusions

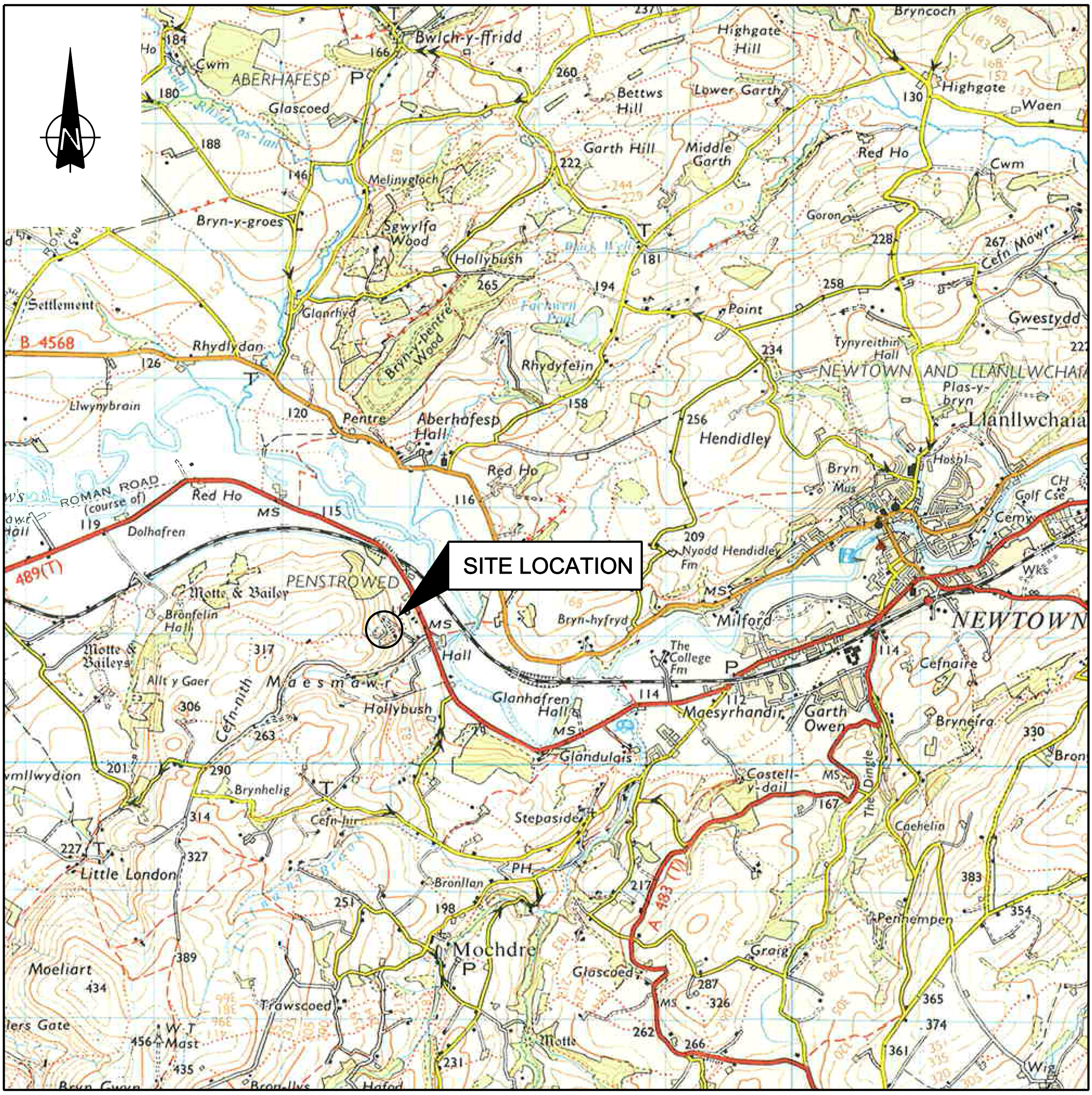
From the above information it can be concluded that the work:

- Will improve the visual appearance of the quarry,
- Will make inspections of the sedimentary structures significantly safer,
- Will cater for any surface drainage,
- Will not have an affect on controlled waters.

REFERENCES

1. Site Management Report Series, Penstrowed, Dr Bob Mathews, 1994, CCW.

FIGURES



SCALE - 1 : 50000

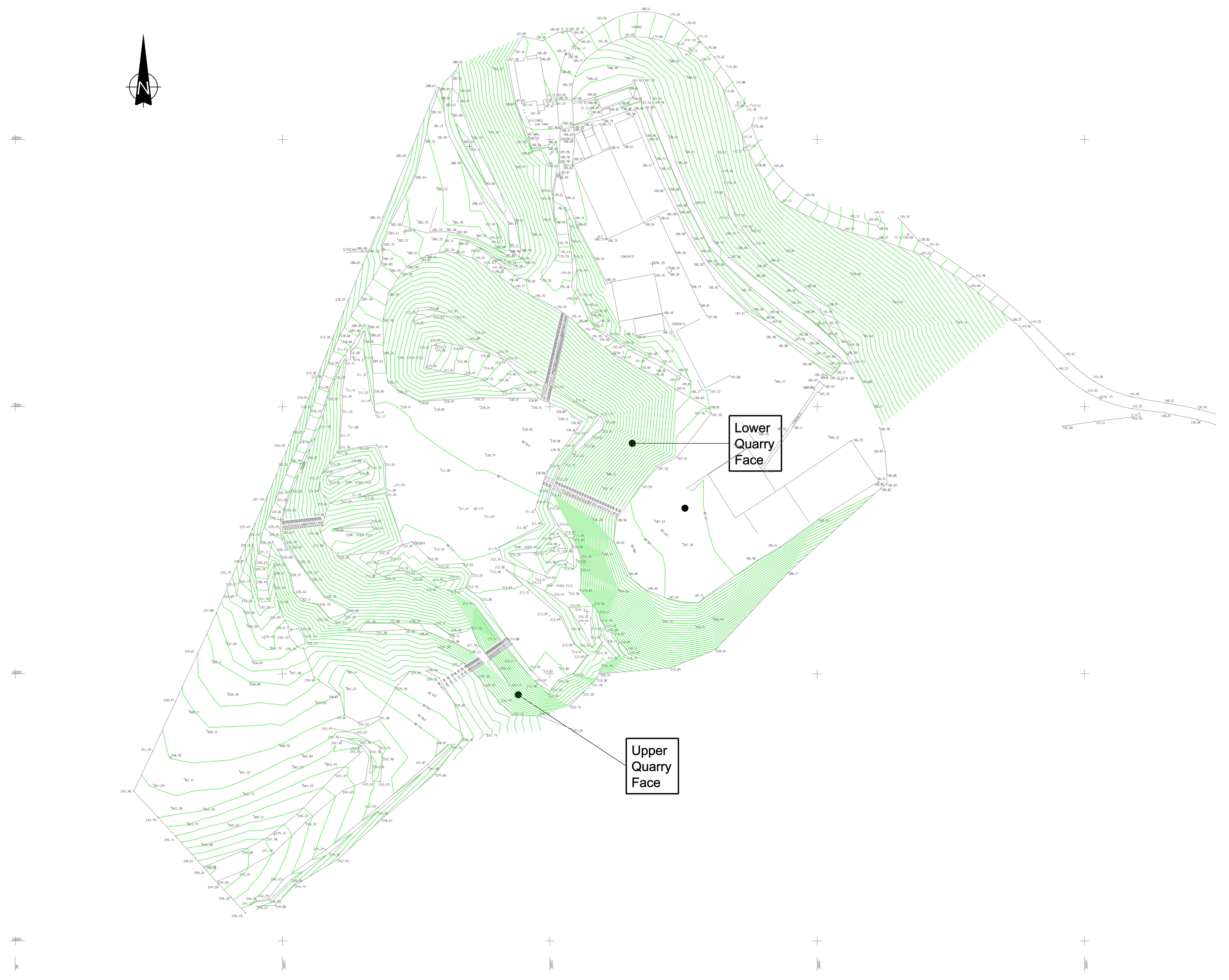
LICENSE No. 100030802

SITE LOCATION

FIGURE **1**

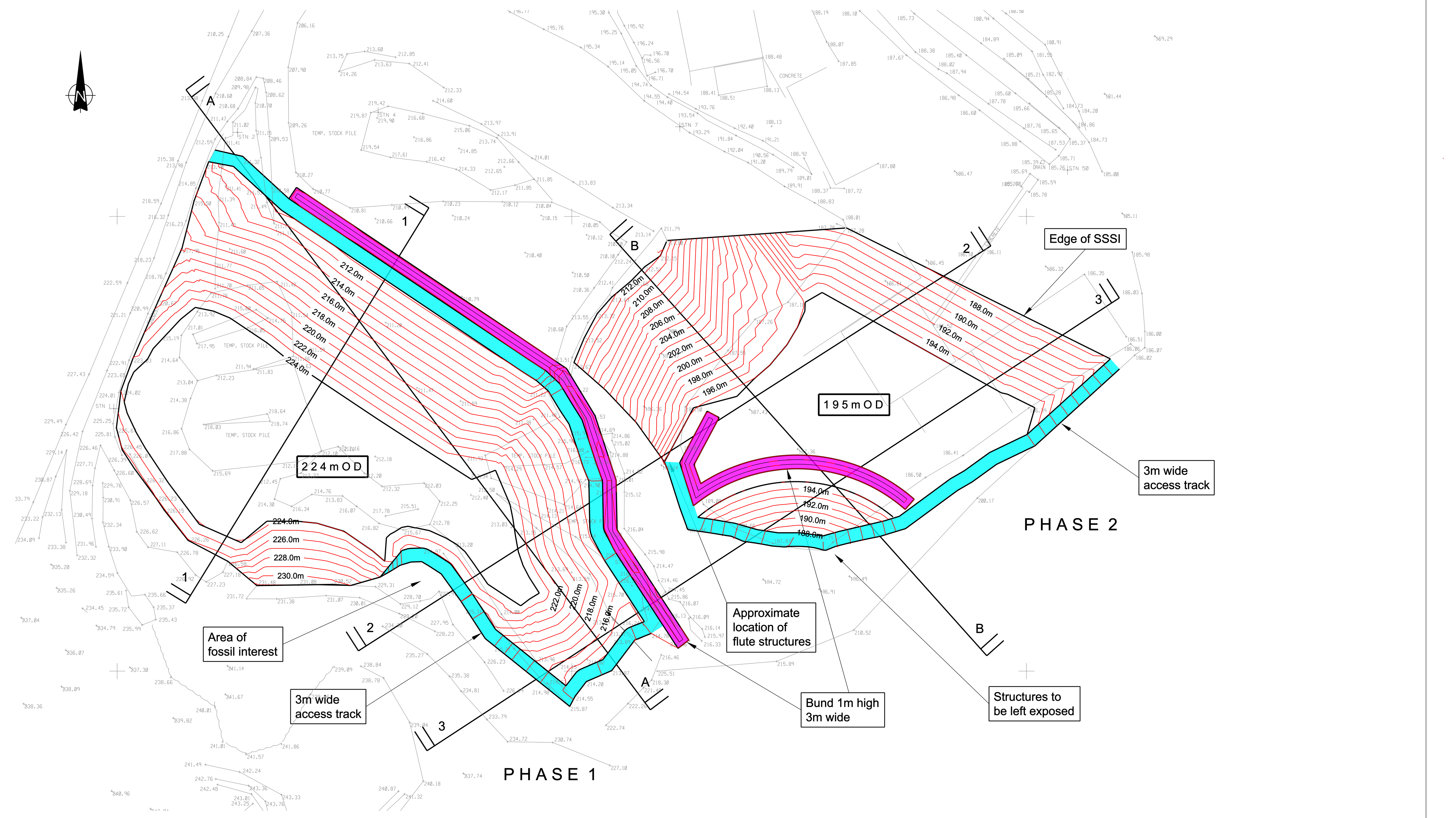
DRAWINGS

A0



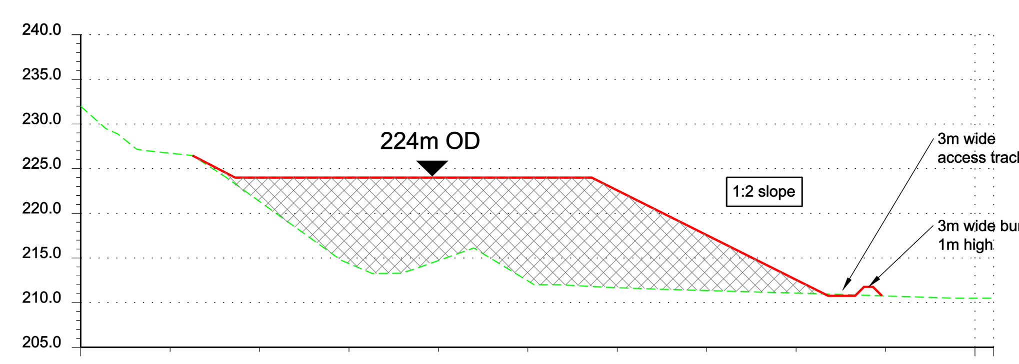
Existing Site Layout

Scale 1:1000



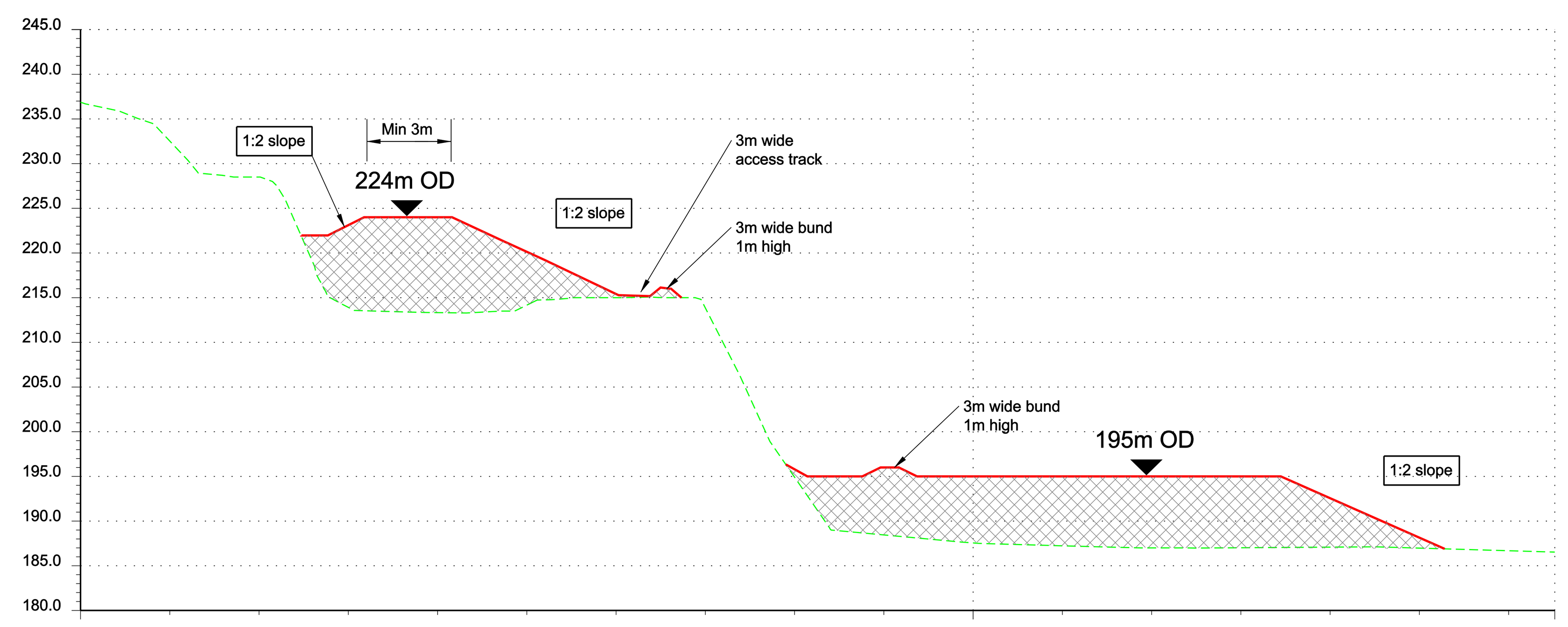
Proposed Works

Scale 1:500



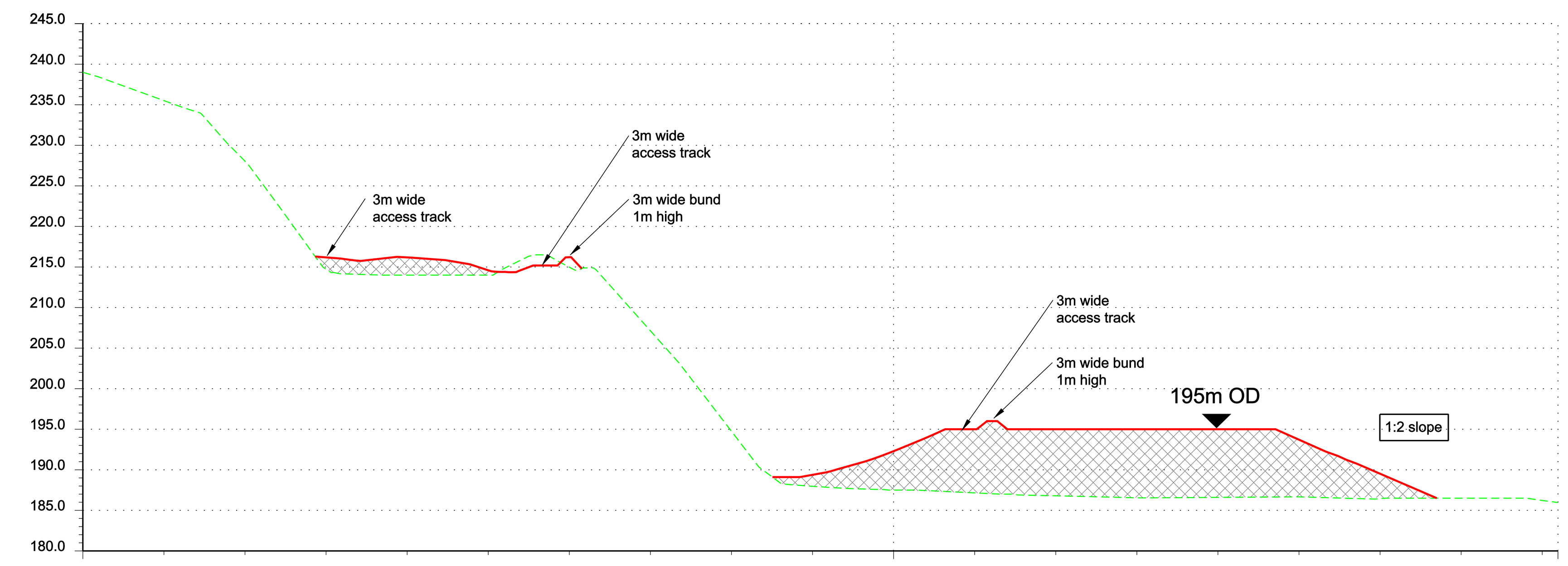
Section 1 - 1

Scale 1:500



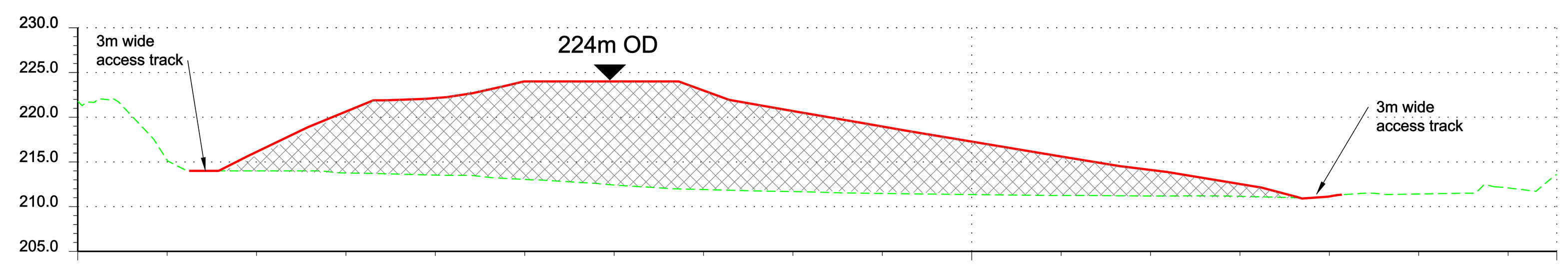
Section 2 - 2

Scale 1:500



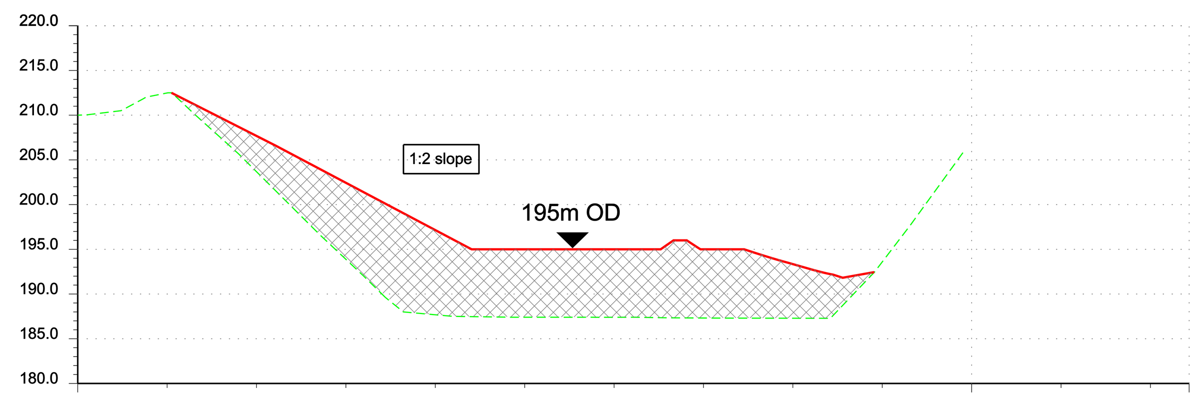
Section 3 - 3

Scale 1:500



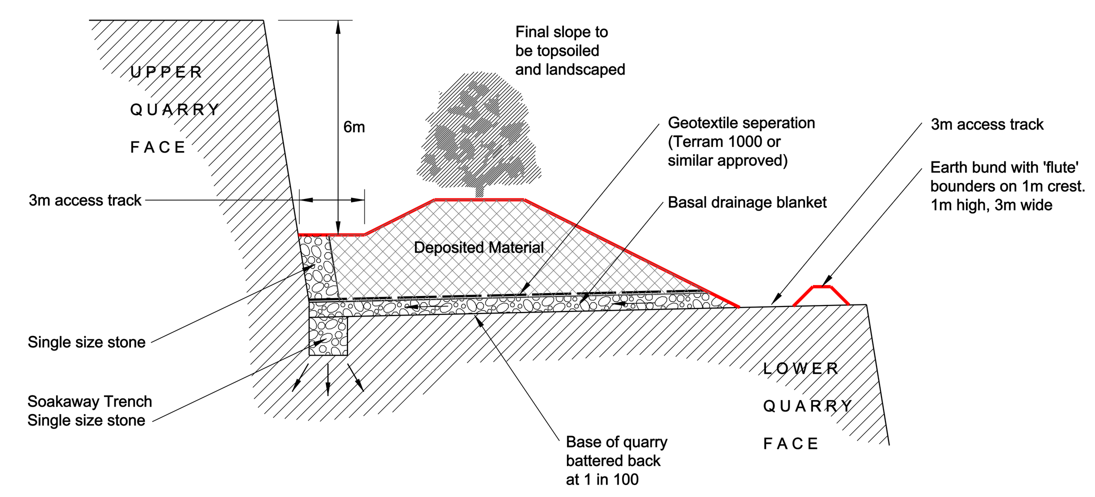
Section A - A

Scale 1:500



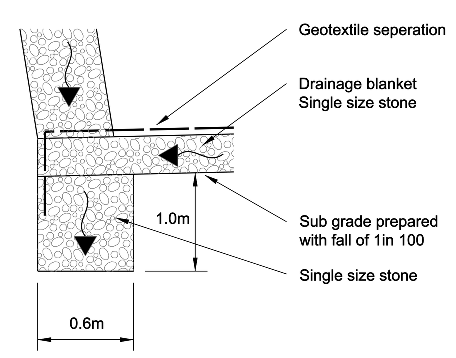
Section B - B

Scale 1:500



Proposed Construction Detail

N.T.S.



Drainage Detail

Scale 1:100

GroundSolve Ltd

Consulting Geotechnical, Engineering Geology and Environmental Engineers

Unit 7, Well House Barns
Chester Road Bretton
Flintshire CH4 0DH

Tel. 01244 661361
Fax 01244 661289

Client

G F Grigg Ltd

Job Title
Penstrowed Quarry

Drawing Title
Proposed Earthworks

Scale @ A0: **As Shown**

Drawing Status
Planning

Drawing No	Issue
CG01	B

APPENDIX A

CCW Report

SITE MANAGEMENT REPORT SERIES DYFED AND MID-WALES REGION

PENSTROWED

Dr Bob Mathews

General view of GCR site

GCR BLOCK: Wenlock

ASSOCIATED SSSI: Penstrowed Quarry

CYNGOR
CEFN GWLAD
CYMRU
COUNTRYSIDE
COUNCIL
FOR WALES

November, 1994

CONTENTS

SUMMARY SHEET

GCR No:	952 GCR File No: W/PS 12
GCR Site Name:	PENSTROWED
GCR Block:	Wenlock
Associated SSSI:	Penstrowed Quarry
Issued by GCR:	01.11.81 P5P Date: 06.04.83
Notified/re-notified:	01.04.86
Site Nature:	ED - Disused quarries, pits and cuttings
County:	Powys
District:	Montgomery
Maps:	1:10,000 SO 09 1:50,000 136
Grid Reference:	SO 068910
Keywords:	SILURIAN, WENLOCK, TURBIDITES, BOUMA SEQUENCE, SOLE STRUCTURES, GRADED BEDDING, RIPPLE MARKS
Original GCR worker:	Dr K. Dorning, University of Sheffield
GCR Volume:	Silurian
Ownership:	Conber Properties Station Yard Abermule Newtown Powys SY15 6NL
Monitoring date:	13.04.92

Required monitoring frequency: Every two years

Other local GCR interests: GWERN-Y-BRAIN DINGLE (GCR 1076; Caradoc-Ashgill); MEIFOD (GCR 1771; Llandovery); BUTTINGTON BRICKWORKS (GCR 1772; Llandovery); BUTTINGTON BRICKWORKS (GCR 955; Wenlock)

GCR STATEMENT OF INTEREST

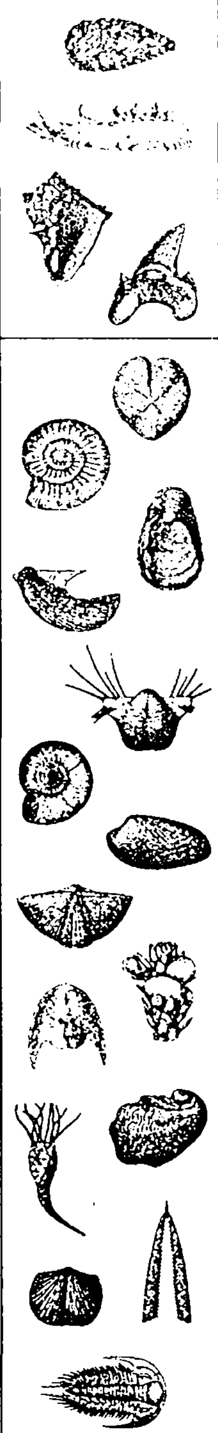
A sequence is here exposed in the basinal turbidite facies of the Wenlock Denbigh Grits (Sheinwoodian in age). The site is outstanding for the sedimentary structures it displays, particularly bottom structures such as flute and load casts, groove, prod and skip marks etc. Excellent examples of the Bouma sequence of turbidity current structures may be seen. The section here contrasts with the shallow marine, shelf carbonates and shales of the Welsh Borderland to the east. This superb example of deepwater, graptolitic sediments is essential to our understanding of the palaeogeography and facies of the Wenlock in Wales and the borders.

EXPLANATORY GEOLOGICAL NOTE

The purpose of this note is to describe the nature and importance of a site, avoiding specialist terms, for the site owner and/or occupier. This note does not form part of the formal notification documents.

Penstrowed, Montgomery

For much of the Lower Palaeozoic portion of geological time (400-500 million years ago), the area which became mid- and north Wales was covered by a deep area of open sea, known as the Welsh Basin. Thick deposits of mud and sand accumulated on the bed of this sea and became consolidated into the shales and sandstones which appear in the landscape today. The rocks exposed at Penstrowed Quarry were laid down in the deep water part of the Welsh Basin and contain a number of small-scale structures preserved within the sedimentary sequence which indicate the exact mode of formation of these rocks. These structures include ripple marks, graded bedding (changes in grain size) and various types of sole structure (hollows and grooves formed on the sea bed). Collectively, these structures are interpreted as the product of fast-moving, sediment-laden currents, which flowed into the deeper parts of the Welsh Basin from shallow shelf areas to the south-west and east. In other parts of Wales and the Welsh Borders, the water was much shallower at this time (late in Silurian times, about 410 million years ago) and these continental shelf-type conditions gave rise to rocks which contrast sharply with those seen at Penstrowed.



present day / Approximate dates - in million years before the present***	Geological Period		Wider and Global Events	Events in Wales
1.6	QUATERNARY	CENOZOIC	global warming from about 10,000 years onwards - ice caps retreat to polar regions Ice Ages - polar and continental ice caps grow and retreat several times, sea level falls and rises in tandem, as warming and cooling alternate. Man makes his appearance	Modern landscapes and vegetation develop Glaciers modify an older, eroded, landscape - deepening valleys and depositing glacial boulder clays Neanderthal Man in Wales 250,000 years ago
23	NEOGENE	CENOZOIC	Colliding crustal plates cause formation of the Alps	Britain reaches its present-day latitude Erosion following Alpine mountain building means that no rocks of this age are preserved if they were formed at all
65	PALEOGENE	CENOZOIC	Mammals dominant and land floras more like those of the present Indian plate collides with Asia, forming Himalayas	Very rare rocks, pockets of clay, let down into faulted or eroded depressions in the Carboniferous rocks of S & SW Wales. In N. Wales igneous rocks resulting from volcanic activity related to plates splitting and opening of the north Atlantic Britain moving North, into cooler temperate latitudes
135	CRETACEOUS	MESOZOIC	Dominant reptiles, including the dinosaurs, become extinct Dinosaurs still rule the Earth and pterosaurs the air, first flowering plants	Chalk thought to have been deposited in a late Cretaceous sea which spread onto the Welsh landmass, but subsequently removed by erosion no rocks of this age
205	JURASSIC	MESOZOIC	First birds Continents start to split apart - opening the new south Atlantic Ocean	
250	TRIASSIC	MESOZOIC	Seas advance onto the continents Reptiles dominant, first dinosaurs and first mammals evolve late in Triassic	Epicontinental sea floods most of Britain and Europe, but only the southern and western margins of Wales. Britain in northern warm-temperate to tropical latitudes Wales and most of British isles are land and in the tropics, covered by red sandy deserts, salts pans and rocky scree - uplands formed by the Variscan mountain building are eroded away
290	PERMIAN	PALAEOZOIC	Replacement of dominant land floras by new forms including conifers S. European plate collides with northern Europe closing the ocean between and forming the Variscan mountains. 'Ice age' affects southern continents	Britain at the equator. Continental collision causes deformation of the crust - coalfield basins of Pembrokeshire, South Wales and Clwyd formed
355	CARBONIFEROUS	PALAEOZOIC	Plants in equatorial swamp forests decay and give rise to most of the world's coals	The sea floods south Wales and then, much later, N. Wales, but retreats by mid -Carboniferous times
410	DEVONIAN	PALAEOZOIC	Ocean between N. America and Europe closes - continents collide - Caledonian mountain building Armoured, primitive (jawless) 'fish'	Wales (and most of Britain), lying in the southern tropical belt, are land and part of the Old Red Sandstone continent Wales is uplifted, its rocks crumpled and, where deformation was strongest, in the north, the Slate Belt was formed
440	SILURIAN *	PALAEOZOIC	The greening of the continents - the higher plants evolve and colonise the land	First diversification of land floras, proved by Welsh fossil plants Britain around 30 degrees south of the equator
510	ORDOVICIAN	PALAEOZOIC	Enigmatic large algae as first land plants Marine invertebrate life diversifies	Seas, shallower in the east and deeper in the west, cover Wales and the Borders, depositing sediments with remains of abundant invertebrates. The Welsh marine basin is famous for its Cambrian, Ordovician and Silurian rocks - all three globally-used terms named after characteristic fossiliferous strata in the principality Volcanicity widespread - great thicknesses of volcanic rocks erupted on the mid-Ordovician sea bed and subaerially
570	CAMBRIAN	PALAEOZOIC	First fish Animal sea life abundant and widespread for the first time - molluscs, trilobites and brachiopods preserved as fossils	
600 / 800 / 1,000 / 1,500 / 4,500 / 4,600	PRECAMBRIAN		Worms, jelly fish and sponges appear 'Ice Age' affects northern continents 'Ice Age' affects Australia Green algae appear Blue-green algae form marine reefs in many parts of the world, and excess oxygen released into the atmosphere Water forms on Earth's surface Earth's crust begins to form: later in Precambrian time crustal plates break apart and collide many times Origin of the Earth - formed by accretion of part of a cloud of dust orbiting the Sun	late Precambrian faunas: worm traces and algal limestones in N. Wales, jellyfish in S. Wales

***Age estimates and chronostratigraphy: Cowie & Bassett 1989. International Union of Geological Sciences Global Stratigraphic Chart *Episodes* 12(2) Supplement
Whittaker *et al.* 1991. A guide to stratigraphical procedure *Journal Geological Society London* 148, 813-824

* THIS SITE

SITE MAPS

1. O.S. Sheet 136, Newtown and Llanidloes (extract)

2. Present GCR boundary

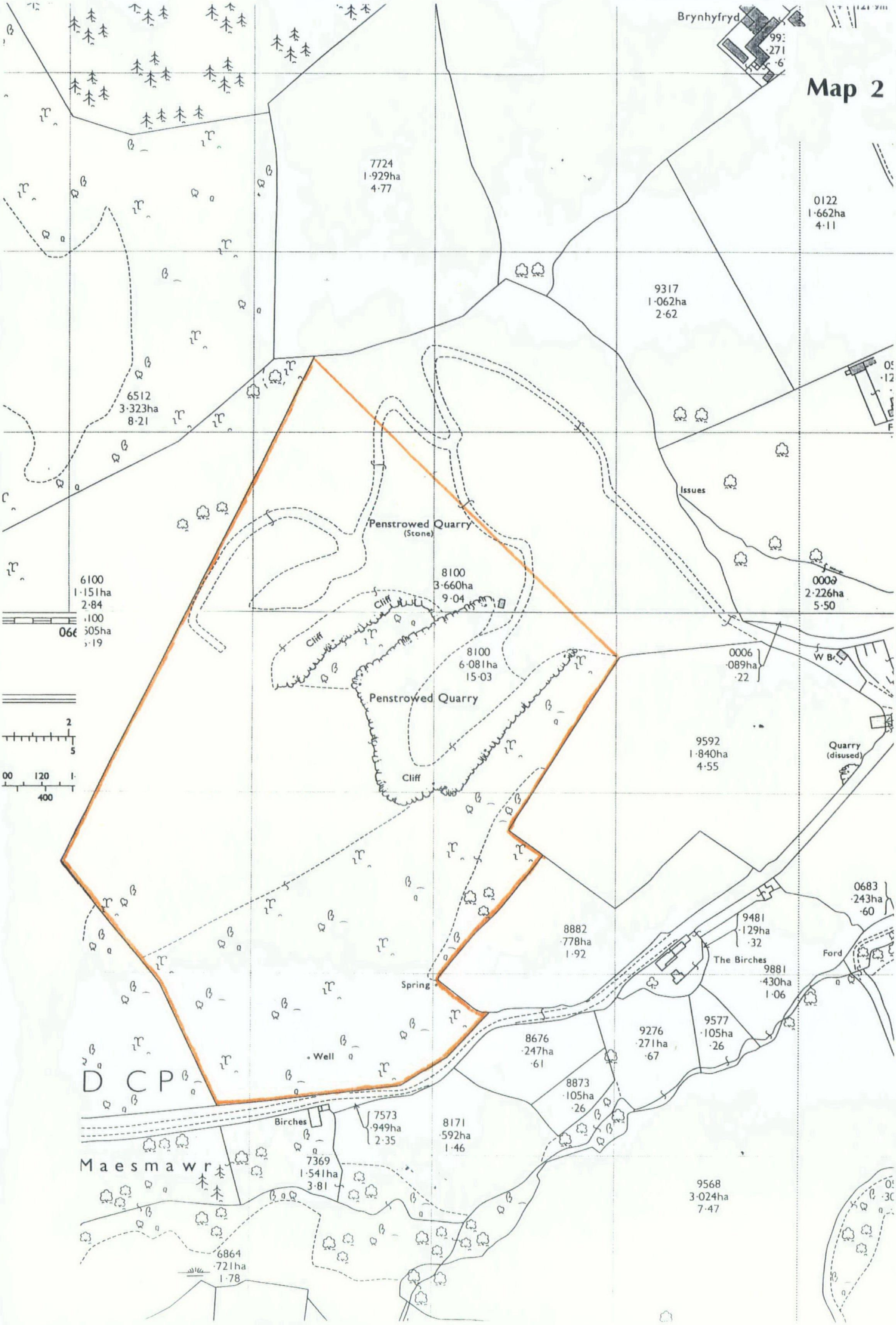
3. Geology of the area around Penstrowed (BGS Sheey 52N 04W, 1:250,000 Mid Wales and Marches)

4. Map showing location of figures

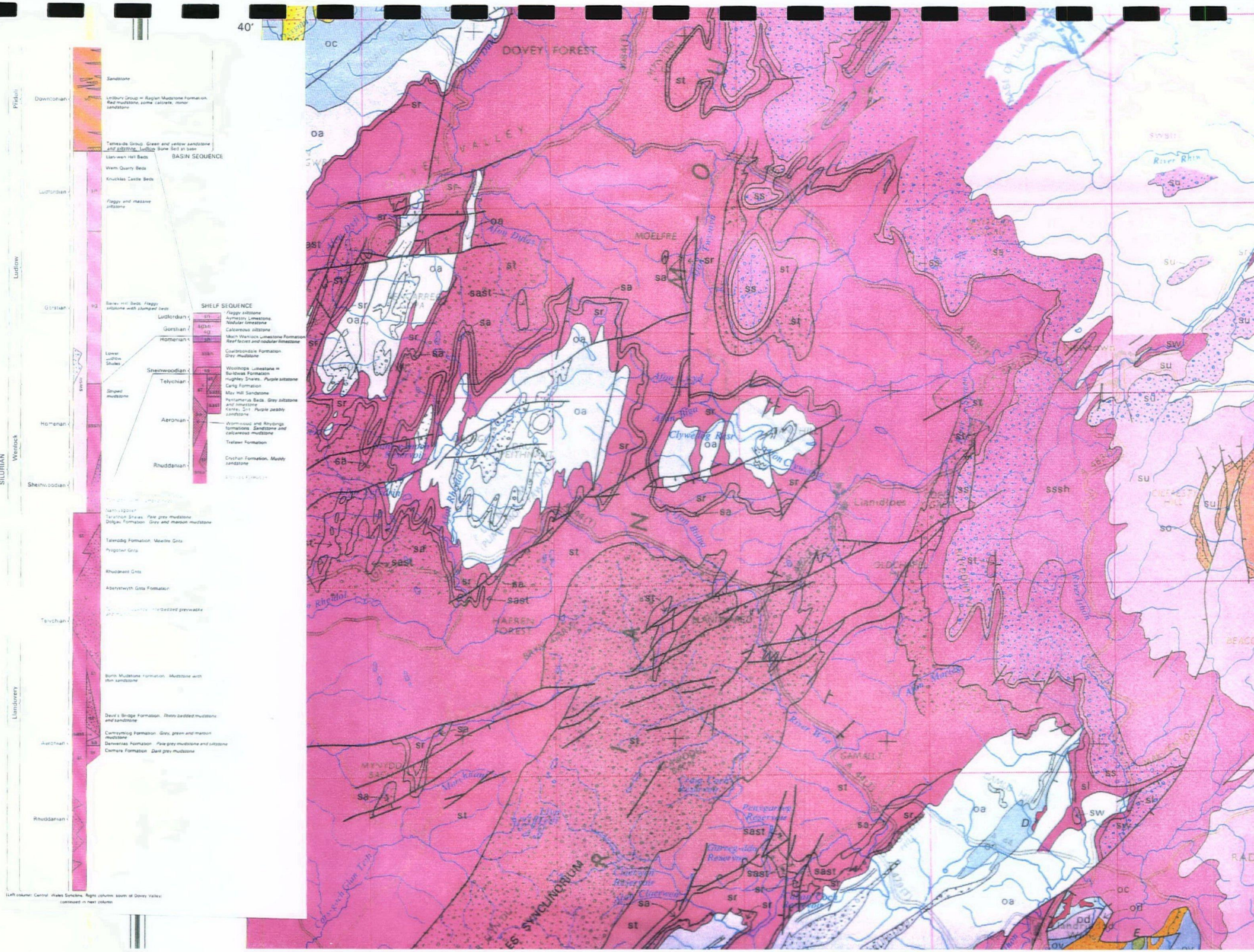
Map 1


Hafod-lom
Cefn-gwyn
Mynydd Clogau
Mynydd Trigllwydion
The Heath
Bryn-du
Bryn y Fawnog
Ffrwd-wen
Celynog Hill
Mynydd Llwytgoed
Bwlch-cae-haidd
Gelli
Alltyffyrnon
Gwern-y-pwll
Llwynywyn
Penbedw
Gwynfynydd
Llanwnog
Settlement
Roman Road (course of)
B 4568
Llwynybrain
Hospl
Roman Fort
Caersws
Maesmawr Hall
Red Ho
Dolhafren
Carnedd
Maes-mawr
Motte & Bailey
Bronfelin Hall
Allt y Gaer
Cefn-nith
Penstrowed
Hollybush
Llandinam Hall
Cwmllwydion
Little London
Llandinam
Moeliart
Cerrig Gate
W.T. Mast
Bryn Gwyn
Pwllan
Yr Allt
Trawsgelli
Argoed
Castell-isaf
Bryn-coch
Cochsidan
Bronhafod
Waen-y-pant
Brynheulog
Cefn-llydan
Llwydcoed
Bwlch-y-ffridd
New Ho
Glascoed
Melinyglach
Bryn-y-groes
Sewylfa Wood
Hollybush
Glanrhyd
Brynypentre Wood
Rhydlidan
Pentre
Aberhafesp Hall
Red Ho
Rhydyfelin
Dolgau
Birch Ho
Bryn
Dolymelinau
Tregynon
Neuadd-lwyd
Skew Br
Cemy
Ty'n y Bryn
Gregynog
Cefn-gwyddfod
Caecappin
Coedtrefe
Highgate Hill
Lower Garth
Bettws Hill
Garth Hill
Middle Garth
Point
Hendidley
Nyodd Hendidley Fm
Bryn-hyfryd
Milford
The College Fm
Glanhafren Hall
Glandulais
Maesyrhandir
Garth Owen
Stepaside
Brynhelig
Cefn-hir
Bronllan
Mochdre
Trawscoed
Bron-llys
Hafod
Penthryn
Old Nee
Pentre
Glascoed
Pwllan
Bancyn y Beddau
Red Ho
Brithdir Br
Henfaes
Ty'n-y-banadl
Bryncoch
Highgate
Red Ho
Goran
Tynyreithin Hall
Plas-y-bryn
Bryn
Hospl
Cefnaire
The Dingle
A 470(T)
A 492(T)
A 483(T)
B 4389
B 4355
Old Court
Beckan Brook
Mochdre Brook
Giant's Grave

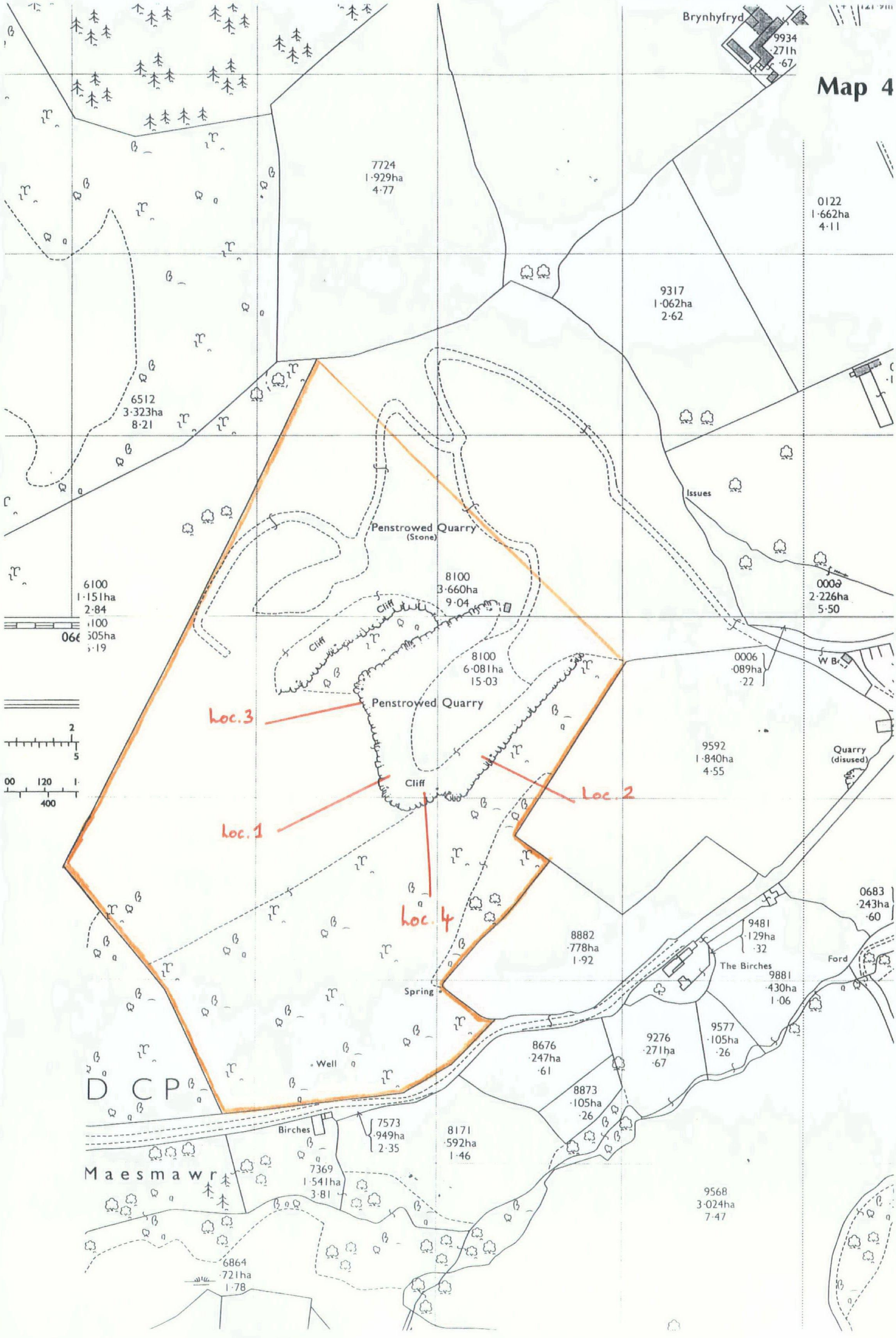
Map 2



Brynhyfryd
7724
1·929ha
4·77
0122
1·662ha
4·11
9317
1·062ha
2·62
6512
3·323ha
8·21
6100
1·151ha
2·84
Penstrowed Quarry
(Stone)
8100
3·660ha
9·04
Cliff
Cliff
Cliff
8100
6·081ha
15·03
Penstrowed Quarry
Cliff
Issues
0002
2·226ha
5·50
0006
·089ha
·22
W B
9592
1·840ha
4·55
Quarry
(disused)
0683
·243ha
·60
9481
·129ha
·32
The Birches
8882
·778ha
1·92
Ford
9881
·430ha
1·06
Spring
9577
·105ha
·26
9276
·271ha
·67
8676
·247ha
·61
Well
8873
·105ha
·26
D C P
Birches
7573
·949ha
2·35
8171
·592ha
1·46
Maesmawr
7369
1·541ha
3·81
9568
3·024ha
7·47
6864
·721ha
1·78
120
400


40′
SILURIAN
Přídolí
Ludlow
Wenlock
Llandovery
Downtonian
Sandstone
Ledbury Group = Raglan Mudstone Formation. Red mudstone, some calcrete, minor sandstone
Temeside Group. Green and yellow sandstone and siltstone; Ludlow Bone Bed at base
BASIN SEQUENCE
Llan-wen Hill Beds
Wern Quarry Beds
Knucklas Castle Beds
Ludfordian
Flaggy and massive siltstone
Gorstian
Bailey Hill Beds. Flaggy siltstone with slumped beds
Lower Ludlow Shales
Striped mudstone
Homerian
Sheinwoodian
SHELF SEQUENCE
Ludfordian
Gorstian
Homerian
Sheinwoodian
Telychian
Aeronian
Rhuddanian
Flaggy siltstone
Aymestry Limestone. Nodular limestone
Calcareous siltstone
Much Wenlock Limestone Formation. Reef facies and nodular limestone
Coalbrookdale Formation. Grey mudstone
Woolhope Limestone = Buildwas Formation
Hughley Shales. Purple siltstone
Carig Formation
May Hill Sandstone
Pentamerus Beds. Grey siltstone and limestone
Kenley Grit. Purple pebbly sandstone
Wormwood and Rhydings formations. Sandstone and calcareous mudstone
Trelawr Formation
Crychan Formation. Muddy sandstone
Tarannon Shales. Pale grey mudstone
Dolgau Formation. Grey and maroon mudstone
Talerddig Formation. Moelfre Grits
Pysgotwr Grits
Rhuddnant Grits
Aberystwyth Grits Formation
Telychian
Borth Mudstone Formation. Mudstone with thin sandstone
Devil's Bridge Formation. Thinly bedded mudstone and sandstone
Cwmsymlog Formation. Grey, green and maroon mudstone
Derwenlas Formation. Pale grey mudstone and siltstone
Cwmere Formation. Dark grey mudstone
Aeronian
Rhuddanian
(Left column: Central Wales Syncline. Right column: south of Dovey Valley)
continued in next column
DOVEY FOREST
VALLEY
MOELFRE
River Rhiw
Afon Dulas
Clywedog Resr
Llanidloes
HAFREN FOREST
River Wye
Afon Marteg
Afon Rheidol
Claerwen Reservoir
Craig Goch Reservoir
Penygarreg Reservoir
Caban-coch Reservoir
SYNCLINORIUM
GAMALLT
CEFN HILL
oa
oc
st
sr
sa
sast
ss
su
sw
sssh
sl
pd
D
E

Map, 3



Map 4
Brynhyfryd
9934
·271h
·67
7724
1·929ha
4·77
0122
1·662ha
4·11
9317
1·062ha
2·62
6512
3·323ha
8·21
Issues
Penstrowed Quarry
(Stone)
8100
3·660ha
9·04
6100
1·151ha
2·84
Cliff
Cliff
Cliff
8100
6·081ha
15·03
0006
·089ha
·22
W B
Penstrowed Quarry
Loc. 3
9592
1·840ha
4·55
Quarry
(disused)
Loc. 2
Cliff
Loc. 1
Loc. 4
0683
·243ha
·60
8882
·778ha
1·92
9481
·129ha
·32
The Birches
9881
·430ha
1·06
Ford
Spring
8676
·247ha
·61
9276
·271ha
·67
9577
·105ha
·26
Well
D C P
8873
·105ha
·26
Birches
7573
·949ha
2·35
8171
·592ha
1·46
Maesmawr
7369
1·541ha
3·81
9568
3·024ha
7·47
6864
·721ha
1·78

1. SITE DESCRIPTION

1.1 Site location and access

Penstrowed GCR site (Figure 1) is situated approximately 400m east of the A 489(T), mid-way between the towns of Newtown and Caersws. The site comprises a disused quarry which has been cut into the north-eastern flank of a small hill known as Maesmawr. Little is known of the working history of the quarry. However, prior to 1946 it was apparently owned and worked by the local Council, which exploited the hard sandstone layers for use as road and building stone. In its early years, the quarry was connected by a short rail link (Figures 2 and 3) to the main Shrewsbury-Aberystwyth permanent way, which is located some 600m to the north-east. However, this link was closed down in 1937 owing to competition from road haulage contractors. The present owners purchased the site in 1946, and continued to work the quarry for stone up until about (?)10 years ago, when it was finally abandoned.

Access to the site is strictly by permission of the owners, who operate a gas supply stores in Abermule, 6km north-east of Newtown. The site is entered via a gateway adjacent to the concrete manufacturing plant. This gate is always locked, but the owners will generally ensure that a key is provided by the manager of the adjacent concrete plant. The quarry is reached *via* a narrow track which crosses the hillside. Vehicles can be taken up to the site if required, but are probably best left at the entrance since the track is quite overgrown.

1.2 Geological background and setting

Much of Wales is underlain by a thick succession of Lower Palaeozoic rocks, which constitute the fill of a major sedimentary basin referred to as the Welsh Basin. This basin is probably floored by Precambrian to earliest Cambrian rocks, examples of which are exposed along the basin's marginal zones in Anglesey, the Welsh Borders and in South Wales (Figure 4). Palaeogeographic reconstructions of southern Britain (Figure 5), based on ***facies*** variations, show that the Welsh Basin was separated by the Irish Sea Shelf Platform from an ocean seaway to the north-west, and was bounded on its south-eastern margin by the Midland Shelf Platform.

The Welsh Basin suffered prolonged subsidence throughout most of Lower Palaeozoic times, with fine- and coarse-grained sediments being supplied to the basin from surrounding shelf areas. The inland region of mid-Wales exposes an important component of this basin fill. Rhythmic alternations of mudstones and ***greywacke*** sandstones of the Penstrowed Grits and their northerly equivalents, the Denbigh Grits, which are Middle Silurian (Wenlock Series; Sheinwoodian Stage) in age (Figure 6), crop out in an extensive north-south trending belt running east of Newtown (Map 3). The Penstrowed Grits represent a classic example of a

turbidite sequence which was deposited from sediment-laden density currents, or more precisely, turbidity currents, which flowed generally northwards into deeper parts of the basin from tectonically active, shallow shelf areas in the south-west Dyfed region. Graded bedding, characterized by an upward-fining in grain size, together with an abundant variety of sedimentary structures (e.g. flute casts), seen on the underside of some coarse-grained units in the Penstrowed Grits (Section 1.3), testify to the high energy depositional environment associated with turbidity currents. These basinal sediments contrast with the thinner, fossiliferous limestone and mudstone facies which developed contemporaneously on the adjacent shallow marine shelf regions (Figure 5).

The chief minerals found in the greywacke sandstones of the Penstrowed Grits are quartz, feldspar (commonly oligoclase-albite), muscovite and carbonate minerals. Investigations of similar, although older Llandovery turbidites in the more southerly parts of the basin, for example in the Aberarth area, have revealed that the coarser zones at the base of some sandstones may comprise fragments of acid volcanic rocks, (?)Precambrian quartzite and a variety of other rock types, supporting the view that the ultimate source of all these types of sediment may have been an uplifted basement terrain to the south. The sedimentological characteristics of these deep water basinal deposits was studied in detail by Bouma (1962), who erected five terms (T_{a-e}) to describe the intervals making up the complete sequence in an individual turbidite unit. The nomenclature and sedimentological characteristics of each interval are shown in Figure 7.

The sedimentary fill of the Welsh Basin was strongly deformed during a late Silurian to early Devonian phase of the ***Caledonian Orogeny***. This deformation was characterized by the formation of a single set of folds on upright, mainly NE-SW trending, ***axial planes*** (Figures 4 and 8), which are accompanied by a ***cleavage***. Penstrowed Quarry is located close to the core of the Central Wales Synclinorium (Figure 8) and on the north-western limb of a smaller-scale anticline (Map 3). These structures are commonly described as the "regional" or "main" structures. In certain parts of Wales (e.g. the Clarach and Allt Wen areas) a clearly defined non-axial planar fold-cleavage relationship (i.e. where the cleavage is oriented obliquely to the fold axial planes) has been interpreted as the consequence of ***transpressional*** deformation resulting from the oblique closure of the Welsh Basin. The divergent orientation of fold axial planes and cleavage in Wales has recently been attributed to north-west - south-east Caledonian compressional deformation which involved ***strike-slip*** movement along long-lived basement fractures, located along the margins of the basin (e.g. the Church Stretton and Pontesford-Linley faults) and also within the basin itself (e.g. the Glandyfi Lineament).

1.3 Nature and distribution of geological features

Penstrowed Quarry is the type locality for the Penstrowed Grits, which are particularly well-exposed in the south-west and north-east faces of the workings. The quarry was worked at two different levels (Figure 9) and in its current state of abandonment the 10m high south-west face of the upper level provides an excellent cross-section through the succession (Figure 10), whilst the 20m high south-east face of the lower level (Figure 11) and a rock spur at the north-west edge of the upper level (Figure 12) provide an excellent opportunity to inspect the surface of individual bedding planes.

The Penstrowed Grits at this locality consist of a rhythmic, alternating succession of cream-coloured greywacke sandstones, and dark-grey siltstones and shaley mudstones. The beds are steeply inclined to the north-west at angles of up to 60° (Figure 13), reflecting their position on the north-west limb of a tight anticlinal fold (see Map 3). The fine-grained mudstones are cut by a finely-spaced cleavage which is oriented sub-parallel to bedding (Figure 14), and the succession is also transected by several north-south striking faults (Figure 15) which have a normal downthrow to the east. Some sandstone beds are cut at high angles by well-defined system of ***joints***, which are infilled either by quartz (Figure 16) or by iron-rich dolomite (Figure 17). Interestingly, the latter often occur on the joint planes as discrete rhombohedral crystals (Figure 18) and are frequently associated with chalcopyrite (copper/iron sulphide) mineralization.

However, the most important geological feature at Penstrowed Quarry, on account of which the site was notified, lies in the wide variety of sedimentary structures found in these rocks. Individual greywacke sandstone units are typically characterized by graded-bedding (Figures 19 and 20), whereby coarse-grained basal zones (T_a; Figure 7), comprising glassy and milky-white, sub-angular quartz grains in a clay matrix, pass up into finer-grained laminated sandstones ($T_{b/d}$). Occasionally, some sandstone beds display an internal reversal of grading, with the appearance of coarse-grained horizons higher up in the bed (Figure 21). The bases of many of the sandstone beds are characterized by abundant ***sole structures*** including flute casts and tool marks. The former are visible as bulbous or ramifying casts (Figures 22 and 23) which were formed when hollows were eroded into the top of the underlying bed and subsequently filled with coarser sediment. The application of cartographic projection techniques, reveals that these structures were formed by a current moving towards 010°, which confirms their derivation from a source terrain lying to the south or south-west. The tool marks appear as linear grooves (Figure 24) and were produced by an object ('tool') such as a pebble, being dragged under traction along the sea floor. The tops of many sandstone beds often display well-defined ripple marks which can be seen both in plan view (Figure 25) and also in cross-section (Figure 26).

The sedimentary structures described above are all features which have been collectively associated with turbidity currents and turbidite formation. Modern turbidity currents are known to transfer large quantities of sediment from shallow to deep marine environments, and flow down continental slopes at remarkably high velocities. It is the coarser-grained material which falls out of suspension under gravity first to produce the sandstone beds, followed by finer-grained silty material. Indeed, it is the high-energy environment associated with the deposition of the coarse sands which facilitates the generation of structures such as flute casts and tool marks. The fine-grained shaley mudstones overlying the sandstones, represent the background sedimentation immediately preceding the arrival of the next turbidity current, and often these units contain the fossil remains of pelagic organisms such as ***graptolites***.

1.4 GCR boundary

The original GCR boundary, as shown on Map 1 (Section 5.1), did not follow any clearly defined ground features, and was not used in the construction of the SSSI boundary. The latter, which is shown on Map 2, successfully incorporates the geological interest at Penstrowed Quarry and requires no modification. For the most part, the boundary follows clearly defined fence-lines, with the exception of the north-eastern limit of the site which follows an arbitrary straight line, defined at the south-east end by a bend in the fence-line and by a fence intersection at the north-west end.

A large area of geologically uninteresting land, situated above the main quarry faces, has also been incorporated within the SSSI boundary. This is presumably to incorporate that area for which planning permission has been granted to quarry stone, and to ensure that any new faces will fall within the boundary, should quarrying operations re-commence.

1.5 Summary of scientific research

There is very little information in the literature pertaining directly to the geology of Penstrowed Quarry. Cummins (1957), in a regional study of the Wenlock Denbigh Grits, made brief mention of the greywacke turbidites exposed in the quarry faces. He described the lithological characteristics of these rocks and the various types of sedimentary structures present, commenting on the regional implications of their use to determine palaeocurrent directions.

Davies *et al.* (1978) gave a brief geological description of Penstrowed Quarry, summarizing the lithological and structural features of the Sheinwoodian succession.

The origin of the term Penstrowed Grits remains unclear. The term was not employed by Cocks *et al.* (1992), who continued to use the term Denbigh Grits to describe these rocks. However, the BGS (1990), in their 1:250,000 scale map compilation (see Map 3), describe the Denbigh Grits and Penstrowed Grits as discrete, laterally equivalent rock-types.

1.6 Further reading

ANDERTON, R., BRIDGES, P.H., LEEDER, M.R. & **SELLWOOD,** B.W. 1979. *A dynamic stratigraphy of the British Isles.* George Allen and Unwin, London. 301pp.

BGS. 1990. *Mid Wales and Marches, Sheet 52N 04W, Solid Geology.* N.E.R.C.

CAVE, R. & HAINS, B.A. 1986. *Geology of the country between Aberystwyth and Machynlleth.* Memoir of the British Geological Survey, Sheet 163 (England & Wales), H.M.S.O., London.

COCKS, L.R.M., HOLLAND, C.H., RICKARDS, R.B. & STRACHAN, I. 1971. A correlation of Silurian rocks in the British Isles. *Journal of the Geological Society of London,* **127**, 103-136.

CUMMINS, W.A. 1957. The Denbigh Grits; Wenlock greywackes in Wales. *Geological Magazine,* **94**, 433-456.

DAVIES, J.H., HOLROYD, J., LUMLEY, R.G. & OWEN-ROBERTS, D. 1978. *Geology of Powys in outcrop.* Powys County Council.

GREEN, C.C. 1981. *Cambrian Railways album.* Ian Allan Ltd. London.

HOLLAND, C.H. 1992. Silurian. In: **DUFF, P. McL.D. & SMITH, A.J. (eds)** *Geology of England and Wales.* Geological Society of London, 147-177.

TREAGUS, J.E. 1992. *Caledonian structures in Britain, south of the Midland Valley.* GCR Series **No.3,** Chapman and Hall, London.

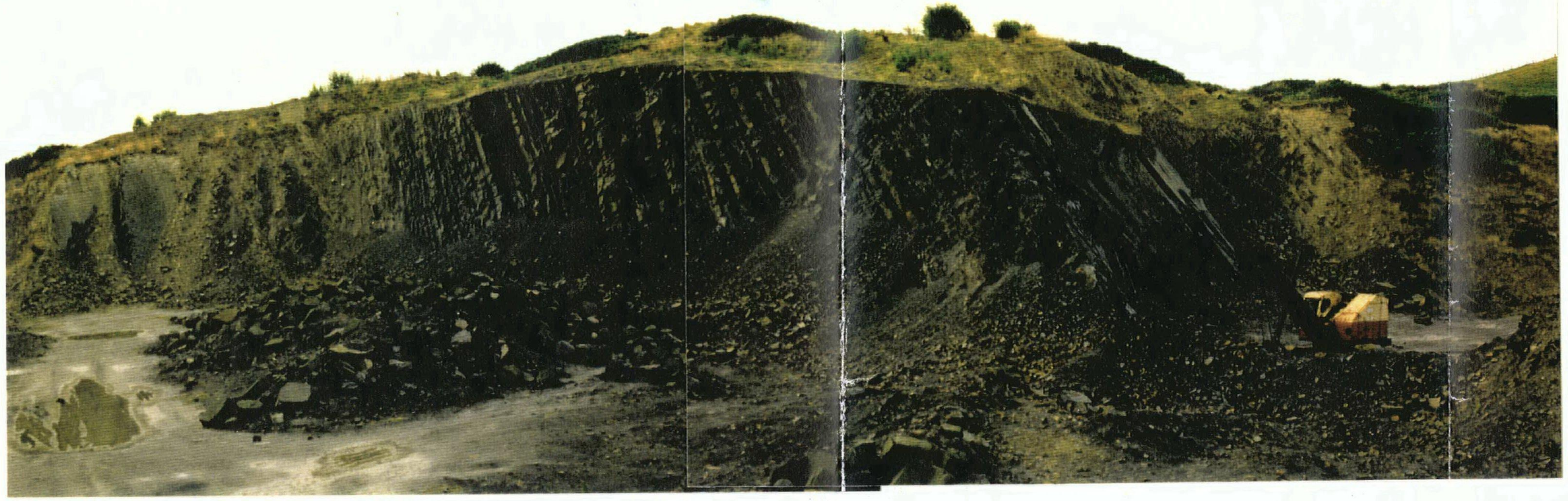


Figure 1 General view of rapidly degrading, 10m high faces on the upper level, showing steeply-inclined sandstones and shales of the Penstrowed Grits.

Figure 2 Curved embankment (arrowed) marking the former route of an old rail link from the quarry to the permanent way.

Figure 3 View of the old railway siding at Penstrowed Quarry, where wagons were loaded with aggregate and building stone (Green, 1991). The quarry is visible in the top right of the photograph.

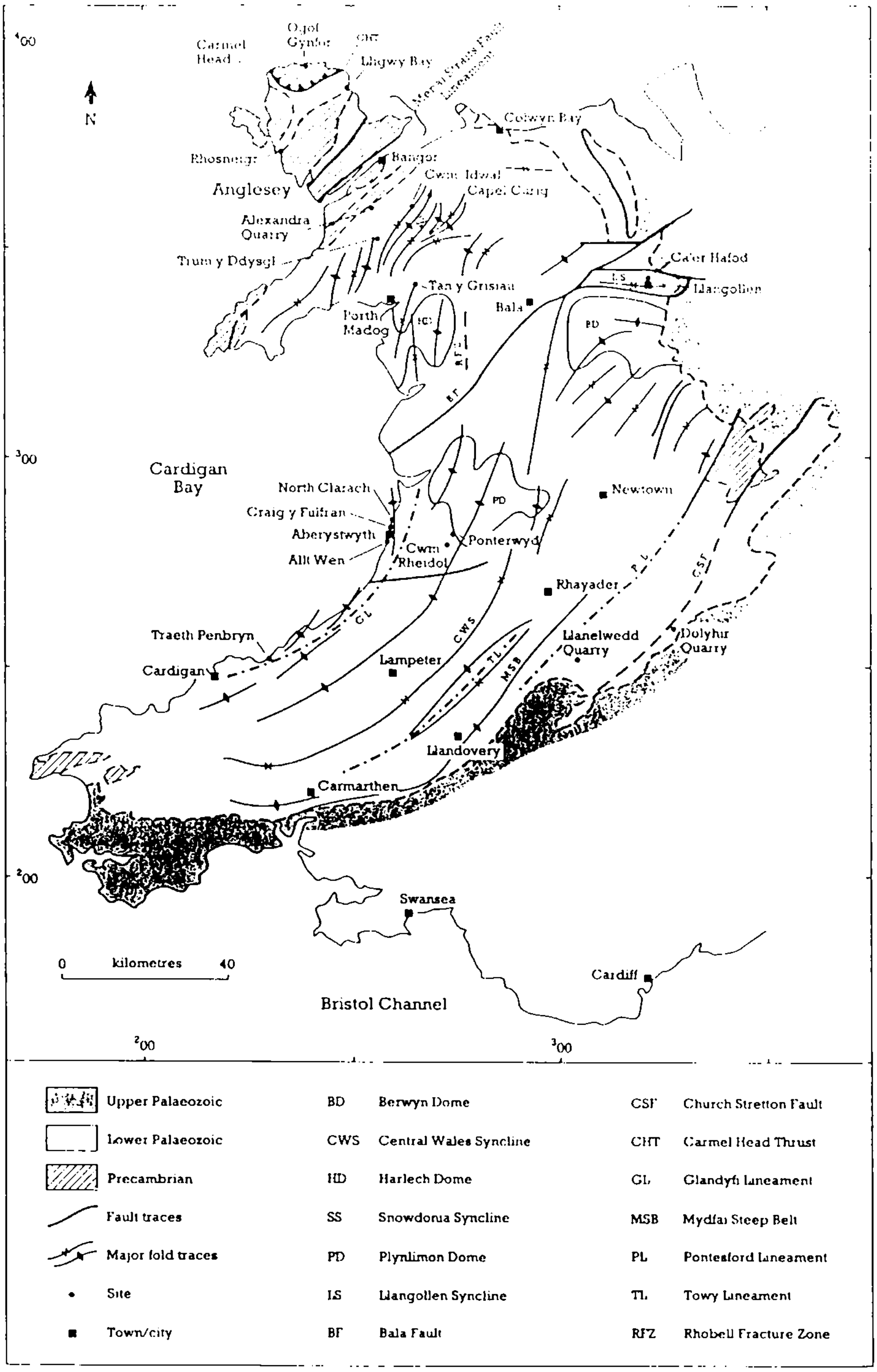


Figure 4 Simplified geological map of the Welsh Basin, showing the traces of the principal Caledonian structures (Treagus, 1992).

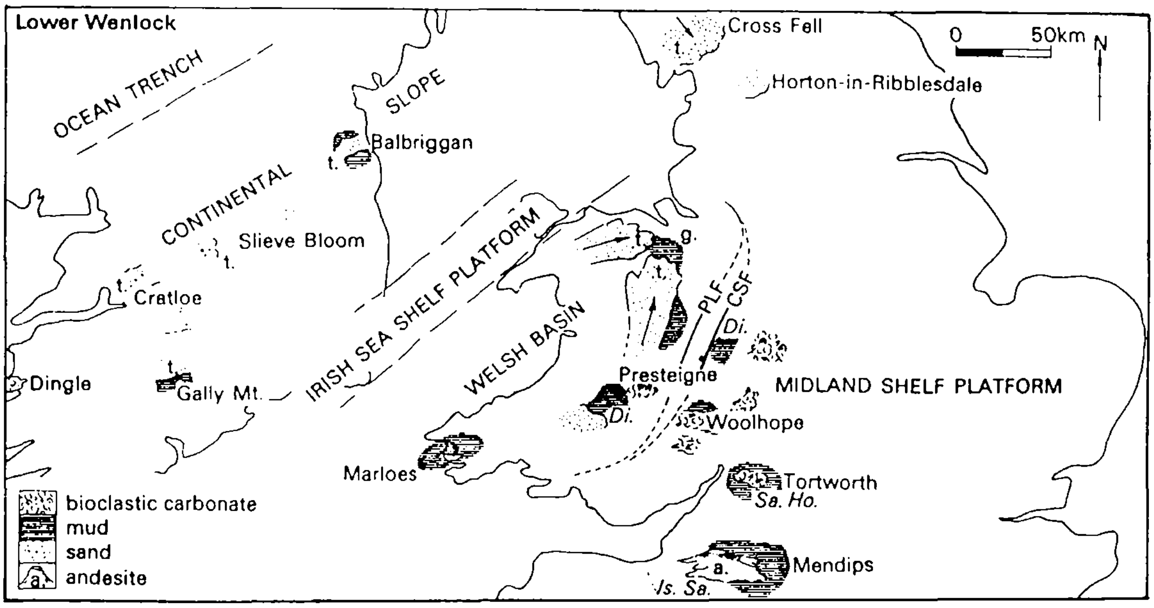


Figure 5 Palaeogeographic reconstruction of southern Britain during Wenlock times (Anderton *et al.*, 1979).

SILURIAN	PŘÍDOLÍ SERIES	—	
	LUDLOW SERIES	LUDFORDIAN STAGE	*Bohemograptus* proliferation
			leintwardinensis
		GORSTIAN STAGE	*tumescens* / *incipiens*
			scanicus
			nilssoni
	WENLOCK SERIES	HOMERIAN STAGE	*ludensis*
			nassa
			lundgreni
		SHEINWOODIAN STAGE	*ellesae*
			linnarssoni
			rigidus
			riccartonensis
			murchisoni
			centrifugus
	LLANDOVERY SERIES	TELYCHIAN STAGE	*crenulata*
			griestoniensis
			crispus
			turriculatus
		AERONIAN STAGE	*sedgwickii*
			convolutus
			argenteus
			magnus
			triangulatus
		RHUDDANIAN STAGE	*cyphus*
			acinaces
			atavus
			acuminatus

Figure 6 Silurian chronostratigraphy as currently agreed internationally. The right hand column shows Silurian graptolite biozones (Holland, 1992).

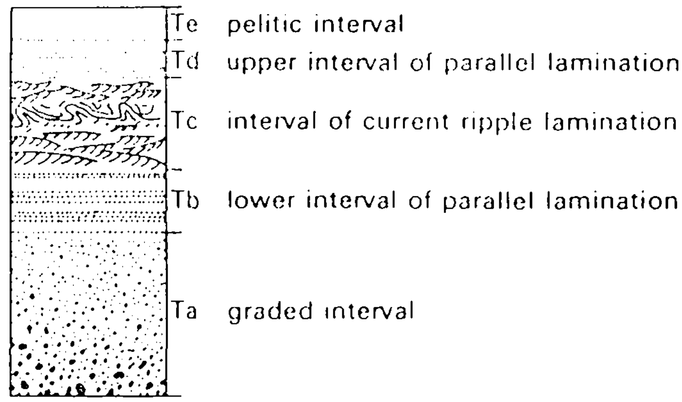


Figure 7 The sedimentological characteristics of the intervals within a turbidite sequence (Cave and Hains, 1986).

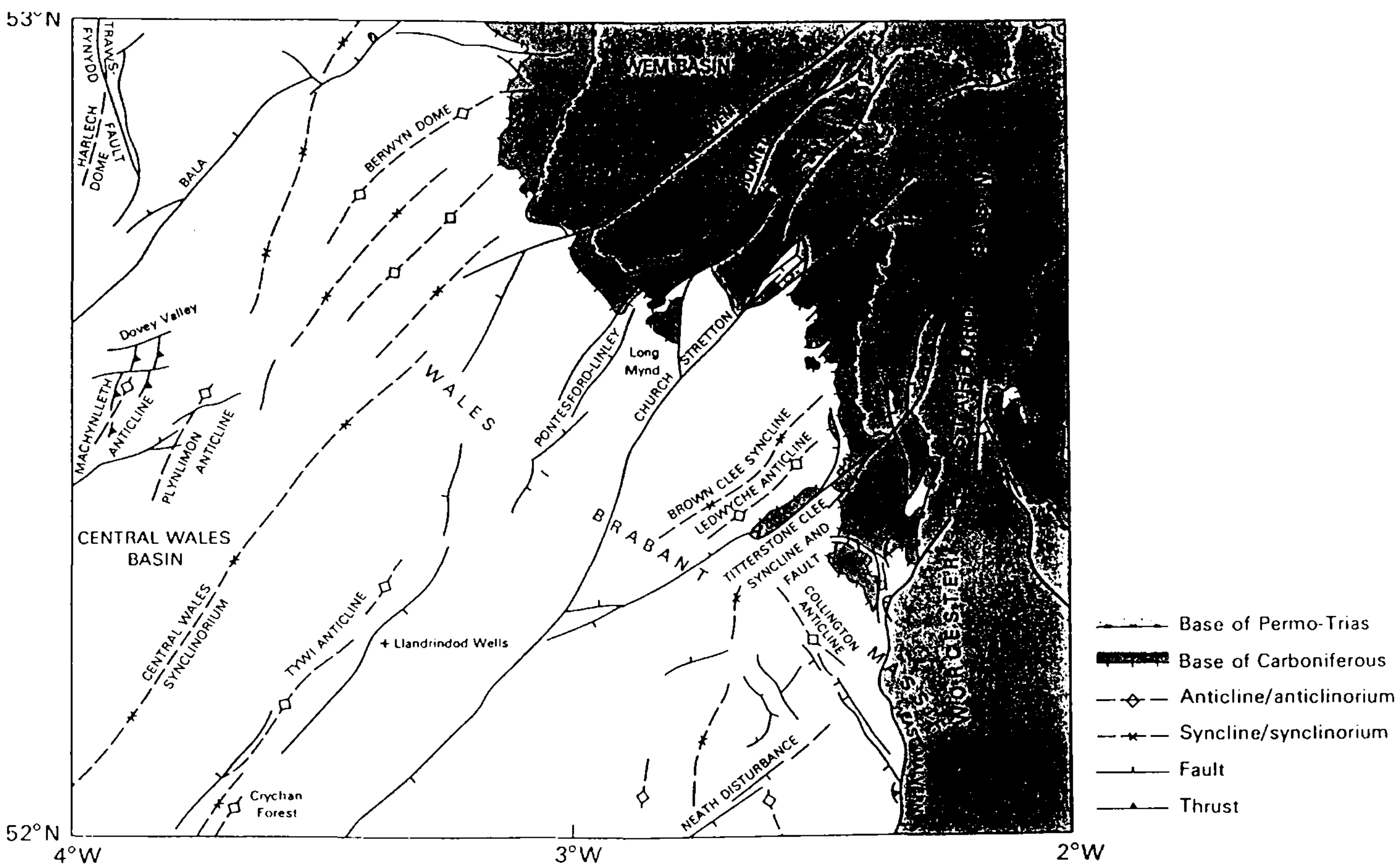


Figure 8 The principal structural elements of the central part of the Welsh Basin (BGS, 1990).

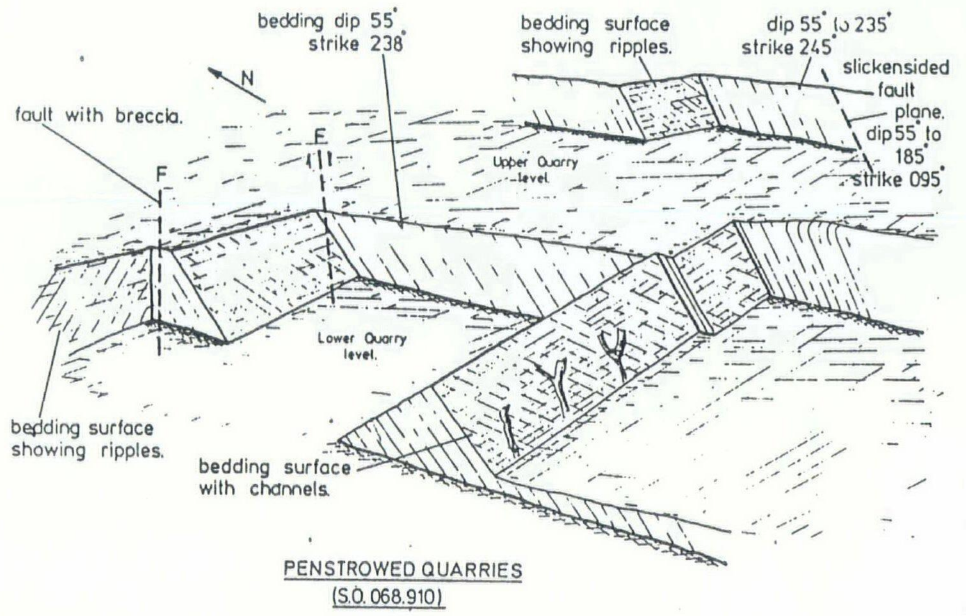


Figure 9 Schematic diagram showing the disposition of the quarry faces and major structures at Penstrowed Quarry (Davies *et al. 1978)*.

Figure 10 South-west face of upper level showing steeply-inclined, pale-coloured greywacke sandstone beds, interbedded with dark-grey shales.

Figure 11 Degraded face of lower level. Bedding surfaces at left of view display excellent ripple marks and quartz/iron-rich dolomite veining.

Figure 12 Steeply-inclined bedding planes exposed along rock spur on the upper level provide excellent examples of ripple marks.

Figure 13 Rhythmic, alternating succession of light-coloured greywacke sandstones and dark-grey shales of the Penstrowed Grits (Loc. 1; Map 4).

Figure 14 Finely-spaced penetrative cleavage cutting grey shaley mudstones (Loc. 2; Map 4).

Figure 15 Steeply-inclined normal fault (marked). Arrow shows direction of downthrow (Loc. 3; Map 4).

Figure 16 Quartz-filled joint plane in thick greywacke sandstone unit (Loc. 1; Map 4).

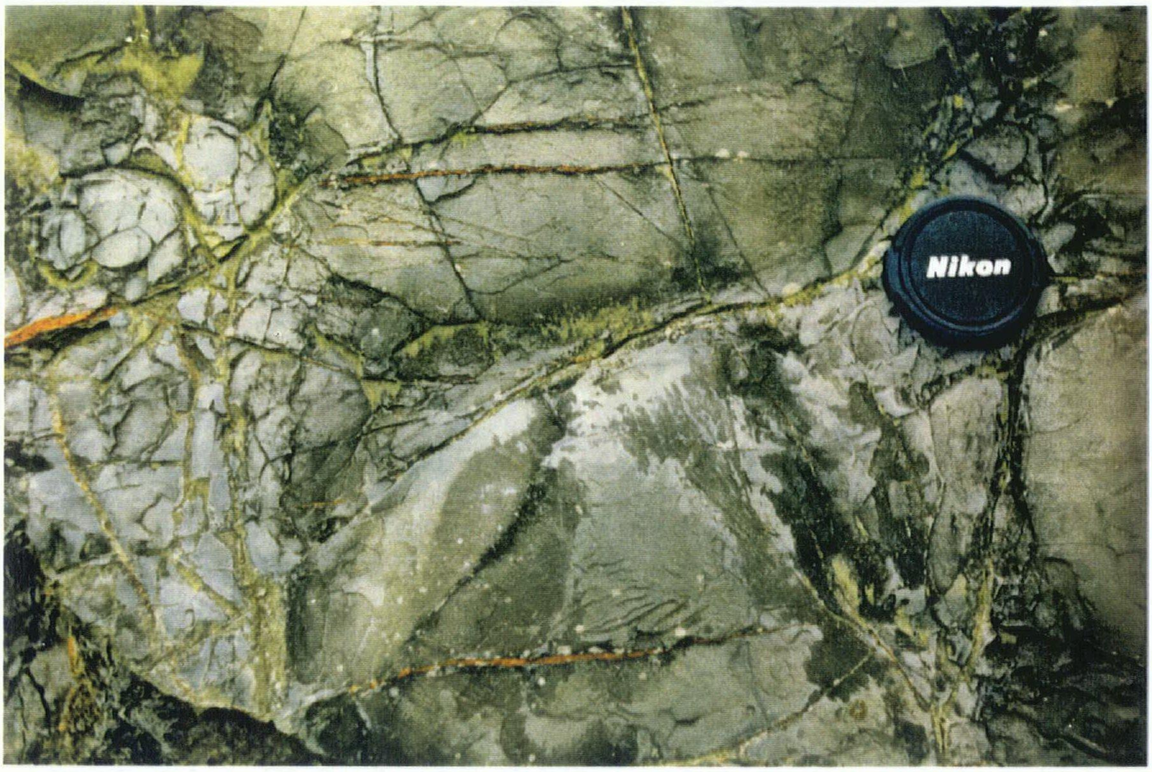


Figure 17 Joint planes infilled with brown iron-rich dolomite (Loc. 4; Map 4).

Figure 18 Rhombohedral crystals of dolomite on joint plane. These crystals are locally associated with chalcopyrite mineralization (Loc. 1; Map 4).

Figure 19 Typical coarse-grained base of greywacke sandstone bed. Grains consist dominantly of sub-angular quartz but with some small rock fragments.

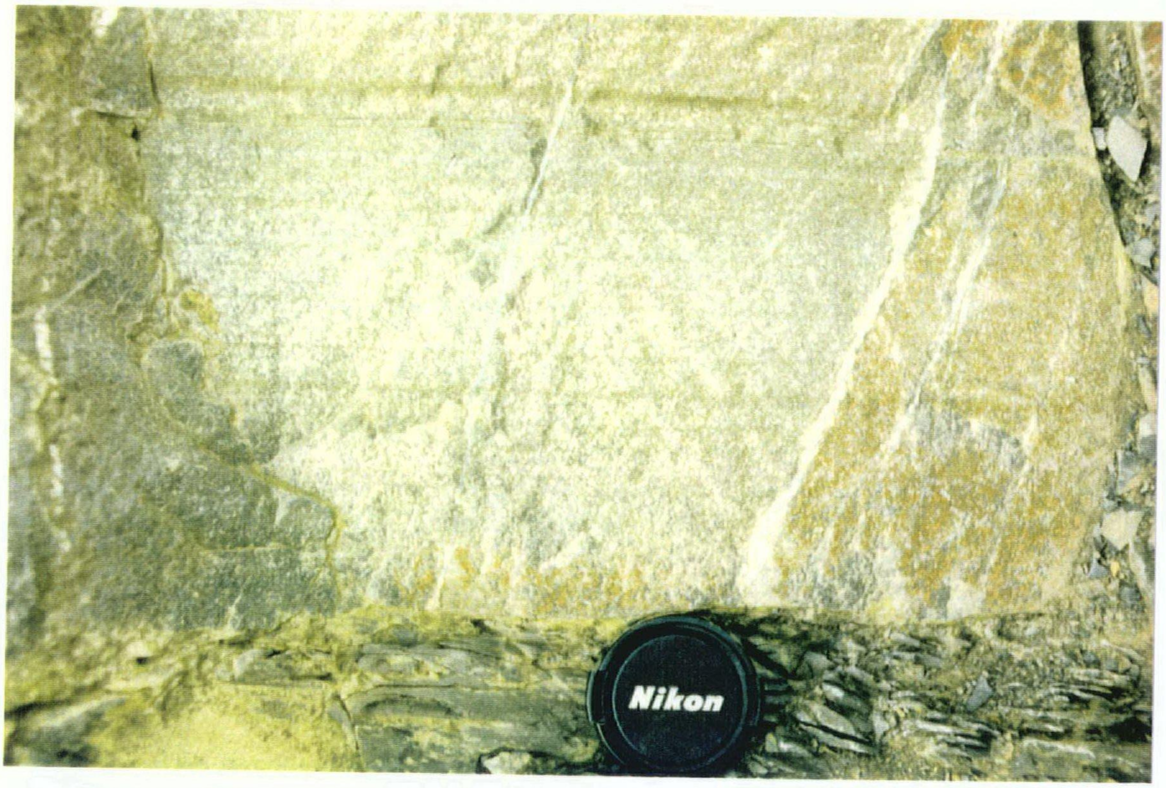


Figure 20 Laminated greywacke sandstone unit (Loc. 1; Map 4).

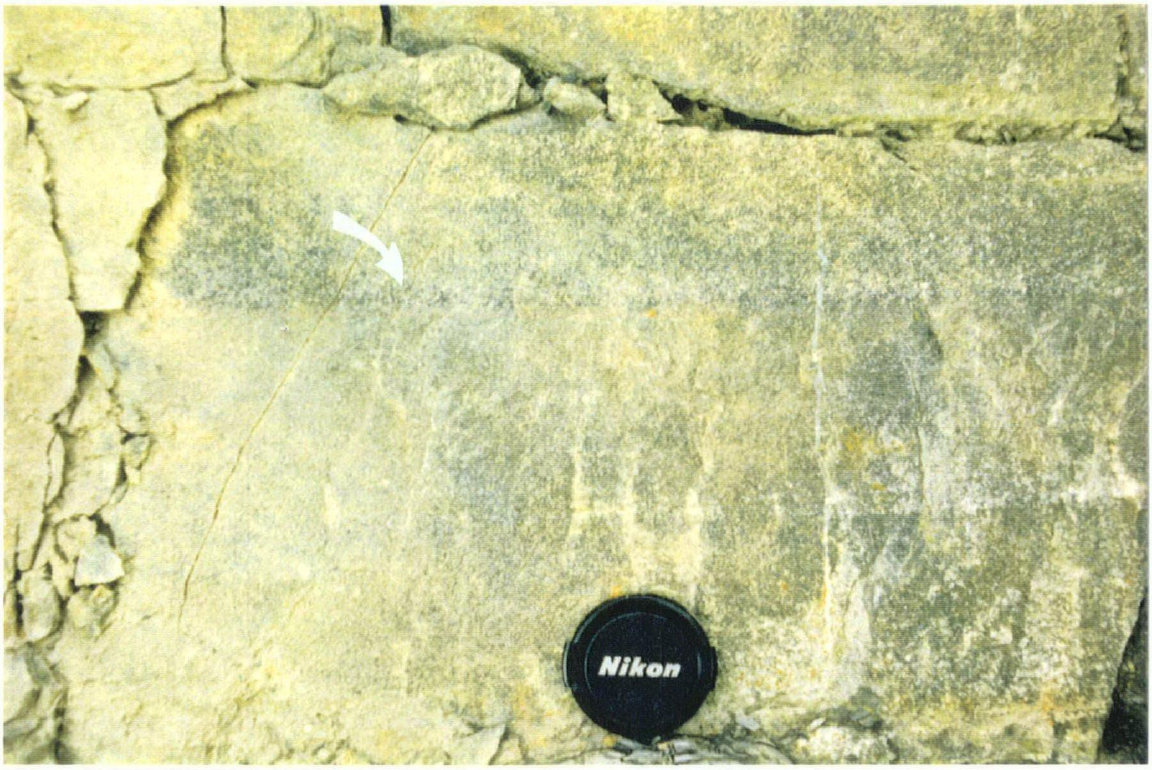


Figure 21 Typical example of reverse grading within sandstone bed, with the appearance of coarser-grained horizons (marked).

Figure 22 Base of sandsone unit characterized by the development of numerous bulbous load casts (marked). Location 1, Map 4.

Figure 23 Load casts exposed on block lying on floor of upper level. Note how these structures show a preferential alignment (marked) which is used to determine palaeocurrent direction.

Figure 24 Linear groove casts exposed on underside of greywacke sandstone are commonly seen *in situ* along the faces of the upper level. These structures are widely used to determine palaeocurrent direction.

Figure 25 Ripple marks on the top surface of greywacke sandstone bed (Loc. 4; Map 4).

Figure 26 Ripple-marked surface of sandstone in cross-section. Surface is covered by thin mudstone band, prior to the deposition of next sandstone unit (Loc. 1; Map 4).

2. CONSERVATION MANAGEMENT

2.1 Current status and land-use

This GCR site [illegible] from a currently abandoned quarry, which was notified in April 1986 on account of the Wenlock turbidites which are exposed along the quarry faces. Operations at Penstrowed Quarry apparently ceased within the last 10 years, and most of the plant, including drilling, excavating and crushing equipment, was left on site (Figures 1, 27 and 28), often in the places where last used.

Although planning permission was granted to extend the workings to the south-west (see Map 1; Section 5.1), no further quarrying has taken place as yet. However, discussions with employees of the local concrete manufacturing company, based at the entrance to the workings, informed that the quarry has been "moth-balled" until construction work begins on the Newtown by-pass, a route which may be built by the end of the century. The quarry is then expected to be re-opened, since it will offer the nearest source of road-stone.

The site is currently kept on a 'care and maintenance basis', being regularly inspected by the quarry owners, who do grant access to the many parties of visiting geologists, provided that they are suitably insured and wear hard hats. The entrance gate is locked at all times, and notices warn that trespassers will be prosecuted. Indeed, prosecutions have apparently taken place in the past. As a consequence, very little tipping has taken place, since vehicles are not able to gain access to the workings. However, vandalism has been a problem in recent years, with damage being caused to buildings and equipment.

2.2 Brief history of site casework

Photographs held on file record a site visit by NCC personnel in September 1982, at which time it is apparent that the quarry was still operating. Following completion of a site assessment, a list of notifiable operations was despatched on 06.04.83.

A meeting was held on 09.07.85 between I. Soane (ARO, Radnor and Montgomery), Mrs Bayliss, the local quarry manager, and Mrs Corfield, a director of Goetre Ltd, to discuss the proposed designation of the quarry as an SSSI. Concern was expressed over the effects that notification would have on the future operation of the quarry. In a note to Mrs Bayliss, dated 17.07.85, I. Soane outlined the various notifiable operations pertaining to the site. In a further note, dated 17.05.85, I. Soane expressed concern to A. McKirdy (G&P Section) that the GCR boundary did not coincide either with the existing area of working or the areas for which the owners had planning permission for extraction. A map showing these areas was supplied by I. Soane and forwarded to L. Richards (CSD, Peterborough) who proposed a revised GCR boundary (20.11.85), which subsequently was employed as the SSSI boundary. Penstrowed quarry [illegible] on 01.04.86.

The site was visited by Dr R. Mathews (CCW, Bangor) on 13.04.92, to carry out a preliminary geological photo-monitoring survey of the area (See Section 5.2) and to collect information pertaining to the future conservation and management of the site. The site was then revisited by him on [illegible].09.93 to gather information and photographs for inclusion in this Site Management Report.

2.3 Conservation principles and management objectives

The primary conservation objective at Penstrowed Quarry is to maintain the integrity of, and access to, the rock faces, particularly those which are located on the upper level, since it is in this area that the best examples of the critical sedimentary structures are to be found. It is the combination of the clear rhythmic alternations sediment (sandstone and shale) and the superbly developed sole markings which make this site significant for understanding the mechanisms of turbidite sedimentation in the Welsh Basin. Conservation of this key site would not be problematic if the quarry were to remain in its current state of abandonment. However, it is important that CCW maintains a close liaison with the quarry owners, especially in view of the possibility that extraction may resume in the future (see Section 2.1). In this event, CCW should attempt to ensure that worked faces are left in a condition which would allow continued access by geologists both to the rhythmic sequence of sediments and to a full range of the sedimentary structures.

Although the site is not perceived to be under any threat at present, it is considered expedient to inspect the site at least once every two years.

SSSI consultation areas
The critical exposures which constitute the geological interest at Penstrowed Quarry are not considered to be under current threat from any activities (e.g. agricultural practices, afforestation, construction) which might take place in areas lying outside the site boundary. Therefore, no consultation area is required at this site.

2.4 Potential threats and PDO list

Natural degradation
The process of natural degradation is leading to the progressive concealment of some rock faces at Penstrowed Quarry, particularly those on the upper level. Figure 29 shows how the friable nature of this turbidite sequence has resulted in the accumulation of a considerable quantity of debris at the base of the cliff. Indeed, when the site was visited recently, it was noted that rock falls in this area are a major hazard when approaching the cliff faces. The sediments and structures are in general well displayed and no site clearance is yet necessary (see quarrying).

Change of use
The site is currently under 'care and maintenance', in anticipation that quarrying may resume in the future. However, if this does not take place it is possible that the site might be sold off and/or used for some other purpose. In this context, its use as a land-fill is a potential threat, especially in view of the close proximity of large and expanding centres of population such as Newtown. Alternatively, the quarry might be used for other purposes which could, for example, involve the grading or battering of the cliff faces to improve stability. Activities such as these could severely damage or result in the loss of the geological interest at the site.

Resumption of quarrying
In the event that quarrying should be resumed at Penstrowed, it is probable that operations will be centred on the south-west face of the upper level. If this work is carried out sympathetically, a similar face, providing an accessible cross-section through the turbidite sequence, should be left once quarrying has ceased. However, it is possible that the final rock faces might be left in a poor condition, concealed beneath debris, or in such a dangerous condition that access will not be possible. It is for this reason that CCW should maintain a close liaison with the quarry operators to ensure that sufficient exposure is left in such condition that the geological interest is not lost. Renewed quarrying would clearly obviate the need for any site clearance.

List of notifiable activities

7 Dumping, spreading or discharge of any materials.

14 The changing of water levels and tables and water utilization (including irrigation, storage and abstraction from existing water bodies and through boreholes).

15 Infilling of pits.

21 Construction, removal or destruction of roads, tracks, walls, hardstands, fences, banks, ditches or other earthworks, or the laying, maintenance or removal of pipelines and cables, above or below ground.

22 Storage of materials on or against rock faces or outcrops.

23 Erection of permanent or temporary structures, or the undertaking of engineering works, including drilling.

24 Modification of natural or man-made features, including battering, buttressing or grading rock faces or outcrops.

Figure 27 Crushing plant and conveyor belts which were used for processing and transporting stone to distribution point.

Figure 28 Crushing plant and fuel storage facility at on the north-eastern margin of the GCR site. Drilling equipment is currently stored behind the corrugated iron shed in background.

Figure 29 Accumulation of scree at base of unstable faces along the upper level. The continued build-up of this material will eventually result in the loss of exposure. Without further quarrying at the site, some clearance may eventually become necessary.

3. [illegible]

3.1 [illegible]

The GCR boundary satisfactorily incorporates the geological interest at this site, and the GCR citation adequately describes the important geological features contained within the rocks. In addition, all the geological features are easily accessible, although care should be taken when approaching the faces owing to frequent rock falls. Therefore, no action is required at present.

3.2 Site enhancements

Previously, mention has been made to the highly friable nature of the rocks at Penstrowed Quarry, a feature which has led to the progressive accumulation of debris at the foot of the rock faces. This is slowly leading to the concealment of the rock faces, such that in time, and in the event that there is no further quarrying, it may be necessary to clear away the debris and possibly to reduce the gradient of the faces to increase stability and minimize further falls.

The quarry attracts large parties of geologists, since it provides an ideal opportunity to study various aspects of turbidite sedimentation as well as providing some of the most spectacular sole markings known in Wales. A useful site enhancement would be the placement of an information board providing a brief outline of the geological interest at the site and its relationship to other sites within the GCR network. Implementation of such a guide would also serve to highlight CCW's active role in Earth Science Conservation throughout Wales.

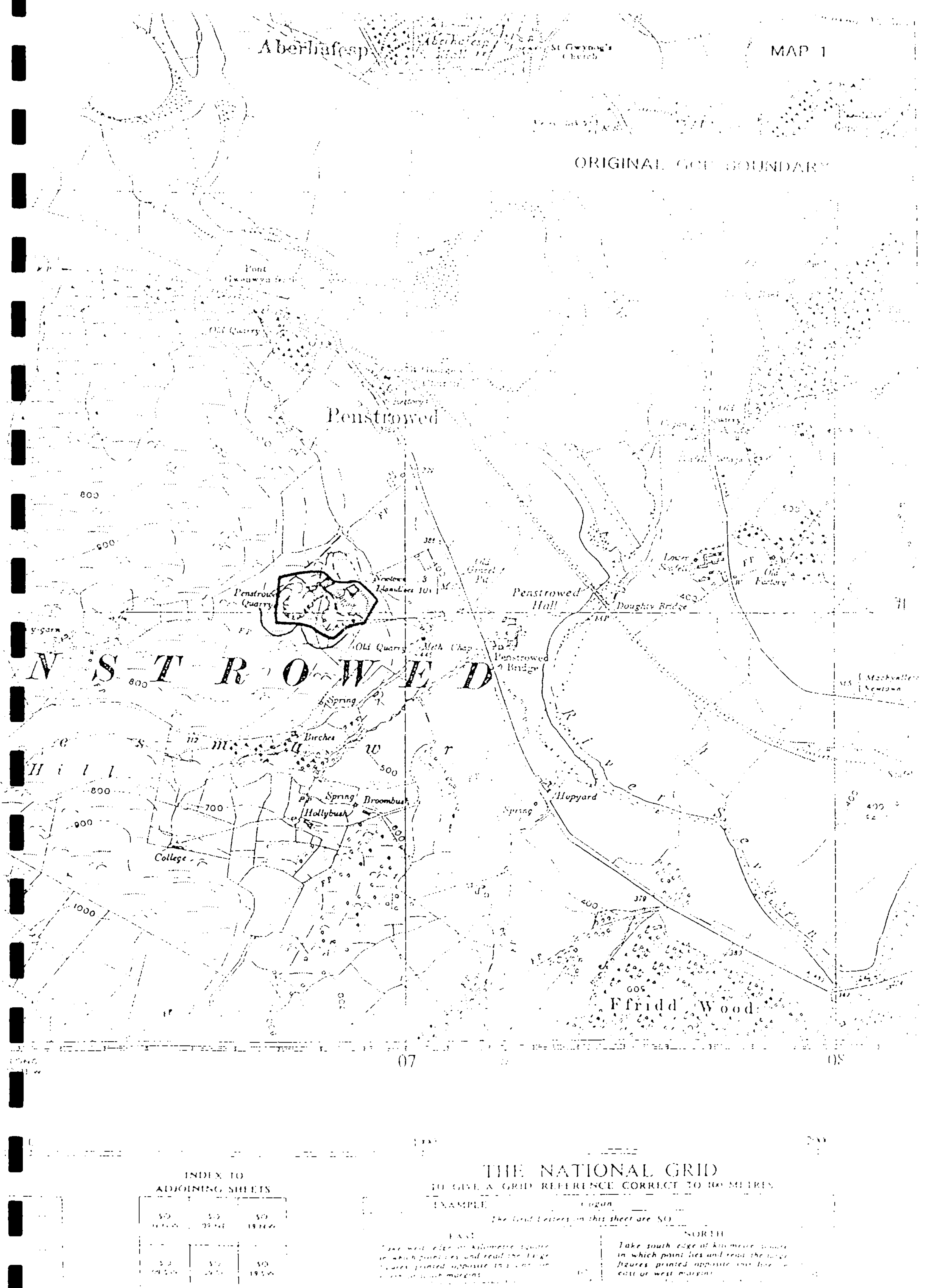
4. THREATS AND RECOMMENDATIONS

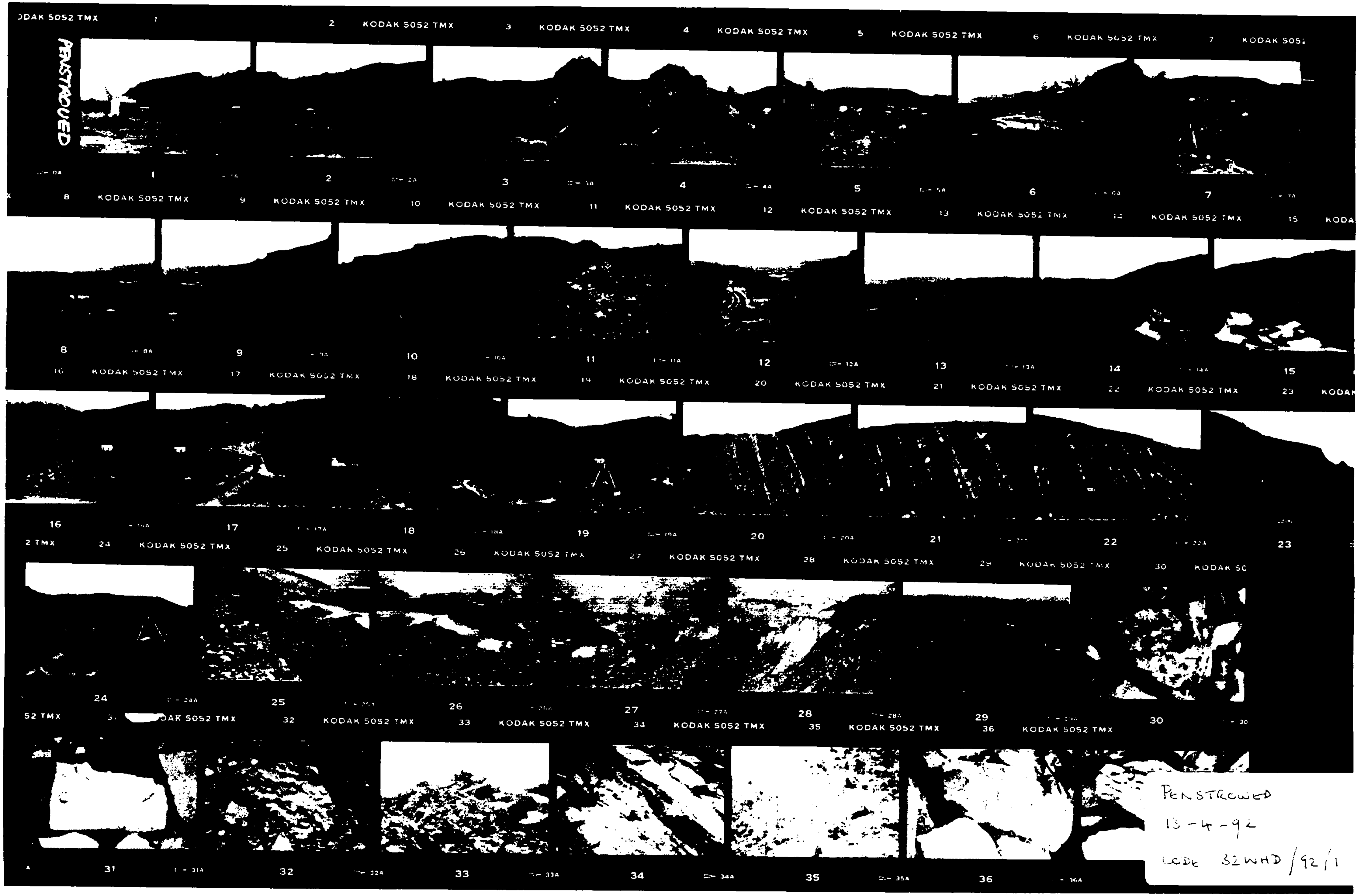
Penstrowed Quarry is the type locality for the Penstrowed Grits, which are particularly well exposed in the south-west and north-east faces of the workings. These sediments, which are of Wenlock (Middle Silurian) age, consist of a rhythmic, alternating sequence of greywacke sandstones, siltstones and shaley mudstones, which are thought to have been deposited from sediment-laden turbidity currents which flowed into the Welsh Basin from shallow marine shelf areas lying to the south and south-west. Deep-water sediments such as these, are in marked contrast to those fossiliferous, shallow water sediments, of a similar age, which are exposed further to the east. The outstanding geological feature of these rocks is their great wealth of sedimentary structures, which include sole structures such as flute casts and groove casts, together with graded bedding and ripple marks. These structures, which are typical of high-energy turbidite sequences such as the Penstrowed Grits, have provided important information regarding their environment of deposition and mode of formation.

After consultation with the site owners, and extensive modifications of the initial GCR boundary to incorporate the geological interest, Penstrowed Quarry was notified in April 1986. Quarrying at Penstrowed ceased within the last 10 years, since which time the site has remained under 'care and maintenance'. However, taking into account the large area for which planning permission has been granted, it seems likely that the quarry will be a primary source of road-stone should plans go ahead to build a Newtown by-pass.

The geological interest at the site is faced by several threats. At present, natural degradation of the unstable quarry faces is leading to the progressive accumulation of large quantities of scree, and concealment of the sedimentary structures. It may become necessary at some time in the future to clear this debris away from the faces. A change of use, should the quarry not be re-opened, is a distinct possibility; in this context, its use as a land-fill site is a major threat, given the close proximity of a large town. If quarrying is resumed, CCW should liaise closely with the operators, to ensure that sufficient outcrop, displaying the important sediments and geological structures, is left intact.

Despite these threats, the site is currently in excellent condition, and no immediate action is required, although the site should be inspected by CCW personnel at regular intervals of about 2 years. Great care should be taken when approaching the faces owing to frequent rock falls, especially on the upper level. In view of the large numbers of geologists who visit the site, the placement of an information board at the quarry entrance would be of great benefit.


MAP 1
Aberhafesp
ORIGINAL GCP BOUNDARY
Pont
Old Quarry
Penstrowed
800
900
Penstrowed Quarry
Penstrowed Hall
Doughty Bridge
Lower
Old Factory
Old Gravel Pit
Old Quarry
Penstrowed Bridge
N S T R O W E D
Spring
Birches
500
Hill
700
1000
Spring
Broombush
Hollybush
College
Hopyard
Spring
400
Ffridd Wood
07
08
THE NATIONAL GRID
EXAMPLE
INDEX TO ADJOINING SHEETS
NORTH
Take south edge of kilometre square in which point lies and read the large figures printed opposite this line on east or west margins


PENSTROWED
PENSTROWED
13-4-92
CODE 32WHD/92/1

5.4 Glossary

Axial plane. The plane which bisects the limbs of a fold.

Caledonian Orogeny. A phase of mountain building which took place approximately 400 million years ago in Wales.

Cleavage. The plane of mechanical fracture in a rock, usually controlled by the parallel orientation of partially recrystallized platy minerals such as micas.

Facies. The sum total of features such as sedimentary rock type, mineral content, structures, fossil content, bedding characteristics, etc. which characterize a sediment as having been deposited in a given environment.

Graptolites. A primitive, and now extinct, colonial organism, consisting of one or more branches (stipes). The individuals of the colony (zooids) were situated in cups arranged in one or two rows along the stipe, the whole being covered by an external layer of chitinous material. The graptolites belong to the most primitive class within the phylum Chordata.

Greywacke. A sandstone consisting of fine to coarse, angular to sub-angular particles which are mainly rock fragments (lithic fragments). The grains are usually poorly sorted (i.e. of different sizes), and the cementing material is generally argillaceous (i.e. clay minerals).

Joint. A fracture in a rock between whose sides there is no observable relative movement.

Sole structures. The term used to describe a wide variety of primary sedimentary structures, which were formed by the scouring of hollows and grooves into the sea bed and their subsequent infilling with sediment.

Strike-slip. A particular style of deformation involving the lateral movement (shear) between blocks on either side of a fault plane.

Transpression. A deformation mechanism involving pure compression with a superimposed element of lateral shear.

Turbidites. A repetitive sequence of sandstones and shales deposited from seismically-induced sediment slurries which flow at high velocities from shelf-edge into deep water basinal areas.

Acknowledgements

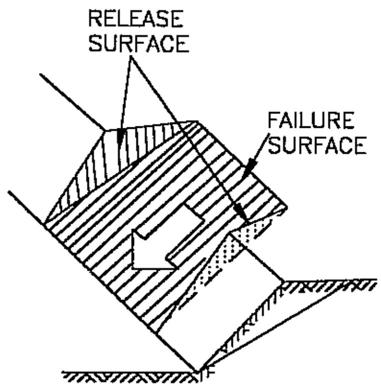
The author wishes to thank the following involved in the production of this report.

1. Editing: Dr Stewart Campbell.

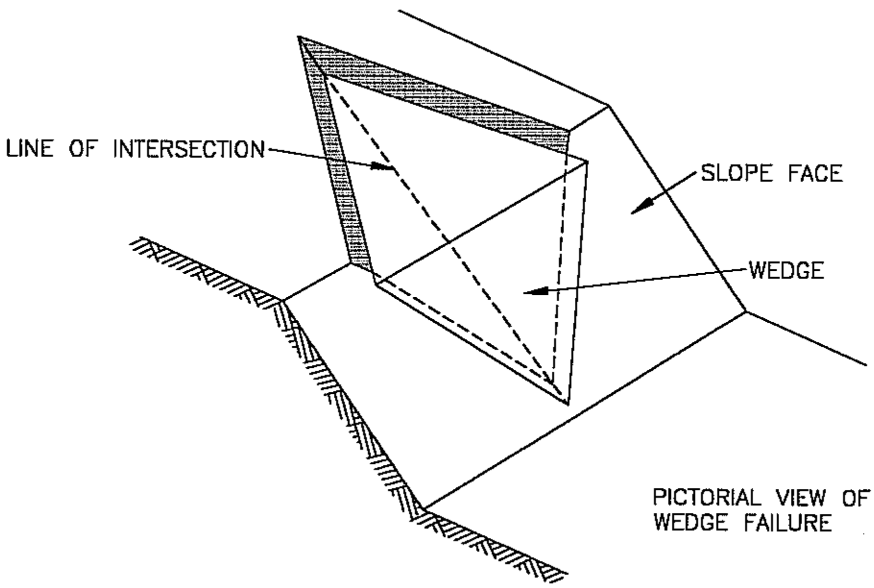
2. Report compilation, distribution, maps and photocopying: Jo Hughes and Carl Rose.

APPENDIX B

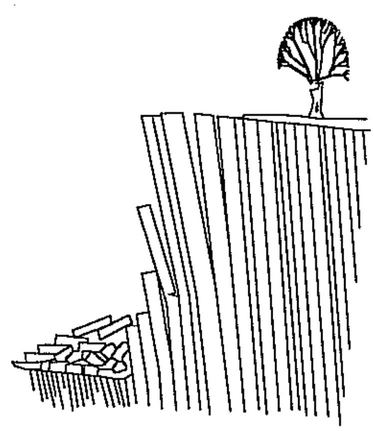
Stability Mechanisms



PLANAR FAILURE.



WEDGE FAILURE.



TOPPLING FAILURE.

COWI
in association with
Thomas Garland
& Partners
and
Fehily Timoney
Gifford

Convent Road,
Delgany,
Co. Wicklow,
Ireland

Tel: +353 1 2017748
Fax: +353 1 2017749

email: cowi@eircom.net

Iarnród Éireann—Coastal Defence Works	Contract Number CE 641/13/02		
Drawing Title: FAILURE MECHANISMS	Scale: NOT TO SCALE		
	Date: 22/11/'00		
Drawn: J.C.	Checked:	Approved:	Drawing Number: