ES18.2

ASSESSMENT OF

MYNYDD LLANGYNIDR

AS A POTENTIAL SITE OF SPECIAL SCIENTIFIC INTEREST

COMMISSIONED BY

THE COUNTRYSIDE COUNCIL FOR WALES

Under

Contract number ES01700

by

Professor John Gunn

LRC Report 2012/13

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SUMMARY

Field mapping has confirmed published statements that Mynydd Llangynidr contains the finest array of collapse (caprock) dolines and subsidence basins seen anywhere in Britain, and clearly demonstrates the surface geomorphic effects of interstratal karst. Moreover, discussion with colleagues in other countries indicates that this is not just the best of its kind in Great Britain, it is of global importance. In addition to the surface landforms three caves are of particular importance as they allow the boundary between the grit and the limestone to be viewed in further detail from underground and provide further insights into the development of interstratal karst. Two short caves in Blaen Onneu Quarry are also considered to have interstratal karst interest. A suggested revision to the Statement of Interest for the GCR Site that reflects the additional cave interest is provided and a revision to the indicative boundary for the GCR site to encompass the core area of interstratal karst is also suggested. The proposed GCR site includes the minimum area required to represent the assemblage of densely concentrated dolines, whilst excluding areas that do not contain interstratal karst. The boundaries are not extended to include those few individual outlying caprock dolines that are separated from the core area by areas with no interstratal karst.

Given the clear national and international importance of the Mynydd Llangynidr GCR site it is recommended that it should be protected as a SSSI. The value of the interstratal karst lies both in the individual landforms and the fact that within the proposed SSSI (pSSSI) area the density and variety of caprock dolines is unsurpassed anywhere in Britain.

The pSSSI encompasses land being considered for inclusion as a "preferred area of search for mineral extraction" in the draft Blaenau Gwent LDP. It is recommended that this proposal should be opposed as the area contains over 70 caprock dolines and is an integral part of the pSSSI. Moreover, with the exception of a small strip close to the rim of the present quarry, the limestone is overlain by Millstone Grit and superficial deposits. The exact thickness is unknown but on the basis of dolines close to the rim of the present quarry it is estimated to be at least 3m, rising to over 10m deep further north and east. This implies that a large amount of material would have to be removed and tipped before the limestone could be extracted.

1. BACKGROUND AND BRIEF

1.1 Surveys of Britain's karst regions were undertaken between 1978 and 1990, as part of the Geological Conservation Review (GCR). During this process, Mynydd Llangynidr was registered as a GCR site on 1st June 1982. The GCR statement reads as follows:

"The site covers the summit area and upper dipslopes of Mynydd Llangynidr, where the solid outcrop is nearly all Millstone Grit. It includes the most spectacular assemblage of collapse dolines to be found anywhere in Britain. These have formed by solutional erosion in the underlying limestone, with consequent collapse, pitting and foundering of the grit. The result is a surface geomorphology which is an excellent doline field and Britain's best example of interstratal karst."

1.2 As with all GCR sites, an indicative boundary was drawn at the time of registration. The GCR survey of British karst was published in the GCR volume entitled "*Karst and Caves of Great Britain*" (Waltham et al., 1997). A report on the scientific value of the Mynydd Llangynidr site is given (pp 236-239), expanding on the above GCR statement.

1.3 The Geological Conservation Review identifies sites of national and international importance needed to show all the key scientific elements of the Earth Heritage of Britain. The final decision on the case for notification is made by the Council of the respective country agency, in this case the Countryside Council for Wales. In order to progress notification a formal SSSI boundary needs to be defined. As the current GCR boundary does not always reflect the karst features seen on the ground CCW have commissioned Limestone Research & Consultancy Ltd to undertake research aimed at ensuring that a subsequent SSSI boundary is drawn that encompasses all the important features without including any unnecessary extraneous areas of land.

1.4 A proportion of the GCR site, as it is currently defined, is at potential risk from future quarrying, as it is under consideration for inclusion as a "preferred area of search for mineral extraction" in the draft Blaenau Gwent LDP. CCW requested a detailed survey of this area to ascertain whether it is worthy of notification as SSSI.

1.5 The project specification has three main components:

1. A desk-top review of available literature sources on Mynydd Llangynidr.

2. A field survey of the entire GCR site, identifying and surveying important features. This survey needs to be sufficiently accurate to inform the delineation of a scientifically robust potential SSSI boundary, and to support notification of the entire area, with particular attention paid to that area being considered for mineral extraction.

3. A report detailing the nature and location of important features as pertaining to the GCR statement, and detailing the extent to which such features extend and hence a suggested SSSI boundary.

2. LITERATURE REVIEW

2.1 The literature review requested as part of the project specification refers specifically to Mynydd Llangynidr. However, it was felt that a brief review to provide background on dolines (the primary landforms on Mynydd Llangynidr) and interstratal karst (the highest level interest feature on Mynydd Llangynidr) would provide useful background to the more detailed review. In addition, the stratigraphic nomenclature is also briefly reviewed.

Stratigraphic nomenclature

2.2 The nomenclature for the rocks that crop out in South Wales has been revised several times over the years and it was felt useful to briefly outline the main units to avoid confusion. Virtually all published accounts relating to Mynydd Llangynidr and the surrounding area, and the most recent 1:50 000 Series BGS Sheet 232 which covers the area, and the Memoir (Barclay, 1989) refer to the stratigraphic sequence as:

Lower Coal Measures
Millstone Grit
(also referred to as the Namurian Millstone Grit Series and as the Millstone Grit Group)
Carboniferous Limestone
(also referred to as the Dinantian Limestone)

2.3 These terms are used in this report in the sense used by the original authors and in particular the term 'Millstone Grit' is used throughout in an informal sense. However, it is recognised that they have been superseded and Waters et al (2009) outline the most recent nomenclature at Group level as:

South Wales Coal Measures Group (Westphalian age)
Marros Group (replaces Millstone Grit Group; Namurian age)
Pembroke Limestone Group (Tournaisian to Visean age)
Avon Group (Tournaisian age)

2.4 At formation level there is lateral variability in South Wales but in the Mynydd Llangynidr area the sequence is:

Bishopston Mudstone Formation
Twrch Sandstone Formation (locally the base of the Marros Group and of Marsdenian to Yeadonian age; formerly called the Basal Grit(s) or Basal Grit Group)
Dowlais Limestone Formation (Holkerian age)
Garn Caws Sandstone Formation (Arundian age)
Llanelly Formation (Arundian age)
Gilwern Oolite Formation (Chadian age)
Coed Ffyddlwn Formation (Courceyan age)
Blaen Onnen Oolite Formation (Courceyan age)
Pantydarren Formation [Courceyan age)
Pwll y Cwm Oolite Formation [Courceyan age)

2.5 Importantly there is a substantial unconformity between the top of the Dowlais Limestone Formation and the base of the Twrch Sandstone Formation. The uppermost limestone beds were deposited before the end of the Holkerian about 333 million years ago whilst the gritstones at the base of the Twrch Sandstone Formation were laid down at the start of the Marsdenian about 315 million years ago. It is possible that limestone deposition continued into the Asbian or perhaps even to the end of the Brigantian, about 326 million years ago and that any related deposits were subsequently removed by erosion. This means that there was a period of around 11 million years before the deltas in which the grit was deposited began to transgress the area and that is sufficient time for substantial karstification of the exposed limestone. Jones & Owen (1966) describe the top of the limestone as being highly irregular with slumped masses of Millstone Grit filling depressions in the limestone and this has also been observed on Mynydd Llangynidr during the present project.

Dolines

2.6 Williams (2004, p. 304) provides a good introduction to these landforms:

A doline is a natural enclosed depression found in karst landscapes. Dolines are also sometimes known as sinkholes, particularly by engineers and especially in North America. They are usually subcircular in plan and tens to hundreds of metres in diameter, though dolines can range from a few metres to about a kilometre in width. From the lowest point on their rim, their depths are typically in the range of a few metres to tens of metres, although some can be more than a hundred metres deep and occasionally even 500 m. Their sides range from gently sloping to vertical, and their overall form can range from saucer shaped to conical or even cylindrical. Their lowest point is often near their centre, but can be close to their rim. Dolines are especially common in terrains underlain by carbonate rocks, and are widespread on evaporite rocks. Some are also found in siliceous rocks such as quartzite. Dolines have long been considered a diagnostic landform of karst, but this is only partly true. Where there are dolines there is certainly karst, but karst can also be developed subsurface in the hydrogeological network even when no dolines are found on the surface.

2.7 As dolines are present in almost every area in which karstifiable rocks crop out or are present at shallow depth the literature contains a varied terminology reflecting form, process, materials and local conventions. However, since 2003 six main doline-types have been recognised by leading international experts (Figure 1; Waltham & Fookes, 2003; Williams, 2004; Waltham et al., 2005; Ford & Williams, 2007).

2.8 Dissolution of bedrock is the initial formative process in all dolines and the sole process in the development of solution dolines. The two other formative processes are collapse (which is commonly rapid and involves fracturing of the surface material) and subsidence which is a more gradual process. Collapse can only occur if there is a void for the material to collapse into. In the case of collapse and caprock dolines the void is formed by bedrock dissolution and must become sufficiently large that the stress exceeds the strength of the overlying bedrock. Proximity to the surface is also important and collapse of a cave roof at depth may have no surface expression (Figure 2, Type ‘E’) although Thomas (1974) has argued that collapse of a cavity as much as 250m below the surface can lead to doline development. Conversely, Bull (1977) has argued that doline development can lead to breakdown and the development of boulder chokes in caves as much as 250m below the doline base. In dropout dolines the void forms in cohesive superficial deposits which are evacuated down a dissolutionally enlarged conduit. Suffosion dolines (commonly called shakeholes) form when non-cohesive superficial deposits are washed down a dissolutionally enlarged conduit. As dropout and suffosion dolines are formed in superficial deposits over karstified bedrock they tend to be short-lived landforms on a geological timescale. Solution, collapse and caprock dolines are longer-lived and where they become filled with sediment they are classed as buried dolines.

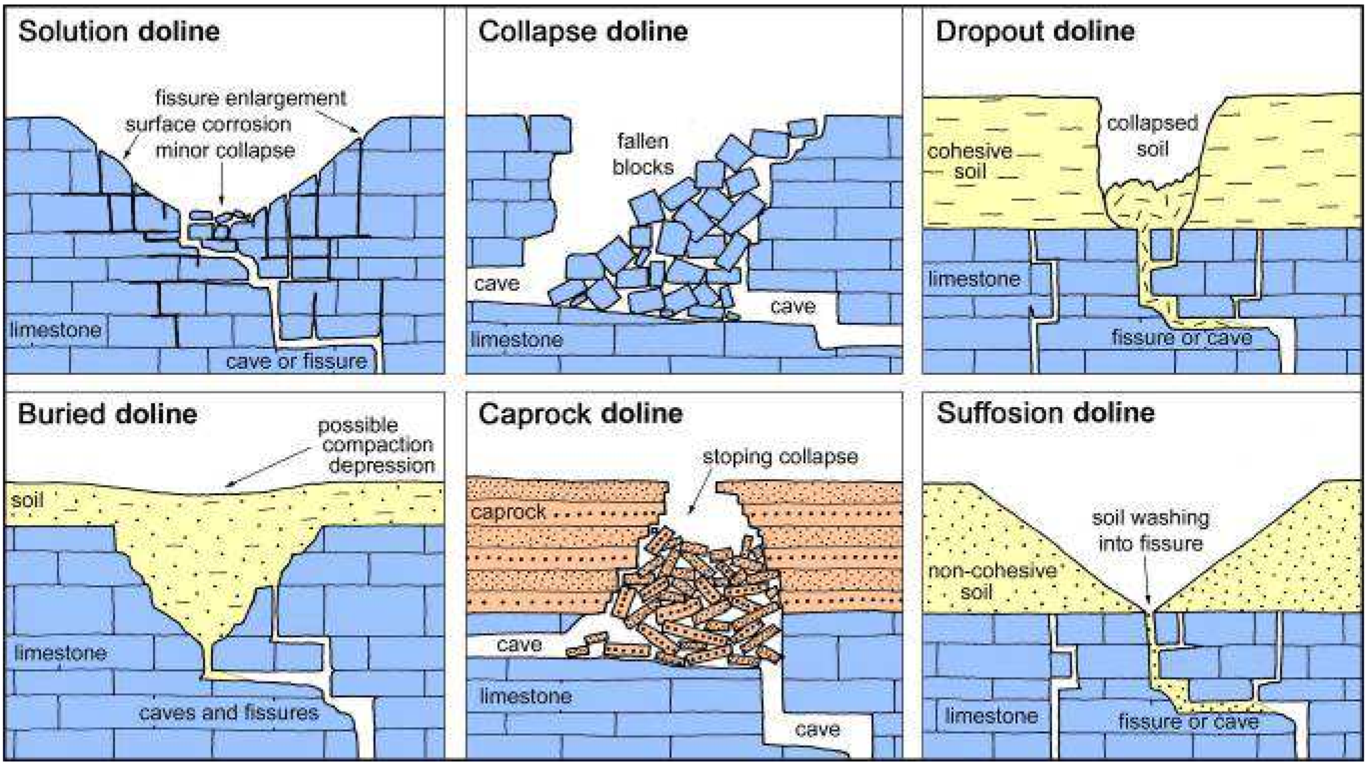

Figure 1 : The six main types of dolines (diagram courtesy of Tony Waltham)

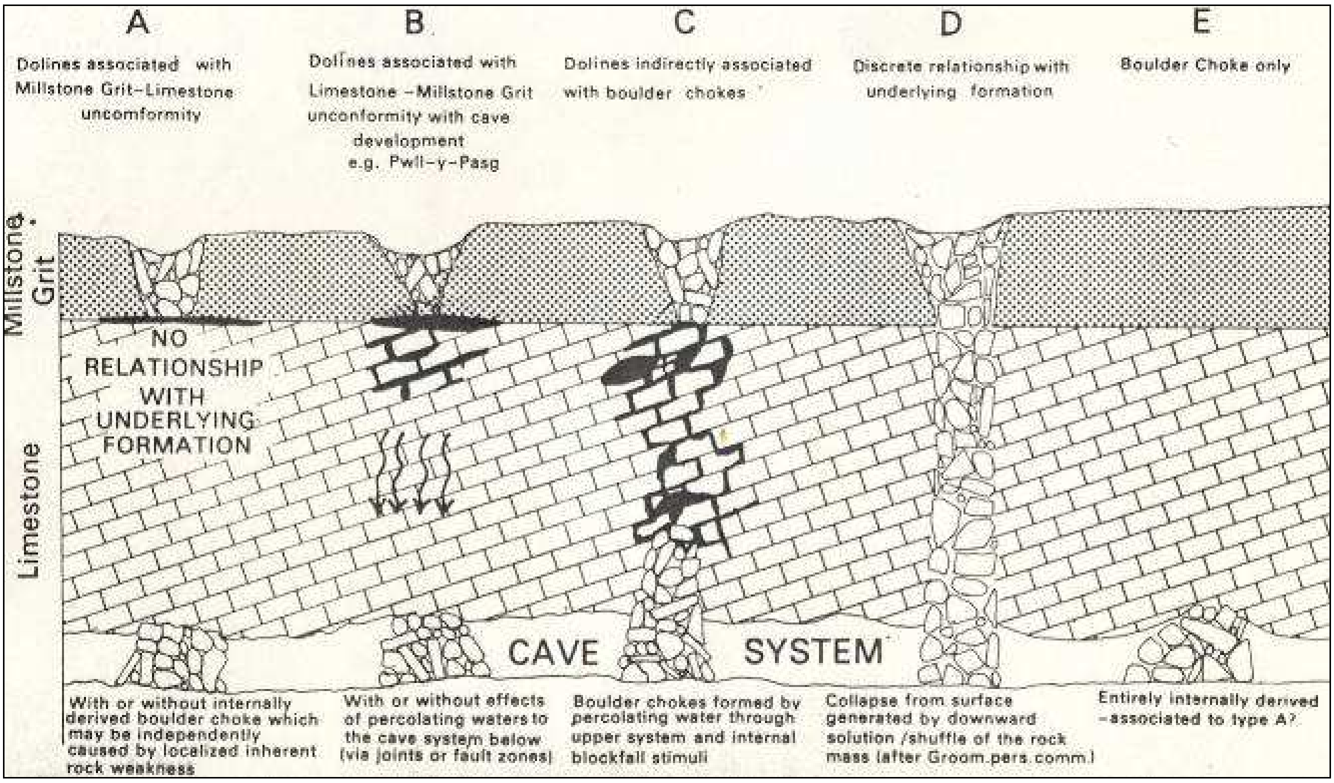

Figure 2

Possible relationships between caprock dolines and cave boulder chokes in South Wales (from Bull, 1977; note that the geology is highly simplified).

2.9 Where karstifiable rock crops out or has a thin cover of superficial deposits solution dolines are the commonest form but as the thickness of superficial deposits increases suffosion dolines become more common. Collapse dolines are much less common than solution dolines. Caprock dolines are quite common over evaporite bedrock but much less common in carbonate bedrock. In the karst regions of Great Britain collapse dolines and caprock dolines are rare outside of South Wales, as discussed further below.

2.10 The doline-type classification is process based and dolines may also be classified by shape. In an early paper Cvijic (1893) used the diameter/depth ratios to distinguish three primary forms: bowl-shaped (flattish floor; diameter ~ 10 x depth); funnel-shaped (diameter 2-3 x depth) and well-shaped (diameter < depth). Over time collapse and caprock dolines may evolve from well-shaped, through funnel-shaped to bowl-shaped (Figure 3).

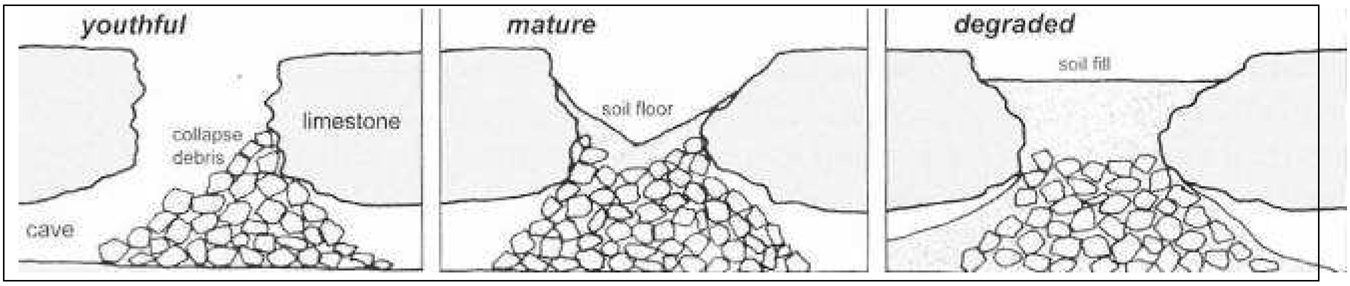

Figure 3 : Change of collapse doline shape over time (from Waltham et al., 2005

Interstratal karst

2.11 Where karst rocks do not crop out but are present beneath less soluble or insoluble cover strata subsurface dissolution is termed interstratal karstification (Quinlan, 1967). Interstratal karst is common where the karst rocks are sulphates or halites but less common in carbonate rocks. In some areas there is no surface evidence for dissolution of the karst rocks but in others dissolution of the karst rocks is manifest by collapse or subsidence structures in the overlying rocks and these structures may extend to the surface as caprock dolines. Interstratal karstification is sometimes confused with intrastratal karstification which “refers to the preferential dissolution of a particular bed or other unit within a sequence of soluble rocks” (Ford & Williams, 2007, p3).

2.12 In Great Britain the only extensive interstratal karst region is in South Wales and extends with minor breaks for 60km between the western end of Black Mountain and the Blorenge area in the east” (Thomas, 1974, pg 139; see also Figure 4 below). In North Wales Battiau-Queney (1984) identified what she termed “flat-bottomed basins” excavated in Millstone Grit rocks in and around Moel Garegog, south of Mold. She describes them as being completely closed and having an average length of 100m with long-axes following the strike. I am not familiar with this area and do not know of any other descriptions of what may be a small area of interstratal karst, although Battiau-Queney (1984) ascribes the origins of the depressions to dissolution of silica and its evacuation by groundwater. Elsewhere on the Carboniferous limestones of Great Britain there are no known examples of interstratal karst or caprock dolines in the Peak District karst but there are several small areas of interstratal karst with isolated caprock dolines in northern England, around Simon’s Seat to the northeast of Craven (Dr David Lowe, pers comm) and near Grassington (Dr Andrew Farrant (British Geological Survey, pers comm., 2012). Dr Farrant has also informed me that in the Forest of Dean there are caprock dolines in the Cromhall Sandstone Formation where it overlies the Black Rock Limestone and on the Mendip Hills where the Harptree beds overlie the Carboniferous Limestone but there are no extensive areas of interstratal karst.

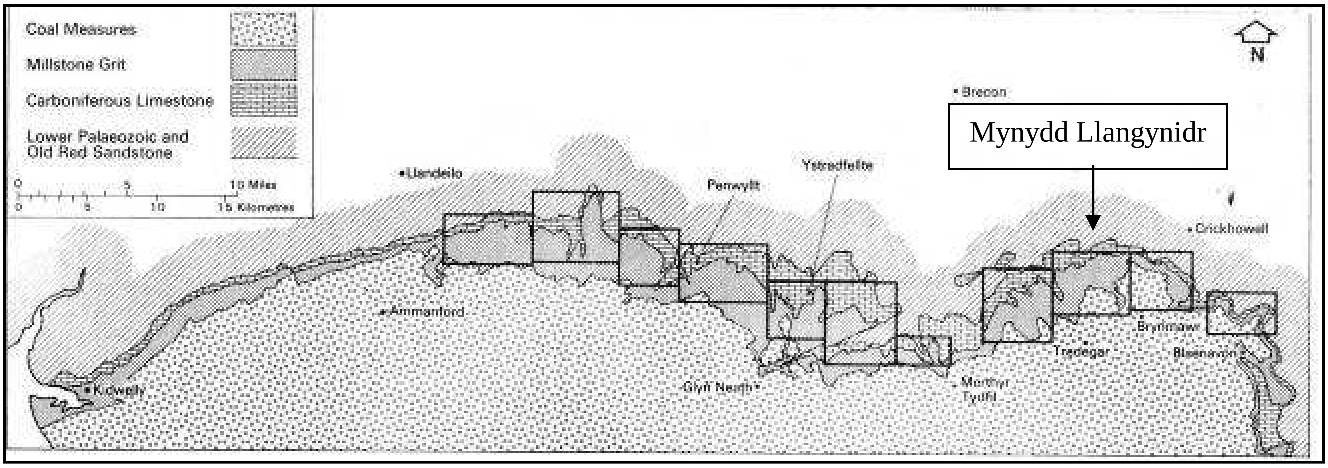

Figure 4

Generalised geological map of the North Crop region of the South Wales coalfield (Thomas, 1974). The eleven boxes show the areas of interstratal karst that were surveyed by Thomas

2.13 Outside of the Carboniferous limestone areas Thomas (1974) notes that pitting of non-calcareous cap or cover rocks by dolines and allied forms has been recorded in the middle Thames valley (Hare, 1947) and in the Dorchester area (Fisher, 1859). Dr Andrew Farrant (British Geological Survey, pers comm., 2012) has confirmed that these and are other similar examples are a consequence of dissolution of Chalk beneath a cover of Palaeogene and London Clay. These areas have previously been described as covered, as opposed to interstratal, karst and the depressions have been regarded as subsidence forms rather than caprock dolines (see discussion of Cull-Pepper's Dish and Devil's Punchbowl in Waltham et al., 1997). Although there is some similarity with the South Wales examples there is much less variability in form.

The South Wales interstratal karst

2.14 Thomas (1974) summarised the results of his detailed studies of the South Wales interstratal karst undertaken over a period of over 20 years and reported in a series of papers (Thomas 1954a, 1954b, 1959, 1963, 1973). As this is thought to be the most detailed research undertaken on an interstratal karst in carbonate bedrock anywhere in the world it is summarised briefly below. The research covered eleven blocks (Figure 4) each of which were surveyed in detail on the ground. Thomas identified four main groups of interstratal karst features: collapse dolines, shallow subsidence depressions, foundered Millstone Grit masses and dry valleys.

<u>Collapse dolines</u>

2.15 Thomas (1974, pg 150) considered the fields of collapse dolines (which would be referred to as 'caprock dolines' using modern terminology) to be "*the outstanding feature of the South Wales interstratal karst*". He mapped the whole area using aerial photographs and ordnance survey maps and examined 437 dolines in detail, including all those with a long axis greater than 25m. For these 437 he measured and recorded:

- Lateral dimensions
- Depth
- Sidewall slopes
- Slope of the land surface that is pitted by the doline
- The nature of the sidewalls and any bedrock exposure

2.16 Where rock sections were present these were surveyed to ascertain whether they conformed with the regional dip or "*provided evidence of some degree of up-ending or buckling as a consequence of subsidence*" (pg. 140). Thomas also assessed the role of faults and joints in doline evolution and constructed cross-profiles to determine whether the doline should be classed as a single-cycle feature resulting from a single sudden collapse or whether there had been "*a process of long drawn-out foundering occasionally varied by cycles of movement of greater order over segments of individual depressions*" (pg 140).

2.17 Thomas (1974) classed the 437 dolines according to the Cvijic scheme (see para 2.5) as follows:

Funnel-shaped	314
Bowl-shaped	85
Well-shaped	38

2.18 The larger dolines surveyed by Thomas are largely developed on low angle slopes with 63% on slopes less than 5º and only 18 (4%) on slopes greater than 12º.

Surface slope angle (degrees)	Number
<5	277
5-8	92
8-12	50
>12	18

2.19 Just over 25% of the dolines surveyed had a practically perfect circular outline and the majority of the others were elliptical. Thomas explained this as being due to the influence of faults and joint sets, with individual fractures showing close spacing.

2.20 Of the 314 well-shaped dolines, almost one-third (101) contained freely-exposed rock-sections but these were generally of restricted extent and embraced less than 10% of the sidewall area. Thomas noted that many of the sidewalls had a mantle of loose grit blocks with variable quantities of clayey head that largely masked the bedrock. He also concluded that "*the majority of the depressions are single-cycle features originating as a consequence of one major catastrophic collapse*" (page 141).

2.21 Thomas (1974, pg 151) argued that the caprock dolines were formed by cavern collapse and that "*major elements, such as large caverns or passageways of considerable cross-section, within substantial cave systems formed the foci of the main collapses*". Bull (1977, 1980) expanded on these ideas and investigated the relationship between caprock dolines and boulder chokes in South Wales cave systems. He put forward a simplified model (Figure 2) with five 'types' that were considered to represent components of a continuum that could occur in isolation or in combination. The geological relationships shown on the model are highly stylised but it provides a simple visualisation of possible relationships that might evolve over time. At least initially, the dolines were considered to develop independently from the production of boulder chokes in deep caves by breakdown processes (A and E on Figure 2) with the possibility of convergence over time (B, C and D on Figure 2).

Subsidence depressions

2.22 These depressions are described as being shallower (maximum depth commonly <5m) and more scattered than the dolines. They are broadly oval in outline but have no consistent elongation that might reflect possible structural guidance.

Foundered Millstone Grit masses

2.23 On the basis of his own field surveys and mapping by the Institute of Geological Sciences (now the British Geological Survey) Thomas (1974, pg 148) identified areas that had been mapped as Carboniferous Limestone but were covered with "*the collapsed and soliflucted residue of a former Basal Grit cover, let down to a maximum of 250m*". Importantly for the present report he noted (pg 148) that "*In places therefore it is virtually impossible to define with any degree of precision the exact boundary of these two major formations despite their sharply contrasting lithologies*" (Figure 5). Thomas went on to identify three major types of foundered mass:

i. *Segments of rock pavements which have been disrupted and tilted along the lines of major joints*
ii. *Beds which have subsided gradually without major rupturing to form structural basins normally discernible in the surface relief*
iii. *Successions which have been subjected to collapse of varying amplitudes and lateral extent so as to provide a jumble of loose blocks preserving no indications of the former structure at least not in the uppermost and visible sections of individual accumulations.*

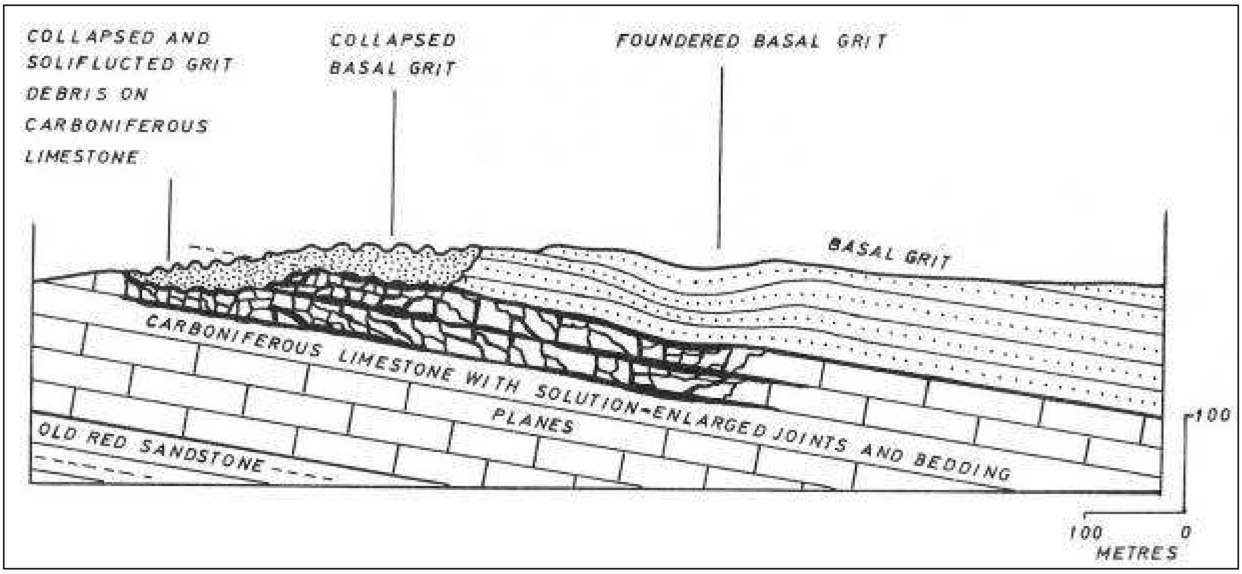

Figure 5 : Schematic cross-section illustrating foundered Millstone Grit masses (from Thomas (1974)

Dry Valleys

2.24 Thomas identified several short (up to 2km) stretches of dry valley in the Millstone Grit area. He divided them into two types:

i. Shallow features whose floors are punctuated by collapse dolines or broader subsidence depressions but show a decrease in elevation in a down-dip direction
ii. More sharply defined gorge-like features up to 15m deep and occasionally with collapse dolines extending laterally into the valley-side.

Both types of valley are largely confined to areas where the limestone is <50m below the grit and Thomas suggests that they are dry because the grit is well-jointed and can absorb rainfall.

Development of the South Wales interstratal karst

2.25 Thomas suggested that the unprecedented development of interstratal karst in South Wales is attributable to three factors:

1. In contrast to other parts of Britain, there is a very abrupt lithological break between the Carboniferous Limestone and the Millstone Grit. In the west there are thin shales between the limestone and grits but in the east (including Mynydd Llangynidr) the limestones are directly overlain by massive, jointed quartzites and quartz conglomerates. These have a higher permeability than the shales that directly overlie the Carboniferous limestones in most other British karst areas.
2. The regional surface gradient is broadly similar to the dip of strata so that the thickness of the grit cover beds (the Twrch Sandstone Formation on Mynydd Llangynidr) increases slowly from a fine feather edge.
3. Many of the main drainage areas in South Wales are directed generally down-dip.

2.26 As noted above, Thomas (1974) ascribed the development of the interstratal karst in general, and the dolines in particular to dissolution of the carbonate bedrock and the formation of cave systems. However, Burke & Bird (1966) suggested a mechanism whereby caprock dolines could form by dissolution of carbonate without the necessity for integrated conduit systems (Figure 6). This fits better with observations on Mynydd Llangynidr where there are few known caves and those caves that are known have no clear relationship to caprock dolines. This is discussed further below.

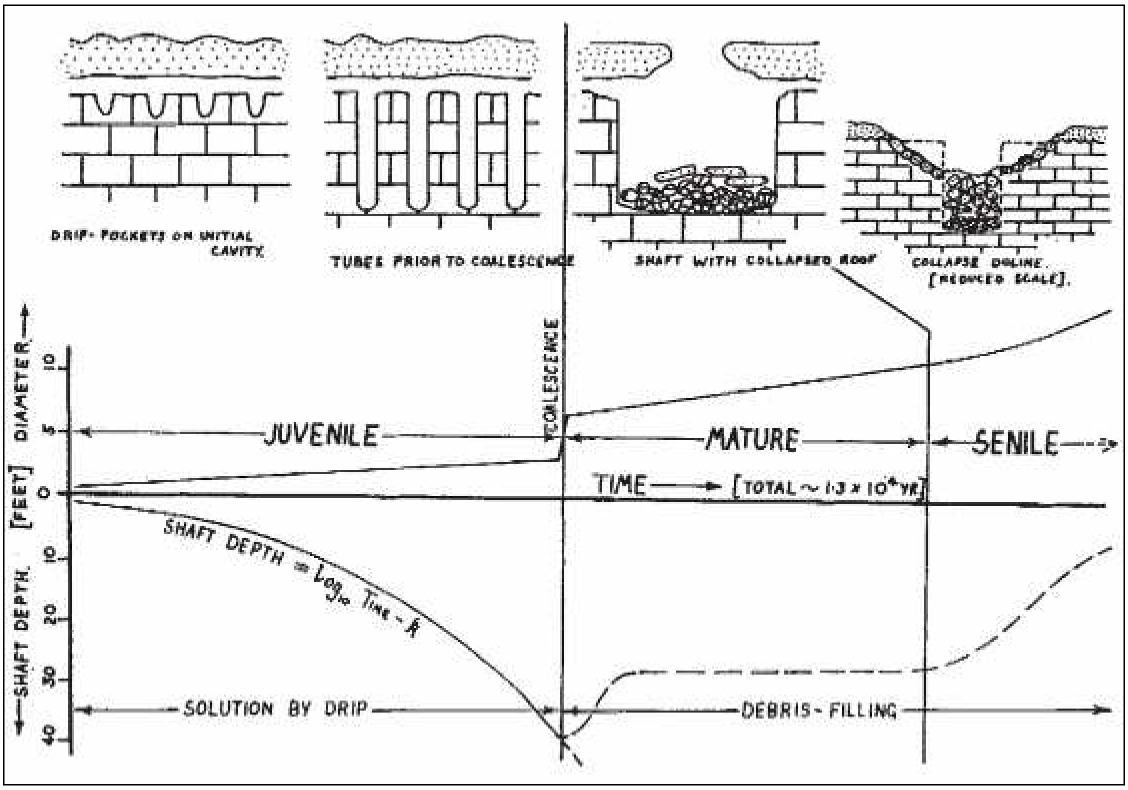

Figure 6 : The Burke & Bird (1966) model for the development of caprock dolines from drip pockets

2.27 An alternative explanation was provided by Battiau-Queney (1984) who suggested that chemical weathering of the Millstone Grit quartzites during a period of warmer climate was an important process in landform evolution in South Wales. In particular, she argued (pg 238) that "*Under a climate hot and wet enough to allow a rapid solution and massive export of silica, the decay of some beds could create dolines without the prior formation of caves in the underlying limestone*." Dissolution of limestone was not thought to occur until some time later following tectonic opening of fractures in this rock to allow water circulation. The dolines would then act to focus drainage and the process would be self-reinforcing as it would channel aggressive water down to the limestone increasing the rate of dissolution. A major flaw in this argument is that it is implicit that there was already some form of drainage system in the limestone such that the dissolved silica could be exported underground. It seems likely that such a system would have developed at the time represented by the late Holkerian to early Marsdenian unconformity and it is known that some of the early grits filled voids in the limestone. However, further research is required to develop a convincing unifying theory for caprock doline formation and Mynydd Llangynidr is the ideal location for this to take place.

Literature specific to Mynydd Llangynidr

2.28 Thomas (1974) surveyed eleven areas of interstratal karst (Figure 4) and stated that of these Mynydd Llangynidr had the most spectacular assemblage of collapse dolines (Figure 7). The GCR Volume (Waltham et al., 1997) states that there are over 500 dolines concentrated in an area of less than 10 km^2 (Figure 7) although it is not clear how this was derived as Crowther (1989, pg 35) gives the number in the same area as 600. In any event this is a very much greater doline density than anywhere else in Great Britain and it is large by global standards.

2.29 Thomas states that sample blocks of 250m by 250m on Mynydd Llangynidr contain up to 12 large dolines, 20-40m in diameter and 5-8m deep. The majority are in the area underlain by the Basal Grit but seven have collapsed upwards into the overlying shales and one is recorded as extending up to the Lower Coal Measures which are about 30m above the top of the limestone at this point. Interestingly, this doline, which lies to the east of the B4560 and is within the Mynydd Llangatwg (Mynydd Llangattock) SSSI is the largest in the area being some 55 m wide and 17 m deep (Figure 8). On the 1 25 000 map supplied by CCW it is labelled as Pwll Coch but on the 1:10 000 base map supplied by CCW and on the Ordnance Survey 1:25 000 Brecon Beacons (East) Sheet that name has (probably erroneously) been given to a much smaller doline a few metres to the northwest and on the opposite side of the road.

2.30 Thomas (1974) estimated that within his Mynydd Llangynidr survey blocks what he terms the maximum total volume of doline craters is some 180,000 m^3. It is not clear how this figure has been derived but it does illustrate that a substantial amount of limestone, and probably also some gritstone, has been removed in solution.

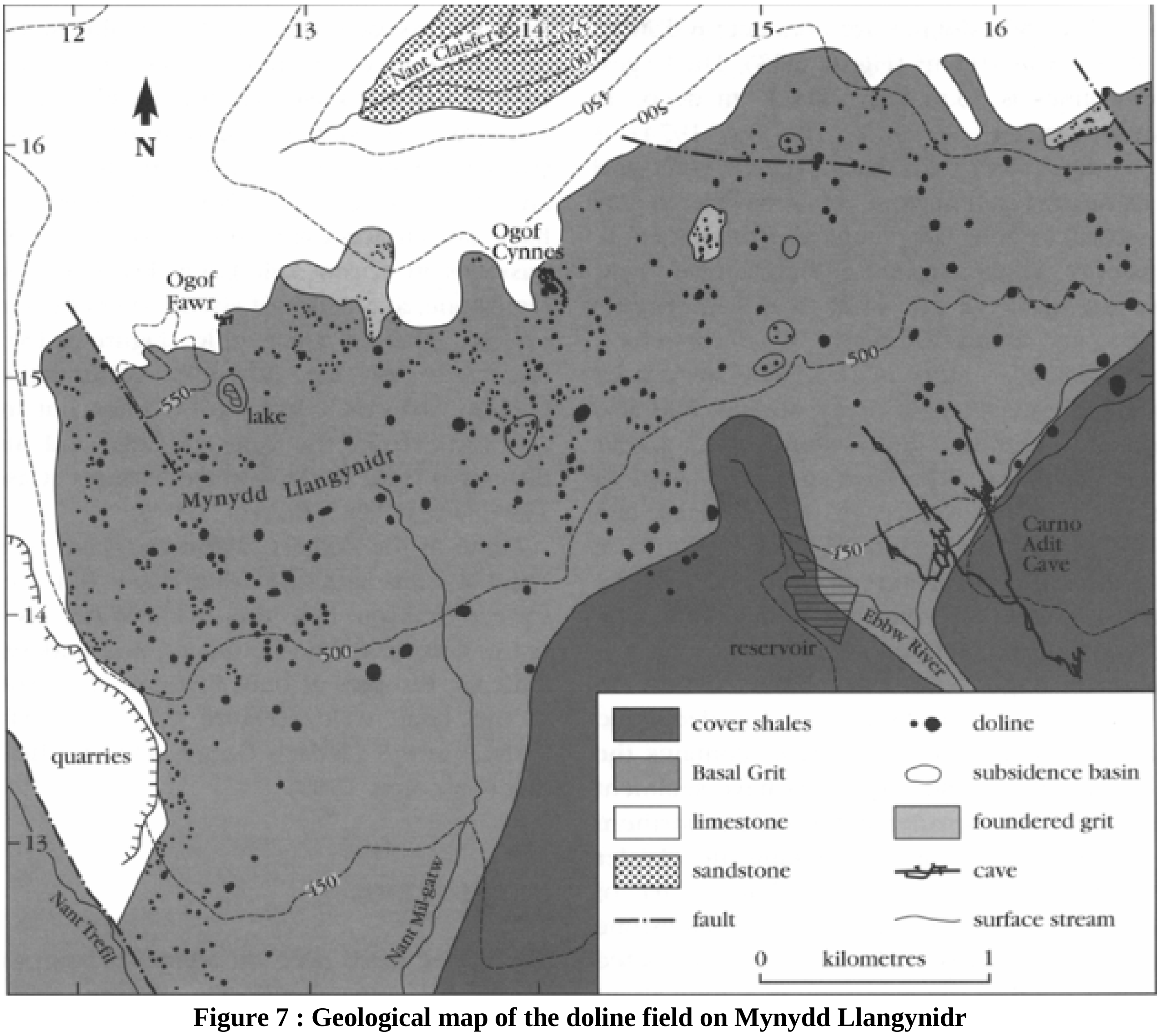

Figure 7 : Geological map of the doline field on Mynydd Llangynidr

(from Waltham et al., 1997; partly after Thomas, 1974: Ogof Carno survey by Brynmawr Caving Club). The 'cover shales' are Bishopston Mudstone Formation and South Wales Coal Measures Group; the 'Basal Grit' is the Twrch Sandstone Formation; the 'limestone' is Pembroke Limestone Group and the sandstone beneath the limestone is Devonian. Much of the limestone outcrop is covered by soliflucted grit blocks.

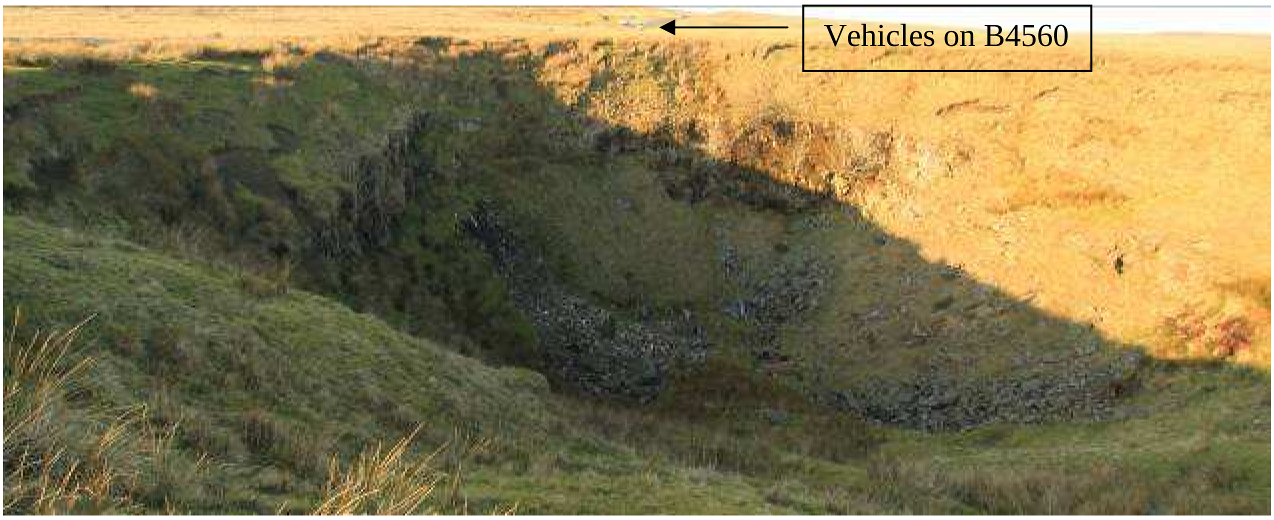

Figure 8 : Pwll Coch, the largest caprock doline in the area (photo by John Gunn).

2.31 In addition to the many caprock dolines Thomas (1974) identified six subsidence depressions on Mynydd Llangynidr. They comprise Llyn y Garn-fawr which has a flat floor and a lake that expands and contracts seasonally and five depressions to the east that have sediment floors pitted with what are probably suffosion dolines (Figure 7). He also identified three substantial areas of foundered basal grit (Figure 7) the easternmost of which lies to the east of the B4560 and is within the Mynydd Llangatwg (Mynydd Llangattock) SSSI. The two eastern areas occupy ground mapped as being Millstone Grit but the western area overlaps the Millstone Grit-Carboniferous Limestone boundary. Thomas also identified a much larger area that he described as the collapsed and soliflucted residue of a former Basal Grit cover lying on Carboniferous Limestone. This runs for about 4km along the northern edge of the escarpment, overlooking the Claisfer Valley, and extends some 200m to the north of the mapped boundary between the Millstone Grit and Carboniferous Limestone. In the GCR Volume Waltham et al (1997) estimate that is has an area of more than 12 ha. This is a particularly interesting zone and the present writer would concur with Thomas that in much of this area it is virtually impossible to define with any degree of precision the exact boundary of these two major formations despite their sharply contrasting lithologies. This is discussed further in Section 3.

2.32 Thomas (1974, page 150) makes brief mention of Ogof Cynnes and suggests that "*other substantial cave systems not yet fully described and completely explored*" are known beneath Mynydd Llangynidr. However, the writer is only aware of four caves of any size on Mynydd Llangynidr: Ogof Cynnes (~1300m long), Chartist Cave (~440m long), Crescent Cave (675m long, 81m deep) and Blaen Onneu Quarry Pot (426m long, 74m deep). There are also two shorter caves in Blaen Onneu Quarry (also referred to the the Old Blaen Onneu Quarry) referred to by Oldham (1986) as No 1 (~20m long) and No 2 (~7m long).

2.33 The caves are described in two cavers publications (Oldham (1986) and Stratford (1986)) and in more detail on three main web-sites:

1. The Cambrian Caving Council : http://www.cambriancavingcouncil.org.uk/registry/
2. UK Caving : http://ukcaving.com/wiki/index.php
3. http://www.ogof.org.uk

2.34 Ogof Cynnes, Chartist Cave and Crescent Cave each has an entrance in, and is partially roofed by, the Millstone Grit (Figures 9-16). They provide interesting insights into the relationships between cave passages and interstratal karst features and as such they are considered to be important GCR and SSSI features. They are also important in providing access to the unconformity between the Millstone Grit and the Carboniferous Limestone which has clearly played an important role in the development of the interstratal karst.

2.35 Figures 17 and 18 are surface related plans of Chartist Cave and Ogof Cynnes both of which have rectilinear patterns that are indicative of a strong structural influence on their development. No surface related plan is available for Crescent Cave but a survey and profile on www.cavinguk.co.uk/info/cresSurv/ show the horizontal and vertical complexity of this cave that has developed entirely under a cover of Millstone Grit.

2.36 The Blaen Onneu Quarry Caves (no 1 and No 2) provide an important contrast to Ogof Cynnes, Chartist Cave and Crescent Cave in that they are developed a short distance below the Millstone Grit-limestone unconformity. No surveys are known to exist and the caves are only accessible for a few tens of metres but they appear to be trending beneath the grit. The roof of the lower cave (Oldham's No 1) has a mammelated form that could be a paleokarst horizon. Oldham (1986, pg 2) also states that the No 2 cave has been smoke tested to Cave No 3 and Cave No 4 and that "The northern side of this quarry appears to be one large boulder ruckle". However, the location map that he provides has no north point and when it is correctly orientated it is clear that the No 3 and No 4 caves, and the 'boulder ruckle' lie to the west in an area of Millstone Grit. No description is given of the No 3 and No 4 caves and they were no located during the present study. However, Blaen Onneu Quarry Caves No 1 and No 2 clearly form an integral part of the interstratal karst interest.

2.37 The hydrology of Mynydd Llangynidr is described by Gascoine (1989) who reports water tracing experiments that showed two sinks to the west of the GCR site (presumably in caprock dolines as this is well within the area where Millstone Grit crops out) drain south to Ffynnon Shon Sheffrey. However, a sink in a caprock doline northeast of Ogof Cynnes, another sink about 1km to the east and Pwll Coch were all traced east to Ffynnon Gisfaen. A sink about 360m northnortheast of Pwll Coch was traced to the Ace of Spades inlet in Agen Allwedd. The tracing experiments were undertaken with Lycopodium spores and have not been replicated but it would appear that there is an underground watershed beneath Mynydd Llangynidr. Figure 12.3 in Smart & Gardener (1989) also shows a trace from Ogof Cynnes to Ffynnon Gisfaen and from Blaen Onneu Quarry to the Turkey Streamway in Agen Allwedd.

Figure 9 : Caprock doline with entrance to Crescent Cave (behind figure)

Figure 10 : Entrance to Crescent Cave – exposed bedrock is all Millstone Grit

Figure 11 : Millstone Grit exposed in roof of entrance chamber, Crescent cave

Figure 12 : Arched entrance (in Millstone Grit) to Chartists cave

Figures 13 : Looking back towards entrance of Chartist Cave. Roof Millstone Grit; walls limestone

Figure 14 : Caprock doline with gritstone arch and entrance to Ogof Cynnes

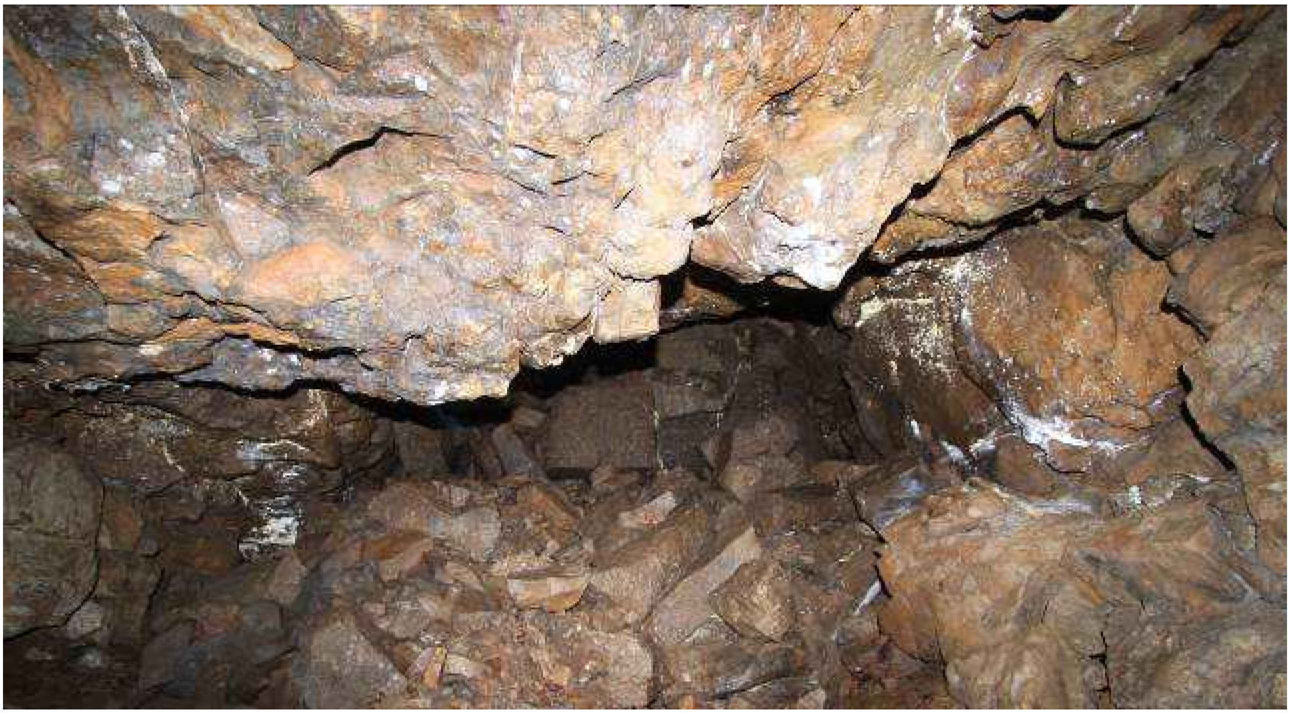

Figure 15 : Entrance chamber of Ogof Cynnes. Roof Millstone Grit; walls limestone

Figure 16 : Lens cap is at junction of Millstone Grit and limestone, Ogof Cynnes

Figure 17 : Surface related plan of Chartist Cave (compiled by John Stevens)

Figure 18 : Surface related plan of Ogof Cynnes (compiled by John Stevens)

3. FIELD SURVEY & PROPOSED SSSI BOUNDARY

3.1 The Mynydd Llangynidr interstratal karst extends over an area of ~12km^2 and budgetary constraints limited the time for fieldwork to three days. It was clear from the descriptions in Thomas (1974) and in the GCR Volume (Waltham et al., 1997) that the core of the GCR site is of very high value and hence it was decided to focus mapping along the indicative boundary of the GCR site with a view to determining the location of any areas of interstratal karst importance outside the indicative boundary and any areas inside the indicative boundary that did not have interstratal karst interest features. Unfortunately on 2½ of the days the visibility was less than 50m, dropping to less than 25m for part of the time and this both made for slow progress and meant that features more than 50m from the transects could not be seen. However, very good aerial photograph coverage is available for the area and this has allowed those areas that could not be visited to be assessed using information gained from those areas that were visited.

3.2 The procedure adopted was to create a series of Waypoints using a hand-held Garmin GPS 12. At each Waypoint photographs were taken and notes made. The locations were exported to Excel and CCW imported them into a GIS and overlaid them onto aerial photographs and 1: 10 000 Ordnance Survey sheets allowing the field notes and photographs to be placed in context. The majority of the Waypoints are considered to be accurate to less than +/-5m horizontally based on recording of the same point at the start and end of each transect and on the recording of known points such as Garn Fawr and a trig point. However, Waypoints in the base of steep-sided dolines have a lower accuracy.

3.3 During the transects over one hundred dolines were recorded, confirming the density of these features. There was a remarkable variability in diameter, depth, shape and materials. They included a full range of morphologies from shallow flat-floored to deep and steep-sided. Several dolines acted as stream-sinks, some contained standing water bodies and some contained reeds but the majority were free-draining. Exposed in-situ bedrock was only present in a few dolines but coarse grit blocks were a feature of many and a small number appeared to be developed entirely in foundered grit.

3.4 As expected from the published work of Thomas reviewed in Section 2 it is clear that the special scientific interest of the site derives from both the individual landforms and from the remarkable density of the caprock dolines, far greater than in any other part of Great Britain. These are not fully reflected in the indicative GCR boundary as there are important interstratal karst areas outside the boundary whilst some areas where no interstratal karst interest has been identified are within the boundary. To correct these imbalances a new GCR boundary is proposed that contains all of the interstratal karst interest features identified with the exception of a small number of outlying caprock dolines that are separated from the core zone of interstratal karst by areas that contain no interest features. The proposed GCR/SSSI Boundary for the eastern part of the site is shown on Figure 19 and the western part is on Figure 20. The key differences between the indicative and proposed boundaries are discussed below.

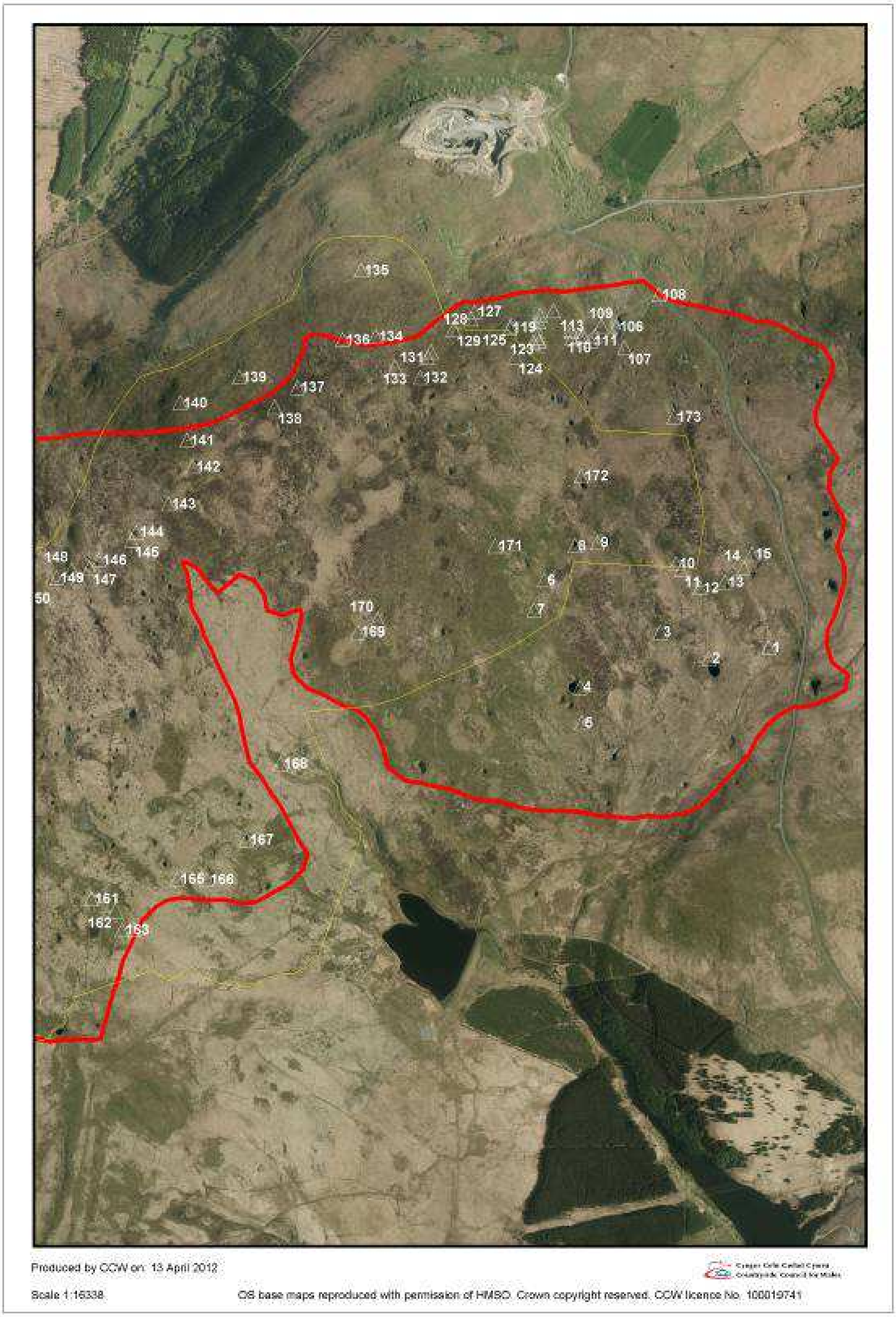

Figure 19 : Eastern Mynydd Llangynidr.

The yellow line is the indicative GCR boundary and the red line the proposed GCR/SSSI boundary. The numbers are surveyed Waypoints

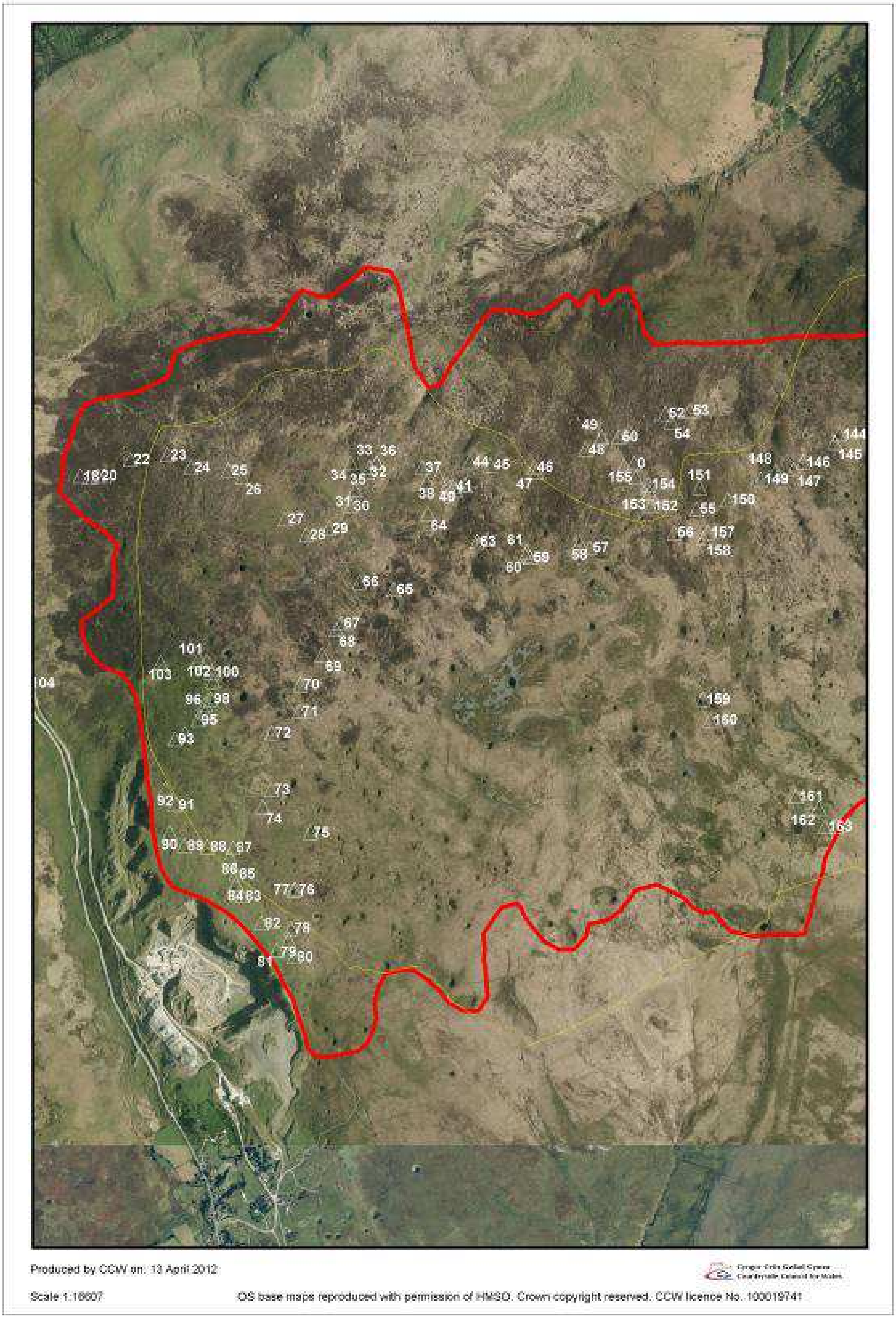

Figure 20 : Western Mynydd Llangynidr.
The yellow line is the indicative GCR boundary and the red line the proposed GCR/SSSI boundary.
The numbers are surveyed Waypoints

3.5 The eastern boundary of the pSSSI has been drawn to the east of the B4560 to enclose a group of large caprock dolines that are an integral part of the Mynydd Llangynidr interstratal karst. They lie within the current Mynydd Llangatwg (Mynydd Llangattock) SSSI which incorporates the Mynydd Llangattwg Caves GCR site and is notified for this cave feature as well as various biological special interest features. These dolines include Pwll Coch, the largest of the caprock dolines (Figure 8). There are several isolated caprock dolines to the east of the proposed boundary but they do not form part of the core doline assemblage.

3.6 The northern edge of the eastern pSSSI boundary crosses the B4560 close to the old Blaen Onneu Quarry at WP108 and then trends west past the northern edge of the quarry. This former limestone quarry is important as the caves provide access beneath the unconformity at the top of the limestone sequence (see paragraph 2.35). They also contain speleothems that have formed on collapse blocks. Their basal age would provide a minimum date for the end of collapse.

3.7 Immediately to the west of the quarry edge lies an area of foundered grit that was not recorded by Thomas. Continuing west there are several caprock dolines followed by a more extensive area of foundered grit that contains unusual dolines (Figures 21 and 22). Another doline in the same area (which is outside and immediately west of the indicative GCR boundary) has in situ Millstone Grit bedrock in the backwall but appears also to be part of an area of foundered grit (Figure 23).

Figure 21 :
Extensive area of foundered grit close to Waypoint 120

Figure 22

One of several small dolines in the foundered grit close to Waypoint 120

Figure 23 : Doline close to Waypoint 125

Millstone Grit is in situ behind the figure and there is an extensive grit scree downslope

3.8 Continuing west, the boundary of the pSSSI initially runs well to the south of the GCR boundary as no features of special interest were located in this area. However, to the west of Waypoint 141 the pSSSI boundary encompasses an area of land to the north of the GCR boundary. This was only partially mapped on the ground but the aerial photograph confirms that it contains numerous dolines. On the BGS 1:50k Sheet 232 most of this area is mapped as Dowlais Limestone. However, Thomas (1974) suggests that the limestone only crops out as a series of outliers and that most of the area is what he terms “Collapsed and Soliflucted Grit on Carboniferous Limestone”. The boundary was placed using the aerial photographs and encloses virtually all of the dolines. Similarly, continuing west the pSSSI boundary varies from the GCR boundary as it is drawn to contain the majority of dolines and an area of foundered grit. It is recognised that some of these dolines in this area, particularly the smaller ones, may not be caprock dolines but instead are probably ‘normal’ solution dolines formed in limestone bedrock. However, the complexity of the area is such that inclusion of all dolines is justified. This can be illustrated by reference to WP50 and WP52 on Figure 10. Both are well within the area shown on the BGS map as being Dowlais Limestone but whereas limestone crops out at WP52 (Figure 24), some 150m to the east at WP50 there are several dolines with extensive trains of grit boulders (e.g. Figure 25) that are similar to those well inside the area underlain by grit. Moreover, the limestone at WP52 is at a height of 521m (OD, from GPS) whereas the doline rims are at 510m OD.

Figure 24 : Limestone cropping out at WP52 (shown by GPS unit)

Figure 25 : Caprock doline with extensive train of grit boulders adjacent to WP50

3.9 The western limit of the northern boundary of the pSSSI is placed at WP18. As in the areas to the east, this area is mapped by BGS as Dowlais Limestone but is better described as “Collapsed and Soliflucted Grit on Carboniferous Limestone” and there are several dolines such as the one shown in Figure 26 that contain water bodies and hence are unlikely to be simple solution dolines. South of WP18 the boundary is again drawn to include the majority of dolines and extends south of the GCR boundary to abut Trefil Quarry. The pSSSI encompasses all of the land being considered for inclusion as a “preferred area of search for mineral extraction” in the draft Blaenau Gwent LDP and this is discussed in more detail in Section 4.

Figure 26 : Shallow interstratal doline with water body near WP18

3.10 From Trefil Quarry the proposed boundary trends east, briefly coinciding with the indicative GCR boundary before trending north to exclude areas that have no (or very few) dolines and no interstratal karst interest. This includes the large, shallow valley at the head of Cwm Odyn-ty that extends to within 450m of the proposed northern boundary.

3.11 The pSSSI boundary follows the head of the valley and then trends southsoutheast across the indicative GCR boundary before heading west and then northwest to meet the B4560 close to Pwll Coch as described in paragraph 3.5. The area to the south of the indicative GCR boundary contains many interstratal dolines including several with standing water bodies (Figures 27 and 28).

Figure 27 : Shallow doline with water body at WP2 in east of pSSSI

Figure 28 : Large doline with water body at WP4 in east of pSSSI.
A stream enters the doline but there is no evidence that the lake ever overflows

4. THE “PREFERRED AREA OF SEARCH FOR MINERAL EXTRACTION”

4.1 The western boundary of the pSSSI encompasses all of the land being considered for inclusion as a “preferred area of search for mineral extraction” in the draft Blaenau Gwent LDP. In March 2010 this area was examined by a CCW geologist, Gareth Owen, who mapped 73 dolines in the area in addition to 12 that are shown on the 1:10 000 Ordnance Survey map. He concluded that the area is “packed with features key to the GCR interest and so is a key part of the GCR site”.

4.2 The present survey was undertaken under adverse weather conditions that precluded a detailed assessment of the whole area. Instead a north-south transect was made along the eastern boundary followed by a transect from south to north close to the quarry margin and then north (Figure 29).

4.3 The survey, and the aerial photograph on which it is plotted, clearly shows that this is an area with a high number of dolines. Some of the dolines that are closest to, and largely within the curtilage of, the quarry are in an area where the Dowlais Limestone is shown as cropping out on the BGS 1:50k Sheet 232. It was not possible to confirm this on the ground but some of these dolines appear to be only a few metres in diameter and depth which would be consistent with a solution doline on limestone rather than a caprock doline. However, Thomas (1974) shows a narrow zone that lies between what he terms “Basal Grit” and “Carboniferous Limestone Series” to be occupied by “Collapsed and Soliflucted Grit on Carboniferous Limestone”. He shows the same zone as extending northwards along the western boundary of the Basal Grit and then eastwards along the northern boundary of the Basal Grit. The northern and western boundaries of the pSSSI have been drawn so as to include the majority of this zone (see discussion in paragraphs 3.8 & 3.9). Using the same logic the pSSSI boundary has been drawn closer to the quarry than the indicative GCR boundary which appears to have been drawn primarily on the basis of the mapped boundary between the limestone and basal grit. Hence, the western edge of the pSSSI (and part of the “preferred area of search for mineral extraction”) may include some areas of limestone outcrop and some solution dolines but these are surrounded by areas of collapsed and soliflucted grit that are clearly GCR/SSSI interest features. This is a very complex area that requires further research and this in itself provides further support of its inclusion in the pSSSI. To the east of this zone the “preferred area of search for mineral extraction” is underlain by Millstone Grit strata with many caprock dolines that are fundamental interstratal karst interest features.

4.4 Although it is outside the scope of this report it should be noted that, with the exception of a small strip close to the rim of the present quarry, the limestone in the preferred area of search is overlain by Millstone Grit and superficial deposits. The exact thickness is unknown but Figure 30 shows the doline at WP81, a few metres from the quarry boundary, which is about 5m deep and Figure 31 shows the doline at Waypoint 83 which is about 3m deep. To the north and east there are even deeper dolines (for example, the doline at Waypoints 76 and 77 is over 10m deep) so it is clear that before any limestone could be quarried from this area a substantial thickness of Millstone Grit would have to be removed. If a figure of $2.5t/m^3$ is assumed for the density then for each one hundred square metre area of surface that is cleared of overburden around 7500 tonnes of material will be generated. It is assumed that this will be waste that would have to be tipped. At least some of the Millstone Grit is likely to be intact and coherent and hence may require blasting prior to removal. Moreover, there are also extensive areas of foundered gritstone boulders such as those between Waypoints 85 and 86 (Figure 32). It is assumed that this would also be waste that would have to be removed prior to quarrying of limestone.

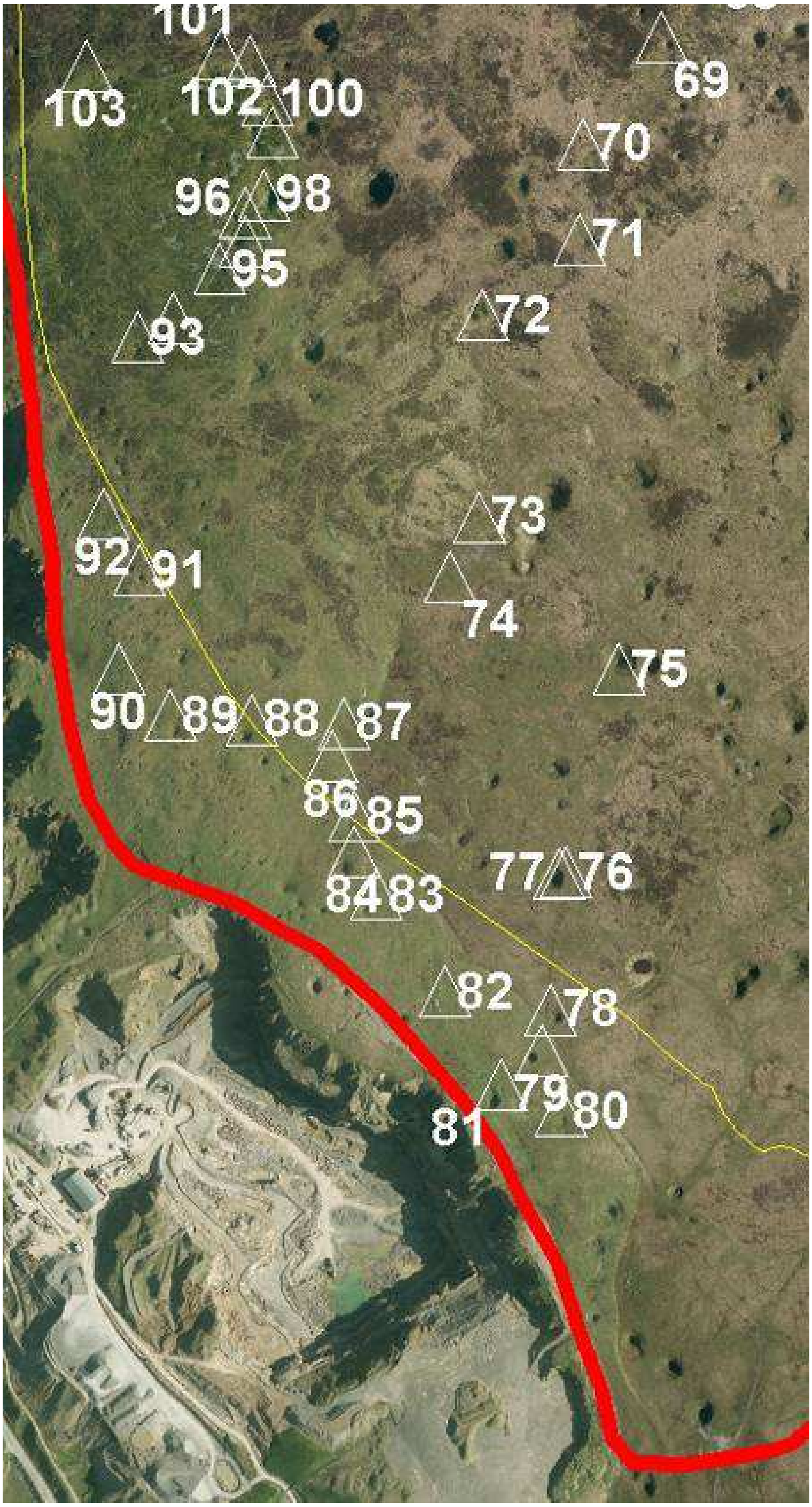

Figure 29 :

Aerial photograph of the preferred area of search showing the many caprock dolines. The yellow line is the indicative GCR boundary, the red line is the proposed GCR/SSSI boundary and numbered triangles are GPS surveyed Waypoints

Figure 30 : Doline at Waypoint 81. Quarry fence posts barely visible in background

Figure 31 : Doline at Waypoint 83

Figure 32 : Extensive area of foundered gritstone extending between Waypoints 85 and 86

5. SUGGESTED REVISED GCR STATEMENT OF INTEREST

5.1 Having re-evaluated the site features the following revised statement of interest is proposed:

Mynydd Llangynidr GCR Site Statement of Interest (DRAFT)

The northern edge of the South Wales Coalfield provides the best British example of an interstratal karst, extending from Black Mountain in the west to the Blorenge in the east. Within this area Mynydd Llangynidr is exceptional for the morphological variety and density of caprock dolines whilst also containing shallow subsidence depressions and foundered rock masses of varying topographical form.

The site covers the summit area and upper dipslopes of Mynydd Llangynidr, where the solid outcrop is dominantly the Twrch Sandstone Formation, locally the base of the Marros Group of Namurian age and informally referred to as the 'Millstone Grit'. The Twrch Sandstone Formation is underlain by the Dowlais Limestone Formation, locally the top of the Pembroke Limestone Group (informally referred to as the 'Carboniferous Limestone') but there is an unconformity that covers several million years between the two formations. To the north of the site the Carboniferous Limestone forms an escarpment that overlooks the Usk Valley.

The site includes a densely packed doline field that clearly demonstrates how subsurface interstratal karst solution can induce collapse, pitting and foundering in the overlying non-carbonate outcrop. Although broadly classified as caprock dolines there is an array of depression morphologies ranging from shallow-sided forms that commonly contain permanent or ephemeral water bodies through to deep, steep-sided depressions. Some of the caprock dolines appear to have captured small surface streams and function as sinks and there are also unusual dolines developed entirely in grit boulder fields. In addition to surface landforms, Ogof Cynnes, Chartist Cave and Crescent Cave are of particular importance as they allow the interface between the grit and the limestone to be viewed in greater detail from underground, and provide further insights into the development of interstratal karst. Blaen Onneu Quarry Caves No 1 and No 2 provide a contrast to these caves as they are developed at a slightly lower horizon but appear to have connections to the grit. Hence they are also part of the interstratal karst interest.

Mynydd Llangynidr is of international importance and provides tremendous potential for future research into caprock doline morphology and interstratal karst development.

6. CONCLUSIONS

6.1 The Millstone Grit country fringing the upturned northern edge of the South Wales coalfield is undoubtedly the outstanding British example of an interstratal karst. and within this area Mynydd Llangynidr has the most spectacular assemblage of collapse dolines together with other features of interest. As part of the present study three leading international karst experts who have particular knowledge of doline karsts were contacted and asked whether they were aware of equally good examples of caprock dolines and interstratal karst: Dr Alexander Klimchouk (Ukraine), Dr Art Palmer (USA) and Professor Paul Williams (New Zealand). Their collective experience, and that of Professor John Gunn, extends to over 60 countries and all of the world's major karst regions. With respect to Mynydd Llangynidr they all concur that there is "***no better site with such fine expression of collapses in competent limestone under a strongly cemented caprock***" (Williams, 2012, pers. comm.). In short, this is a site that is not just the best of its kind in Great Britain, it is of global importance.

6.2 A revised GCR statement of interest and boundary have been proposed. The revised boundary encompasses the interstratal karst interest surface features (caprock dolines, subsidence depressions, foundered basal grit) and five caves that are integral to the interstratal interest. It is recommended that the GCR site should be protected as a SSSI. It is considered essential that the entire doline field is included since one of the aspects that makes the site special is the number, variety and density of caprock dolines. As discussed in paragraphs 3.8 and 3.9, there are some areas within the boundary where limestone crops out and these are clearly not part of the interstratal karst. However, these limestone outcrops are surrounded by complex areas described by Thomas as containing "collapsed and soliflucted Grit on Carboniferous Limestone" and these form an integral part of the interstratal karst interest. Although time has not permitted examination of the ground, evidence from aerial photographs and from Thomas (1974) suggests that most of the dolines outside the pSSSI are solution dolines on limestone bedrock and not part of the interstratal karst. There are also a small number of probably caprock dolines that are several hundred metres outside the pSSSI boundary but in the absence of any interstratal karst interest features in the intervening area it was felt that extension of the boundary to include these isolated features could not be justified. In contrast, the area identified in this report as being within the recommended pSSSI boundary is of special interest and all of the interstratal karst features within the boundary (dolines, shallow subsidence depressions and foundered rock masses together with the five caves) should be preserved.

6.3 The proposed SSSI encompasses land being considered for inclusion as a "preferred area of search for mineral extraction" in the draft Blaenau Gwent LDP. It is recommended that this proposal should be opposed as the area contains over 70 caprock dolines and is an integral part of the pSSSI. Moreover, with the exception of a small strip close to the rim of the present quarry, the limestone is overlain by Millstone Grit and superficial deposits. The exact thickness is unknown but on the basis of dolines close to the present quarry it is estimated to be at least 3m, rising to over 10m deep further north and east. This implies that a large amount of material would have to be removed and tipped before the limestone could be extracted.

ACKNOWLEDGEMENTS

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