Limestone Research & Consultancy Limited

THE HYDROLOGY & HYDROGEOLOGY OF COWDALE QUARRY AND ENVIRONS

COMMISSIONED BY
EXPRESS PARK (BUXTON) LTD

PREPARED BY
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1. Scope

1.1 This report has been commissioned by Express Park, Buxton Ltd to support a planning application to develop Cowdale Quarry, Buxton, Derbyshire. The development comprises a water bottling plant and associated storage areas with new access off the A6, internal roads and a heritage visitor centre.

1.2 The present report describes the hydrology / hydrogeology of the site and assesses the potential impacts from the proposed development. A separate report by Jubb Consulting Engineers Ltd addresses the flooding risk arising from surface runoff from the site.

1.3 This report has been prepared exclusively for Express Park, Buxton Ltd and their professional consultees in relation to the proposed development. It may not be relied upon or reproduced by any third party without the written agreement of Limestone Research & Consultancy Ltd.

1.4 All statements and opinions contained within this report arising from the works undertaken are offered in good faith and compiled according to professional standards. No responsibility can be accepted by Limestone Research & Consultancy Ltd for any errors of fact or opinion resulting from data supplied by any third party, or for loss or other consequence arising from decisions or actions made upon the basis of facts or opinions expressed in this report howsoever such facts and opinions may have been derived.

2. Context

2.1 Cowdale Quarry is located south of the A6 at Ashwood Dale in Derbyshire and approximately 1.5km east of the edge of Buxton. The site occupies approximately 17.8 hectares and is located at OS National Grid Reference SK 07940 72340.

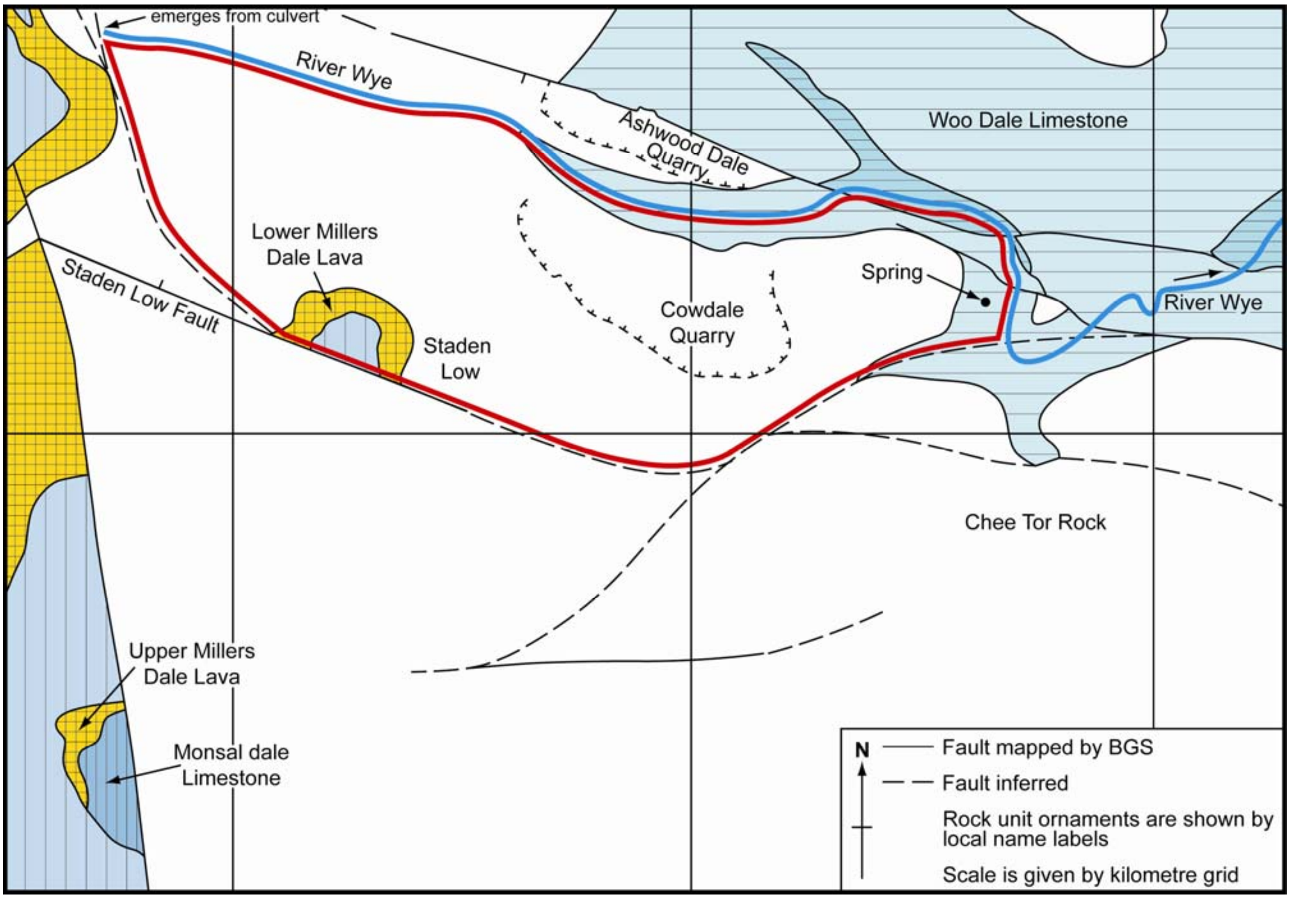
2.2 The quarry was excavated in Carboniferous Limestone (Chee Tor Rock) using black powder. Working commenced in 1898 and active working ceased around 1948 although the quarry was subsequently used for the storage of stone and not finally closed until 1955. Since 1955 the quarry floor has been partly reclaimed and is under pasture. There are also piles of waste rock in the quarry.

2.3 The site currently drains by natural infiltration into the underlying limestone. No surface runoff has been observed from the site and there are no obvious surface drainage lines but analysis by Jubb Consulting Engineers suggests that there may be overland flow from the site to the River Wye during extreme rainfall events.

2.4 The quarry is situated in the catchment for Rockhead Spring (see Figure 1 & Section 3.2 below) which was recognised as a Natural Mineral Water in 2000.

2.5 The Carboniferous Limestone that underlies the quarry is a major aquifer and the site is in a large Source Protection Zone (SPZ) that is nominally an inner zone but was drawn to encompass the potential catchment zone of all the licensed sources in the Buxton area. It is important to recognise that unlike many SPZ this does not represent the area that is required to supply the sources with the licence quantities but instead indicates an area where there is a possibility that conduits may exist that could provide water to the sources. Such an approach is necessary because the area is underlain by karstified limestone bedrock and the pathways followed by dispersed and concentrated recharge cannot be predicted on the basis of geology and topography alone.

Figure 1 : Geology of the area around Rockhead Spring (putative proximal catchment shown in red)



2.6 It is planned that water from Rockhead Spring will be bottled in the factory. Hence, protection of groundwater quality is of paramount importance to the developer as any contamination of the spring water, particularly by hydrocarbons, would have very serious consequences.

2.7 As part of the present Abstraction Licence for Rockhead Spring it is necessary for the abstractor to provide compensation water to the River Wye when the discharge of the river (and that of rivers to which it is a downstream tributary) falls below certain threshold levels. Currently the compensation water is provided by a borehole at Staden, some 1.6km from the river, but subject to agreement from the Environment Agency it is proposed that some compensation water will be provided from the development area (see below).

3. Hydrogeology

3.1 The geology and hydrogeology of the Carboniferous Limestone in the vicinity of the site are poorly understood and the published maps of the British Geological Survey provide only a general view of the geology based on a limited number of exposures and boreholes.

3.2 As part of the process of obtaining recognition of Rockhead Spring as a Natural Mineral Water, an initial geological appraisal was undertaken by the Limestone Research Group, University of Huddersfield. This suggested that the proximal catchment area of the spring is likely to be bounded to the south by a fault; to the west by an unnamed valley that joins the Wye at Lovers Leap; and to the north by the River Wye.

3.3 In 1997 a more detailed appraisal was undertaken by Dr D J Lowe, who was a Principal Scientific Officer with the British Geological Survey and had previous experience of mapping in the Buxton area. Dr Lowe has now retired from BGS and acts as a sub-contractor to LRC Ltd.

3.4 The stratigraphy, structure and probable proximal catchment area of the spring are shown on Figure 1 and Dr Lowe's report is included in Appendix A. The proximal catchment area is approximately 65 ha.

3.5 The water chemistry and flow regime appear to indicate that the Rockhead Spring water is derived from more than one source and the proximal catchment area is smaller than would be expected from the discharge of the spring. Following field mapping, Dr Lowe suggested that there may be a fault, not shown on published maps, running roughly along the line of Cowdale and that this may have influenced the location of the spring. On the basis of other research it seems highly likely that there is a much larger groundwater body feeding from the south directly into the Wye through the bed of the river and discrete springs. Rockhead spring is likely to be the lowest 'overflow' point for some of this water (see Appendix A and particularly Figure A4) but the boundaries of this distal catchment are uncertain; hence the large SPZ.

4. Hydrogeological aspects of the proposal

4.1 As there has been no quarrying or industrial activity on the site for over 50 years the potential risk of contamination from historic activities is considered low and an initial walkover survey has found no evidence of any materials that might present a risk to groundwater quality. However, a detailed assessment would be undertaken before any construction work is undertaken.

4.2 The water from Rockhead Spring is currently piped to the Staden Industrial Estate for bottling. It is proposed to take a spur from this line into the new bottling plant in the quarry. No impacts on groundwater are foreseen from this work.

4.3 Subject to agreement with the Environment Agency it is proposed that clean water from roofs will be channelled to storage lagoons on site and that 6000 cubic metres of water will be stored during the winter for use as compensation water if required later in the year.

4.4 Once the storage lagoons have reached 6000 cubic metres any additional clean water from roofs will be directed to a soakaway or soakaways. As part of the design process a water tracing experiment will be undertaken from each soakaway to establish the direction and speed of groundwater movement. The objective will be to ensure that as possible of the original proximal catchment continues to supply recharge to Rockhead Spring.

4.5 No water from roads and vehicle parking areas will be allowed to infiltrate or be sent to soakaways to avoid any possibility of groundwater pollution. All such water will be passed through interceptors and discharged directly to the River Wye at an agreed rate.

4.6 If it is assumed that under natural conditions water from roads and vehicle parking areas would have infiltrated and recharged groundwater flowing to Rockhead Spring then this represents a loss of flow from the spring. The extent of the loss is impossible to assess because of uncertainties in the area of the distal catchment.

5. Conclusions

5.1 The proposed development is situated within an inner Source Protection Zone that has been drawn to protect groundwater discharging from Rockhead Spring.

5.2 The risk of derogation of water quality at Rockhead Spring as a consequence of the development is considered to be very low as no potentially contaminated water will be allowed to infiltrate.

5.3 The development is likely to result in a small derogation of water quantity at Rockhead Spring as water from roads and vehicle parking areas will not be allowed to infiltrate or be sent to soakaways to avoid any possibility of groundwater pollution. It is impossible to assess the degree of derogation, particularly given uncertainties regarding the distal catchment, but it is likely to be small and to pose no risk to the licensed abstraction.

APPENDIX A
REPORT ON THE GEOLOGY OF THE ROCKHEAD SPRING AREA BY DR D J LOWE

Geological Setting

A1.1 Published maps of the British Geological Survey provide a general view of the geology in the Cowdale area (Table A1). Much of the information that can be gained from the maps is not readily apparent to casual users. Many observations not detailed explicitly on the maps underlie the interpretation depicted, and the significance of what is shown may be apparent only to those with a wide experience of the conventions used in presenting geological map data. Additional fieldwork around Cowdale suggests firstly that the area is more heavily faulted than the published interpretation implies and, secondly, that the area has a more complex fold structure.

A1.2 Solid rock is not exposed at or immediately adjacent to the spring site, which is covered by recent alluvial deposits of the River Wye and possibly also by older, unconsolidated, sediment derived by erosion and downslope movement of material from nearby valley sides. This lack of exposure precludes definite identification of the underlying bedrock and prevents direct observation of the attitude of the rocks (particularly their dip direction) and any associated fracture patterns. However, on the basis of the closest exposures and landscape features, and a knowledge of the regional situation, it is possible to make informed deductions.

Table A1: The solid rock units present in the area around Rockhead Spring

Name of rock unit	Local combinations of units	Local thickness
Monsal Dale Limestone		up to c.100m
Upper Miller's Dale Lava		0 - ?5m
Miller's Dale Limestone	} } Undifferentiated, combined as	c.30m
Lower Miller's Dale Lava	} the Bee Low Limestone, where } the lava cannot be identified	?0 - c.25m
Chee Tor Rock	}	c.120m
Woo Dale Limestone	} } Woo Dale Limestone (which } includes the dolomites once	} c.70m } } 340m+
Woo Dale Dolomite	} termed the Woo Dale Dolomite) }	} 270m+ }

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A1.3 The spring lies well below the base of the distinctive Chee Tor Rock unit, which was formerly extracted from the now disused Cowdale Quarry. Consideration of known rock thickness suggests that the spring is at or very close to the junction between the Woo Dale Limestone (beneath the Chee Tor Rock) and the underlying Woo Dale Dolomite (in the sense used on published geological maps). Recent practice is to view the Woo Dale Dolomite as a local facies variation, and the two former units are known simply as the

Woo Dale Limestone, but in this discussion it remains advantageous to recognise the dolomitic rock type as a separate local division. Geological cross-sections constructed in three directions through the spring site indicate that the solid rocks must be bent upwards into a significant anticlinal fold (Figures A1-A3). Thus, there is a possibility that the lower, dolomitic, formation reaches the rockhead surface at the spring site, though the superficial cover prevents this being confirmed.

A1.4 Locally the axial trace of the anticline referred to above trends approximately along the line of the Wye Valley, plunging westward along Ashwood Dale towards Buxton. Several major rock fracture (or fault) zones also follow this roughly east-west trend. The combined effect of the east-west faults and the inferred fold structure is to make it very unlikely that any significant amount of shallow underground drainage approaches the River Wye from the north in the vicinity of the spring site. However, it is known from tracing experiments that drainage from the north does enter the Wye along reaches both upstream and downstream of Rockhead.

A1.5 A series of gentle "interference" folds crosses the areas north and south of the Wye Valley, rippling the rock beds on the limbs of the major anticline and running approximately at right-angles to its trend. Their presence is not readily discerned on the published geological map, but is indicated by local variations in the limestone dip, by the nature of the surface landforms and by exposure in Cowdale Quarry. A gentle syncline, plunging southwards, is visible at the eastern end of the quarry, and there is a complementary plunging anticline to its west. By implication, a second gentle syncline runs sub-parallel to the two visible folds and passes beneath the high ground of Staden Low. Even such gentle folds can have great hydrological significance.

A1.6 The whole series of southward plunging fold ripples on the southern limb of the main anticline is cut, and potentially displaced, by a west-east fault just south of Staden Low. This fault probably continues eastwards towards Cowdale Village, beyond the supposed limit shown on the published geological map. Eastward of the published limit the fault crosses, and is possibly offset by, another previously unmapped fault that runs towards Cowdale from the south. Beyond the fault intersection, the west-east fault continues eastwards towards King Sterndale and the other fault continues northwards in the steep gap that carries the minor road from Cowdale towards the A6.

A1.7 Beyond Staden Low the west-east fault discussed above continues westward towards Buxton town. Another fault, not shown on the published map, is deduced to splay from it, passing through a steep-sided gully to link to the termination of a previously mapped fault that runs southwards towards the A6 from eastern Buxton.

A1.8 Thus, the spring site lies within a block of gently folded limestone that dips regionally towards the south, though locally east or west within minor fold ripples, and which is probably limited on all sides by fault fractures of various magnitudes. Those to the north and south appear to be the most significant fractures in terms of vertical displacement and potential effects upon subsurface hydrology, but those to the west and east may also play a part in defining at least one element of the spring catchment (see below).

The Rockhead Spring catchment.

A2.1 The geological situation suggests that underground water from at least three sources could contribute to the output of the Rockhead Spring.

(a) Young local water

A2.2 The probable local surface catchment, comprising a surface area of about 65ha, is defined by:

- The Wye Valley faults in the north (though according to the published map there is an unfaulted section close to Buxton);
- The "Staden Low" fault in the south and its deduced eastward extension;
- The fault deduced as running through the Cowdale "gap" in the east;
- A fault deduced as running from Staden Low towards eastern Buxton in the west.

A2.3 Between these faults much of the surface is composed of Chee Tor Rock, dipping generally southwards, but rippled by minor faults as described above. Most meteoric water falling on the Chee Tor Rock within this fault-bounded area will be absorbed directly into the ground and will tend to move downwards through the lithologically homogeneous rock unit via the most advantageous combination of fissures and bedding planes. Locally some of this seepage will penetrate into the underlying Woo Dale Limestone. Likewise, any precipitation falling onto exposed Woo Dale Limestone will tend to move downwards through the rock. However, the Woo Dale Limestone is not homogeneous. Included beds of impure limestone and clay would be expected to have guided preferential development of drainage conduits at specific levels within the rock. Thus, whether precipitation falls directly onto the Woo Dale Limestone or passes into it from higher beds, its generally downward seepage or flow is probably arrested and/or diverted within the Woo Dale Limestone itself, and water will be held "perched" at one or more levels. The overall southward dip will establish "prism-shaped" water bodies, lying above the atypical beds, with further southward (down-dip) migration blocked by juxtaposition against rock with less favourable hydraulic properties south of the "Staden Low" fault line (Figure A4). Minor folds on the anticlinal flank will have a local modifying effect on the shape and water movement directions into and out of the reservoirs. The detailed geometry of these water bodies, and how they behave, will depend upon the detailed relationships of the atypical horizons within the rock mass, the nature of the rocks (and any complementary atypical horizons) south of the "Staden Low" fault line and the precise nature and attitude of the beds at the spring site. It is highly likely that at least some of the spring water derives from up-dip overflow of one or more of these prism-shaped water bodies (Figure A4).

(b) Fault guided water

A2.4 Details of the structures affecting the rocks beneath the spring site are unknown. Thus, it is unclear whether the means of outlet for groundwater at this point is via a bedding plane that opens to the surface (as would be one explanation of the situation discussed in (a) above), via upward widening joints (as would be expected in case (c) below) or whether one or more fault fractures is present beneath the site. Fault fractures, if present, could function as hydraulic pathways, allowing upward escape of deep water or (by breaching conduits associated with atypical horizons in the Woo Dale Limestone) shallower local water. On theoretical grounds it is likely that whereas the dominant regional function of the Woo Dale Limestone may be as a compound aquitard or aquiclude, the underlying dolomitic beds (the Woo Dale Dolomite) may function overall as an aquifer, or at least contain beds that display relatively favourable aquifer properties. Thus, fractures that penetrate the dolomitic beds and the non-dolomitic Woo Dale Limestone may allow upward transfer of "deep" water within the dolomite, driven into the spring area under hydrostatic pressure from more distant areas.

(c) Deep anticlinal water

A2.5 Though not explicit on the published map, it is clear that the hypothesised west-east trending anticline beneath the Wye Valley must plunge generally westwards towards Buxton. Being a component of the overall imperfect domal structure of the Peak District it may also plunge in the opposite direction, with the highest point on its axial trace being in the general area of the Rockhead Spring, or perhaps slightly eastwards towards Woo Dale. If the structure is present beneath Buxton (where other geological complications exist), it will be roofed by younger limestone beds than those in the spring site area. Conversely, the beds at rockhead in the spring area will be deeply buried by younger rocks beneath Buxton. Buxton itself is well known for its many springs, including several that emit thermal waters. The precise origin of the various spring waters met in the town is unknown, but the thermal nature of some of the springs indicates that these are fed at least partly from deep rock sources. Whereas under gravitational drainage conditions the axes of plunging synclines provide the preferred guiding structures for significant underground water transfer, under "confined" conditions a reciprocal situation would be expected to prevail, with anticlinal axes guiding the major foci for water transfer. If the Buxton springs are associated with upward leakage of groundwater from different preferred horizons in an essentially anticlinal core situation, it can be imagined that different types of spring water can be produced by the mixing of waters of different age, different chemistry and different temperature rising from conduits or reservoirs that are confined at various stratigraphical levels within the folded carbonate succession. Depending upon the local interplay of the bedding related conduits and fracture systems that allows this upward leakage, different sources may contribute different proportions of water to the emergent spring water at each site.

A2.6 If this type of pressure-driven mechanism is accepted as a possible explanation of the Buxton springs, it is a small step to broaden the extent of the deep confined flow system to allow water transfer at various stratigraphical levels towards the high point in the anticlinal crest that, as discussed above, would be expected to lie somewhere between Cowdale and Woo Dale. At this locality the higher beds in the sequence are missing due to erosion, but drainage held beneath or within the effective compound aquitard of the Woo Dale Limestone could be driven into the area. Once in the highest available position within the fold the waters could be tapped off via fractures. These could be fault fractures or simply joints, which would be expected to widen upwards in an anticlinal situation. As in Buxton, a degree of mixing with waters at shallower level within the succession, for instance that discussed in case (a), would be expected.

Discussion

A3.1 The water chemistry and flow regime appear to indicate that the Rockhead Spring water is derived from more than one source, and the cases discussed above provide examples of the types of source that are potentially involved. Water collection, storage and transport mechanisms in each case are only viable on the basis of the view that carbonate rock successions of the type met in the Peak District do not provide de facto aquifers, but are only enabled as aquifers by the presence within them of voids that are almost entirely the product of dissolutional activity. Many such voids are related to specific horizons within the carbonate mass and the presence of conduits associated with these "inception horizons" allows the establishment of discrete zones of permeability and storativity within the rock that are effectively confined by less permeable carbonate beds below and (more importantly) above. These vertically discrete systems may be juxtaposed or connected by other void systems that have developed by dissolutional widening along fault or joint planes. Thus, it is possible to envisage a complex 3-dimensional "plumbing" system in which water at a particular level within the succession can exist and behave according to the constraints of local geological guidance and be independent of other water bodies above, below or even laterally displaced from the zone in question.

A3.2 This same acceptance that the Dinantian limestone succession does not provide a single, homogeneous aquifer allows for the possibility that water could enter the complex "plumbing" system described across stratigraphical or faulted contacts under buried, confined, conditions, from adjacent rocks, such as Namurian sandstones, that are more efficient aquifers. Flow at great depth beneath the Peak District may thus be driven by head pressures remote from the present area of interest. Due to the remoteness of these potential source areas and the attenuated hydraulic links involved, the water movement would be slow and hence the water may be of considerable age.

Figure A1 : Southwest – Northeast section of Wye Dale and Ashwood Dale

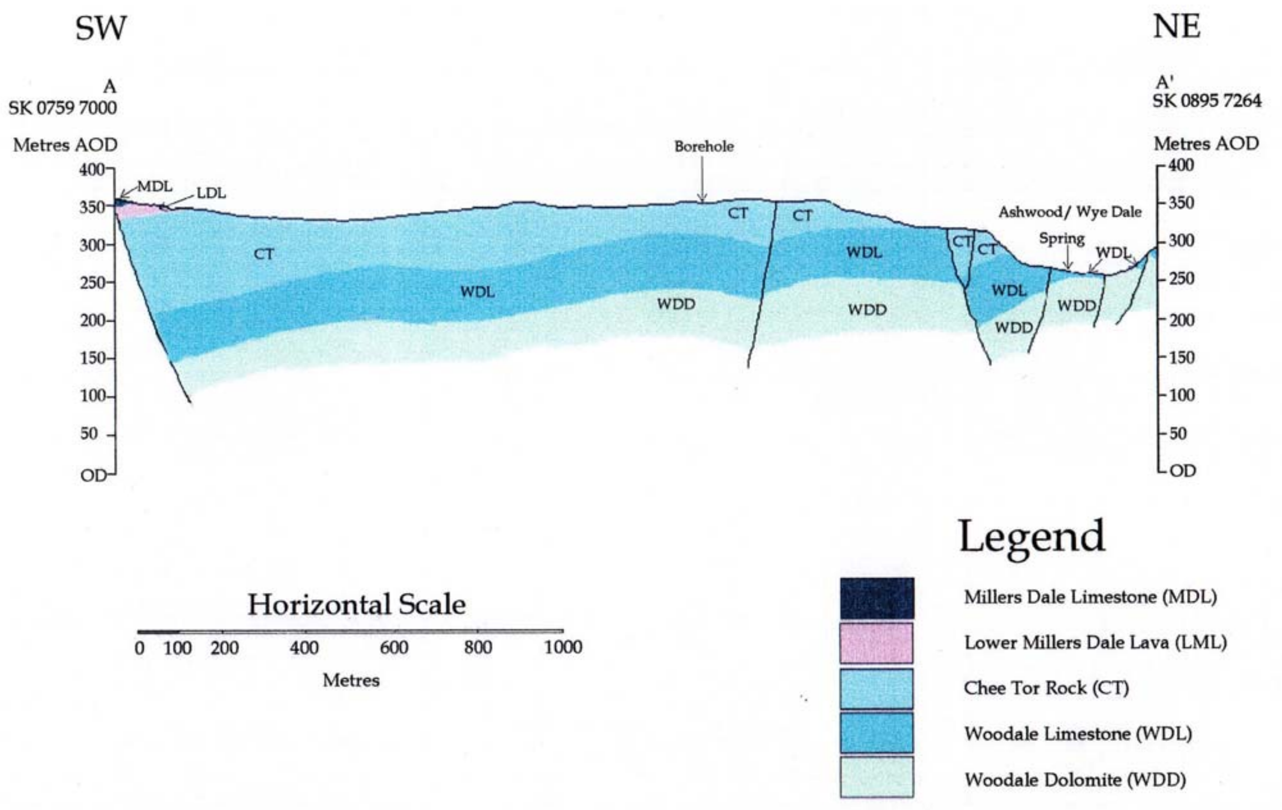

Figure A2 : West – East section across Wye Dale and Ashwood Dale

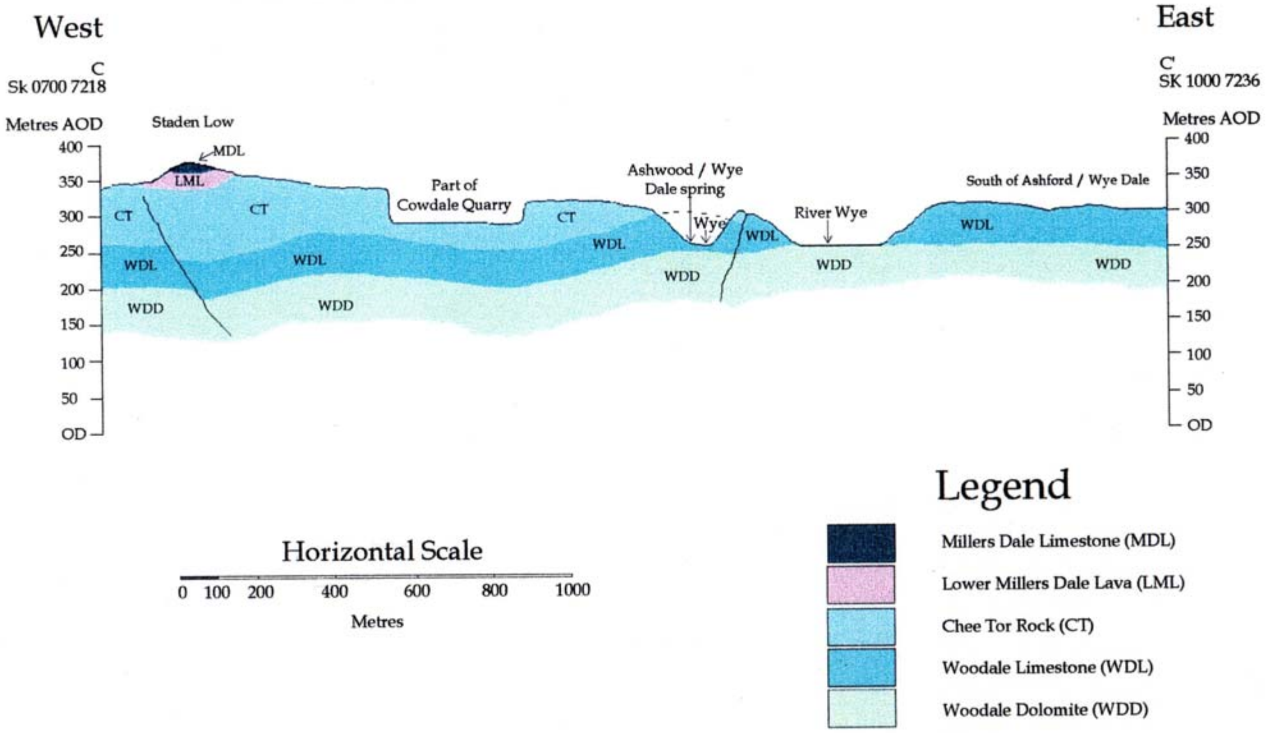

Figure A3 : Northwest – Southeast section across Wye Dale and Ashwood Dale

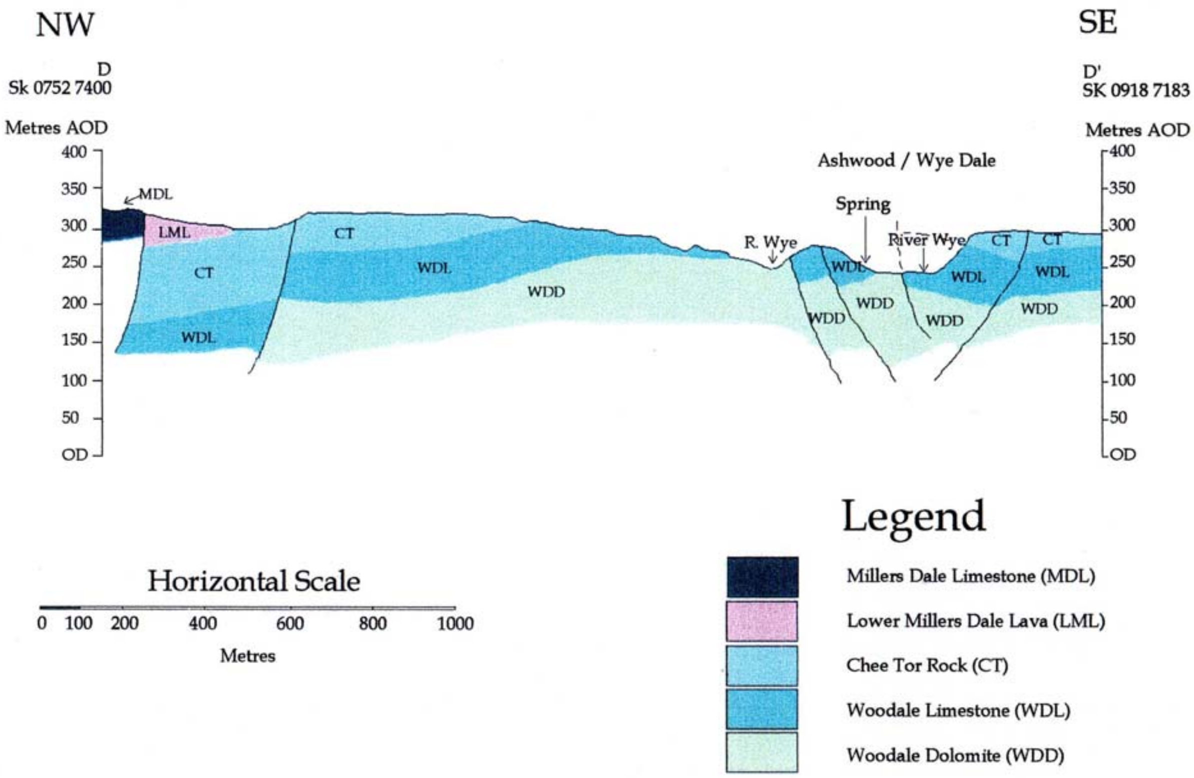

Figure A4 Schematic geological section through Rockhead Spring