THE ARTIFICIAL DRAINAGE OF THE WIRKSWORTH - CROMFORD AREA

by C.D. Oakman

INTRODUCTION

Studies of the artificial drainage of the Wirksworth-Cromford area have so far been limited in scope mainly to history. Pioneer research was published by Nellie Kirkham (1951/2; 1953; 1963). Ottery (1969) and Gould (1978a; 1978b) have added detail chiefly of economic and social content, while Flindall and Hayes (1975) and Flindall, Hayes and Rieuwerts (1977) discussed the technology and progress of sough drivage.

The driving of the soughs depended on contemporary knowledge of the geology, and, in turn, studies of sough records can improve geological interpretation today. Details of the geology have been given in the Geological Survey Memoir for the Derby sheet (No. 125) (new edition in press 1979), by Shirley (1958) and Worley (1978).

A large amount of manuscript data lies in collections in the Derbyshire Record Office, Derbyshire County Library, Ilkeston Library, the Barmasters' Collections at Chatsworth, and elsewhere. Much of this data was collated on to 25 inches to 1 mile maps for the purposes of the author's thesis (Oakman, 1979), and is expanded in this publication. The author is indebted to the Severn-Trent Water Authority for a grant which made the study possible.

THE GEOGRAPHY OF THE AREA

The area under discussion is one which combines the usual picturesque beauty of Derbyshire - bare limestone moorland and deeply incised wooded valleys, and lowland shale topography with the scarps of the stark Millstone Grit - with one of the most heavily industrialised parts of the Peak District. The present day populace is centred on three closely linked communities. The village of Middleton-by-Wirksworth in the west, a linear village nestling below the high lands of Middleton Moor and overlooking the deep Via Gellia valley to the north and the Black Rocks to the east. The second village, Cromford, is located in the north of the area at the confluence of the Via Gellia valley and the Derwent gorge. The small market town of Wirksworth, one and a half miles from both Cromford and Middleton, is in the south of the area, located at the head of the valley of the river Ecclesbourne.

The present day populace is supported by the heavy quarrying industries, and its associated road haulage outlets, as well as the textile industry and farming. However, less than a century ago, the picture was very different. The textile industry was more important than at present, with mills at Wirksworth and the famous Arkwright mills at Cromford, but by far the most significant difference was the importance of the now defunct lead mining industry. The acme of lead mining in the area was from about 1600 to the 1880s, when the price of lead plummetted. Although small-scale mining continued in the area intermittently until the second World War, only ghosts of this vast industry are seen today.

Topographically, the area under consideration is delimited to the north by the deep Via Gellia valley, running from Grangemill to Cromford and the Derwent valley at 280 ft OD. From Cromford, the Derwent runs eastwards to Whatstandwell bridge, and upstream to Matlock further north. To the south the area is delimited by the lowland shale valley of the Scow Brook, soon to be the site of the Carsington reservoir, and the lowland shale valley at the head of the Ecclesbourne around Wirksworth. To the west is the highland of Middleton Moor at 1100 ft OD, and the lower limestone moorlands between the moor and the hamlet of Godfreyhole. In the east are the high gritstone scarps and moors of Barrel Edge and the famous Black Rocks. Thus the area is essentially one of highland limestone, containing one of the most concentrated mineral areas in the whole of Derbyshire.

GEOLOGY

The geology of the area is both stratigraphically and structurally complex, and only in recent years has a better understanding developed (Oakman, 1979). Many facts about the surface geology are well known, and the expansion of many of the quarries in recent years has improved ideas on the stratigraphy. Past workers (Shirley, 1958; Smith *et al.*, 1967) have advocated a series of strong unconformities between the three different lithological formations of the limestone (Cawdor, Matlock and Hoptonwood formations). The importance of these unconformities has been overstressed, many of the lateral variations being more easily explained by facies variations.

The basic lithostratigraphy can be summarised as follows:- the oldest formation is the Hoptonwood formation, consisting of up to 300 ft of pale grey to white massive bedded bioclastic limestones, containing a series of clay wayboards. This formation is overlain in part by the Lower Matlock lava, up to 40 ft thick in the north and west of the area, but absent at Wirksworth. The Matlock formation, up to 150 ft thick, overlies the lava or rests directly on the Hoptonwood formation, and consists of grey to black thick bedded bioclastic limestones, with locally developed chert, shale and reefy horizons, and a series of clay wayboards. The Cawdor formation, up to 100 ft thick, the youngest limestone sequence, consists of dark thin bedded bioclastic limestones, with locally developed reefs and chert horizons. This Viséan limestone sequence is overlain with strong unconformity by the shales of the Namurian Millstone Grit Formation. These shales are up to 500 ft thick, and are capped by the Ashover Grit and the higher Chatsworth Grit.

The structure of the area is dominated by the southeasterly plunging Bolehill anticline (Middleton - Alderwasley anticline of Worley, 1978). This anticline is delimited to the north by the Bonsall fault zone, of WNW - ESE trend at Cromford, and to the southwest by the NW - SE trending Gulph fault. The faults have a net effect of producing a graben within which the Bolehill anticline is confined. Southwest of the Gulph fault there are no discernible fold structures, the strata gently dipping to the east, effectively the relics of the southern limb of the anticline.

Complex block - faulting has truncated the area into a series of horsts and grabens. All of these faults have a NW - SE or W - E trend. The Bonsall fault to the north of the area has a net southerly downthrow of several hundred feet (Butcher, 1976), the Gang vein fault at Bolehill downthrows up to 100 ft to the north. However, at its western limit, this fault is also known to have an element of lateral movement, and a variable hade of up to 15° to the south. The Gulph fault has a northeasterly downthrow of between 350 and 400 ft, and also demonstrates lateral movement and a hade of 5 - 25° to the north. In the wedge formed on the southwestern limb of the Bolehill anticline by the Gulph and Gang Vein faults is a wide shatter belt, dominated by the Ranter fault of 100 to 150 ft downthrow to the south, forming the Wirksworth gulf, a graben structure with the Gulph fault. Between these two faults, the shatter belt is strongly developed.

In the south of the area, the east - west Yokecliffe Rake fault downthrows some 150 to 200 ft to the south, again with some lateral movement and a variable southerly hade. Thus a horst wedge is formed between this fault and the Gulph fault, and this structure is divided into a series of minor blocks by many small WNW - ESE faults, progressively stepping down the strata to the south. The area under Wirksworth where all these faults converge is another complex shatter belt.

MINERALISATION AND MAJOR WORKINGS

The whole of the area has been extensively mineralised, with a dominance of rake and scrin type veins. The mineralisation is controlled by the extensive faulting and strong joints in the shatter belts, and the strong fractures in the Bolehill anticline. The control of impermeable horizons in restricting the mineralisation is less important in this area than in the rest of Derbyshire due to the lack of major lava horizons. The shale cover in the Gulph was a major factor in concentrating the mineralisation in the Cawdor Limestones.

The most noteworthy areas of mine workings are as follows - around Cromford, the Alabaster and Rose rakes, the Dragoneye and Dunrake veins, Tinley and Bedehouse veins, and the extensive scrin deposits in the Dene area. The Gang vein has been one of the major rake type fault veins, with the Gang and Brandrix mines of Steeple Grange, and Jacksons Grove at Rise End. One of the major belts of mineralisation was in the area between the Gulph and Ranter faults, with Rantor, Ratchwood, Orchard, Twentylands and Northcliffe veins. In the Wirksworth area, in the complex shatter belt were the Baileycroft, Blackmans Croft, Goodluck and Meerbrooksough mines, and to the south of the town, the Yokecliffe rake mines and the Dream mine complex near Godfreyhole.

NATURAL SUBSURFACE DRAINAGE TRENDS

Natural trends of subsurface flow of groundwater can be divided into three groups, which, under real conditions, all work together. These divisions are as follows: stratigraphically controlled, based on the lithology of impermeable and permeable horizons; structurally controlled, based on the dip of the strata and natural fractures within it, and a third control by the mineral veins and cavities.

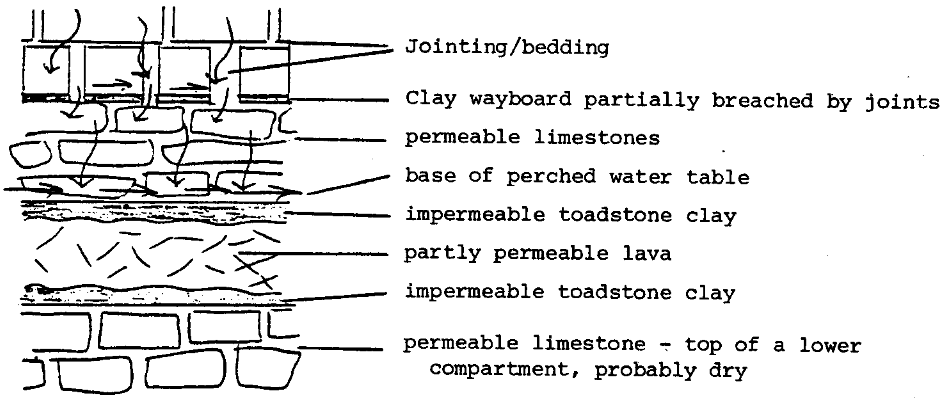
All of these forms are intimately associated, and in the driving of the soughs, the miners attempted to intersect such drainage trends to give maximum relief to a certain area of mines.

Stratigraphic control

Limestone is always considered a highly permeable rock, which is not strictly true. The void space in solid limestone is very small, and flow ratios are negligible. However, limestone is a well-bedded rock with a high frequency of jointing. Also, it is very soluble in slightly acidic rainwater, so that both bedding and jointing planes are enlarged by the action of percolating rainwater. It is essentially this principle that gives rise to the cavities and planes for hydrothermal mineralisation to occupy, though the first flushes of mineralising fluids may also have been aggressive water. Karstic solution has thus produced voids in the limestones, although there is little evidence of either large caverns or integrated cave systems. Water flow in the limestone is along widened bedding and joints, and, where flow on a bedding plane occurs, the direction is structurally dependent.

However, basaltic lavas show very little, or if present, very weak bedding. Also, being thick units, frequency of jointing is poor, and generally highly irregular. Thus water flow in a lava is very restricted. But by far the main reason for the impermeability of the lavas is due to what is locally known as Toadstone Clay. For various reasons, but mainly due to the action of hydrothermal fluids, the feldspars and augites in the lava decompose to clay minerals such as mica, illite, montmorillonite and the characteristic K-bentonite to form a bluey-green clay. With thick lavas, this clay tends to form a zone at the top and bottom of the flow, but as the hydrothermal fluids somewhat penetrated the weak jointing, zones of clay form there. On thin lavas, or ash fall deposits, the decomposition into clay can affect the whole horizon, forming the clay wayboards so common in the Derbyshire limestones.

The thixotropic clay so formed is impermeable, and as it tends to fill the jointing, it thus makes the lavas impermeable, although no doubt some seepage can occur through fractures. The effect of jointing on thin clay wayboards will often breach them so that they are not totally impermeable over a wide area.



It can be said, therefore, that the subsurface water flow is virtually stopped in vertical component by the lavas and clay wayboards, but will flow in the limestones above, the direction dependent on structure.

The lava has been breached by some of the soughs, and so natural trends are diverted. One must also consider the significance of dolomitised limestone. In Derbyshire, dolomite is somewhat more porous than limestone so water flow in the rock mass is increased.

Structural control

A structural flow trend literally means that the water flows down dip along a bedding plane, probably dropping down widened joints and continuing on a down dip trend on a lower bedding plane. Of course, water accumulating on the top of an impermeable lava or clay wayboard will flow along their surface in the direction of any inclination.

Hence, if one assumes a hypothetical situation of a plunging anticline with an impermeable lava bed in it, then subsurface flow will radiate from the crestal regions down dip around the nose. However, axial regions of anticlines are strongly jointed, and then the flow may be in a combination of bedding planes and joints, still trending towards the nose down dip in the structure. This pattern of flow is seen in the Matlock and Bolehill anticlines, the latter being strongly jointed and demonstrating a more 'direct to the nose' flow from the crestal regions or feeders to the fold.

Thus in a plunging anticline, water accumulates in the nose. If the nose is capped by an impermeable horizon (e.g. shale), then under natural conditions the plunging nose of the fold approximates to a sub-surface reservoir.

When large faults with wide shatter belts occur, open hydrological zones are formed, and flow trends, say above a lava, may be breached and fall into the fault plane for free flow. The fault zone flow is independent of dip and impermeable horizons, and the only way one can tell the direction of flow in a fault zone is if the water table at one end of it is higher than the other. However, fault zones are not always open over the whole length of the fracture, and constrictions may occur, restricting the free flow. The southeastern end of the Gulph fault displays such constriction where both walls at higher levels are composed of shale.

Mineral cavity control

Much of the above is applicable to rake and scrin veins, which are mineralised fracture zones acting as open hydrological conduits. However, under natural conditions, mineral veins are constricted, and thus flow in the cavities is retarded. But once the miner has worked out the vein, one approaches a condition of a maze of cavities, analogous to a natural cave system.

Mineral deposits fall into basic categories - veins perpendicular to the bedding (i.e. rakes and scrins in faults and joints), and 'veins' parallel to the bedding (i.e. flats and pipes in hydrothermal solution cavities), again often intimately associated. Both these forms are analogous to joints and bedding, and thus water flows either in joints, or down dip, aided by these mineral deposit cavities.

SOUGH HYDROGEOLOGY

Introduction

Before considering the hydrology of the soughs, one must take into account what the lead miner did to assist subsurface flow. He enlarged the joints and faults by working scrin and rake veins, and he worked the pipe and flat deposits - action which enabled much more rapid percolation of the groundwater to the level of the water table below his workings, natural or otherwise.

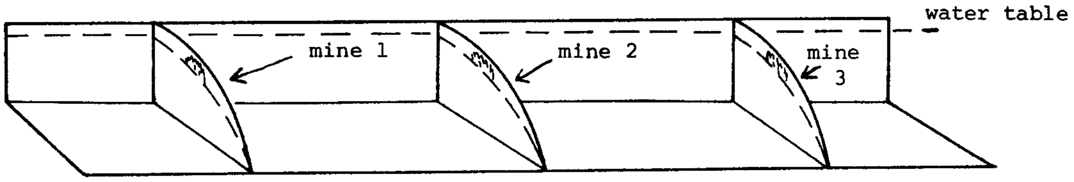
This was fine while he worked above the then water table, as the water always went downwards in his workings. However, soon most of the ore had been worked out of these areas, and **early** pumping methods and dry summers enabled him to work a little lower. He also employed a method to work a mine deeper by working below a dipping lava horizon which acted as a natural umbrella to his mine.

One suspects that the old miner got his early ideas for making a sough from observing the natural flow of groundwaters above the water table. He had probably seen a natural cavern system draining water out of his mine to a resurgence in a nearby valley, and thought that if he made his own cave by driving an adit in from a handy valley to flooded parts of his mine it would take away the water. Alternatively, he could employ natural trends if a swallet was convenient, driving a tunnel from it into a flooded zone.

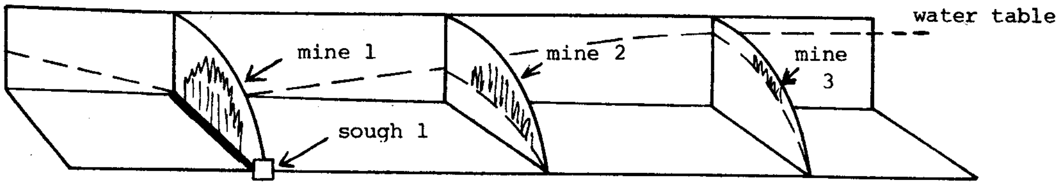
Thus from such primitive beginnings, the sough was born, which, in later years, was to be the dominant force in lowering water tables all over the mineral field in Derbyshire.

The earliest soughs were small affairs, employing little imagination and speculation, and driven to a local mine from a nearby convenient topographic low. Thus with all the soughs being small and local, many were driven from a single valley, and between them they progressively lowered the area water table:-

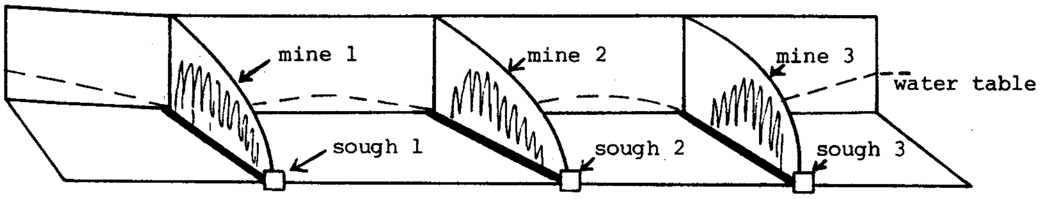
A) Natural conditions



B) With one old sough



C) With all soughs

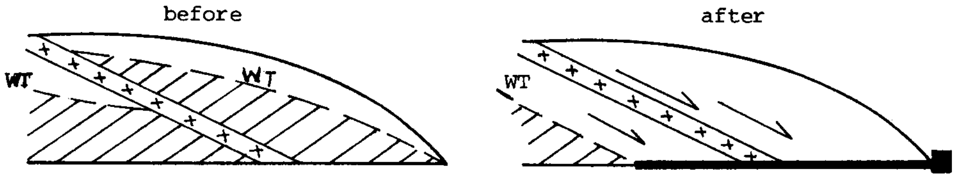


Before discussing the larger soughs, it is suitable to examine how the sough affected the drainage of an area by the geological confines into which it was driven.

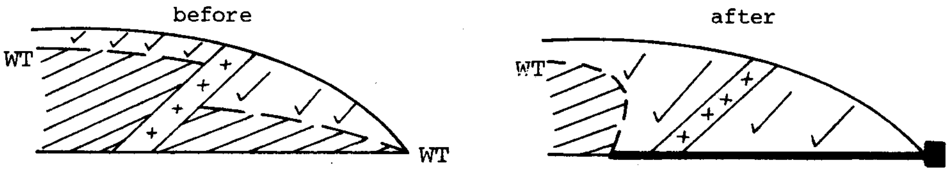
Sough regime and catchment control

This is affected by varying geological conditions:

A) Against the dip - a sough driven against the dip can intersect down dip flow and affect a considerable area in advance of the forefield, although at a higher level than the sough:-



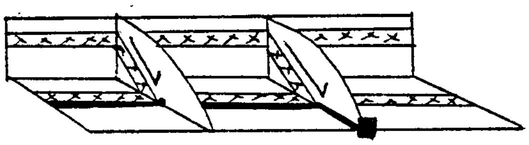
B) With the dip - in driving a sough with the dip it would have to be driven further to affect a larger area, as partial relief will only be given ahead of the forefield if strong joints are present:-



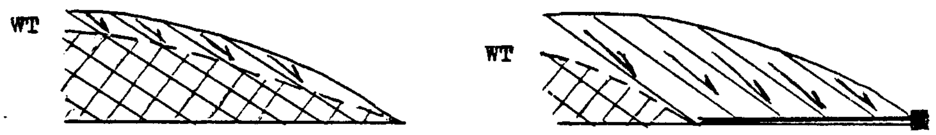
C) In a vein or fracture - providing the fracture was not constricted, the sough could affect an area well in advance of the forefield, with both down dip and joint flow getting into the sough - affected vein cavity and hence having a wide effect on reducing water levels not only ahead of the sough in the vein, but also to the areas flanking the vein.

Naturally, there are many permutations on the driving in vein cavities - intersection of pipes or flat deposits would not only drain that cavity, but any other connected to it. However, before a vein had been worked out, it was often constricted, and to achieve total drainage, the sough would have to be driven all the way in a vein - literally enlarging the cavity and removing constrictions for more rapid release and flow of water.

D) The sough and impermeable horizons - often an impermeable horizon could act as an advantage to the sough. If it were driven along the top of a lava, it would take direct down dip drainage from it:-



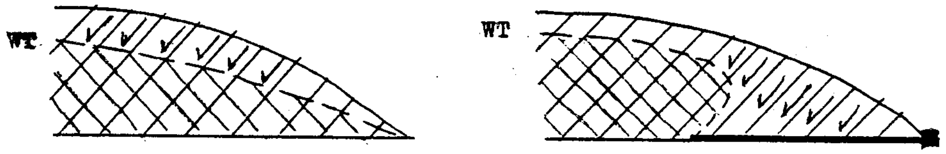
If it passed through a lava, it would intersect the flooded zone below it, thus reducing two regimes of water:-



before

after

These confines have assumed against the dip driving, whereas if the sough was driven with the dip, one would have a situation of case B, except with the lava present:-



before

after

These are the four basic confines on groundwater flow into a sough. In one single sough one can get all of the features, which makes the evaluation of the direction of groundwater flow into a sough difficult. The governing factors in evaluating catchment areas to the soughs can be reasoned out under the following categories:-

A) The sough altitude in relation to the surface - the factor which results in the maximum depression of the natural water table.

B) Fractures intersected by the sough - direction of flow in such an open hydrological zone would be directed towards the sough, and thus the catchment to such a fracture, which would act as a natural 'sough branch', is then governed by dip direction to the fracture, by other fractures it may connect to and any constrictions in such a fracture system.

C) The limit of impermeable horizons with the regime controlled by them affected by the sough. For example, if a sough approaches a totally impermeable lava, but does not pass through it, the catchment area can be delimited by the area between the lava outcrop and the direction of approach of the sough to it. If a sough passes through such a lava, the first catchment is enlarged by a second regime drained by the sough through the lava and its associated catchment. This second regime and catchment can be delimited if there is another lava ahead of the sough, otherwise, one can say the catchment for the sough once through the lava is governed by trends already discussed - dominantly structural, i.e.: down dip flow and which fractures are hydrologically connected to the sough.

Because of this complexity in determining, or even estimating sough catchments, it is useful to divide them into:-

A) **Proximal Catchments** - those areas in close linkage to the sough directly hydrologically connected. These are areas which can be delimited by one or more impermeable horizon(s) or known range of fractures likely to be connected to the sough. The regime related to such catchments rapidly responds to the sough on rainfall over the proximal catchment.

B) **Distal Catchments** - those areas likely to be in hydrological linkage with the sough, although indirectly, and having no reliable impermeable horizons from which limits can be made. The control on water from a distal catchment reaching the sough dependant purely on the structure of the area, i.e. one can say that if the dip is directed towards the sough, the outcrop areas of such dipping strata may well be within the sough catchment area. A regime associated with a distal catchment has slow response to the sough, and is therefore always likely to be flooded well above sough level.

Controls on major sough driving

Over the years of sough driving, one can see a progressive improvement in their effectiveness. Early ones were often trial and error, but later, larger ones were feats of engineering, not only in the perfection of sough construction, but also in their drainage of flooded areas of mines, and the tapping of feeders into the area they drained.

During the compilation of this project, the author has sometimes mused on how much the sough engineers knew of the hydrogeology of the area before a sough was made. Did they have a concept of the geology and subsurface water flow in the limestone that we can only speculate on today, or was it that they knew which areas were more affected by flooding due to the extensive and accessible mines, and thus drove the large soughs to intersect as many flooded areas as possible?

Accounts in the Meerbrook Sough Company documents show that the soughers on this major project knew where they would tap strong feeders, but in some accounts they also admit surprise when they tapped other powerful springs.

Analysis of the courses of the large soughs in the southeastern limestone outcrop - Hillcarr, Yatestoop and Meerbrook, show just how much sough construction was dominated by the geological structure of the area. Both Hillcarr and Yatestoop soughs are driven at the lowest possible point into the floor of the Stanton syncline. Yatestoop sough was driven in a large fracture in the mineral field of limestone, with branches driven against the dip to the south in the limestone of the south flank of the syncline. Hillcarr sough was driven to the Alport mines by an indirect route along the shale/limestone boundary contour at sough level, branches out of it heading northwards against the dip in major fractures in the limestones of the north flank of the syncline. Its branches continued to the north to intersect the main feeders into the mineral field.

Meerbrook sough was driven direct into the nose of the Bolehill anticline, a naturally confined reservoir beneath the shale, with branches going into the core of the anticline and major fractures on the crest (i.e. Gang Vein). It then continued to intercept the feeders to this reservoir by crossing all the major faults and fractures under Wirksworth (Fig.2).

Thus the large soughs were driven to drain naturally flooded zones, the water flow in which was controlled under natural conditions by the structure, and after the initial drawing off of the water, all the soughs continued to tap the water flowing into such areas nearer its source.

HYDROGEOLOGY OF THE AREA

The hydrogeology of the Wirksworth - Cromford area has been evaluated from the detailed study of the soughs. Although the picture is far from complete, enough is known of the general trends from documents concerning the Cromford and Meerbrook soughs, giving data as to where the soughs intersected subterranean streams, and the effect that such tappings had on proximal and distal mines. The picture compiled from the data on the Cromford and Meerbrook soughs fits almost perfectly with the predicted trends evaluated from the known geology and its theoretical control of groundwater flow and the location of subterranean reservoirs. What is more, with such details on the Cromford sough and the structure of the area, the course of the last great Meerbrook sough was the final logical step to drain

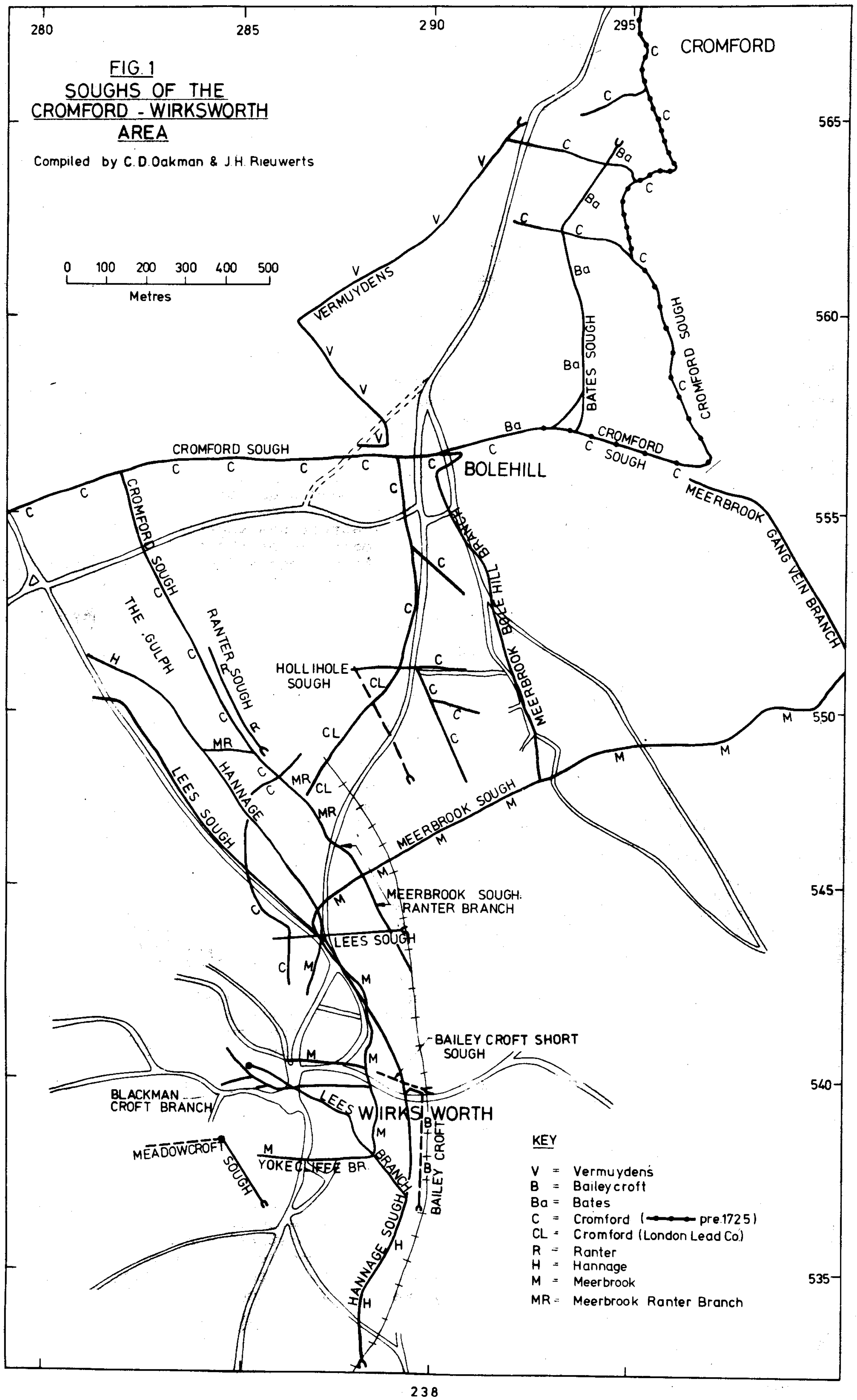


FIG. 1
SOUGHS OF THE
CROMFORD - WIRKSWORTH
AREA

Compiled by C. D. Oakman & J. H. Rieuwerts the whole area and tap the subterranean feeding streams to the original natural subsurface reservoirs (Fig.1.).

Old water table levels can be calculated from the altitude of the oldest soughs. For example, the first sough to the Gang vein area at Steeple Grange was Vermuyden's sough, or Dutchman's Level, at approximately the 450 ft contour. At Steeple Grange, the topography is at 700 ft OD, so as one can estimate that the old water table must have had an elevation between these two figures, say at 500 ft OD. Considering the level of the Derwent at Cromford is 280 ft OD, this implies a regression curve of the magnitude of 300 ft in less than ¼ of a mile. This figure is somewhat high in an area with perched water levels having little significance, but when one examines the structure, water in the vadose zone would be flowing easterly down dip, and also eastwardly in the main E-W mineral vein cavities. In the phreatic zone, water would be confined to the east by the shale overlying the limestone, and phreatic flow would be impeded by the tight nature of the unworked mineral veins. Thus outfalls may have existed at Cromford.

Some resurgences are known in the Wirksworth area, with the recorded outfall of two thermal springs, locality still uncertain. Many of these springs disappeared during early sough construction, demonstrating the effect of even the old soughs, in this case the Warmbrook (Meadowcroft) and Hannage soughs.

Naturally, the water in the area would all flow eastwards down dip in the vadose zone, all of it culminating in the nose of the Bolehill anticline. As most of this natural reservoir is confined to the east by shale cover, the shale-limestone boundary on the surface running from Cromford to Wirksworth and then west to Hopton, all water flowing east, either directly down dip or obliquely around the flanks of the Bolehill anticline, will eventually reach the natural underground reservoir. It is likely that all around the shale-limestone boundary at outcrop that many overflow springs existed with most of the water flowing into the river Ecclesbourne, which is now only a mere trickle of a river taking runoff water from the Millstone Grit shales.

Apart from down dip flow into the natural reservoir, one of the major hydrological carrier zones was the wide shatter belts of the faults. Thus one can assume that the Gang vein, Ranter, Gulph, and Yokecliffe Rake faults acted as both vadose and phreatic water carriers, with flow directions in the area south of the Via Gellia and west to the limit of the easterly dipping strata in a generally easterly direction, all feeding the reservoir.

The story of the soughs can be simplified by saying that, they all attempted to drain this reservoir and tap the feeding subterranean streams at different levels. The higher the sough, the less the effect, which can be compared to just taking the skin off the custard. The deeper the sough, the more effective it was in draining the reservoir of water. Each time a deeper sough was made, the smaller the reservoir became, and the importance of tapping the feeding streams became more important in the total relief of the mines of water. The earliest soughs started from two points, (a) the area of Cromford and (b) the area of Wirksworth, both conveniently topographically low. These soughs approached the natural reservoir in the core of the anticline from the north and south respectively. It was only the last two soughs that finally relieved the area of water, Cromford sough approached from the north, the tail at Cromford, although the sough only reached the heart of the reservoir in its later years of construction, intersecting many of the feeding streams then. Meerbrook sough, the youngest and deepest, intersected the reservoir deep in its heart under Bolehill, and then went on to tap the feeding streams over a wider area to the south.

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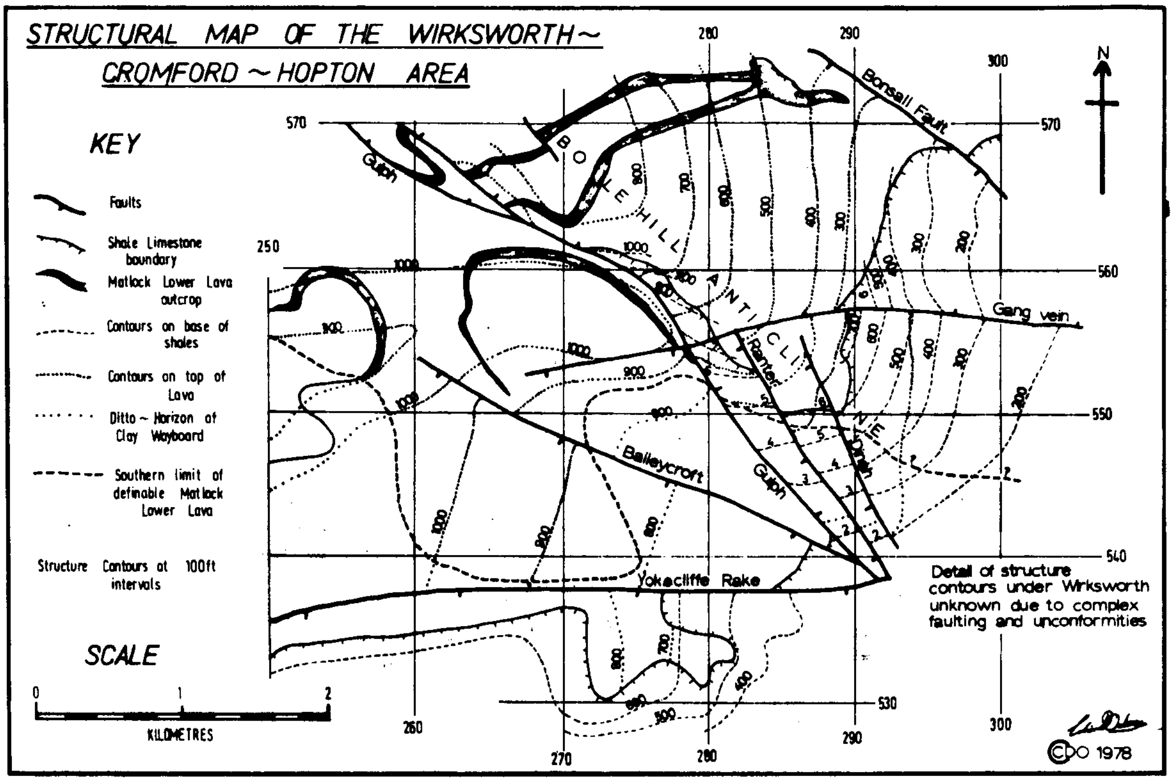

Fig.2.

Colin D. Oakman,
Geology Dept.,
University of Aberdeen,
Aberdeen.