## *THE ANSEL DUNHAM LECTURE*

# CONSULTING GEOLOGISTS AND THE BRITISH EXTRACTIVE INDUSTRIES

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## ABSTRACT

This paper reviews the changes that have taken place over the last half century in the direct employment of geologists within the extractive industries in the UK and the associated rise in the use of consultancy.

Industry employs consultants in a variety of ways. These range from detailed problem solving and the preparation of technical designs and reviews with attendant support in court or public inquiries to acting as replacements for, or additions to, existing staff in routine activities. Consultants are also used to deal with technical burdens imposed by regulators and planners. These will be considered together with the attributes or capabilities that the industry should be looking for and consultants should be offering.

Geological consultants and consultancy firms offering expertise to the industry vary from large multi disciplinary organisations to smaller specialist firms and individual experts. Some act as contractors rather than consultants and this can lead to confusion at various levels. There is also a swathe of organisations dealing with consultancy ranging from academia and institutions through consultants and contractors to industry that may also itself act as a consultant in certain circumstances.

Particular attention will be given to the uses that the extractive industry and others could be making of the different types of geological consultants and consultancies and the areas that are not currently covered, but could be beneficial in the longer term. One particular topic of concern is the issue of corporate memory in respect of geological issues that have proved important in the past and could be overlooked in the future.

*Walton, G. 2012. Consulting Geologists and the British Extractive Industries.*
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## INTRODUCTION

The word 'consult' comes from the Latin '*consultare*' which means deliberate, take counsel, confer about, mediate or plan. The Oxford English Dictionary (OED) defines a consultant *inter alia* as a person who gives professional advice or services in a specialist field. Ideally the consultant should be an expert. Consulting or consultancy is therefore the work of a consultant. It should be noted that a contractor has a completely different definition in the OED *viz* a person who undertakes a contract to provide materials or labour for a job. This paper is concerned with the former rather than the latter although the understanding of the terms is confused both by practitioners and the industry.

## CONSULTING GEOLOGISTS IN THE BRITISH EXTRACTIVE SECTOR

For the British Extractive Industry the use of consulting geologists has changed partly as a result of changes in the industry and in employment policies, as will be discussed, and partly as a consequence of the changing regulatory regime in which the minerals industry operates in Britain. The Extractive Industry Geology Conferences comprise the only venue at which the full range of those providing geological services to the British extractive industry as employees, consultants or contractors can meet.

Geological consultants to the sector may be placed in one of four categories:-

i. Resource and reserve geologists

ii. Geotechnical specialists

iii. Hydrogeologists and hydrologists

iv. Environmental geologists

Resource and reserve geologists are typically involved with assessing the tonnages of mineral and their characteristics or properties and commonly undertake some form of quarry/mine design work often in conjunction with geotechnical and hydrogeological specialists. Geotechnical specialists include both geotechnical engineers and engineering geologists – there is allegedly a difference, but in reality they have to solve the same rock and soil engineering problems as

required in Regulation 2 of the Quarries Regulations. Hydrogeologists have a clear role in assessing and managing the impact of excavations on the groundwater regime and groundwater quality; few hydrologists are geologists, but hydrogeologists often have some input into hydrological work. Environmental geologists cover a wide area and often dabble in geotechnics and hydrogeology, but their specific role usually relates to potential contamination and emissions from mineral operations including dust; they may also be involved with restoration and energy issues.

Table 1 presents the number of papers in these different categories that have been read at this and the four previous EIG Conferences. It should be appreciated that many of the papers presented cover areas within the general interest of extractive industry geologists, but are not specifically in the domain of one or other of the four categories noted above; this is particularly true of a number of planning issues. Each of those categories may be sub-divided into various specialisms, sometimes with only a few practitioners in any one interest area in the country.

Geological consultants come from a variety of backgrounds and organisations. They range, on the one hand, from individual practitioners and experts (the classic one man band) through SME partnerships and limited companies to much larger consultancies with several hundreds or thousands of staff that may be multi national as well as multi disciplinary. Consultants are not restricted to separate companies or partnerships, but may also be found in institutions, former institutions that are becoming consultancies and academia. A number of larger firms in the industry will have separate service sections that provide some or all of the geological consultancy requirements of the firm. On occasions an operating minerals company may also itself act as a consultant or organise its geological services as a consultancy, especially for overseas work, whose assistance may or may not be sought by different divisions of the main operating company. Figure 1 is a representation of this structural arrangement. There are strengths and weaknesses associated with each of these business groupings as discussed below and some firms may act both as contractors and consultants and blur the line between the two.

| **Number of papers** | 2002 Leicester | 2004 Leeds | 2006 Edinburgh | 2008 Cardiff | 2010 Portsmouth |
|---|---|---|---|---|---|
| | 29 | 28 | 46 | 45 | 47 |
| **Theme of papers and number of papers** | | | | | |
| Resource and reserve geology | 10 | 11 | 18 | 17 | 11 |
| Geotechnics | 4 | 4 | 5 | 6 | 8 |
| Hydrogeology | 7 | 1 | 5 | 4 | 8 |
| Environmental geology | 3 | 6 | 9 | 5 | 10 |
| Other | 5 | 6 | 9 | 13 | 10 |

***Table 1.*** *Categories of papers in recent EIG Conferences*

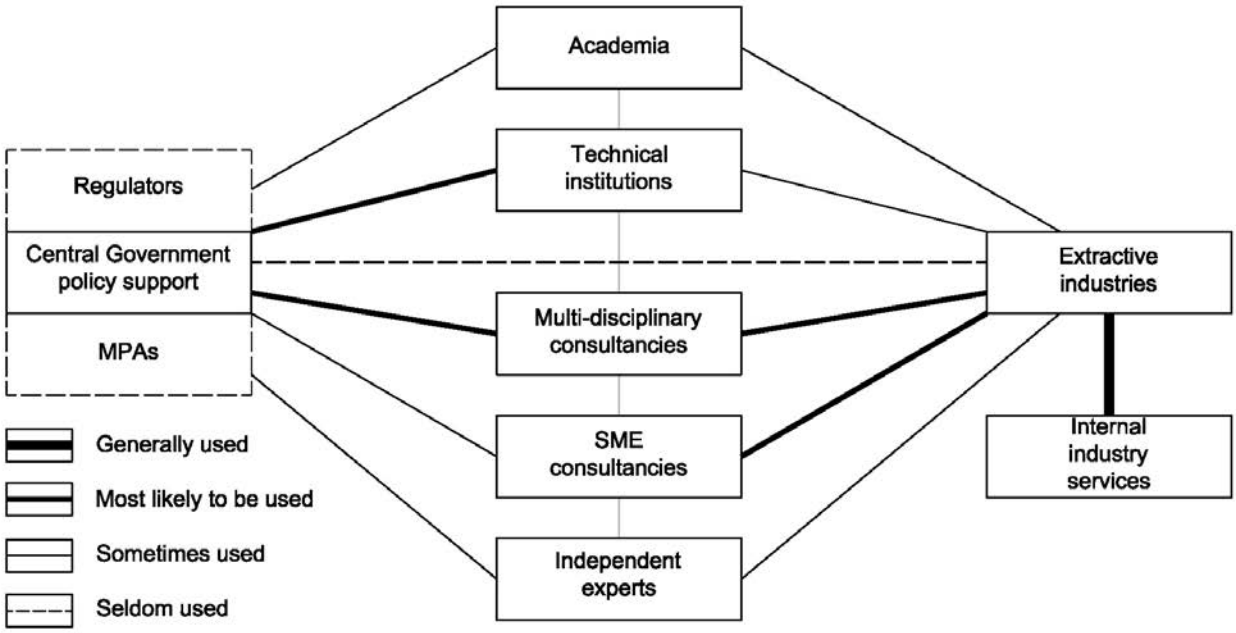


***Figure 1.*** *The consultancy framework for extractive industry consulting in Britain.*

The number of consultants who practice in the extractive sector is difficult to ascertain. The Office of National Statistics does not separately record the number of geologists in active employment let alone those who are in some form of geological employment. Similarly there are no statistics for geologists employed within the extractive sector or working in the service sector.

Many geologists employed within the extractive sector are Fellows of the Geological Society, some but not all of whom may be Chartered Geologists, and others, including some of those in the Geological Society, may be Members or Fellows of the IMMM, again some of whom may be Chartered Scientists or Chartered Engineers. Hence there is no comprehensive listing of the numbers.

The Institution of Geologists produced its first Directory in 1980. It did not list the numbers of geologists employed in different sectors of industry, but it did include 57 firms or individuals listed as consulting geologists, but of these, only 15 mentioned minerals or resources, 12 referred to geotechnics or engineering geology and only 6 noted hydrogeology as a service. None of the consulting geologists mentioned environmental geology.

The latest Geologist's Directory for 2010, ostensibly endorsed by the Geological Society, but basically produced by an advertising company, is much more specific in the services noted. Geotechnical services are offered by 104 firms, but many of these do not work in the extractive sector, even though some think they are suitable to do so. 32 hydrogeologists and hydrogeological consultants are listed together with 87 environmental consultants, some of whom are also listed in the hydrogeological consultants section. Only 15 consultants are listed as being involved in the extractive industries (actually described as mining and quarrying engineers).

No directory is perfect, especially when it is driven by advertisers and collects payments for entry. Clearly not all consultants practicing in the extractive sector are included in this or any other directory or database. However the first directory of the Institute of Geologists probably reflected the national situation quite closely in 1980. A review of the 2010 Geologists Directory shows that not all consultants commonly active in the extractive sector are included and those that are, are variously categorised as mining engineers, geologists, geotechnical engineers, hydrogeologists etc. On the basis of contacts with operating companies it is estimated that there are less than 35 firms and individual practitioners who provide geological services to the extractive sector on a regular basis as their principal business. This does however represent a significant increase from the situation in 1980 when there were less than 10 firms, plus a few individuals, providing regular services to the sector.

## Geologists Directly Employed in the British Extractive Industry

It appears that direct employment of geologists in the extractive sector can only be assessed by collecting data from operating companies in the industry. Table 2 sets out approximate total numbers of the four categories of geologists employed by the British extractive industries in Britain, rather than overseas. This table does not include those who trained as geologists and may have originally worked as such in the industry, but have gone into management and other roles within the sector.

| Extractive Sector | Approximate direct employment numbers of Practicing Geologists, Engineering Geologists etc in the British Extractive Industry. | | |
|---|---|---|---|
| | 1970 | 1985 | 2010 |
| Opencast coal | 80 | 95 | <10 |
| Aggregates | 10 | 45 | 35 |
| Non-metalliferous industrial minerals | 20 | 25 | <10 |
| Other | 15 | 15 | <5 |

***Table 2.*** *Employment of persons as geological practitioners by the extractive industry*

As can be seen, significant changes have occurred within the last four decades. The largest change has been in the opencast coal sector. This sector once employed approximately 100 geologists; it still produces a significant mineral output even compared with that of 1970, but now employs less than 10% of the manpower of the 1970s and 80s. By contrast it is apparent that there has been a significant growth in the number of practicing geologists in the aggregates sector over the last 30-40 years although there has been a decline in the last decade reflecting to some degree the falling sales of aggregates since the mid 1990s (Jackson 2010). There has however been a more marked decline in the number of geologists directly employed in the non metalliferous industrial minerals sector such as clays, cement raw materials, gypsum etc. The other category covers underground metalliferous and coal mining and reflects the relative decline of both since the 1980s. There has therefore been a decrease of more than 60% in the number of practising geologists employed directly by the British extractive industry over the last 25 years.

## Factors affecting the direct employment of Geologists in the Sector

These are many and varied and have worked at different times in different directions. As a starting point the number of individual active mine and quarry operations has decreased since 1970. With economies of scale mineral recovery units have become fewer and larger; this is clearly reflected in the size of mothballed aggregate quarries at the present time. The planning and regulatory environment has also substantially increased over the same period, especially since the early 1990s having an impact on the number of operations a firm is prepared to investigate, although the attention given to any one site has often increased. The British Drilling Association have no statistical records of metres drilled for exploration purposes, but some of the members have indicated a widespread decrease in drilling for all mineral sectors over the last 25 years although there has been some counterbalance in increased geotechnical and environmental drilling investigations for the sector.

**Aggregates sector** factors that have aided the growth and demise in direct employment within the sector usually vary in relation to the productivity, production

and regulatory constraints. Hence for the aggregates sector key issues have been:-

- The growth, variations and decline in output to meet the requirements of the construction sector from the 1960s onwards.
- Takeovers within the industry. In some firms this required geological Due Diligence and in others the due diligence was a *post-hoc* function that required additional drilling to investigate what had been purchased by the directors. At times redundancies and early retirements of geological staff occurred.
- Changes in the regulatory environment, initially with the impact of the Aberfan disaster on tips legislation and subsequently the Quarries Regulations 1999 followed by The Environmental Assessment Regulations and other European Directives. Concurrently there has been a growing involvement of the Environment Agency (EA) and more complex planning arrangements, both requiring geological input.
- Changes in accounting procedures that require more diligent attention to resources and reserves.
- Outsourcing geological services; this appears to have been the case with respect to some geotechnical engineers and hydrogeologists.
- Reduced levels of exploration drilling to reflect the need to focus on extensions and sites with perceived planning potential.

**Opencast coal sector** employment was initially dominated by the artificial nature of public ownership. NCB/British Coal did not operate any of their sites; these were the responsibility of contractors and the owner/contractor relationship with the multi-million pound contracts always had the potential for significant contractual claims. Although ground conditions were excluded from the contract they clearly exercised a major constraint on relationships when coal tonnages and coal quality varied beyond those defined within the contract. To overcome this problem NCB/British Coal employed a large number of geologists to prove sites at close centres of drilling and resolve problems in respect of the presence or absence of old mine workings given the unreliability of shallow depth old mine plans and the inability to adequately assess the presence or absence of coal by any means other than drilling. Boreholes were commonly drilled at 50m centres which were subsequently reduced to 25m or 30m centres, especially in areas of structural complexity.

With the demise of British Coal the requirement for further exploration work was greatly reduced as the new site owners could rely upon the data already obtained by British Coal and provided through the Coal Authority. The new owners worked their own coal and drew up contracts for their own contractors that addressed the need to reduce risks without the requirement for further, detailed geological information. The new opencast coal operators still had growing obligations with respect to legislation, but unlike the aggregates sector, few geologists were employed to accommodate changes, and those that were, largely dealt with reserve management within operating sites.

**Non-metallic industrial minerals sector** employment was, in the early 1970s, at a higher level than that in the aggregates sector, but has subsequently fallen significantly. The output levels have fallen and takeovers have impacted on employment. Many of the firms that were originally British firms are now in foreign ownership and management arrangements are different (Scott 2008). The cement sector has seen a significant fall in the number of operating quarries with very little exploration work required. Similar reductions have occurred with some brick and ceramic clay operations and alternative sources of gypsum have reduced for blending with cement clinker; employment has been affected.

## Why does the industry use Geological Consultants?

The trends and reasons for employment and off-loading labour have been considered above. To some extent what is not available in house has to be met from elsewhere from consultants or from previous staff contracted in. It is recognised from, albeit limited, statistics that there has been an increase in the number of firms and sole practitioners supplying services to the extractive sector since 1970 and particularly since the mid 1990s. Part of this may be in response to the employment levels within the industry.

It is clear that the industry employs consultants in many ways and consultants see themselves as having different roles. Typical reasons for employing geological consultants include the need for expert skills or advice, assistance at peak workloads and the provision of independent third party assurance. This is considered further below.

The industry uses consulting geologists to cover each of the four categories noted in Table 1; this is generally more concerned with assisting in quarry/mine design than the quantification and character of mineral deposits and with the specialist sectors of geotechnics, hydrogeology and environmental issues.

One of the principal areas of involvement is to fill specialist niches in the preparation of planning applications and particularly Environmental Impact Assessments (EIA) and Statements (EIS). Assessments and Statements are required by industry and mineral planning authorities alike. They may or may not be involved with the overall project management. The preparation of Geotechnical Assessments in compliance with Regulation 33 of the Quarries Regulations is a major consulting area that has largely been outsourced by the industry as has hydrogeological and hydrological investigations to support planning applications and EISs. Where contamination and other geochemical issues are involved external environmental geologists are sometimes used.

Consultants are also regularly used to act as expert witnesses in public inquiries and other litigation since the evidence rules require a degree of independence from the mineral company.

## The appointment of Geological Consultants

This is a contentious area and varies greatly between firms and how those firms are structured with respect to procurement.

In many firms the geological team or the head of the team is concerned with the appointment of the geological consultant. In others the estates manager makes the appointment and sometimes the procurement department. What should be sought is a competent and experienced firm or individual. Other attributes that have been noted as essential in consultants are: honesty, confidentiality, reliability, the ability to play as part of a team, clarity in thinking and reporting and particularly an industry track record. Clients should, of course, have similar virtues (Wardrop 2008). Many of these attributes are listed in the publication on consulting produced by the Institution of Geologists in the 1980s and further developed by others (Fox 2002).

There are a number of pitfalls for consultants. Reports are not required that indicate more consulting is needed. Consultants are not *prima-donnas* and need to work with, and understand, the aims and objectives of others in the team even if they sometimes need to question them. Reports must be delivered on a timescale that accommodates the client and not necessarily the consultant. It is clear that the technical competence of those making appointments can vary considerably and the geological consultant must be prepared for this. It is also not uncommon to find a lack of communication between sections of an operating company such that the brief is confused or requires checking. This is often the case with respect to the allocation of the design of excavations and of restoration where phasing and interpretation of materials such as soils, overburden and discards (non-waste by-products) are differently understood by different disciplines.

Operators views on the sort of firm employed vary. Some operators, to reduce the number of 'suppliers' involved appoint large firms with multi-disciplinary skills and regularly appoint such firms as project managers. Other operators in the extractive sector appear to be very wary of such consultancies, some stating that whilst the key managers or partners in the consultancy may be sound, work is sometimes undertaken by less experienced and less able staff with consequential delays, errors and gaps. When consultancies are appointed as project managers, prudent operating companies reserve the right to nominate the source of the individual disciplines and ensure that the project managers do not necessarily appoint members of their own firm, rather than the most appropriate.

The manner of the appointment also varies considerably. All operating companies would say that the two key issues were price and the quality of the work. There are several approaches to this, some of which have the potential for gross technical errors; some methods are more appropriate to the employment of larger consulting firms than smaller expert businesses. Some of the methods are more likely to be used by smaller operators. Table 3 groups the methods of appointing, most commonly found by consulting geologists.

The writer is of the opinion that the methods used in 3 and 4 are most suited to the more technical aspects of consulting and especially when working as part of a team. Methods 1 and 2 can stifle innovation and creative problem solving. Experience suggests that technical problems are most likely to occur when those involved in appointment are non-technical, including some estates personnel and procurement managers and non technical pre-qualification criteria operate. It is important for this reason that technical personnel are incorporated in the general management structure to overcome the ignorance that exists in some quarters.

| | |
|---|---|
| 1. | Firms where procurement receives a brief from technical or estates staff and seek tenders from a list that may have been included with the brief. More than five firms may be invited to tender. Contracts are awarded primarily on price when the brief appears to be understood by all. Lowest tenderers may be called for interview and asked to re-price competitively. |
| 2. | Firms where three to five may be asked to tender and a few invited to interview with technical and other staff. A similar approach has been used in the past by government in appointing consultants to undertake research work. Their work may be awarded on the basis of perceived value for money, and not necessarily price. At times further refinement of the task may require a re tendering process. |
| 3. | Firms where technical staff directly contact one or more of two or three firms and ask for a price and proposals. The consultant may have been pre-selected on the basis of previous experience, but prices sought from others to maintain a degree of competitiveness. |
| 4. | Firms where technical staff directly appoint a consultant, with the approval of management, without a tender or comparative pricing process, but on the basis of previous experience or recommendations. |

***Table 3.*** *Methods by which geological consultants are appointed*

This problem is not restricted to the extractive industries, but extends into Government both central and local and to some regulators. When the old Department of Environment (DoE) was split it became the Department of Food and Rural Affairs (DEFRA) and another department variously called DETR, DTLR, ODPM and now Communities and Local Government (CLG). Minerals expertise went to the predecessor Department of CLG and none was left in DEFRA; the research activity in CLG has largely evaporated along with its technical staff, as far as minerals are concerned. DEFRA has been left with no in-house minerals expertise and it is perhaps unsurprising that it and the Environment Agency have had difficulties in adjusting to many issues, the most evident of which is the Mining Waste Directive. The contrast between the Environment Agency and the Health and Safety Executive (HSE), who have technically experienced staff, is stark. It is possible to see a major opening for consultants to advise the EA on quarrying issues, provided of course the EA can recognise consultants experienced in extractive industry technology.

Much, but not all, of the industry is keenly aware that in many cases only three or four firms or individuals, and in some cases as few as one or two, have experience of

particular circumstances, events or settings that might occur within the industry and be relevant to the particular task in hand. This has arisen not only as a result of the centralisation and reduction in size of the extractive industry sector, but as a consequence of not training graduates to a proper technical level in the relevant disciplines. It is hardly surprising that the industry has a poor record in research and in training when it has so signally failed to support the funding of university departments of mining engineering and of applied geology, although perhaps the greatest guilt lies with the multinational mineral companies. However rubbish joint degrees in geology and media studies *etc*., half baked training schemes and a non-graduate institution are not recipes for progress.

## CONSULTANTS WORKING FOR THE INDUSTRY

Consultancy is an unusual relationship, but now widespread across industry compared with 60 or 70 years ago. A consultant has a privileged position with significant opportunities. However it is a position that is not permanent and things can go disastrously wrong. Inherent in the definition of a consultant is the implication that a consultant is an expert. It is essential that the consultant maintains this expertise by continued reading and learning and keeping abreast of case histories and legislation. There are many opportunities for things to go wrong, not least a failure to realise that the environment in which we have our being is like many natural phenomena, subject to significant variations. There is also a need for applied geologists to maintain an interest and understanding of the pure geological background of the rocks and geological setting of the minerals worked. Seat earths remain seat earths in spite of usually being called something else by engineering geologists who may describe them as *"pale grey stiff silty clay (or very weak rock) with polished surfaces"* and thereby fail to understand the sedimentological and structural setting of these materials. There is no alternative to a sound 3D understanding of geological structures and a detailed knowledge of the geology of the rocks with which one is working.

Poor advice and errors can lead to professional negligence and the end of a career or business, unless appropriate indemnity insurances are in place. The expertise element is a vital part of consultancy and may define the difference between consultancy and contracting.

### *Things to look out for*

These are many and varied. The following list is by no means comprehensive:-

- Have the buried services been investigated?
- Have all the borehole records been examined and made available?
- Have all the records and history of previous workings in these minerals and this area been considered?
- How might the geology and the character of the mineral vary?
- How have ground conditions varied in similar sites?
- What modes of failure typically/rarely occur in these materials?
- Have all previous reports been considered and were they correct?
- Have the computations been checked and do they appear reasonable?
- Is the brief and project context clear and the client reasonable, or seeking to off-load responsibility?

Problems can arise in a number of situations including:-

- Changes in company ownership that may lead to a less benign approach to the provision of a report or its findings.
- Changes in management in the client company.
- Deaths and departures of key staff.
- Changes in reporting timetables.
- Changes in legislation.
- Failure to fully assess the requirements of the study and the time required to report.

The key to all professional consulting is to practice at the state of the art of the profession at that time. When problems arise neither side should remain silent regardless of whether the consultant is working as part of a team or as an independent.

### *Benefits for industry of good consultants*

Not all operators seek or obtain the maximum benefit from good consultants who have a wide experience of the industry and a close understanding of the company's requirements. The direct benefits that can accrue in such a situation are:

- *Easing the burden.* This can sometimes be misinterpreted. The consultant is there to assist and prepare the appropriate reports and accept responsibility for that work; he is not there as a person or a business on to which the operator can off load liability and all responsibility. Even less is he there as a cheap alternative to doing things properly. There have been cases of operators tying consultants with responsibility for recoverable reserve assessment linked to slope engineering without accepting responsibility for the provision of acceptable site investigation information or appropriate land acquisition. Fortunately some of these operators are no longer in existence.
- *Avoiding show stopping problems and getting things in proportion.* This is perhaps the key function of a consultant; to identify the problem areas and to rank these in order of significance without engaging in alarmism. Typical amongst such matters are the potential for major slope instability. Consultants should always be aware of the type of failures that can occur in a particular suite of rocks and in a range of structural settings.
- *Identifying the viability of a case in Public Inquiries and in Court.* This is an expert witness role. The consultant's role in this situation is not to act as a

hired gun as sometimes happens in other parts of Europe, but to frankly and impartially explain the technical strengths and weaknesses of the case or argument. Professionalism is not just membership of an institution or society or adherence to professional codes; the professional has an immutable obligation to wider society beyond the individual consultant/client relationship. He also must demonstrate the ability to present competently and honestly a sound review of the facts and conclusions. The expert witness is just that - an expert at the state of the art of the practice.

When long-term relationships have developed the operator has a chance of further in-depth benefits. It should be recognised that consultants gain considerably from their experience with other operators for whom they work. The prudent can gain much information on the success or otherwise of different methods of operation and working etc. Amongst these are:-

- *Training.* Consultants can, and should, have an important role to play in health and safety training. This is not just for the plant and quarry workforce, but for the management. There are however other areas of training in terms of changes in methods of analysis, in volumetric assessment and in working methods and techniques where the consultant can help in training. By this means key staff can be updated when the consultant has the necessary skills and understanding.
- *Reviews and research.* The competent consultant, who is abreast of new developments and techniques beyond UK industry, acquires a wider understanding than many in a firm who are generally involved in complex day to day issues. An operator ought to be able to call on an industry research organisation for this, but they would have to go to the same small pool for advice. Moreover the direct use of consultants is more secure.
- *Corporate memory.* Perhaps this should be called corporate amnesia. The churning and turnover of staff in many operating companies is quite large and especially so when production levels fall. Ideally a balance should be kept in the age spectrum of technical staff. There is a sound case for ensuring that the more mature members of staff, when they retire or given early retirement, should be kept on board especially when these people have significant recall of major events and problems. Major projects require long term commitments to cognisant staff or consultants to avoid the expensive re-visiting and re learning otherwise involved. Some consultants work sufficiently closely with regular clients that they acquire or become part of what should be the client's corporate memory; this itself brings a responsibility. The type of problems that sometimes arise from lack of corporate memory include those relating to:-

    - Major variations in rock character or structure
    - Specific types of slope failure
    - Groundwater rebound issues
    - Product quality control/blending issues
    - Interpretation of site investigation and testing
    - Methods that succeed or fail
    - Knowing what has been done, or not done, in the past

Frequently these are not written up, and even when they are reported in literature the industry, and some consultants, fail to take into account the full implications for their own or client's sites. In Britain there is a natural reluctance to publish the details of things that have gone wrong as inevitably they are seen to rebound on the individuals concerned. However the history of mineral operations is one where real progress on safety and proper mine planning has only followed major events and fatalities. Memory is important both within a firm and across the industry. The following are examples of serious problems that have arisen that could have been foreseen, but for incompetence, ignorance and failure to read around the available geological and engineering literature, even at times to read internal company files:-

***i*** The Aberfan disaster triggered the Mines and Quarries Tips Regulations in 1971 and it is arguable that the experience of the sidewall failure at St. Aidan's Extension Opencast Coal Site in Yorkshire in 1988 led to the Quarries Regulations in 1999. This failure (Hughes and Clarke 2001) included bank failures in the River Aire which flooded into the site and cost many millions of pounds to correct (see Figure 2). The geotechnical engineer responsible had failed to account for ribside fissuring from shallow longwall workings that were curtailed by minor faulting and a boundary marked by the River Aire. They also failed to use the correct residual shear strength for intra-formational shear zones (Stimpson and Walton 1970, Jameson 1995) believing it to be too low. Advice that could have been received at the stage of mine design was not sought and no reference made to similar events which had occurred in identical settings near Cannock in 1969 (Walton and Taylor 1977).

***ii*** In 1955 a major collapse occurred on an opencast coal site on Meltonfield Coal in the East Midlands. The collapse occurred as a result of penecontemporaneous slumping. Extensive multi-directional shears within the collapsed debris that occupied 12m of strata immediately above the seam were re-activated on excavation and it was impossible to maintain slopes higher than 5-6m in this material. The characteristics were noted and published (Shirley, J. 1955), but the presence of similar strata above the Alex Seam in Staffordshire in opencast workings in 1966/67 was not anticipated and led to major collapses and near fatal accidents. Figure 3 shows a diagrammatic illustration of the slumping encountered. This matter was not reported until similar workings occurred, again above the Meltonfield Coal, in 1973 when Miller Mining was unable to operate a dragline as a result of these sedimentary features. At today's prices the cost of these latter two events would have amounted to several million pounds. Such features still occur today and Figure 4 shows similar features present in recent workings on an opencast coal site.

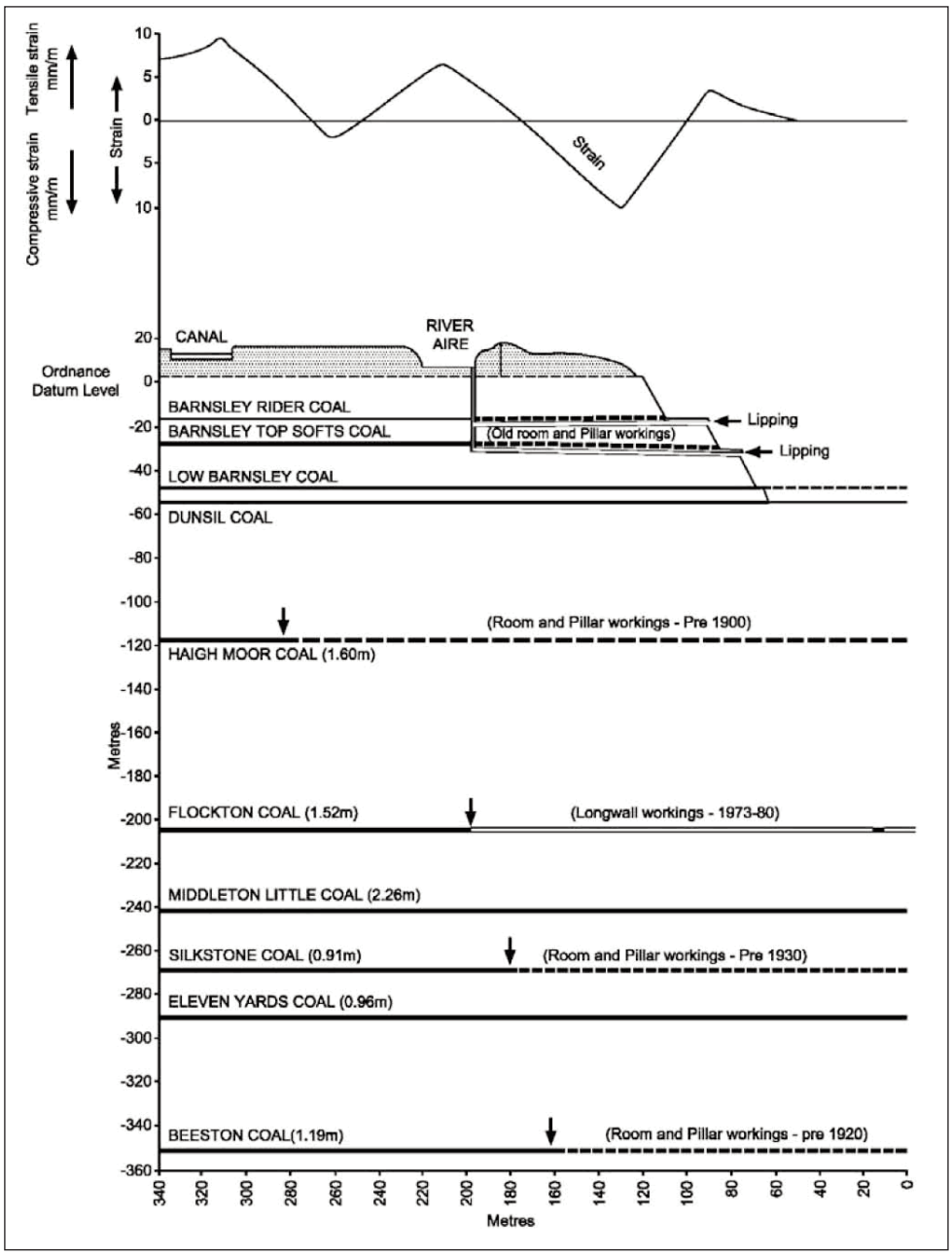


***Figure 2.*** *A cross section through the side wall of the St Aidan's Extension open cast coal site, Yorkshire, showing the proximity of the River Aire and nearby canal. The location of ribsides in underground coal workings produced differential strains, sub-vertical fissuring and tilting within the Coal Measure strata. Sliding occurred on very low angle intra-formational shear zones associated with the Barnsley Rider and Barnsley Top Softs coal seams with displacements visible before collapse.*

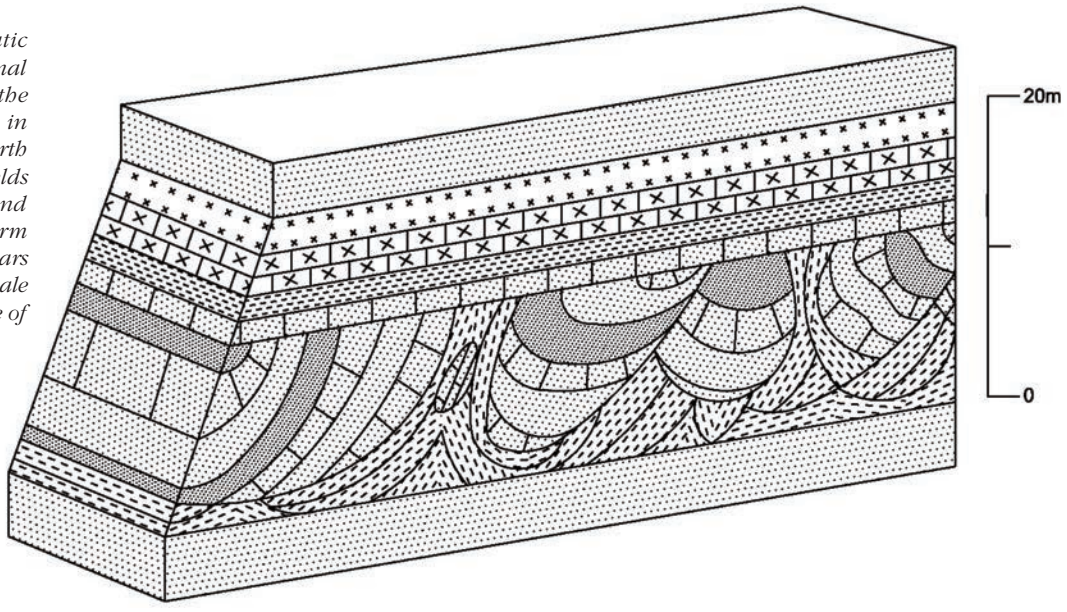


***Figure 3.*** *A diagrammatic illustration of intra-formational shearing associated with the Melton Field and Alex Coals in the East Midlands and North Staffordshire coal fields respectively. Strata above and below the slumping is of uniform inclination but multiple shears exist giving rise to bench scale failures and restricting the use of drag lines.*

***Figure 4.*** *Penecontemporaneous slumping in inter-seam strata including contorted bedding and intra-formational shear surfaces inclined in different directions. The face height is approximately 12m and the open cast coal site is in Scotland.*

***iii*** Clay way-boards have been known in the Carboniferous Limestone for many decades and have been noted in numerous geological publications (Smith *et al* 1967, Walkden 1968). Equally landslips have been known to be a major cause of instability if intersected at the margins of quarry workings (Barrett and Walton 2002). Techniques and methods for the identification of potentially hazardous areas have equally been known for many decades, but at times both the industry and consultants have ignored the need for investigations, and in the case of clay way-boards, failed to undertake the literature searches and site investigations required to ascertain their presence and the low shear strengths that obtain with these materials. Numerous examples of stability problems can be quoted from South Wales (see Figure 5), the Welsh Borders, the Bristol area and the Peak District of slope failures that need not have occurred and caused significant operational disruption and sometimes loss of reserves.

***Figure 5.*** *Sliding movements occurring on a clay way-board in a Carboniferous Limestone quarry in South Wales. The inclination of the strata and the location of the way-board are visible above the backhoe boom; the vertical and lateral displacements were approximately 1m and 2m respectively at this stage of movement.*

Many other examples could be quoted of things that have gone wrong and lessons that have not been learnt. It is suggested that the time has come for operating firms and for consultancies together to look at the causes of problems and to comprehensively address the items that should be reviewed as part of the exercise to avoid show stopping negligence. Since no individual firm of consultants, or operating companies, has omniscient attributes in this respect a case could be made for leading experts to prepare new check lists appropriate to different minerals and structural settings to avoid these ongoing problems.

## The Future

The increasing tendency for procurement departments in both industry and government to make appointments where cost is the major issue is understandable at a time of financial stringency. However the extractive sector must not lose sight of the fact that technical matters in the design and operation of quarries are a vital part of the business and that technical understanding should extend to the top and not be an optional consideration for accountants, estates managers and procurement staff. Without this the future is bleak and the HSE and the EA will be kept busy.

Financial stringencies and cuts are going to lead to a further decline in central government strategic research and likely constraints on the Aggregates Levy Sustainability Fund. However this will give a gap that could, and should, be filled by consultants, possibly aided by a re-focussed MIRO. Consultants should be able to work with the new agenda of less central government control and more localism with potential to advise local authorities and even parish councils even though it is doubtful whether such work will ever be forthcoming.

An active EIG that can continue to provide a technical basis for vital parts of the industry is therefore an important part of the future, not least because we are a separate specialist 'association' with common interests that do not necessarily coincide with other professional groups with which we may be associated. It is important to maintain our skills and understand where these fit in to the whole discipline of exploring for, and designing, mineral operations, operating them safely and economically and restoring them with minimal environmental impact. What we need to do is to interest undergraduates in the merits of applied science and technology in general and the value of the extractive industries in particular and to encourage research and further university based training. This way we can compensate for what has happened before and ensure that the nation can at least maintain security of supply of some of the minerals it needs.

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