Manchester Geological Association
The Broadhurst Lectures

Saturday 12th November 2011 – The Coal Measures

The Coal Measures is the name given to a set of beds laid down in late Carboniferous times in which coal constitutes the most valuable mineral though forming only a minor part of the succession ("Measures" is an older term for "Beds").

As we shall discover during the day, the coal formed from incompletely decomposed plant matter that collected in equatorial swamps, which, following compaction and heating subsequent to its burial, gave rise to the coalfields of Lancashire, Yorkshire and elsewhere.

With its forests of exotic trees, inhabited by large amphibians and giant dragonflies, its patterns of cyclic sedimentation (cyclothems) and its ice-sheets spreading across the southern continent of Gondwana (present-day Southern Africa and South America) the Coal Measures era and its associated rocks provided much to interest Fred Broadhurst and, as we shall hear, the speakers today.

10.30 – 11.15	Rates of Sedimentation in the Namurian and Westphalian Dr. Derek Brumhead MBE, Manchester Geological Association
11.15 – 12.00	Coal Depositional Environments and Effects on Mining in Northern England Dr. Paul Guion, Honorary Fellow, University of Derby
12.00 – 13.30	Lunch
13.30 – 14.15	The Rise and Fall of the Coal Forests Dr. Howard Falcon-Lang, Royal Holloway, University of London
14.15 – 15.00	Brymbo Fossil Forest: Fossils from the Brymbo Steelworks Site Dr Jacqui Malpas, Association of Welsh RIGS Groups
15.00 – 15.30	Coffee Break
15.30 – 16.15	Opencast uncovers the Past Alan Davies, formerly Curator, Lancashire Mining Museum
16.15 – 17.00	Coal-Mining in Lancashire, The Photographic Record Alan Davies, formerly Curator, Lancashire Mining Museum

Rates of Sedimentation in the Namurian and Westphalian
Dr. Derek Brumhead MBE, Manchester Geological Association

Calculating rates of sedimentation must take into account the rate of sea level change, subsidence, compaction, the available accommodation space, the character and thickness of bed, the amount of time involved with the environment of deposition, climate, supply of sediment, tectonic movement (difficult to distinguish from compaction), erosion, and hiatuses (is a bedding plane a hiatus ?) More time may be represented between beds than the beds themselves. And what about diachronous lithologies so common in the Westphalian and Namurian, giving rise to lateral variation in sedimentation ? This can be on a vast scale.

Namurian - A number of workers have attempted to calculate the average duration of the 60 Namurian cyclothems. Ramsbottom who anticipated the advent of sequence stratigraphy, postulated that a new goniatite fauna and the associated cyclothem occurs every 200,000-250,000 years, i.e. making a total of between 12 Ma and 15 Ma years for the Namurian. This traditional biostratigraphical method of dating has been supplanted by radiometric methods. Hess and Lippolt used radiometric dating ($^{40}Ar/^{39}Ar$) of tonsteins (weathered volcanic tuffs) and sanidines (variety of orthoclase feldspar) interdigitated in the Carboniferous sediments to calculate a figure of 11 Ma for the duration of the Namurian.

Westphalian - In general, the Westphalian rocks in NW Europe represent flood-plain deposits of mudstones, diachronous sandstones which show much lateral variation in thickness, siltstones and coals, with marine transgressions that became less common through time. The cyclothems are thinner than in the Namurian, the deltas are not so laterally extensive, they do not have turbiditic aprons and have proportionally thicker fluvial-deltaic sediments which indicate deposition by major low-sinuosity distributary channels in a lower alluvial/upper delta plain environment. The humid tropical climate resulted in a largely waterlogged plain. Gradual vertical accretion raised the delta surface until vegetation was able to get a hold on abandoned channels and infilled lakes and established swamps or raised peat bogs. The duration of the Westphalian is calculated as 10 Ma. If this is the case, the maximum thickness of the Coal Measures of 7,425 feet (2,283m) in the Manchester-Oldham region means an overall sedimentation average rate of the order of 1,347 years per foot (4,380 years per metre). Since it was all deposited at or near sea level, it follows that the subsidence rate was huge.

Coal seams accumulated on raised mires or swamps where clastics are excluded and maintained through several thousands of years. They depend on a widespread slowly rising water table, achieved by a base-level rise on a regional scale, and the creation of space landward.

It is difficult precisely to quantify rates of peat accumulation to coal because considerable compaction (perhaps as much as 5:1) takes place within a peat in a mire environment. Ratios have been calculated to be between 1.4:1 and 30:1. Assuming a median average ratio of 15:1, then 1 metre of coal represents peat accumulation in the tropics over a period of 6,500 years. Mudrock partings in coals probably represent events with a periodicity of thousands or even tens of thousands of years.

Mires therefore maintained themselves through many thousands of years. The Limestone Coal Group (Pendelian) of Scotland attains a thickness of some 200-450m, of which 4.2-9.2% is coal resting mainly on sandstones and seat earths with some mudstones. Since this group has been shown to occupy the upper part alone of one goniatite zone (E1a) probably less than 200,000 years, the time for the accumulation of up to 40m of coal is c. 1m in 5000 years. In 1986, Fred Broadhurst and Tony France in their article on 'Time represented by coal seams in the Coal Measures of England' estimated the accumulation rate as 1m in 7,000 years.

Marine bands in the Namurian and Westphalian are condensed sections due to the marine incursions, The rapid rise in sea-level means sedimentation rates are very slow in response to the great area of accomodation space made available on a regional or continental scale, exposed to sedimentation on the sea floor and the landwards shift of the sediment source. Thus a condensed section results. Although they may be in total less than a metre in thickness, the time taken for their deposition will be of the order of tens of thousands of years.

Upright trees are evidence of very rapid sedimentation of the enclosing sediments. The trunks were surrounded by sediment before the interiors were decomposed, otherwise the trees would have fallen over. A fossilized tree has been described in position of growth from the Coal Measures at Blackrod near Wigan. Fred Broadhurst and a colleague refer to a 13 ft (4 m) cast, probably once 38 ft (12 m), completely buried in sediment and rooted immediately above the underlying coal seam.. He calculated that a life span of the tree of say, 100 years, after inundation would involve a rate of sedimentation of 4½ inches per year.

Seasonal Sedimentation - Evidence for seasonal controls of sedimentation in the Westphalian is best sought in sediment sequences formed in environments with seasonal changes in rainfall and fluctuating rates of sediment supply. The sequence of sediments between two coals in the Lancashire Coalfield (Westphalian A) is described by Fred Broadhurst and colleagues in 1980, with particular reference to Ravenhead Quarry near Wigan. Part of this succession consists of regularly-bedded laminated sandstone/siltstone units containing non-marine bivalves and their escape shafts. The sandstone/siltstone units were due to cyclic sedimentation controlled by monsoons. The sandstone accumulated during wet seasons, the intervening siltstones during dry seasons, so that the rate of sedimentation is measured in days. The escape shafts of the non-marine bivalves are evidence of rapid sedimentation.

Tidal sedimentation - There is a paucity of examples of tidal deposition in the European Westphalian. In the Francis Creek Shale of Westphalian D in NE Illinois, the laminated succession of the silty clayrock includes clay bands forming couplets or pairs. Variation in the thickness of the silty clay layers within and between the clayrock pairs appear to be cyclic. The development of alternating thin and thick groupings of the paired-clay sequences has been interpreted to result from deposition during neap and spring tidal cycles. It is possible therefore to measure the rate of sedimentation which appears to have averaged 1m/yr (i.e. 34 years to deposit a total maximum thickness of 34 m). But this includes compaction, reworking and subsidence so that the minimum time of deposition may be significantly longer.

Coal Depositional Environments and Effects on Mining in Northern England
Dr. Paul Guion, Honorary Fellow, University of Derby

The extensive coalfields of northern England formed during the late Carboniferous by deposition in the Pennine Basin, bounded by the Wales – Brabant High to the south and the Southern Uplands to the north. The basin was initiated as a consequence of late Devonian to early Carboniferous extension accompanied by dextral strike slip. This caused the formation of a series of half-grabens, which greatly influenced the thickness and facies of early to mid-Carboniferous sediments. By the late Carboniferous, the effects of these structures had gradually reduced, and the basin was dominated by gentle regional sag, with the depocentre of the basin being situated in the north Staffordshire area.

During the late Carboniferous, the area of deposition lay close to the equator, within a narrow seaway with only tenuous connections to the open ocean. Sediment was supplied to the basin from a variety of different source areas. The majority of economic coals formed from the mid-Langsettian to mid-Bolsovian in a generally waterlogged fluvio-lacustrine environment. Sediment was transported into the basin by a series of major channels, which fed into shallow lakes by means of minor channels, lacustrine deltas and crevasse splays. Infilling of the water bodies enabled periodic accumulation of peat close to the water table, ultimately giving rise to coal seams.

Extraction of coal in the Pennine coalfields mainly takes place in surface (opencast) mines or underground mines where coal is generally worked by means of longwall faces. Surface mines are relatively flexible, and any geological problems can usually be worked around. Underground mines require a high level of capital investment, and longwall faces are generally inflexible, hence the prediction of potential geological problems is of paramount importance. Various geological phenomena which arise as a consequence of the depositional environment of the Coal Measures will be described, and techniques suggested so that ‘unforeseen geological problems’ can be avoided.

Lunch Break

The Buffet Lunch will be available in the nearby ground-floor laboratories in the Williamson Building. There will be a collection of coal and related rocks on display in the laboratory.
Also, during the lunch break, there should be time to see the display of Coal Measures plants displayed in the Manchester Museum, directly opposite the Williamson Building across Oxford Road. This includes Williamson’s Tree – the root system of a tree, about 20 feet across, found in a quarry in Bradford and transported to Manchester by horse-drawn cart.

The Rise and Fall of the Coal Forests
Dr. Howard Falcon-Lang, Royal Holloway, University of London

The rise of the Carboniferous Coal Forests is one of the best-known episodes in the History of Life. Although often reconstructed as steamy tropical rainforests, these ancient ecosystems were a far cry from anything we might encounter in the Amazon today. Bizarre giant club-mosses, horsetails and tree ferns were the dominant plants, not flowering trees as in modern rainforests. At their height, the Coal Forests stretched all the way from Kansas to Kazakhstan, spanning the entire breadth of tropical Pangaea.

Most of what we know of their biodiversity and ecology has been quite literally mined out of the ground through two centuries of hard labour. Without coal mining, our knowledge would be greatly impoverished. Over the past few years, I've been exploring underground coal mines in the United States, where entire forested landscapes have been preserved intact over huge areas. Never before have geologists had the opportunity to walk out through mile upon mile of fossilized forest. In this talk, we'll travel from Illinois to New Mexico and explore some exciting new discoveries. In particular, we'll consider how recent studies of palaeoclimate fluctuations are radically transforming our understanding of the Carboniferous tropics.

Brymbo Fossil Forest: Fossils from the Brymbo Steelworks Site
Dr Jacqui Malpas, Association of Welsh RIGS Groups

Brymbo is a village west of Wrexham, North Wales, in the north of the Denbighshire Coalfield. Local records tell of coal being mined in 1410 and mines are recorded in Harwd, the old name for Brymbo. Brymbo was a centre for iron, and later steel production, for almost 200 years until the huge steel plant closed in 1990.

During redevelopment of the derelict site in 2005 invitations to a fossil hunt were sent out to geological groups in North Wales & North West England as plant fossils had been found while digging a large pit in the Carboniferous Duckmantian (Westphalian 'B'), Middle Coal Measures that underlie the old steelworks site. At this event, many *in situ* plant fossils were found including lycophytes and horsetails. Many of the smaller fossils were taken away. At this event it was realized that this is a unique site in Wales and discussions began to try to conserve this site. Since then a few hardy individuals have been working on the site excavating and rescuing a diverse and abundant flora, which have been found in the sandstones and mudstones between two coal seams.

The *in situ* plant fossils show exceptional preservation of arborescent lycophytes with *Stigmaria*, at three horizons, stands of up to ten *Calamites* stems, pteridosperm and fem debris and megaspores. The mudstones, siltstones and rippled sandstones, palaeosols (seatearths) and coals together with the fossils offer an exceptional insight to the environment where these plants lived and died. The site is a RIGS (Regionally Important Geodiversity Site) and will shortly be a SSSI.

Opencast uncovers the Past
Alan Davies, formerly Curator, Lancashire Mining Museum

Opencast mining of a form could be said to have arrived in Britain and especially Lancashire back in mediaeval times when the divining rod proved mineral deposits and shallow trenches were set out. Unrecorded workings are often found along outcrops at modern day opencast sites providing evidence for this early activity.

Organised opencast working really arrives as a WW2 emergency measure in late 1941 to boost production at a time when many skilled miners had been taken away to serve in the forces. The Directorate of Opencast Coal Production survived until 1952. These early sites were shallow, usually exploiting outcrops, often revealing early unrecorded workings which sadly were rarely documented.

After nationalisation in 1947 the NCB Opencast executive was formed. After the war a combination of a coal industry manpower shortage and a means to boost production led to the Opencast Coal Act 1958 which contained powers to compulsorily authorise sites and allow sites to access tonnages larger than 25,000. The sites of the late 1950's through to the end of the 1960's rarely ventured below 50 metres and many of those sites were to be re-opencasted from the 1980's to recent times.

The NCB Opencast Executive survived until 1987 when British Coal Opencast took over administration. With the passing of the Coal Industry Act in 1994 and privatisation the administrative functions of British Coal were transferred to a new Coal Authority. Its economic assets were privatised, the English mining operations being merged with RJB Mining to form UK Coal plc. Opencasting is now carried out by contractors or UK Coal themselves.

For the mining historian opencasting is the equivalent of mammoth scale archaeology, the removal of strata revealing working evidence from centuries ago. This has to be documented before being obliterated permanently. Regular visits are made to a site, the engineers are there to mine coal and very rarely show concern for the historical importance of what is revealed by their operations. When they do and they keep in touch the results can be spectacular, as with the mid 1990s Ravenhead site at St Helens which uncovered 16th century pillar and stall workings. The most recent site, Cutacre, at Little Hulton south of Bolton was regularly visited, with old workings, artefacts and rare fossils discovered. The speaker has been documenting opencast sites in the North West for over 35 years.

Coal-Mining in Lancashire, the Photographic Record
Alan Davies, formerly Curator, Lancashire Mining Museum

No two collieries in the Lancashire coalfield were ever identical in layout, either below ground or on the surface. The visual record of the industry is very important to the industrial archaeologist or mining historian, as the survival of primary archives is often very limited.

Before the widespread use of photography in the mid to late 1840's, depictions of mainly surface features in the Lancashire coalfield relied on artists and engravers. The wide range of illustrated newspapers from the 1850's onwards often documented the sites of colliery disasters and occasionally featured the miners themselves in detail. The Illustrated London News was particularly active in this area.

Photography of both surface features and life below ground in the Lancashire coal mines arrives around 1890-3 with an unlikely practitioner, the Revd. William Wickham, vicar of St Andrews Church, Wigan. His photographs taken below ground may be the first ever taken in British mines. Most of the vicar's parishioners worked at the adjacent Douglas Bank Colliery, the women (pit brow women) working on the surface. The arrival of the sixteen-week miners' strike in 1893 led to the vicar documenting both surface and underground life.

From Wickhams' work in the 1890's to the arrival of the picture postcard around 1904 images of the Lancashire collieries could usually be found in company boardrooms or publications, and rarely in the work of amateur photographers. The arrival of the picture postcard around 1904 led to an increase in the photographic documentation of the industry, with images of the pit brow women selling particularly well in the Wigan area. In 1907, the year of peak production in Lancashire 358 collieries were active in the coalfield. A large number of mines were to close from this period until nationalisation, sadly undocumented by photographers.

The larger mining companies occasionally employed professional photographers to document major projects, such as shaft sinking or deepening, surface reorganisations or the installation of more powerful steam winding engines. With the arrival of the National Coal Board in 1947 full time photographers were to be employed in all the divisions and their sub-areas. They produced a huge number of images for internal and public relations use, in Coal Magazine for example.

The rapid run down of the industry both nationally and Lancashire in particular from the late 1970's led to the new breed of industrial archaeologists and specialist mining museum curators racing around documenting sites in detail. The end was in sight after the 1984 strike for an industry which had been active in Lancashire from at least the late 12th century. Alan Davies was the curator of the Lancashire Mining Museum from 1985 until its closure in 2000, taking thousands of images of the last collieries.

The deep mines have all now closed but the process of photographic documentation of the former coalfield continues, with mine explorers documenting digitally their findings (secretly) in old drift workings. Documentation of opencast sites continues, especially important when old mine workings are exposed. This presentation taps into public and private collections and also work by the author.