EXCURSION

Carsington and Harboro'

Leader: Neil Aitkenhead

Sunday 16th July, 2000

Carsington Water

The day began at the Carsington Water Visitors Centre (SK245515), at the southern end of the Derbyshire Peak District. In a lecture theatre filled with an excellent turnout of members and guests, Neil described the geology and engineering story behind the failure of the original Carsington dam.

In June 1984, a part of the upstream side of the nearly completed dam, about 500m long and 37m high, progressively slipped. Fortunately the reservoir had not yet filled with water, for this could have led to a major disaster. The subsequent investigation (Coxon, 1986) found that "the predominant element in the slide was progressive failure arising from brittleness of the soils and geometry of the section. The weak 'yellow clay' foundation and the existence of solifluction shears within it were also contributory factors to the failure as it occurred". In other words, the design was poor and the site investigation inadequate! Some internal movement would have taken place naturally as the dam compacted under its own weight and this movement seems to have developed progressively into the disastrous slide.

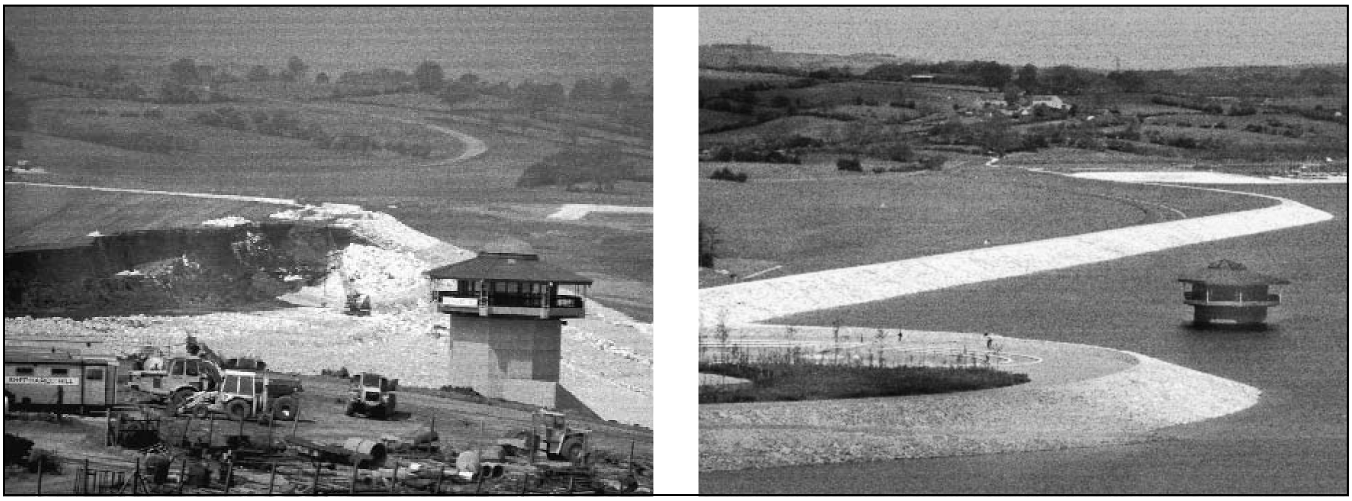
The site is underlain mainly by dark grey shaly mudstones, of the Namurian Edale Shale Group. Some thinly interbedded sandstones and siltstones occur, together with minor ironstones and impure limestones, a bed of cherty siltstone and a few laminae of altered volcanic ash. Marine bands occur at intervals throughout the succession. Key species of the goniatites and bivalves, and their subsequent identification by Dr Nick Riley, proved essential in making an accurate geological map of the site and delineating structural features that needed attention during dam construction.

The mudstones have been weathered near the ground surface to a pale brown clay, and this has been mobilised by solifluction in freeze-thaw periglacial conditions to produce a thin but extensive layer of head immediately beneath the topsoil. The only natural material directly implicated in the failure of the dam was the thin deposit of head. This was known only as the 'yellow clay' to the engineers, and was left in place beneath an extensive area of the embankment. There appears to have been no recognition of the presence of head in the pre-failure site investigation reports. The head was shown to contain weak clay minerals, and David Norbury, of Soil Mechanics, found relict shear planes that had developed during deposition.

Additional problems at the site, investigated by Dr Keith Ball, arose from oxidation of pyrite that was common in the shaly mudstones. Within the embankment porewaters, this produced sulphuric acid that reacted with incorporated limestone to produce gypsum and CO_2. Tragically, the accumulation of this gas caused the death of four men by asphyxiation in an inspection chamber.

Before rebuilding the embankment dam, the underlying head was removed. The clay core of the new dam has a wedge-shape in place of the original boot-shape. Embankment slope angles were reduced, and the reactive internal limestone drainage blankets were not replaced. Completion of the new dam, by September 1991, added tens of millions of pounds to the final cost.

Lunch was taken in Carsington village at the Miner's Arms, after those stranded by hydraulic failure in their coach were ferried by colleagues with cars. From the village we walked north onto the limestone, up the hill towards Harboro' Rocks.



The southeast end of the Carsington dam, on the left immediately after the 1984 failure, and on the right after rebuilding, with the reservoir filled. The bulk of the dam is formed of dark mudstones, with the water face covered by light coloured limestone riprap, for protection against erosion.

Bee Low Limestone

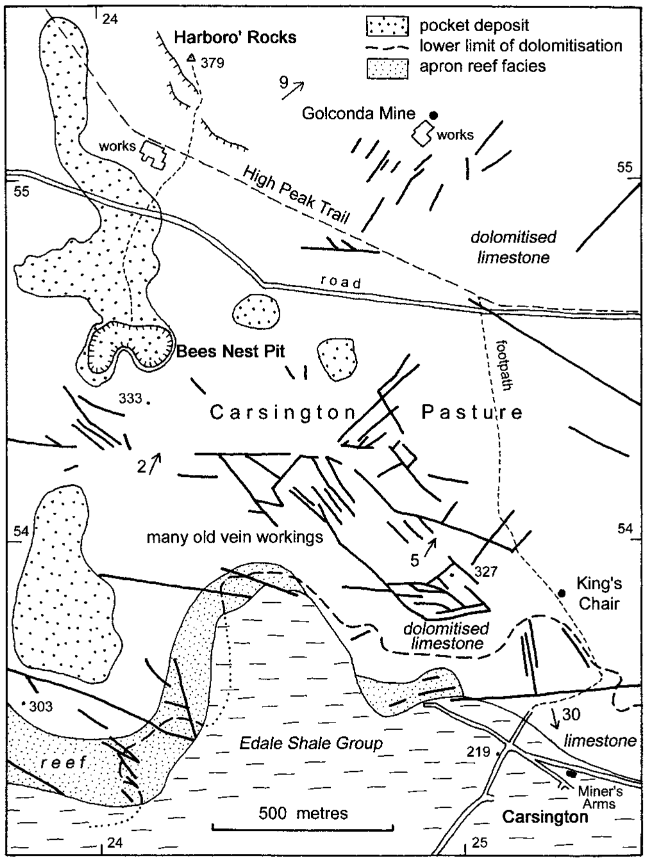
Undolomitised Bee Low Limestones exposed on the lower slopes were interpreted as shelf facies from near the southern margin of the Derbyshire Carbonate Platform adjacent to the subsiding Widmerpool Gulf. The question was raised as to whether it was indeed shelf or apron reef facies. Dave Mundy and Peter Gutteridge, both carbonate sedimentologists, noted that the limestones were mainly fine-grained micrite and showed a typical 'reef fabric' with irregular laminations of fibrous calcite cement. These were originally the linings of numerous cavities, which became flattened subparallel to the bedding during compaction of the lime mud. Dave noticed that the orientation of this fabric seemed to vary randomly from exposure to exposure, suggesting the presence of discrete, variously orientated blocks, reminiscent of the boulder beds at the foot of other apron reef slopes in the Peak District, at Castleton and Chrome Hill. It was agreed that these were tentative findings and that more work was needed, particularly on identification and measurement of the orientation of geopetal cavity fillings.

Mining

Further up the slope onto Carsington Pasture it soon became evident, from the number of old spoil heaps and capped shafts, that the ground had been intensively worked for minerals, mainly galena for its lead. Some minerals from these ores were seen where spoil had been disturbed by rabbits. The discovery of four Roman lead ingots at Lutudarum, now submerged by Carsington Water, suggests that local mining may well date back to Roman times (Willies, 1995).

Many of the spoil heaps are in lines over the veins. Others have a close-spaced but random distribution, probably over flats - orebodies that follow the carbonate bedding, perhaps just below the former shale cover. Other orebodies were developed at the base of the dolomitised limestone, notably at Golconda Mine.

The ores are thought to have been deposited by fluids that were derived from late Dinantian to early Namurian shales that were deposited in basins such as the Widmerpool Gulf, adjacent to the Derbyshire Carbonate Platform. By late Westphalian times, these shales would have been buried to depths of 2.5-3.0 km and, largely as a consequence, heated up to about 100-1200C. Additional heating may have been caused by the decay of radioactive minerals in the shale, and also by heat flow from volcanic centres. Thus the original porewaters in the marine sediments were transformed into hot brines, which became enriched in Pb, Ba, F, Cl, Zn and hydrocarbons. De-watering of the basinal rocks and the repeated build-up and release of crustal stress during fracturing and faulting of both basinal and platform rocks (seismic pumping) took place in the end-Carboniferous Variscan orogeny. By this



Outline geological map of the slopes from Carsington up to Harboro' Rocks. The limestone is dolomitised at outcrop, except in a narrow band adjacent to the shale.

mechanism, the ore-bearing fluids were moved from the source rocks to fracture planes and cavities in the host rocks, where the minerals were deposited by acid neutralization and sulphate reduction reactions during fluid mixing.

The weather was splendid, and, as we climbed higher, so was the view to the south. We could see the Charnwood anticline in the far distance, Madge Hill in the middle distance and the west-facing escarpment of the Ashover Grit overlooking Carsington Water.

Dolomitisation

In the main limestone outcrops in the southern part of the Peak District, dolomitisation has clearly taken place from the top of the limestone downwards. The lower boundary with undolomitised limestone is sharp and greatly undulating, with up to 125 m of relief. Below the King's Chair, Neil demonstrated this with a series of sections from a limestone resource map of the area (Cox and Harrison, 1980). Dolomitisation occurred by the introduction of magnesium, presumably from percolating brines, into the calcite molecules. Dolomites tend to be open textured and vuggy. Although dolomitisation is reputed to cause a volume decrease of 12%, Dave and Peter pointed out that this only occurs under laboratory conditions. In natural conditions the decrease is much less, and subsequent dissolution of calcite remaining in the newly porous rock accounts for most of the typical vuggy character, specially on weathered surfaces.

The source of the magnesium-bearing brines and the timing of the main episodes of dolomitisation remain speculative. They may have occurred during the Variscan orogeny, when deep erosion in semi-desert conditions prevailed after considerable uplift. Brines from the late Permian Zechstein Sea have been considered a source, but evidence from the Permian rocks at outcrop to the east indicates that the nearest shoreline of that sea lay near Nottingham and the Peak District was a land area at the time. Saline ground waters circulating down from the Triassic Sherwood Sandstone, where that formation was in contact with the limestone, is another possible source (see below). Some of the mineralisation at Golconda Mine clearly post-dated both dolomitisation and the development of caverns at the dolomite-limestone boundary. Lesser episodes of both mineralisation and dolomitisation probably occurred up to Jurassic times.

The King's Chair (253538), a small isolated dolomite limestone tor adjacent to the path, looked as though it might have been artificially modified. Discussion led to no firm conclusion.

Further north, we crossed a broad dry valley (251542) with evidence of former excavations, perhaps in search of silica sand. An animal scrape displayed orange-brown silty loam containing glacial erratics that were mainly well rounded quartzitic pebbles derived from the Sherwood Conglomerate. Though shown on early maps of the Geological Survey as boulder clay, this deposit had been reclassified on the new map as head (Chisholm et al, 1988). Here it comprises a pre-Devensian till, that had become remobilised during Devensian periglacial conditions, moving down the slope and mixing with wind deposited loessic silt, to accumulate in the valley.

Harboro' Rocks

We followed the High Peak Trail, and then branched off to climb onto the top of Harboro' Rocks (243554). Here the question was raised as to whether these spectacular little cliffs are best described as tors, or are simply a craggy escarpment, like many others in the Peak District - though the processes of tor formation would have occurred regardless of terminology. The dolomite was perhaps initially subjected to deep chemical weathering in a warmer climate, particularly down major joint planes. Subsequent frost shattering and debris removal by gelifluction and wind erosion in Devensian periglacial conditions were probably also important. Fossils are commonly destroyed during dolomitisation but a few relic brachiopods and crinoids led to suggestion of an Asbian age for the sequence.

At the top, the topography of the southern part of the Derbyshire Carbonate Platform was beautifully displayed, and well-known landmarks were identified. Ian Thomas, from the Stone Centre, pointed out seven quarries, both active and abandoned, in both limestone and sandstone. Several factories visible on the plateau had at various times used limestone, dolomite and sand to produce cement, magnesium, refractory bricks and specialised ceramics. We could also see widespread evidence of former lead mining and some subsequent working for fluorspar.

Bees Nest Pit

We retracing our path to the High Peak Trail and headed south to the Bees Nest Pit (241546) - old excavations into a Pocket Deposit that was worked for silica to make refractory materials.

Pocket Deposits are preserved only in large, steep-sided solution dolines in the limestone plateau, but the succession that they represent (at least 45 m thick) must have been extensive in the area in Neogene times, on top of Namurian shales that rested unconformably on the limestone. The sands and clays are collectively assigned to the Brassington Formation. They have been dated as late Miocene to early Pliocene (perhaps about 7.0-3.5 Ma) from spores preserved in the grey clays of the Kenslow Member at the top of the succession. The clays are thought to have been deposited in a lake very close to sea level. The underlying sand-dominant Kirkham Member is deduced from palaeocurrent and petrographic evidence to have been deposited as alluvial fans emanating from a southward retreating escarpment of Triassic Sherwood Sandstone (Walsh *et al*, 1980), which now lies about 8 km to the south. Restoration of the sandstone escarpment, to the position it must have occupied during deposition of the Kirkham Member implies relative uplift of the limestone plateau by about 300m in the last 5 million years.

This was Neil's last field excursion before leaving us for Yorkshire. It was thoroughly enjoyed by all, and he was happy to see so many of his old colleagues. He has given a lot of time and enthusiasm to the Society, for which we are very grateful and we hope to see him again soon.

References

Chisholm, J.I., Charsley, D.J. and Aitkenhead, N., 1988. Geology of the country around Ashbourne and Cheadle. *Memoir of the British Geological Survey*, Sheet 124.

Cox, F.C. and Harrison, D.J., 1980. The limestone and dolomite resources of the country around Wirksworth. *Mineral Assessment Report of the Institute of Geological Sciences*, 47.

Coxon, R.E., 1986. Failure of Carsington Embankment. *Department of the Environment Report*, HMSO, London.

Walsh, P.T., Collins, P., Ijtaba, M., Newton, J.P., Scott, N.H. and Turner, P.R., 1980. Palaeocurrent directions and their bearing on the origins of the Brassington Formation (Miocene-Pliocene) of the southern Pennines, Derbyshire, England. *Mercian Geologist*, **8**(1), 47-62.

Willies, L., 1995. Roads, agricultural features and mines on Carsington Pasture. *Bull. P. D. M. H. S.*, **12**(5), 19-23.

Judy Small (from notes by the leader)