Bath Geological Society, Bristol NATs (Geology section) and WEGA
North Pennine Field trip

Sunday June 9 – Friday 14th, 2013

Pointing the way was Doug Robinson

Driving the group around in the Minibus was Judy Hible

About one-half the group met at 11:00 on Sunday, June 9th at the minibus rental depot in Bristol, ready for the off. Come midday, we were on the M5 heading north with an uneventful journey and no holdups, arriving at our accommodation base at Fawcett Mill Fields, near Tebay.

Fawcett Mill Fields with waterfall in garden (GC)

Fawcett Mill Fields is set in five acres of wonderful gardens with a 17th century packhorse bridge. The Rais beck flows through the garden and cascades in a waterfall over an exposure of the Stone Gill limestone. The mill dates back to 16th century, and was bought as a derelict building in waste ground by the present owner, Sue, in 1986, and has been restored over many years into the splendid location it is today.

Packhorse bridge (GC)

The garden was host to a variety of birds, and in the mornings before breakfast, and through the evenings, the balcony was the place to be - armed with binoculars. Trevor's list of sightings include the Dipper, Pied Wagtail, Grey Wagtail, Greater spotted Woodpecker, Green Woodpecker, Chiffchaff, Swallow, Chaffinch, Song Thrush, House Martin, Restart, Swift, Dunnock, House Sparrow, Starling and Jackdaw. Perhaps the highlight was the sighting of two young dippers with their fussing parents on the waterfall. One morning there was a rush for the balcony as the local red squirrels made their appearance.

Dipper young (DR)

Trevor's sightings during the field days included the Hooded Crow, Curlew, Buzzard, Lapwing, Mistle Thrush, Skylark, Meadow Pippit, Red Grouse, Golden Plover, Ring Ouzel, Rook and Raven.

Day 1, Monday: Cow Green reservoir, Cauldron Snout, Falcon Clints, Low force

We started with a scenic tour across wild moors to reach Cow Green Reservoir at the site of the former Cow Green Mine. We then spent the morning taking a gentle journey down through the local Lower Carboniferous Limestone sequence to its upper contact with the Whin Sill. This was to prepare us for the climb down Cauldron Snout after the lunch break. Our leader, Doug, had carried out research and mapping here prior to the reservoir construction, using borehole cores to investigate the contact metamorphism associated with the intrusion, and this information added greatly to the overall picture.

On the moor top of Widdybank Fell, the group was gripped by the first excitement of the trip, indeed some were on their hand and knees, but not to examine the Whin sill, nor the contact metamorphic sugar limestone, but examples of the famous artic flora of Teesdale, including swathes of gentians, violas, bird's eye primrose, cottongrass and some anemones.

Close up examination of Artic flora (DR)

Spring gentians (KS)

Birds eye primrose (KS)

Mountain pansy (DR)

From the Smiddy Limestone at the reservoir car park and down to the Melmerby Limestone above the dam we passed through a landscape of harder limestone ridges forming scarps with more rounded features corresponding to sandstone and clay layers. It was cut by small gashes in the hillside, or hushes, where mineral veins containing lead, zinc and barytes had been worked by scouring with water from a temporary reservoir above.

Hushes near Cow Green (SS)

Further down the road we looked more closely at the limestone in a small quarry. Each small unit, from a few cm to a metre thick, is a post, and these are very constant and traceable over a wide area. They occur in a pattern of thickening and thinning with time, in bed sets of about 10 beds. These have been linked to Milankovitch cycles and calculations suggest that each post represents a period of the order of a thousand years of deposition. During the cycles, the radiation received from the sun varied, causing corresponding changes in polar ice and conditions under which limestones formed. The pure scar limestones represent long periods of deposition in clear mud-free water.

Robinson Lst quarry (SS)

Robinson Lst posts (SS)

Further along again, we looked at the surprisingly small shaft into Rod's Vein, only loosely guarded by a wire fence. This had been worked since Roman times for the metals, with the fluorite and baryte gangue minerals discarded. Much later, the mine and the tips were worked again, for another 200 years, to recover fluorite for use in the steel industry. Finally, with North Sea oil exploration, baryte became valuable for adding to drilling mud and the mine was reworked again until finally closing in 1952.

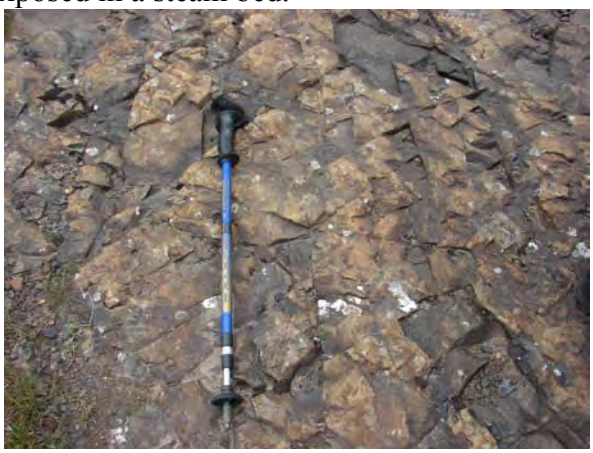
Rod's vein (SS)

Further towards the dam, a roadside block provided a sample of sugar limestone formed by the Whin sill contact metamorphism of the Melmerby Scar lst. Proximity to the intrusion was reflected by a larger grain size, as the calcite crystals attain a lower surface energy by having a larger volume relative to surface area. This limestone is very pure, containing little carbonaceous organic matter, which would prevent recrystallisation. Doug provided photographs of some borehole samples showing the sugar limestone as interlocking grains of calcite with all traces of fossils destroyed; mudstones became spotted hornfels, and grossular garnet formed in muddy limestone. Calcium in this garnet distorts the atomic structure, so it displays interference colours under crossed nicols instead of being dark. He also produced a core sample from the depths of his rucksack to show a banded hornfels from the immediate contact, with the lighter layers containing grossular and pyroxene, and the red layers consisting of albite and known as adinole, (a new word for some of us), representing mudstone that has been albitized at the contact of a basic intrusion.

Banded hornfels (SS)

Turning around, we had a good view towards the dam of the Melmerby Scar limestone cropping out at the shoreline, just above the Whin Sill, which is clearly exposed in a steam bed.

Melmerby Scar lst at shoreline (SS)



Surface of Whin Sill intrusion (SS)

We continued down to the top of Cauldron Snout, below the dam, for a lunch break. The main concrete dam was built on the upper surface of the solid Whin Sill, but the green area to the left, the west end, is an earth and clay bank built to infill a glacial channel.

Cow Green dam (DR)

The river Tees has its original route down the centre of the reservoir emerging through the dam to fall some 75m over large blocks of igneous dolerite at Cauldron Snout to the valley below. The Whin sill intruded the limestone around 295Ma and is about its thickest at this point.

The drop is precipitous but almost all members of the group negotiated the tricky route down and back up. The source of the intrusion is likely to be right beneath where we lunched, where the sill is at its thickest and the metamorphic aureole at its greatest extent of ~ 25m.

Descending Cauldron Snout (KS)

A walk along the Tees valley took us to the Whin sill bottom contact, which is clearly seen as a large overhang sitting on the older Carboniferous limestone. The limestone has been eroded by wind and water, leaving the sill over-hanging by 2m in some parts. The under surface of the sill shows as vertical spire-like shattered sheets. The basement limestone at this contact aureole has metamorphosed to crystalline 'sugar' limestone, a crumbly white marble.

Basal contact of Whin Sill against sugar limestone (DR)

High above and extending downstream in an east/northeasterly curve, the high cliffs of Whin sill are called Falcon Clints. Walking further down stream looking for conglomerates formed during the stronger movements of deeper seas and river systems but none were found, much fallen scree from the Whin sill may have obscured it in recent years.

Birds seen on the walk included curlews and oyster catchers. At the river valley a family of ring ouzels, very exciting to see the feeding of a dishevelled youngster by the smart dark parent with its large white collar.

It was then a long return to the bus ending a round trip of ~10.5 km, and then we continued in the minibus downstream along the Tees to Low Force.

The bus parked at Bowlees Information Centre, which is closed for renovation, but due to open this summer. A walk to the Tees across a beautiful buttercup meadow took us over the single-crossing suspension Wynch bridge built in 1830.

Buttercup meadow Low force (KS)

Crossing Wynch bridge (KS)

Low Force is formed where the Tess flows over the top of the Whin Sill, and it was a very picturesque setting, where it was very tempting to linger.

Group at Low force (DR)

From Low Force we walked downstream through a beautiful bluebell wood, passing over the last of the Whin sill as it dips eastwards, the river initially tumbling over large blocks in a series of falls. A sandstone block caught up within the Whin sill stands relatively uneroded by the river, before the route passes into the Yoredale series. A few metres to the south of the path there are remains of a number of disused trial workings and tips close to the contact of the Whin sill.

Bluebell wood, Low Force (KS)

Crossing back to the north side of the river by the Scoberry footbridge, the Tees flows over slabs of the Cockleshell limestone in which fossils can clearly be seen. Many solitary and some colonial lithostrotion corals up to 40cm were seen, as well as gigantoproductid brachiopods, from which the bed takes its name.

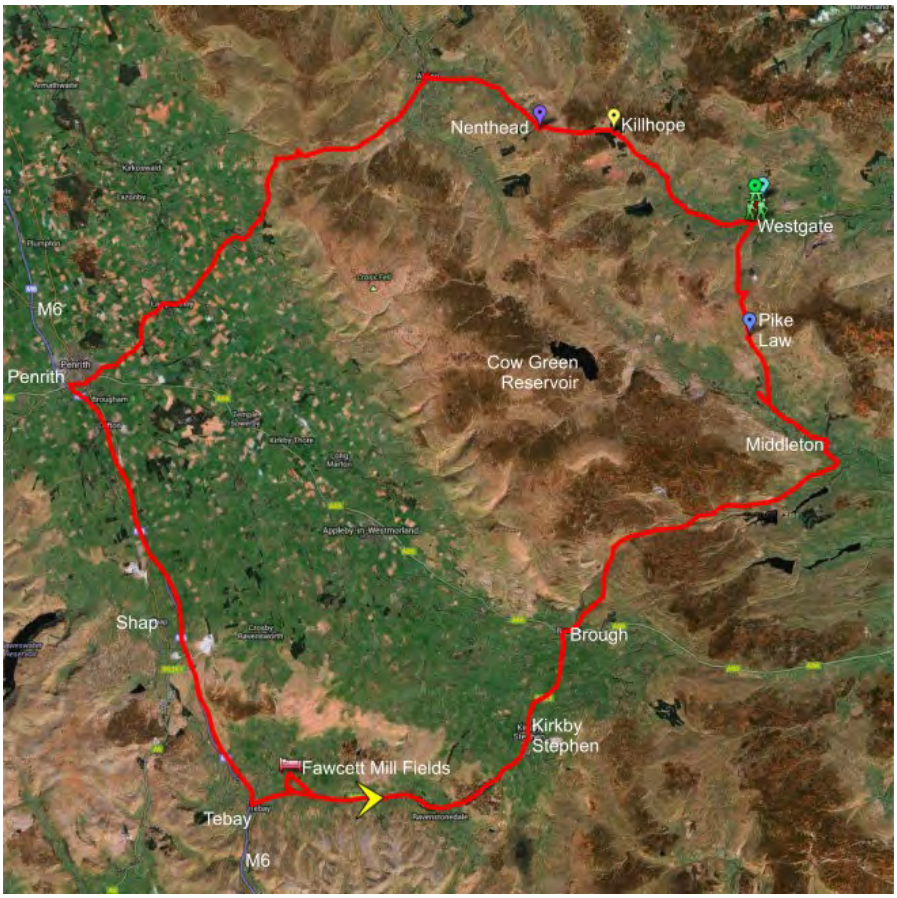
Gigantoproductid, Cockleshell limestone (DR)

The Low Force walk was ~ 4 km, so the grand walking distance for the day was ~ 14.5 km. The return journey to Fawcett Mill Fields followed the outward journey, and then most of the group went to local hostelries in Tebay or Ravenstonedale.

Sandi Shallcross and Rosemary Yeldham

Day 2, Tuesday in the North Pennines concentrated on the minerals and mining history of the area with four stops: 1. Pike Law; 2. Westgate; 3. Killhope Lead Mining Museum; 4. Nenthead Mines. Westgate was quite a long stop with a variety of things to see; the others were shorter and more closely focused.

An ore is a rock that can be mined at a profit.
A mine is a hole in the ground owned by a liar. (attributed to Mark Twain)



(Based on Google Maps)

Pike Law

Pike Law is high up (about 500m) on the moors between Middleton and Westgate. The rocks are all of the Stainmore Formation of Carboniferous age (316 to 327 Ma) and consist of mudstones, sandstones and limestones. The main sandstone is the Firestone Sandstone and the main limestone is the Great Limestone. This is the lower part of the Namurian.

The ore veins run in many directions; many are NE – SW but the Great Vein runs NW – SE. There is a concentration of veins in the area, thought to be due to the Weardale granite being close to the surface at this locale.

The area has been much mined; both surface and underground workings abound and spoil tips are everywhere. They have been much picked over but galena (lead sulphide), sphalerite (zinc sulphide) and fluorite can still be found.

Doug imparts the words of wisdom at Pike Law (GC)

Many were interested (GC)

Old mine workings at Pike Law (GC)

Fluorite from Pike Law (GC)

Westgate

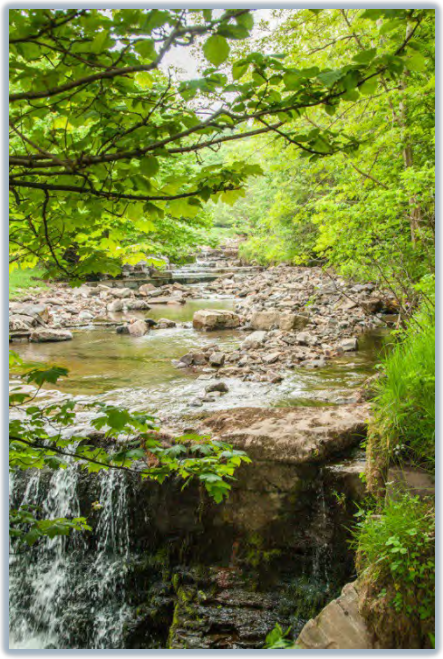
We then drove down to Westgate, a village on the River Wear, which once marked an entrance to the Prince Bishop of Durham's hunting estate. Here our quarry was the Slitt Wood and West Rigg Geotrail.

This gave us the opportunity to look at not one, but TWO mines AND some Yoredale sequences! Joy unconfined! And a pleasant place for lunch.

Slitt Wood

The walk up the Middlehope Burn, through Slitt Wood, was a pleasant walk along a good path with many opportunities to observe several Yoredale cyclothems. Each Yoredale cyclothem ideally comprises, in ascending order, limestone, mudstone, sandstone frequently topped with seat earth, and locally coal. No seat earth or coal was observed in Slitt Wood.

Waterfall over sandstone in Slitt Wood (GC)



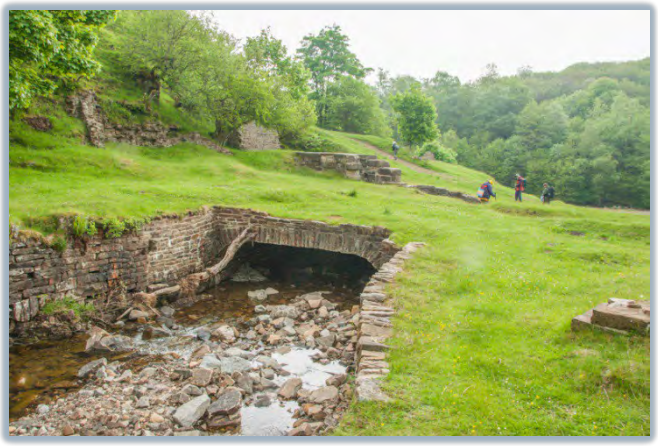
Limestone at the base of a Yoredale cyclothem in Slitt Wood (GC)

At our lunch spot we could see, in the opposite bank of the river, the sandstone at the top of a cycle, eroding into the underlying shale and mudstone.

Lunch-time geology – sandstone cutting into mudstone (GC)

Low Slitt Lead Mine

A little further up the valley we reached the Low Slitt Lead Mine. This was worked from various adits (called levels hereabouts), which tunnelled horizontally into the hillsides, and by a shaft 177m (580ft) deep. The landscape has been shaped and reshaped by the miners but little of their building works remains. The shaft has been closed off.



Remains of the washing floor at the mine (GC)

The mine was worked by groups of men (often members of the same family) and were paid by how much lead they produced. So each group's ore had to be held separately and presumably had to be processed separately. This sounds a recipe for conflict! Level ground was scarce so it was created by bridging over the stream with wide, flat arches which, surprisingly, seem to be very stable.

West Rigg Opencut

A long hard slog up the valley side leads to the West Rigg opencut. This was primarily an iron ore mine but the source was the Slitt Vein, which provided the lead ore at the Low Slitt Mine. Up here there was little galena (the lead ore). The fluids flowing along the vein leaked out of the vein to form "flats" in the surrounding limestone. The fluids were iron rich and iron ore was deposited.

Later the fluids changed and quartz, along with some fluorite and galena. So now we see the hole from which the iron ore was removed, the wall of quartz forming the vein and the fault itself, which was the conduit for the fluid movement. You can see that the vein has been prospected but very little of it has been mined – a rock which cannot be mined at a profit.

Slitt Vein exposed in West Rigg Opencut (GC)

Slitt Vein and various spoil heap (GC)

A long hard slog took us to a small road; looking eastwards shows the West Rigg Opencut; looking westward and back towards Low Slitt it becomes apparent how much work has produced this landscape. The V-shaped valley is a "hush" produced by damming water at the valley head and then releasing it to clear the soil and loose rock. Much of the rest of the view consists of spoil heaps – waste from the mines which are slowly merging into the landscape. This is old and therefore "Heritage". I don't think you would be allowed to do that nowadays but modern mining would be somewhat more subtle, one hope.

Killhope

The reason for stopping here was not to look at the Museum - Doug does not have a high opinion of it - but to find and look at the Frosterley Marble. Technically this is not a marble but a limestone which will take a polish. But what makes it really special is that is packed through with fossil corals. In particular the solitary coral *Dibunophyllum bipartitum*. Doug had read a geological guide which described where to find it at Killhope - "walk up the forestry road to some corner then go down to the river." This must have been written before the trees grew and the fence erected. Getting to the spot proved impossible for most of us, and those who got there would have needed a mighty hammer to get a sample from the outcrop.

However frustration was changed to chagrin when it was noticed that one of the large rocks used to demarcate the car park, and next to which we were parked was, in fact, Frosterley Marble! What was thought to be a large, live, slug on the rock was a fine, long dead, specimen of *Dibunophyllum bipartitum*! So WEGA (and Doug) delivers on another promise!

Nenthead

Our last stop was at the Nenthead mines. These were lead/zinc mines with some silver and were worked for centuries. Mining finished about 1920 and the site closed in 1965 after reworking of the spoil heaps finished.

There were many veins in the area and where they intersected the Great Limestone large “flat” deposits were created surrounded by ankeritized limestone. This is limestone which has been hydrothermally altered by the addition of iron, magnesium and manganese.

The area is pockmarked with small shafts and adits; spoil heaps abound. There was one adit which could be entered but it was very wet and there was little enthusiasm to explore underground. So most people prospected the loose rock of the stream to see what they could find. And everybody found some galena, often well shaped cubes encased in dirty yellow limestone.

Once everybody had their specimen it was time to go back to Fawcett Mill Fields and a fine barbecue prepared by Doug and Katy.

BBQ chef (KS)

Sampling the BBQ (KS)

Where did the ore come from?

The difficulty with explaining the provenance of the ores of the North Pennines is that there is a conflict between the general and the particular. One can try to explain things by looking at

A. the conditions of the North Pennines, or
B. try to explain them as Mississippi Valley Type (MVT) carbonate hosted lead zinc ore deposits.

The theories particular to the North Pennines

One of the earliest of the particular (i.e. particular to the North Pennines) was that fluids coming off of a newly intruded Weardale granite, (known to exist because of geophysical evidence) intruded the Carboniferous succession. These fluids were acidic and when they encountered the alkaline waters of the limestone, there was a sudden change in pH and dissolved metals in the acidic fluid crystallized out as sulphides. This lovely theory got crushed when a borehole found that the Carboniferous was deposited on the eroded top of the granite. The theory required the granite to be younger than the sediments, but the borehole told us that the granite was older than the sediments. Such a pity – it was a lovely theory!

The particularist theory which is the favourite at the moment is that:

1. In the late Carboniferous the limestones are dolomitised and ankeritized by salty fluids derived from nearby shaly basins.
2. Slightly later the area is stretched and fractured and the Whin Sill intruded.
3. In the Late Permian, convective cells form, possibly fuelled by the high heat production of the (slightly) radiogenic Weardale granite. These cells have a low salinity component derived from rainwater AND a high salinity component derived from the Zechstein Sea and the Vale of Eden. It is the high salinity brines which transport the metals from deep levels into the Carboniferous. The fluids are about 220^{o}C.
4. In the Triassic the convection cells continue but at a cooler temperature (50^{o}C) with fluorite and barite being deposited.

The Mississippi Valley Type theory

But the North Pennine ores do not look very different from those of, say, the Mendips, where there is no granite and no nearby salty deposits. The current Mississippi Valley Type theory is that

1. Limestone is deposited as aragonite. This is a low temperature form of calcite which can contain lead and zinc.
2. As diagenesis occurs the aragonite converts to calcite and the metals are expelled.
3. The metals bond with hydrocarbons containing sulphur.
4. The resulting fluid migrates to stratigraphic highs.
5. The fluids are unstable; lead, zinc and sulphur are released, forming an acidic fluid.
6. The ores are deposited.

27 June 2013

Graeme O. Churchard

Day 3, Wednesday: Mallerstang and Lunedale valleys

Wednesday dawned a wet morning with low cloud. A 20 minute drive east took us to Birkett Common to see the western edge of the Askrigg block marked by the Dent fault system. Here the view across the Mallerstang valley was meant to show the contrast between position of the Dent fault marked by the highly disturbed and steeply dipping Great Scar Lst of Birkett Common and the gently eastward dipping Yoredale sequences of the Mallerstang escarpment. However the low cloud and rain totally obscured the view and relationships

View across Mallerstang valley (GC)

Spirits were lifted a little as the stop was alongside a cutting just before the Birkett Tunnel of the Settle to Carlisle railway line that exposed steeply dipping sandstones and mudstones at the level of the Smiddy lst.

Settle to Carlisle railway (GC)

With people feeling a little damp, the group then felt it best to take advantage of a coffee stop at the Eden emporium in nearby Kirkby Stephen.

The one and only coffee stop on the trip (KS)

After being suitably refreshed we headed back westward along the Lune Valley to Flakebridge farm negotiating a very narrow farm entrance and rather dodgy looking cattle grid with the minibus. The farm track sloping up and out of the farmyard gave an excellent exposure of the unconformity between the Carboniferous sequence and the Silurian of the Howgill Fells. The folded, thinly interbedded sandstones and slates were directly overlain by a 10 cm thick dolomite unit dipping gently north, followed by a sequence of interbedded dark mudstones and dolomites. The site was such a good outcrop that someone asked if this was a documented RIGS site, but it has not been designated as such.

Flakebridge unconformity (KS)

With the weather brightening a little, lunch was taken in a quarry of the Stone Gill lst near Wath. Great interest was taken at the pond on the quarry floor, with thousands of tadpoles.

Lunch stop, Wath quarry (DR)

After lunch we headed on foot north onto Ravenstonedale Moor heading for some small old quarries, giving exposures of the Brownber Fm. This rock consisted of vein quartz pebbles up to several cm in size set in a carbonate matrix, and generated discussion about the depositional setting to give such an unusual combination.

Brownber Fm (DR)

Less luck was had in finding the Ashfell sst on the heather covered Ravenstonedale Moor.

Where is that sandstone? (KS)

Limestone pavement (DR)

The final damp stop of the day, was at Little Asby Scar to see excellent examples of limestone pavement. With the five stops today, a total of ~ 7km was covered.

It was then back to Fawcett Mill, and most of the group went to the Butchers arms in Crosby Ravensworth for a very good meal.

Day 4: Cross Fell Inlier, Dufton, Appleby, Kirkby Stephen

The day started with rain that continued while we drove across to Appleby-in-Westmoreland, and then through Knock and onto the fell road to start the geology of the day in the Lower Palaeozoic Cross Fell inlier at Knock Pike. Banded pyroclastic flow and tuffaceous rocks were examined in the Knock quarry, which are Ordovician arc volcanics similar to some of the Lake District rocks. We then walked up the fell road to the start of open access land and then headed south-eastwards between the Carboniferous to the north, and the Ordovician on the eastern side of Flagdaw, passing several small outcrops of Llanvirn, Kirkland slate.

Main geology of the inlier (GC)

First we dropped down into Sink Beck, with slate exposures but no Carboniferous, and then headed onto Swindale beck. The weather started to clear and gave views so that the main features of the inlier could be seen. The twin pointed Knock and Dufton pikes of Ordovician volcanic dominated the western part of the inlier, while to the east rose the Pennine escarpment of Carboniferous sequences with the prominent Melmerby Scar Lst. Positioned between the escarpment and Dufton Pike was Brownber Hill, consisting of Arenig, Murton Fm contorted slates that had been thrust west, so that they rested on top of the Melmerby Scar lst.

Swindale Beck in places was wide and dramatic, looking as though it had been swept by vast floods that deposited huge amounts of debris. Making our way up the beck, the Pennine way was reached, and interbedded mudstones and sandstones of the Basement series beneath the Melmerby Scar Lst were seen. The clearing weather came at a good time with great views across the Eden valley and onto the Lake District.

Climbing up Swindale Beck with view to Lake District (GC)

Is that the microgranite? (KS)

Dufton microgranite

It was then a lunch stop and a descent following the Pennine way southwards past the north side of Dufton Pike. Walking around the pike, careful attention was paid to the drystone field walls looking for the distinctive orange Dufton microgranite, representing an offshoot of the Devonian Weardale granite. Continuing down Hurning Lane near Coatsike farm the outer Pennine fault, juxtaposing the Lower Palaeozoic rocks of the inlier against the Triassic St Bees sst was crossed, but unfortunately without any outcrop or topographic expression to mark its position. A short distance took us into Dufton, with its houses built of the dull red St Bees sandstone. The traverse across the inlier had been about 10 km, and so on reaching Dufton some in the group took refuge in the Stag Inn. Others were still keen for more geology and headed into the nearby Ghyll Wood in a gorge of Dufton gill to examine old quarries in the St Bees sst. Here the sandstone was covered in thick moss, but it was still possible to see the low angle bedding, representative of deposition in a braided NW flowing fluvial system.

Once the group had all re-assembled, we headed to George Gill on the outskirts of Appleby, where a round trip of just under 2 km took us to outcrops of the Penrith sst. Here was an excellent outcrop showing five sets of superimposed aeolian dune sets with steep foresets, and low inclination bounding surfaces.

Dune bedding, Penrith sst (DR)

A close up of the sandstone at this outcrop shows an excellent example of even-grained, frosted quartz grains typical of aeolian sands.

Detail of Penrith sst (DR)

For the last stop of the trip we headed to Skenkrith Park near Kirkby Stephen to pick up the third main facies of the Trias in the area, the Brockram. This last stop was excellent; the river Eden has cut a deep gorge through a thick sequence of the Brockram, with large numbers of potholes of varying size in the river bed.

Potholed Skenkrith gorge in Brockram (GC)

The Brockram was very variable in character with coarse units, often with very angular limestone clasts, interbedded with fine-grained units.

Another full day with some 15 km covered at the different locations. Overall for the trip, a great distance of some 50 km had been covered on foot by the group!

The evening finished with another great meal with catering again by Sue and Babs.