Special Proceedings of the Reading Geological Society

Field Trip to Assynt 22nd – 29th May 2010

Introduction

This was the eighth of a series of major visits undertaken by the RGS at two yearly intervals. These originated from our celebration of twenty years of the RGS in 1996.

Assynt was chosen as our destination by a ballot of the Members.

Bernard Skillerne de Bristow, who has spent many years researching this area, agreed to be the leader for the trip. The party were expected to work at measuring, mapping, drawing and, most important, thinking about the geology.

These proceedings are a chronicle of the member's reports on the excursions, both geological and otherwise. It is presented as half-day reports – mornings and afternoons. Those contributing were: Ailsa Davies, David Ward, Roger York, Roger Lloyd, Brian Mathews, Pam Goldstone, David Price, Kit Brownlee, Beryl Jarvis, Edmund Shirley, Chris and Clare Fone.

David Ward
Technical Editor.

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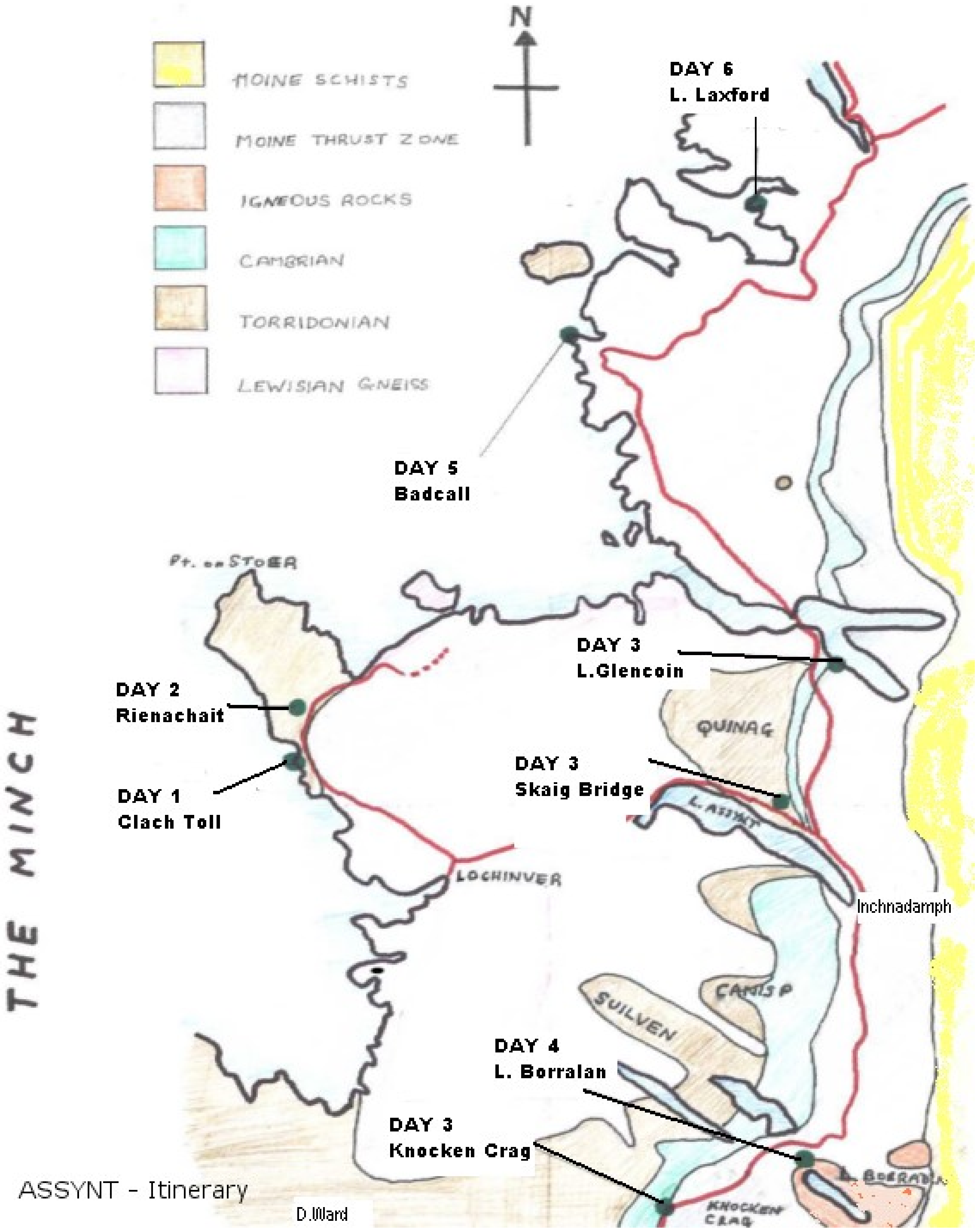
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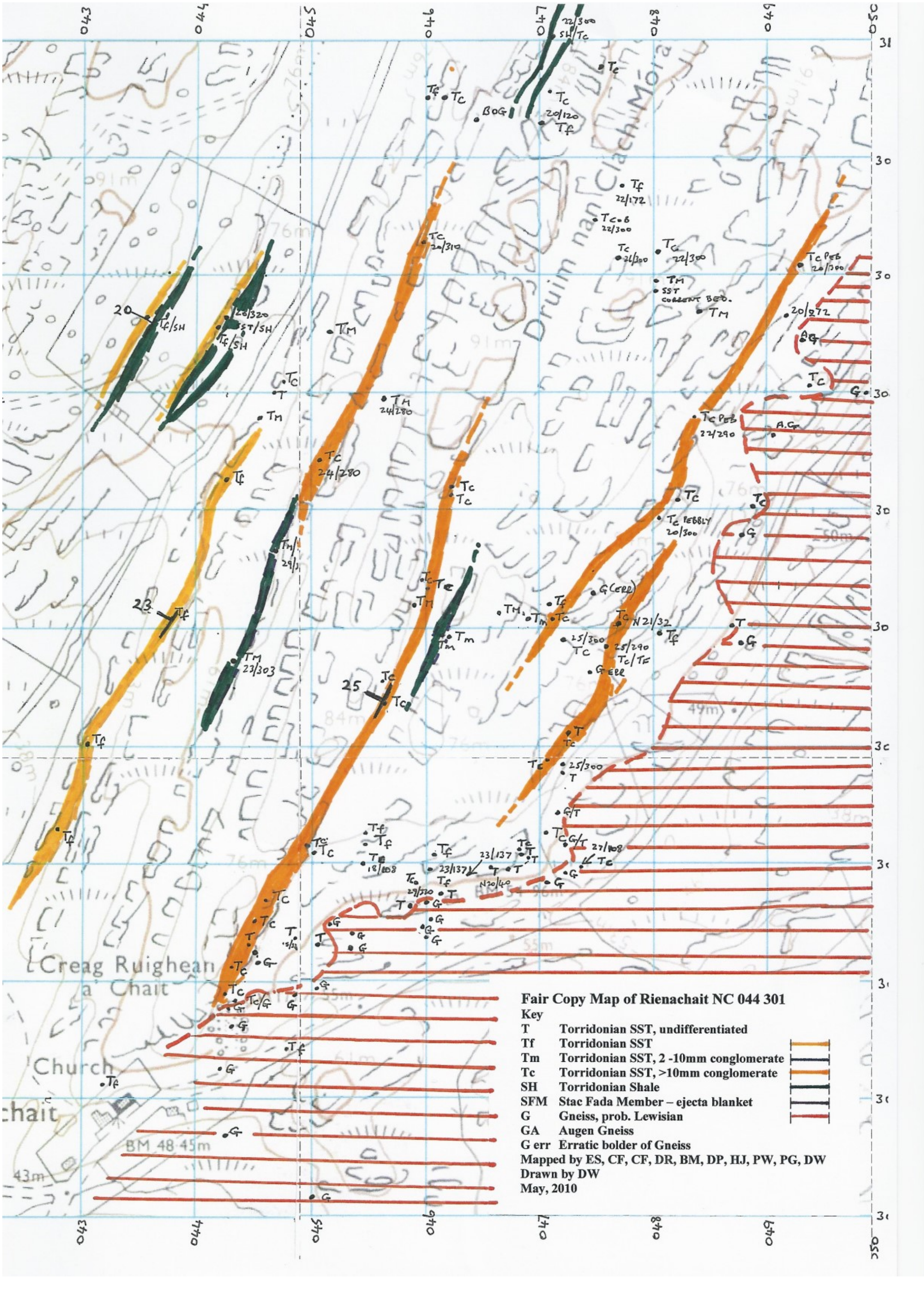

Fair Copy Map of Rienachait NC 044 301
Key
T Torridonian SST, undifferentiated
Tf Torridonian SST
Tm Torridonian SST, 2 -10mm conglomerate
Tc Torridonian SST, >10mm conglomerate
SH Torridonian Shale
SFM Stac Fada Member – ejecta blanket
G Gneiss, prob. Lewisian
GA Augen Gneiss
G err Erratic bolder of Gneiss
Mapped by ES, CF, CF, DR, BM, DP, HJ, PW, PG, DW
Drawn by DW
May, 2010
Creag Ruighean a' Chait
Church
Druim nan Clach Móra

Day 1: Sunday 23rd Sunday a.m.

Following a hearty breakfast (and proceeded by an early morning walk to Loch Assynt by some) we assembled full of enthusiasm in the car park for an initial briefing by Bernard. This included a Google Earth satellite photograph of the hotel and loch showing the River Loanan which feeds Loch Assynt. The meandering nature of the river was clear to see along with an ox-bow lake in formation. A small delta at the mouth of the river could be seen demonstrating a sedimentary basin.

We were reminded by Bernard about one of Charles Darwin's key strengths and mantras – observation. This was to prove vital in our work during the week.

We set off in the minibus to wards the Bay of Clachtoll, 5 miles north of Lochinver. As we were on the way Roger pulled into a lay-by to let the car behind past as our progress was rather slow. The car behind pulled in too! Who was it? It was Chris and Claire who were driving separately. No further incidents occurred and we arrived at our destination.

On arrival at the bay we stopped to look at an information board about whales. It had a quote from Norman McCaig:

> 'I count as gain,
> That once I met, on a sea tin-tacked with rain,
> That room sized monster with a match box brain.'

Bernard explained that the Assynt Estate had been bought by the Crofter's Association to enable new crofters to move into the area. This appeared to be successful as there was a lot of new fencing to be seen.

We walked along the beach to the area where we would be attempting to produce a graphic log of the Stac Fada member of the Stoer Group.

Reported by Ailsa Davies

Day 1: Sunday 23rd May p.m.

Clachtoll Mapping

Having had a detailed introduction to the Lewisian and Torridonian rocks in the morning and eaten a pleasant lunch on a sunny beach, the afternoon had to be contemplated. This was a sediment logging exercise along the beach from approx NC03779 28338 WNW for 1 km. Here, low lying rocks with strikes of 330 deg covered the foreshore from almost waters edge to the low cliffs – ideal exposures for us to work on. Teams were assembled and I was fortunate in having Beryl Jarvis and Ed Shirley to work with – somewhat skilled and persevering might be good terms for us.

Bernard had marked out about 25m sections of foreshore for each team and we sprang into action, compass, GPS, map cases and tape measures at the ready.

Simple – identify the bed, measure dip, strike, thickness, grain size, record all and move on. Problem was, as with all life, the closer we looked, the more we saw, so several iterations of the same bed became the norm.

The 25m of foreshore now seemed much longer than it had when we started – however we limited ourselves to a minimum thickness of bed of centimetre scales and made steady progress.

Behind and in front of us, similar, rather worried looking groups were also striding back and forth, unravelling the mysteries and recording the detail, assisted by the weather which was pleasant, rather weak sunshine.

The rocks themselves were developing character – we now saw mudstones and sandstones, occasional siltstones and conglomerates with colours ranging from the typical Torridonian reds and browns, to much darker mudstones and further, closer observation showed mudcracks and micaceous horizons.

Variation across the foreshore also became apparent – if you wanted a clean, polished surface, then the seaward end was good, but for surface features – mudcracks, surface cracking and the like, then shorewards was the best place. This of course meant (once we had mastered it) that it was no good simply traversing each bed, it had to be investigated down its length.

At the far NW of our section, we were fortunate in having a pair of minor faults which cut the cliff and then passed across "our" foreshore onto the neighbours patch. On the SE side a displacement of 23 cm down on the NW was seen, but displacement on the NW side was below beach level and could not, therefore, be measured.

After a couple of hours work, when we had progressed from considerable doubt in our abilities to rather dubious mild confidence, Bernard called a halt to the exercise.

Our results were to be agreed between each team and assembled into a formal sedimentary log, which would be combined with the other team's logs to produce a log of the complete foreshore.

We now walked about 0.5 km along the coast to the NW, to see a sequence which has stirred up much geological controversy, the Stac Fada Member, found in the cliff to the south of Meall Dearg.

This Member appears as a 6-10 m thick bed, apparently conformable with the Torridonian bedding and composed, apparently, of greenish mudstones with small clasts of other rocks within it. Explanations, up to very recently, suggested that this was a lahar, possibly with volcanic rocks within it. This was slightly difficult to accept because of the complete absence of any contemporaneous volcanic rocks in the whole of NW Scotland.

More, very recent work, has identified unusual isotopes of chromium and platinium group metals as well as shocked quartz grains in and around the site and for up to 50 km away. Current best thought is that this rock was the ejecta from a meteorite strike, splashed over the surrounding area by a meteor arriving about 1200 MYA. This accounts for the conformable bedding, avoids the tricky question of the absence of any eruptive sites and fits very neatly with the observed geochemistry and shock measurements.

Sufficient geology had now been covered to justify pints of Suliven and the excellent Inchnadamph Hotel dinner, so a return was made to the minibus, eventually to the hotel and inevitably to the bar.

Reported by David Ward.

Day 2: Monday 24th May a.m.

After breakfast and before going out for the day, a briefing was held in the drawing room of the hotel. The objective set for this day was to map the rock exposures of an area. We had previously been given a copy of the map square NC (29) 040 300 (OS Explorer Map 442) enlarged to (almost) 5 times. This was the ground north of Rienachait, to the west of the road. The first task at each exposure was to identify the extent of the area on the ground using the GPS and mark it on the map; the second was to identify the rock type of each bed, its dip and strike and note any other characteristics; and the third was to mark the boundaries of the beds on the map.

Rienachait

As on Sunday, the group split up into small teams who investigated the same ground separately. There were two types of rock – Lewisian gneiss and Torridonian sandstone. The latter was mostly well rounded conglomerate, in repeated beds with cobble sized clasts below and smaller clasts in a coarse sand matrix above.

(Note: 5 figure grid references have been given as these were recorded from the GPS handsets but several handsets were in use and only one reading was taken. Photographs are available and the filenames are given in the form RY IMG_0750.jpg.)

Reported by Roger York

Day 2: Monday 24th May 10 p.m.

We had noted from Bernard's brief in the morning that our objective was to map a small area measuring 1km by 1km, in the Assynt area. We were provided with the necessary large scale maps with each 100m grid square measuring 2 cm. i.e the scale was 1:5000. For the afternoon session we were grouped into 5 teams of 3. Each team was told to carry out the mapping exercise independently. By driving around, we first formed a visual impression of the area. The most notable feature was a high central ridge, aligned roughly north south (025/205), upon which a communications site had been constructed at the northern end. Parallel to the central ridge were several other lesser ridges traversing the area. All the ridges gained height towards the north and were separated by short expanses of heathery, boggy ground. There were plenty of rock exposures on the ridges and just a few exposures on the boggy ground.

The selected area covered an important unconformity between the Lewisian gneiss, aged around 2 to 3 billion years old, and the Torridonian sandstones that were deposited in the Late Cambrian. This was an important clue and most of the teams elected to map the junction between the two rock-types. Our first Torridonian rocks we encountered were unmistakeable conglomerates comprising pebbles and very coarse sandstones with distinct layers within. These rocks were generally pale red and very well cemented. Figure 1, a photograph taken near our start point, shows the conglomerate with cobble or even boulder size pebbles. Identifying the Lewisian Gneiss was not so easy since these rocks had been metamorphosed and showed schistosity to varying degrees.

Figure 1 – Well Cemented Torridonian Conglomerate

To make life easy for us Bernard had annotated the grid to make life easier for the groups. Davis Ward issued each team with a hand-held Garmin Etrex GPS. Once the set of switches had been sussed-out , the GPS kit proved to be remarkably easy to use . The positional accuracy was incredible too; within a few seconds of switching on the accuracy figure was down to 8m or even less, certainly within plotting accuracy. So we were a little surprised to find our first plotted positions to be in error by 100 metres or so. Closer inspection revealed that the grid had been labelled in error, in fact Bernard had transposed two digits. The teams quickly sorted this out and half an hour later we were heading out of area following the unconformity. It became clear that the infilling Torridonian sediments had filled-in an old valley that had been weathered into the Lewisian gneiss. We then transferred our attention to mapping the remainder of the area, stomping over each ridge, taking positions, and measuring the dip and strike where it was convenient to take that measurement. In cases of doubt over identification, Bernard's advice was to go up-dip to identify which bed was on top. We were soon adept at using a compass. Most teams subdivided up their responsibilities by having two note-takers and one person to do the dip, strike and GPS readings.

As our leader, Bernard discovered you cannot hide for a moment. He wandered off a couple of times and the assembled throng duly followed him. On discovering that there was nothing to see at the new location Bernard was forced to confide that he was only trying to get away to satisfy natural needs.

Prof Peter Worsley detached himself from the group to find a nearby meteorite impact area. He reported that he did indeed find the site and declared that there were a number of glacial tillites around.

We returned to the hotel around 6pm well satisfied with the day's activities and looking forward to a hot bath and dinner.

Reported by Roger Lloyd

Day 3: Tuesday 25th May a.m.

Skaig Bridge

We drove from the Hotel along the A837 to beyond Skaig Bridge but then reversed course to visit several exposures on the north side of the road. This is in the Torridon Group and separated from the Stoer Group by 7 km of sediment. This has undergone low grade metamorphism at a depth where the temperature was about 275°C. There do not appear to be any obvious visible changes but there has been some alteration in the minerals – from potassium feldspar to sodium feldspar, and with new pumpellyite, clay minerals and illite.

We first stopped by the roadside (NC 23016 24610) where the Torridon Group was overlain by a glacial till. There were several places where the till had been removed and an eroded surface of Torridonian showed glacial striations.

About 500 m further south along the road another exposure displayed the Cambrian Quartzite – feldspar and quartz grains in a quartz cement. Cross-bedding could be clearly seen. Symmetrical ripples had been reported which could give the current direction.

Cross-bedding in Cambrian Quartzite

Further along the roadside(NC 23672 24118) the Pipe Rock was visible. This is a thick massive quartzite bed with vertical burrows (*Skolithos*) The burrows are typically 6-10 mm in diameter and many cm long and occur close together throughout the thickness of the bed.

Pipe Rock – Quartzite with Skolithos burrows

Above this were about two metres of thinly-bedded brown shaly rock called the Fucoid Bed This name was given because marks on the bedding planes were thought to be seaweeds. Horizontal burrows can be seen on surfaces and the trilobite *Olenus* has been recorded.

Fucoid bed

The Salterella Grit was exposed above the Fucoid Bed. This contains minute conical fossils of the gastropod *Salterella*.


Salterella Grit

Above the Salterella Grit was the Ghrudaigh Limestone (NC 23672 24118). This is the basal bed of the Durness Limestone. It has been dolomitised which increases the volume and usually destroys any fossils in the rock.

Loch Glencoul

We then drove to our next site (a car park by the A894 road at NC 2395 2873) from where we walked across the bog towards the waterfall at the northern end of Loch na Gainmhich (NC 2428 2932). (On our way back we used a path which led towards the main car park which was just to the north of where we parked).


Waterfall at Loch na Gainmhich

We crossed the stream above the waterfall and continued north-east until we found a good viewpoint for what we had come to see (NC 24517 29614). On the northern shore of Loch Glencoul was a superb exposure of the Glencoul Thrust). On the shore the Lewisian was capped by cliffs of Cambrian Quartzite dipping to the south-east, and, above them, more Lewisian gneiss could be seen, thrust there from the east on the Glencoul Thrust.

Glencoul Thrust

Just south of the crossing over the top of the waterfall, a very large surface of the Pipe Rock was exposed. This surface showed the tops of the burrows and ripples (RY IMG_0736.jpg).

Loch na Gainmhich itself illustrated an interesting process. Peter Worsley told us how the ice in the loch would freeze and contract, cracking and allowing more ice to form in the cracks. On warming the ice would expand and this takes effect by overriding or fracturing at the edges of the loch. The net effect is of moving rocks in the lake ice outwards. Over time this creates a ring of rocks round the edge of the lake

Loch na Gainmhich

Roadside A894 (NC 23505 24416)

On the way back to the Hotel we stopped at an exposure on the east side of the A894 just short of the junction at Skaig Bridge. At the base of the exposure the Pipe Rock could be seen but above it was a mylonite. This is a rock which has been formed by dynamic metamorphism, by the friction of movement of the rock above. The heat produced is not sufficient to melt the rock and the result is a fine crystalline brittle rock that may show foliation.

Mylonite

Note: 5 figure grid references have been given as these were recorded from the GPS handsets but several handsets were in use and only one reading was taken.

Reported by Roger York

Day 3: Tuesday 25th May a.m.

Skiag Bridge

After quite a bit of rain overnight, we set off at 9am to look at the various strata of the Cambrian, as seen in the excellent roadside exposures around Skiag Bridge, 2mls N of the hotel. Bernard had suggested it might be an easier day than the Torridonian mapping yesterday! So we drove along the fast A837 along the N side of Loch Assynt & turned round. Unfortunately, although this is a Geopark, the planning doesn't go as far as providing suitable small pull-ins for minibuses in the vicinity of the roadside exposures, so we had to leave the minibus sitting there by the roadside, with hazard warning lights on.

We first stopped at NC224247 to look at Torridonian Sandstone of the Torridon Group. Before looking at the rock, Bernard got us thinking about the effect of the 7km stack of sediments above this rock (burial metamorphism) on its mineralogy & structures. Peter found some glacial striations on flat Torridonian surfaces, made visible because of the wet rock. We then moved further E successively to 230246 to see Cambrian Quartzite, to 235242 to see Pipe Rock & Fucoid Beds and to 236141 to see Fucoid Beds, Salterella Grit & Durness Limestone. Apparently, it was Ben Peach's dad who first found Olenellus, already well-known in America, in the Fucoid Beds somewhere near Durness, which led to the first suggestion that Scotland & America were connected at some stage, before the Atlantic was formed.

At around 10.30, we broke off to have a quick trip back to the hotel, allegedly for a loo stop! Then it was back up the A894 to park at a small lay-by at NC240291, with an excellent view of Quinag to W. We were, however, going NE over moorland, with no sign of a path. David P went ahead to locate a crossing point of a stream, which turned out to have good exposures of Pipe Rock nearby. Then we followed a sort of path uphill, to eventually end up (some found it quite hard going) over the crest of a ridge, to see the best geological view (of its type) in Britain. We were at 245296 & were looking NE over Loch Glencoul to the classic view of Lewisian Gneiss down by the loch, Cambrian Quartzite cliff & Fucoid Beds above it and another mass of Lewisian Gneiss **above** the Cambrian, brought there by the Glencoul Thrust. And it was a lovely day with a great all round view & good visibility. Unfortunately, time & effort stopped us going further to see terminal moraines and the highest waterfall in the UK.

We retraced out steps back to the minibus, now 12.30, but no lunch yet. We drove back S & were dropped by the roadside just before Skiag Bridge. Here at 23526 24408, Bernard talked to us about & showed us some mylonite, produced by the lowest of the thrusts, the Sole Thrust, in Cambrian rocks. Then it was down the main road to Knockan Crag, a geological SSSI, where we had briefly stopped on Saturday on our way to Inchnadamph. Lunch at last, at 13.20.

Reported by Brian Matthews

Day 3: Tuesday 25th May p.m

Visit to Knockan Crag (Grid ref NC 188092)

The purpose of this afternoon's visit was to see some more Cambrian sediments and also the Moine Thrust. It was a chance to consider the effects of regional metamorphism (as in the Moine rocks) and what sort of processes were involved, including igneous intrusions.

View from Knockan crag

After a morning of heavy showers, the rain had stopped as we arrived at the Knockan Crag car park, from which was a beautiful view across the road, a pleasurable sight as the group scattered to eat their lunches.

Stac Pollaidh could be seen framed between Cuthall Bheag and An Laogh

After lunch, we gathered in the picnic area, and Bernard talked to us about Faults and their types: Normal faults; Strike slip faults, sometimes include rotational movement; Extensional faults, such as Rift valleys and Compressional faults (overthrusting). A fault isn't always straight or narrow: the Craven Fault is half a mile wide, and a fault shown on a map will often include many small faults within its structure. A Thrust fault, is a type of reverse fault as can be seen here at Knockan, as the Moine Thrust.

Bernard then spoke about deformation in rocks – how they perform under pressure. A brittle or solid rock with increasing pressure would usually form a fault brechia and infillings of rock, but with increasing temperature as well, the metamorphosed rock will form a quartzite such as the mylonlite seen this morning at Skiag Bridge.
The sun had done its usual appearing and disappearing act and the temperature was dropping as the group walked over to start the Knockan Crag trail.

There is the familiar photoboard displayed near the path describing the site…

"The landscapes around you are among the most ancient in Europe. Here at Knockan Crag you can discover the story of how they formed. This they formed. This remarkable place is where scientists first answered key questions about the Earth – how can rocks end up many miles from where they originally formed? And why do we have older rocks resting on top of younger ones?'

Photoboard – welcome to Knockan Crag

Knockan Crag is one of over 50 National Nature Reserves, managed by Scottish Natural Heritage (Dualchas Nadair na – hAlba). The crag is basically a cliff section through the Cambrian strata and up into the Moine.. The lower part of this sequence was seen and photographed on our journey through to Inchnadamph the day we arrived in Assynt.

The photo below shows section from the main road (A835) showing a few metres of the Pipe Rock, followed by the Fucoid Beds.

Lower Beds exposed at Knockan Crag by A835

These strata which were previously seen at Skiag Bridge, were to be seen again along the Rock Route.

There is a gently sloping path leading up to a visitor's centre and beyond to the Rock Route. At the entrance to this path, is a very well designed piece of "rock art" called the Knockan Puzzle which illustrates the layers of rock that could be seen at the site.
The puzzle shows the Assynt geology in a simplified strata sequence. Although the Moine Thrust is the oldest rock, it is at the top of the sequence due to large scale reverse faulting.

This piece of art was studied and photographed with some interest, and agreed it was an attractive piece of art, cleverly designed and showing the sequence of the strata at Knockan very clearly illustrated. Hopefully the general public who visited understood.

The photos below show how the different beds are represented in the Knockan Puzzle:

Strata on the Knockan puzzle

Figure 1
Moine Thrust at the top of the succession

Figure 2
Lewisian Gneiss at the bottom being in in-situ country rock

The complete sequence in the puzzle is shown below*:*

Moine Schist – dark schists, the oldest rocks thrust to the top of the sequence, although ***Proterozoic age***.

Cambrian age
Durness Limestone – a grey limestone weathered to a pale, creamy colour.

Salterella Grit – a pale grey quartzite, with abundant small conical-shaped fossils.
Fucoid Beds – brown shaly mudstones, potassium rich, with ripple marks.
Pipe Rock – the upper parts of the Cambrian Quartzite with fossilised worm burrows.
Basal Quartzite – the white to pink Cambrian quartzite, weathered to grey.

<u>Cambrian Unconformity</u>
<u>Proterozoic age</u>
Torridonian Sandstone – a red-brown, coarse grained sand with pebbles, containing some thin layers of finer grained mudstone.

<u>Archaean age</u> (the oldest rocks)
Lewisian Gneiss – coarse crystalline rock, with black and white striped appearance and individual crystals, visible to the naked eye.

Figure 3
Salterella Grit and below

Figure 4
Basal Quartzite

This photograph below shows part of the sequence seen in situ at Skiag Bridge, at a roadside cutting on the A835 (**map ref NC 236243**), showing the

Cambrian Quartzite above the unconformity cutting across the Torridonian Sandstone. There is more information on these rocks in the write-up for Skiag Bridge for this morning.

The Visitors Centre, or Rock Room, reached after a short walk along the path was a strange gazebo-shaped wooden structure (2 views shown below), which provided an under-cover exhibition area introducing the geology of the area to the public. From a distance it blends well into the hillside, but the exhibits were disappointing, being rather faded and worn.

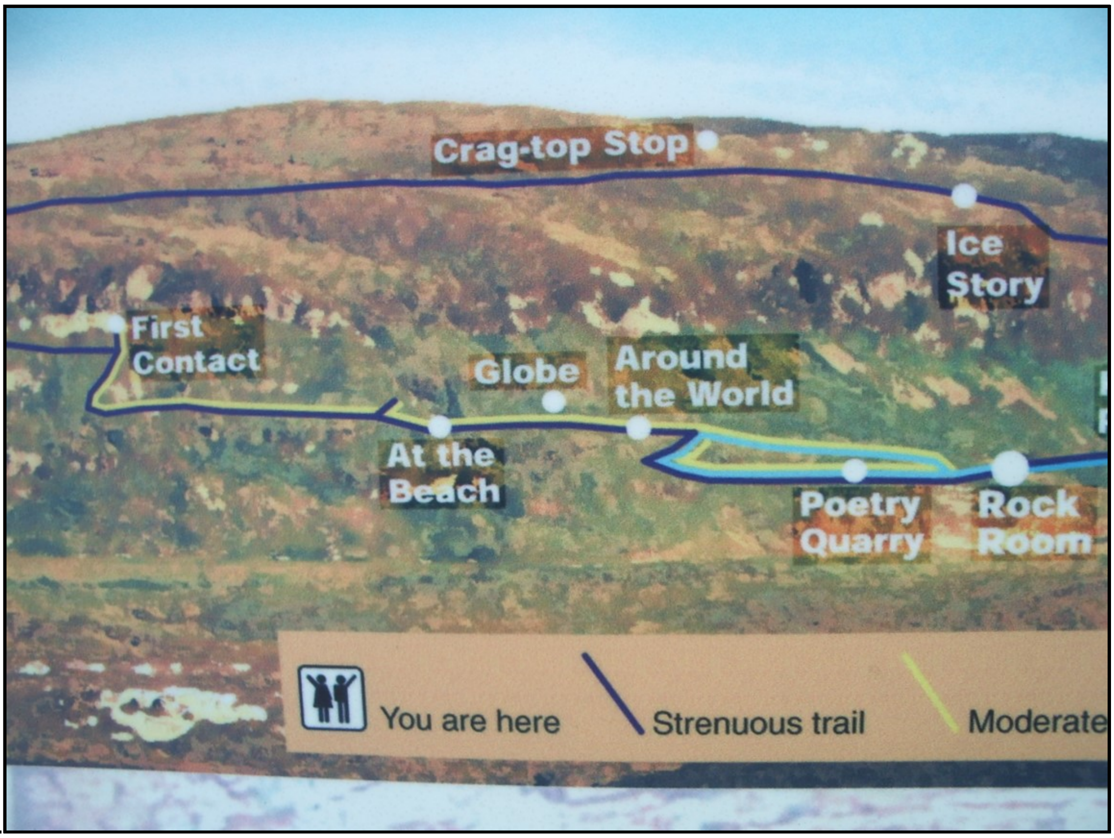
This photo courtesy of Roger Lloyd

A couple of exhibits are shown in the photos below:-

Geologists Ben Peach and John Horne worked out what had happened to the rocks in the Assynt. They stayed at the Inchnadamph Hotel and a copy of the page in the visitor's book with their signatures is on the wall in the lounge of the hotel.

	In the background is an interactive model that shows clearly how the Moine Schists were thrust over the younger rocks.

As we progressed along the Rock Route trail, we passed various themed sections



Annotated illustration of the Rock Route
as shown on the map above: the Poetry Quarry where notes of a geological theme were carved onto stone slabs and some relevant poetic quotes. This was followed by a timeline carved into slabs which each showed over time how Scotland moved by continental drift from the south up to the north of the planet, where it is now.

The Timeline, along the Rock Route

Climbing higher we passed another magnificent piece of rock art, in the shape of a large globe.

The Globe – rock art along the Rock Route

As the path climbed gently higher we came to the main feature – the first point at which the Moine Thrust contact, could not only be seen, but touched and photographed close-up.

	
Moine Thrust contact *(photo courtesy of Chris Fone)*	**Bridging 500 million years**

The creamy coloured Durness Limestone below the thrust line is 500 million years in age, while the grey Moine Schist above the contact line is about 1000 million years old. There are slabs of rock shaped as hands to help visitors physically bridge 500 million years. The contact line can be followed further along the cliff path. As it had now become a lot steeper and narrower, a smaller group continued along the path and up some steps to the top of the crag. Some photos were taken from a viewpoint to the left of the steps.

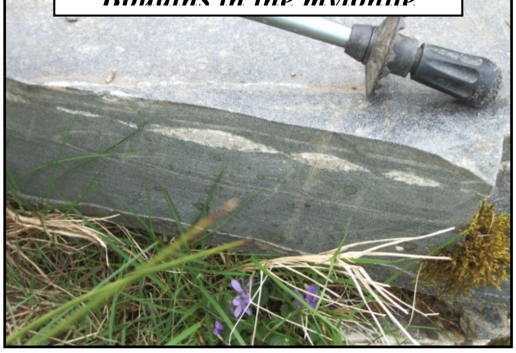
The path was then followed round to the right going southwards behind the crag, with views across to Ben More Assynt to the north-west and to the west, the boggy areas in between.

To the right of the path was the crag with the Moine Schists on the top forming a sculptured wall and Durness Limestone below. In places a thinly banded light-grey, whitish rock could be seen in the path and at the thrust boundary. This is the mylonite, a geological equivalent to filo pastry, pressed into thin layers under the pressure of the Moine rocks! This can also be seen at the southern end of the path, in Eagle Rock, where the rock forms a small cliff face, from where the path leads back to the car park.

Photo courtesy of Brian Matthews

Those of us who didn't complete the route returned back the way we came.
While coming down from the thrust contact point, saw an excellent example of boudinage in the pathway. The term is adapted from the word "boudin", French for sausage.
The photo shows a cross-section of what looks like a string of sausages (boudins), formed by tensional forces during the Thrust event.

Boudins in the mylonite



We then waited for the crag top party to return, so we could return to the minibus and go back to the hotel for dinner.

Reported by Pam Goldstone

Day 4: Wednesday 26th May a.m.

Moine Thrust Zone

Weather at start of day – over cast with a low cloud with a clear sky to the north, promise of sun later?

This was my first visit to the Highlands I find the landscape hard, but with a bold and clean appearance, a freshness to the air that makes you feel that every breathe you take is good for you.

Breakfast was as large and as good as it had been for the previous days. Peter Worsley did an interesting double act with the waitress at breakfast on how he should present his empty plate for collection. I wondered if this would result in a new hypothesis on plate tectonics – would this rewrite the Geology books on which "plate" should be passed first the one at the top or the one at the bottom. The answer was not forthcoming, so we all assembled in the minibus at 9.00 am dutifully fastened safety belts and left Inch at 9.05 am driving south to our first site visit of the day.

The Geology of Day 4

The main focus of day was metamorphic and igneous rocks in the Moine Thrust zone and their formation before during or after the Moine Thrust. The late afternoon was spent looking at Quaternary deposits at the Allt nan Uamh valley.

The Pre-Cambrian rocks cover a period of geological history, in the British Isles, of 2500 to 1000 Ma years, some 1500 Ma of deposition, denudation, and tectonic activity that is over twice as long in time as the remaining geological periods put together. It is important to be aware of this geological time span when viewing sites to appreciate that all we are observing is a very limited window in the geological events that occurred.

Site 1

OS Ref:- NH 202 782	Lay-bye at Corrieshalloch Gorge National Nature Reserve **Observation of the Moine Supergroup metamorphic rocks**

The Corrieshalloch Gorge National Nature Reserve is centred on the river Droma that descends dramatically over the Falls of Measach into the impressive gorge 1.25km / 0.75 mile long and 60m / 200ft deep. The gorge was formed initially by glacial melt waters excavating a channel through rock already weakened by vertical fractures. This was not part of our itinerary.

The purpose of our visit was to observer metamorphic rock of the Moine supergroup. At this location we are east of the Moine Trust Zone (MTZ) in the Morine supergroup of rocks the defining feature of which is that they are strongly metamorphosed. Unlike the Torridonian Group that retains its sedimentary deposition structure, basal conglomerate of which we had observed on Monday. The Moine supergroup lies in north west to south east bands across Scotland with the Loch Eil Group and Glenfinnan Group between the Great Glen Fault and the Sgurr Beag Thrust (SBT) and the Morar Group between the SBT and the MTZ. It was the Morar group that we were observing which originally comprised of a series of psammite (metamorphic sandstones) and pelite (metamorphic clays, shales, mudstones, siltstones and marls). Both the Torridan Group of approximate 7 km thickness and the Moine Group approximately 12 km thickness, lie uncomformably on the Lewisian gneiss.

They were deposited as a series of sedimentary deposits which some workers consider span a 600 Ma period.

Moinian (after the Moine district of Sutherland) is a thick group of metamorphosed sandstones and shales , now granulites and schists , they occupy the area from the line of the MTZ southwards to where they dip below the Dalradian schists south of the Great Glen Fault . Radiometric dating has shown that the Moine rocks are upper Pre-Cambrian in age. The Dalradian schists range in age from Pre-Cambrian to middle Cambrian and terminate at the Highland Boundary Fault and include marble, mica-schists, quartzities and hornblende-schists.

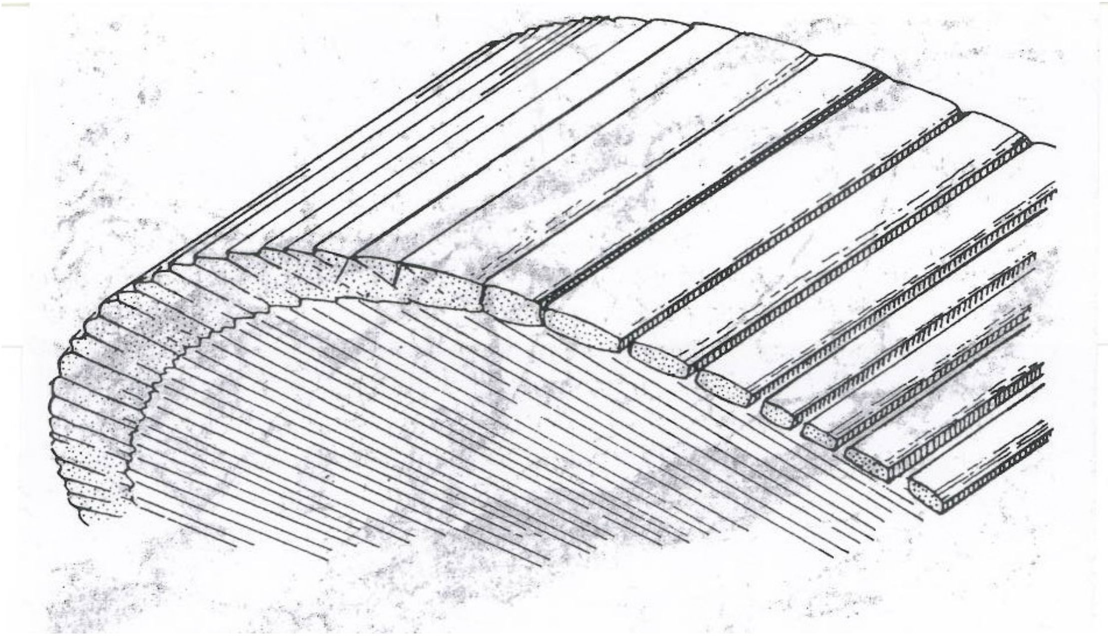
The Events Sequence.

Event	**Millions of Years BP (Ma)**	**Geological Period**	**Orogeny**	**Geological Period – Time Equivalents**
Deposition of sediments of Torridonian sandstones.	**1000 Ma to 800 Ma**	**Pre-Cambrian**		**Tertiary, Cretaceous and Jurassic (200 Ma)**
Deposition of sediments of Moine sandstones and mudstones	**1000 Ma to 873 Ma**	**Pre-Cambrian**		**Tertiary, Cretaceous (144 Ma)**
Moine rocks subject to metaphorphic events	**873 to 430 Ma**	**Pre-Cambrian, Cambrian, Ordovican**		**Silurian, Devonian, Carboniferous, Permain, Triassic, Jurassic, Cretaceous, and Tertiary**
Moine Thrust	**440 – 430 Ma**	**Silurian**		

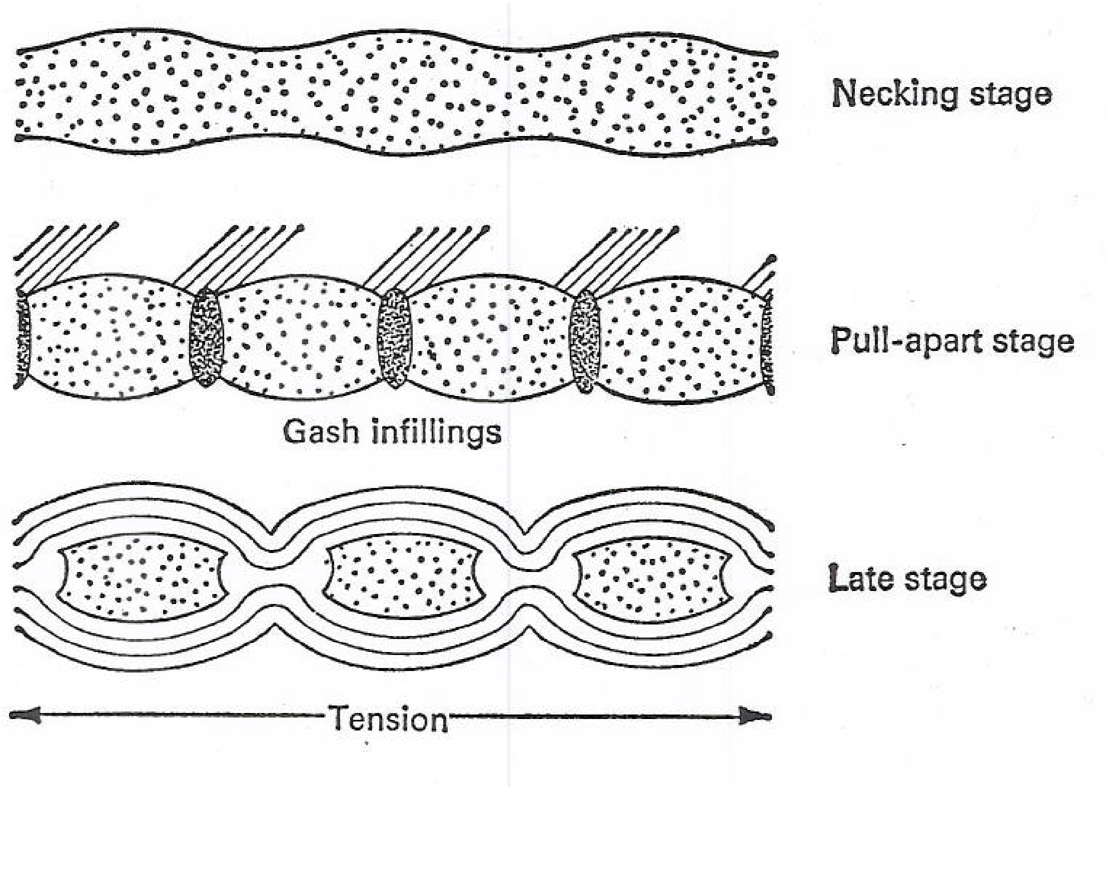
Site 2

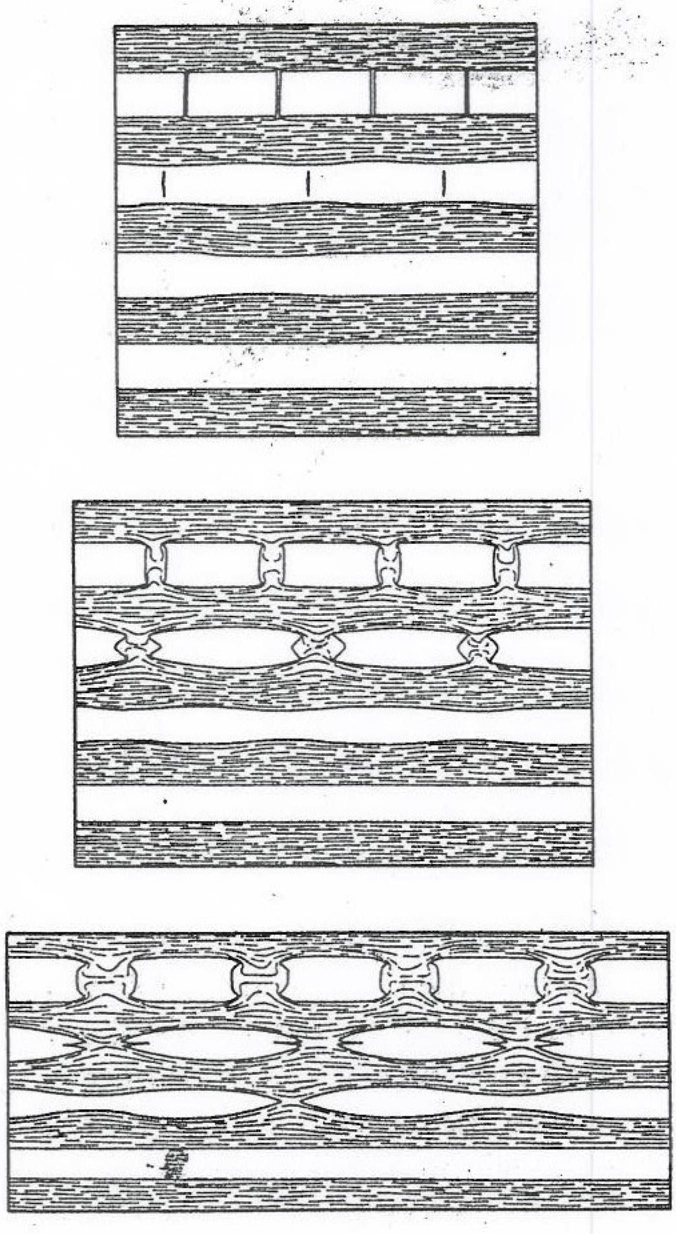
OS Ref NC 385 009	**Oykel Bridge** **Observation of mullian structures**

The classical Oykel Bridge mullion zone



Boudins on the flank of a flank of a fold
(From Introduction to Small-Scale Geological Structures by G. Wilson - Pubs Allen & Unwin 1982.)





PDGEO

"A minor structure arising from tensional forces. It develops by the stretching of a competent bed (during folding flexes without the loss of its cross-sectional appearance) along bedding planes giving rise to pull-apart structures, tension cracks or necks, which may become filled with incompetent material from either side The usual appearance in cross section is that of a string of sausages."

Site 3	
OS Ref NC 286 096	**Aultivullin quarry near Loch Borralan** **Observation of alkaline igneous intrusions**

U-Pb dating (Uranium-Lead radiometric dating) performed on the mineral zircon from syenite intrusions of the early suite and late suite of the Loch Borralan Pluton suggest Morine thrust was active before 430 Ma and complete by 429 Ma, with brittle movement on the Moine Thrust post dating the ductile movement.

The largest body of igneous rock in this area is found around Loch Borralan, and it has been named the Loch Borralan Complex. It is an intrusion composed of a variety of coarse-grained alkaline rock types, from dark to light in colour. The most abundant light-coloured rocks are not granites but syenites*, made up mostly of potassium feldspar. Dark varieties are rich in mafic minerals such as pyroxene and garnet. One intermediate variety is so distinctive that it has been given its own name,* borolanite *(from an old spelling of the name of the loch). The borolanite can be studied in the small disused quarry at Aultivullin.*

The importance of the Loch Borralan igneous rocks for the history of the area is that some of the varieties were intruded before the movements on the Moine Thrust zone, and so are deformed, whereas others were intruded after them, and so cut across the thrusts. Radiometric dating of minerals in the igneous rocks tells us their time of intrusion (about 430 million years) so we can also deduce the age of the thrust movements.

This is the typical white-spotted nepheline syenite, borolanite. However, it also contains a dark green fragment about 10 cm across of a pyroxene-rich mafic rock. Such rocks occur elsewhere in the Complex, and were intruded at an earlier stage in its development. This piece was probably broken off and carried in with the nepheline syenite magma as a xenolith *(literally, a foreign rock). Xenoliths are common in many igneous rocks.*

Crucial relationships between crystallisation of the 430 million year old igneous rocks and movements in the Moine thrust zone are shown by the syenites in Alltivullin quarry. In this view, the white spots in the borolanite have been flattened (since they are solid crystals, this would only be possible at high temperature, before the rock had fully cooled). Also, just to the left of the hammer, a small, later zone of sheared rock cuts the borolanite.

Sites 4 and 5	
OS Ref NC 243 031	**Ledmore** **Observation of metamorphic rocks**
OS Ref NC 250 134	**Ledmore North Quarry.** **Observation of metamorphic Marble .**

Ledmore North Quarry: Alkaline intrusions and contact metamorphism Forsterite and Brucite marble, metamorphosed Durness Limestone

Just north of Ledmore, on the northwestern edge of the Loch Borralan Complex, a quarry has been excavated in carbonate rocks of the Durness Limestone within the Moine Thrust zone. Sheets of igneous rock, mostly varieties of borolanite, are exposed in the quarry, and the main mass of syenite is nearby.

The heat from the crystallizing magmas and the effects of fluids released from them has caused contact metamorphism of the limestones. They are now marbles with spectacular banding, veining and blotching caused by the growth of new minerals. At the time the *photographs were taken, smooth sawn rock faces and slabs of marble could be examined in the quarry. Some of the banding is due to differences in chemical composition (silica, magnesium) between original beds of limestone that would not have been obvious in the original sediment. Other patterns are caused by magma and hot fluids passing along fractures in the rock, adding silica, potassium and other elements, which allow new minerals to grow in the limestone next to the fractures.*

Note: The passages in italics are taken from guide book sources.

Footnote: Use of stone from the Assynt Region.

At the new Scottish Parliament building under the façade of the Canongate building is the Canongate Wall. The overall design of the Canongate Wall was by Sora Smithson and contains a representative range of Scottish stones carved by Gillian Forbes and Martin Reilly. The stones are set in large pre-cast concrete panels and include Lewissian Gneiss – Lochinver, Ledmore Marble - Ledmore Quarry, Torridonian Sandstone - Ullapool and Pipe Rock – Ledmore.

Afterthoughts

"Who possesses this landscape? The man who bought it or I who am possessed by it?

False questions, for this landscape is masterless and intractable in any terms that are

human."

Norman MacCaig (1910 - 1996), A Man in Assynt

Red Deer. Antlers	Due to the ever present Red Deer in the fields around Inch, they had been a considerable topic of conversation, in particular the rate of antler growth and size. Briefly, only stags grow antlers – they start growing in spring and are shed each year at the end of winter. They can grow at the rate of 25mm a day. The fourth and fifth tines form the ‘crown’ or ‘cup’ of the antler, any tines in excess of the fourth or fifth tine will grow radially from the cup. In autumn the antlers stop growing and calcify ready for the rut.
Up turned grass squares	Whilst travelling down the Ucol valley to Oykel Bridge we discovered what the numerous small up turned turves of grass were for, there had been speculation earlier in the week that they were peat drying, in fact they were for planting tree seedling, into the upturned turf.

From David Price

Day 4: Wednesday 26th May p.m.

Allt nan Uamh valley & the Bone Caves

About four kilometres south of Inchnadamph is the Allt nan Uamh Valley (Burn of the Caves). The burn runs under the road and into the River Loanan & thence into Loch Assynt. The valley to the Bone Caves runs East South East toward Breabagr

We drove into the car park, exited the mini van, wriggling into sweaters & jackets,& followed a well trodden, if uneven path on the northern side of the Allt nan Uamh upstream passing the remains of fish farm on the left. A notice board in the car park had announced that the walk took only one & half to two hours there & back. Although not that steep, the path began to sort the fit from the less fit, with yours truly bringing up the rear – my usual position. The sun was shining, the sky was blue & the little valley protected us from any wind. A perfect spring day

At the start of the walk the valley is narrow, the burn almost hidden in a narrow cleft A single birch tree lent towards the burn & I became aware of the music of falling water. A waterfall had formed where a sill of igneous rock had baked the Salterella Grits of the burn. The dark grey igneous rock, formed when magma intruded into the older sedimentary rocks, could just be discerned at the outflow of the pool below the waterfall. By this time I was well to the rear & was keeping my eye on a blue anorak that was disappearing towards the horizon

Walking up the valley , pale Durst Limestone could be seen my left, breaking through the spring greenery, but alas, while spring was in the air that day, the local flora remained staunchly unconvinced & I saw none of the hoped for typical limestone flora in flower. Ah well…..I was supposed to be geologising not botanising!
Continuing on up the narrow valley the path became limestone pavement in places, hugging limestone walls, with little springs bubbling out to join the burn... Next came a limestone crag at the base of which was a scree slope, & at the base of that a major upwelling, bubbling & chuckling around my feet. This was the Fuaran Alt nan Uamh a major spring for the burn. Just beyond as the valley widened out was a second spring this time toward the centre of the riverbed beyond which the river was dry - it is quite odd to see such a large boulder strewn valley that had absolutely no water flowing along its base. Yet at some times it must have, during or after heavy rains, for the there were rocks & boulders bigger than bothys strewn along its centre. Water percolating through the limestone at the head of the valley, runs through a series of caves & fissures to emerge at the springs lower down the valley. Rain had also loosened rocks from the crags on the valley sides, and this debris channelled down gullies to form cone-shaped piles of loose rock at the base of the slopes.

By this time the blue anorak I had been following had disappeared from view so plodded on, deciding to turn about if I hadn't found the caves / the rest of the party an hour after starting out had been reached. About 5 to 10 minutes beyond the spring, the valley opened out, wide & flat bottomed, & the path forked right , to cross the dry stream bed and climb up to the Bone Caves, which I could see on the horizon. A few more minutes walk & I found a comfortable ledge facing the caves & from which I could view the rest of party as they wandered in & out of the caves and along what appeared to a narrow ledge in front of them. My aged knees made resistance calls to scramble up the valley side to join them easy. Unfortunately this meant I missed Prof. Peter Worsley's disquisition on the Quaternary

There are four caves in the shadow of Creag nan Uamh. They formed thousands of years ago, before the last ice age, as water gradually dissolved the limestone along cracks and fissures. The caves here are only shallow and are the remains of a larger cave system that extended over a wide area. Over thousands of years, the valley has gradually deepened, cutting away part of the cave system, and leaving the caves high and dry on the valley side.

Excavations have unearthed the bones of wolves, bears, lynxes and arctic foxes that took refuge in these caves when Scotland's climate was much colder than it is now. Reindeer bones and antlers have also been found, but reindeer are unlikely to have entered the caves, and so it is unclear how these remains accumulated. Human artefacts and bones have been found in the caves, but very few have been dated. However, the discovery of a of a 2000 year old walrus ivory pin in one of the caves tells us that people were here by the Iron Age (-700 BC to AD 500). The caves are now an SSSI*.

Behind me (to the north) as I sat by the track, red-brown sandstone formed small crags at the top of the hill. This was Torridonian Sandstone, twice as old as the limestone below. The presence of older rocks on top indicated that a thrust has pushed the Torridonian Sandstone over the limestone. This was of course the Ben More Thrust sheet, part of the famous Moine Thrust belt which we had seen earlier in the visit. The thrust itself was not visible, as it is covered by scree and by a large landslide
To the east I had a superb view of the quartzite ridge of Breabag at the head of the valley.

By this time the rest of the party were convening at my position & it was time to retrace our steps and return to the hotel for restorative hot baths/showers and dinner.

*Scottish Natural Heritage Information Leaflet

Reported by Kit Brownlee

Day 5: Thursday 27th May a.m.

Scourie Dykes

On Thursday morning we went to the Lewisian Foreland south of Scourie on the coast near Upper Badcall. It was typical Lewisian territory with exposures of the gneiss forming smoothish rocky outcrops sticking up through the heather and mosses of the headland. Some rose to 93m. A number of faults ran through the area forming gullies which were probably Caledonian in origin.

The aim was to look for the Scourie dyke in this particular location and compare it with the map produced in the 1940s by Janet Watson who was one of the great British geologists of the 20C. Dividing ourselves into groups of three with each group mapping a particular section we would soon have the RGS version of the map. No problem. Luckily we had a plan B which went into effect when we realised that the Scourie dyke didn't stick up from the landscape just waiting to be readily identified and mapped. Our approach would have to be a much more communal combined effort with lots of guidance from Bernard and mutual support .

We eventually discovered the dyke. It lurked under heathers and bogs; it disguised itself as Lewisian which was also dark, mafic and crystalline (although the latter also showed foliation); in places slivers of dyke were still in contact with the gneiss that it had split asunder in the Precambrian, the remnants here showing up black against the grey gneiss. We found, (with Bernard's continued encouragement) that there were two main episodes of dyke formation, one producing a dark grey mafic basalt and one producing a black ultramafic basalt full of fine black crystals.

The foreland gneiss told us stories about the past. Small scale foliation and large scale folds revealed that they had been folded and then folded again. Chris found a wonderful boudin in the folded gneiss which made his day

We were looking at rocks that, at the time of their deformation, were deep within the crust and in a rather more plastic condition than they are now. We observed within the gneiss we found, an earlier quartz pegmatite vein that was cut by a dyke and also a dyke that had been cut by a later pink feldspar/muscovite pegmatite vein. Only mapping would sort out these relationships. Not long after this we had lunch.

Reported by Beryl Jarvis

Day 5: Thursday 27th May p.m.

Scourie Dyke

Thursday afternoon was devoted to a mapping exercise of a Scourie dyke across the peninsula composed mainly of Lewisian gneiss at Badcall Bay.

Initially, the dyke was orientated NW-SE, with planar parallel sides. The dyke was of a softer material than the surrounding Lewisian gneiss, forming a small inlet where it had crossed the NW coast, where it split into parallel dykes, which later rejoined. The members followed the dyke from the NW, mapping the NE and SW boundaries.

In the centre of the peninsula, the rock was clearly foliated in an approximately W-E direction, with a dip at this point of 76 deg. At this point the dyke was more heavily eroded than the surrounding gneiss, and obscured beneath a peat bog. The members therefore initially found difficulty in locating the dyke which had been distorted and changed direction to the NNE. The dyke appeared to have been dragged Eastwards, and this has been explained by the later Laxfordian orogeny. The dip also indicates that there was some vertical movement at the time of this distortion. Although the guidebook indicated that the dyke exited the peninsula in the sea loch, members were unable to locate the exact position.

Reported by Edmund Shirley

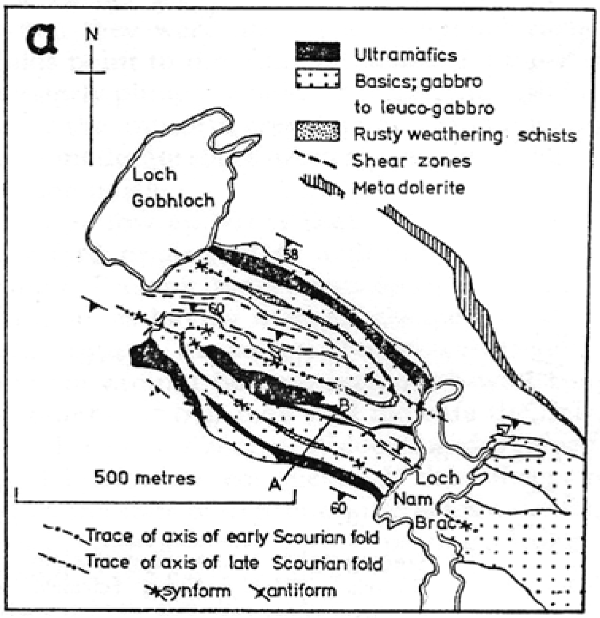
Day 6: Friday 28 May a.m

Laxford Area

During the previous days we had examined a sequence of events which have affected the Lewisian Gneiss. The oldest Scourian rocks have been intruded by a series of obviously younger basic dykes, the Scourie dykes. Some of these dykes have subsequently been deformed and metamorphosed during the Laxfordian orogeny. Radiochemical dating shows the Scourian orogeny was about 3 billion years ago. The original, mainly igneous, rock, known as the protolith, was subjected to high to intermediate pressure metamorphism 2900-2700 million years ago. It is postulated that at this time continents were being built from smaller terrains. In the Laxford area we were able to examine some of the processes which took place in these ancient rocks.

Our first stop was at Loch Gobhloch. This is a complex structure where a fold had been refolded. Although this could be seen on the map we could not make it out on the ground since the area has now become overgrown with heather and willow. At the edge of the loch (17207 49090) we observed the weathering of what looked like Lewisian Gneiss. However, on a nearby hill (1795 49014) the eroded synform structure gave us an opportunity to examine some mafic minerals. At the top of the hill was a small exposure of a dark ultramafic rock. Bernard explained that this is thought to be an example of a layered mafic intrusion within a magma chamber in the Scourian rocks; the mafic minerals settled to the bottom of the chamber followed by a material containing feldspars. L R Wagner, one of the early experts on these layered intrusions, was a lecturer in geology at Reading University in 1929.

Map of interference of major early Scourian isoclinal fold by late Scourian fold, east of Loch Gobloch.



Scourian gneiss (left) ultramafic (centre) and with feldspars (right) rocks.

Our second stop was at a road cutting just to the north of Loch Laxford (22783 47654). Our thoughts were what a confusing mixed up mess (see photograph). However, Collins Geology dictionary gives a more eloquent description of this Migmatite (= mixed rock).

"An intimate mixture of apparently igneous material of granitic composition and high-grade metamorphic rocks characterised by a banded or veined appearance, often accompanied by evidence of plastic deformation."

Theories for the origin of migmatites include the ideas that the granitic material was introduced as magma or through the action of fluids permeating the host rock. In most cases, however, migmatite appears to represent the most extreme case of metamorphism in which less refractory components of gneiss start to melt, leading to the segregation of veins and patches of granitic liquid under conditions of elevated temperature, pressure and shearing stress."

These migmatite rocks were formed by the reworking of the Scourian gneiss and dykes plus possibly some sedimentary material. Radiochemical dating shows this Laxfordian reworking occurred about 1900 M years ago. It is postulated that blocks of the Scourian were sheared off, subducted and remetamorphosed. Small granitic sheets were intruded towards the end of the Laxfordian deformation, about 1700 m years ago.

Reported by David Riley

Reported by David Riley

Day 6: 28th May p.m.

Blairmore

Lunch was spent on the coast at **Droman Pier** (18658 59231). The weather was overcast with spitting rain but a few hardy members braved it and ate their sandwiches outside.

The cove was in the Torridonian quartzite but patches of Lewisian were surrounding the area; Bernard remembered seeing some large garnet crystals in a highly metamorphosed area of the Lewisian but after some investigation was unable to locate the source.

While lunching a Ranger and his two dogs from the Sandwood Estate arrived and explained how the area was conserved through funding by the John Muir Trust. Money was short, however, and his job was under risk in the near future. He warned about the risk of Lyme disease from the sheep ticks as it was a regional hot-spot. Leaflets were distributed.

A loo-stop in **Blairmore** allowed an unplanned view of the coastal machair. This is an area of sandy/shell soil protected by the dunes covering some distance inland from the coast which has a rich, cultivatable soil and a diverse eco-environment for different types of plant and wild-life. Traditionally this was also a concentrated area of crofting which continues to an extent today. Adjacent to the car park a section in the topsoil was exposed and caused some discussion amongst members about the Podzol layering (localised leaching of minerals from a narrow soil depth producing a 'bleached' horizon) and how this may have taken as short a time to develop as 100 years.

An unplanned stop was made at a disused quarry about 1 km south of **Scourie** at 15708 43672. The side of the quarry wall showed a section through a glacial till. Professor Peter Worsley explained the material would be described as a Diamictite; a soil made up of a variety of size clasts in a fine (clay size) matrix. In this case the clasts were mainly angular although a few were rounded and the matrix would be described as 'rock flour'. Rock flour is the fine ground-up bi-product material produced in the glacial movement and abrasion of rock debris. Peter explained this was a typical Highland till and the transport distance would have been very local and short.

There was some layering in the till exposed (see Figure 1) and Peter described the bottom layer as 'basal till' which was material transferred to the ground as the glacial ice began to melt. The main region above this was described as 'ablation till'. This material had visibly a greater number of large clasts which would originally have collected on the top of the glacier but dropped onto the basal till as the glacier melted completely.

Figure 1 – Professor Peter Worsley describing layering in glacial till

The very upper layers were a Podzol showing a bleached horizon below the very top, dark organic layer; below the bleached area an iron rich layer was visible, derived from the leached zone.

Figure 2 – Striations on surface of gneiss

Figure 3 – Garnet crystals (brown) in gneiss

A second disused quarry stop was made at the end of **Loch Glencoul** at 23703 32525. Again the wall of the quarry was a Diamictite. The clasts were examined for evidence of glacial derivation by looking for grooved striations on the surface. Some striations were found on a clast of Lewisian gneiss (see Figure 2) at right angles to the normal lewisian banding. Whilst looking for striated clasts a boulder with garnets in the metamorphic gneiss was discovered (see Figure 3); garnets in the gneiss signify a higher temperature amphibolite facies as opposed to the Greenschist facies. This pleased Bernard, having not found the source at Droman.

With some spare time in the afternoon it was decided to take the scenic coastal road around **Drumbeg and Stoer** back to the Hotel. A short stop was made at the Drumbeg viewpoint (see Figure 4) and to visit the local store; a group of geologists, purporting to come from the RGS were seen wandering up the road in a slow drizzle tucking into ice-creams as if they were on a 'holiday'!

After a bath/shower and the dreaded 'packing of bags' and calculation of 'permitted rock baggage weight' the group celebrated the last evening in style .

Figure 4 - View across Eddrachillis Bay northwards from Drumbeg toward Badcall

Reported by Chris and Clare Fone

Friday's celebratory dinner.

The Inchnadamph Hotel had served us excellently during the week and excelled themselves on the last evening. After dinner, the party continued in the lounge.

Thanks were made to all who had made the trip such a success, notably David Ward for his organisation and Bernard Skillerne de Bristowe for the massive technical preparation, itinerary, leading/ daily education and patience with the RGS amateurs. Thanks also to Peter Worsley for his Quaternary observations made throughout the week. Edmund Shirley celebrated his ?th birthday that evening so the dual celebration included partaking in the locally brewed Suilvan ale (or similar) and a cake shared amongst the group. What a great week.

Final evening celebration.

Sunset viewed over Loch Assynt from the hotel dining room window

Description of the geology of the Rienachait area, Assynt
From the Fair Copy Map created by the RGS

Topography

The topography consists of rocky outcrops surrounded by heathers and grasses, generally low lying with a high point of 91m. The rocks have a lineation on about 30º, so that distinct ridges run across the scene, marked by irregular outcrops of rock. Very minor streams drain generally to the south and the single loch, Loch Neil Bhain which is centrally placed in the area, drains to the west. Between the rock ridges is low ground, tending to bog in places

Lewisian Gneiss

The oldest rock in the area is Lewisian Gneiss, here a grey rock forming very rounded masses and containing dark mineral bands, often deformed and in places (for instance at 04940 30560) containing spherical masses of green minerals, tentatively identified as actinolite hornblende. The main outcrop of Gneiss was to the SE of the mapped area. The other place where it was observed was as large erratics perched on top of the younger sediments, as at 03835 30565, where the erratic is about 1.5m diameter, and at 04750 30538.

Torridonian

All the sediments observed at Rienachait had a dip of between 20 -30 deg to the NW, on a strike of 280 to 320 deg Mag, the harder members creating ridges with a NE trend.
Five identifiable units were recognised, with possibly the coarsest being the basal member.

Conglomerate

It was possible to distinguish between conglomerate with a clast size of <10 mm from units with smaller clast size and the coarser conglomerate ranged up to 25cm diameter.

This coarse conglomerate appeared more at the base of the sediments where it rested directly on the Gneiss and formed tilted masses of pale coloured clasts in a red matrix. The contact is marked by the red boundary on the map. Clast material included gneiss and sandstone rocks. It was possible to trace these deposits along strike.

The 2-10mm clast conglomerate appeared more in the central area and also formed ridges traceable for shorter distances. Internal structures were seen, including current bedding, layers of fine sand and pebble horizons.

Sandstone

The finest, sand sized, member was quartz sandstone, buff in colour and also showing internal structures of cross bedding and coarser horizons. While some formed outcrops close to the Gneiss contact, most was observed to the NW – upper ?- part of the sequence.

Shales

Shales were observed in three places at Rienachait, all to the N or NW of the area.
These shales were laminated, dark brown coloured, about 1 m thick and found beneath the overlying sandstone in the sides of the channels between the rock ridges. The floors of the channels, where more shales could be expected to be found, were either bogs or heavily overgrown with heathers.

Stac Fada Member

A distinct ridge, in places 20m higher than the local surface and running along the NW side of the mapping area contained outcrops of the Stac Fada Member – current interpretation of this enigmatic rock is an impact ejecta blanket. The rock contains much green ash and small pink pebbles, making it very distinctive amongst the Torridonian sandstones and conglomerates and therefore easy to map.

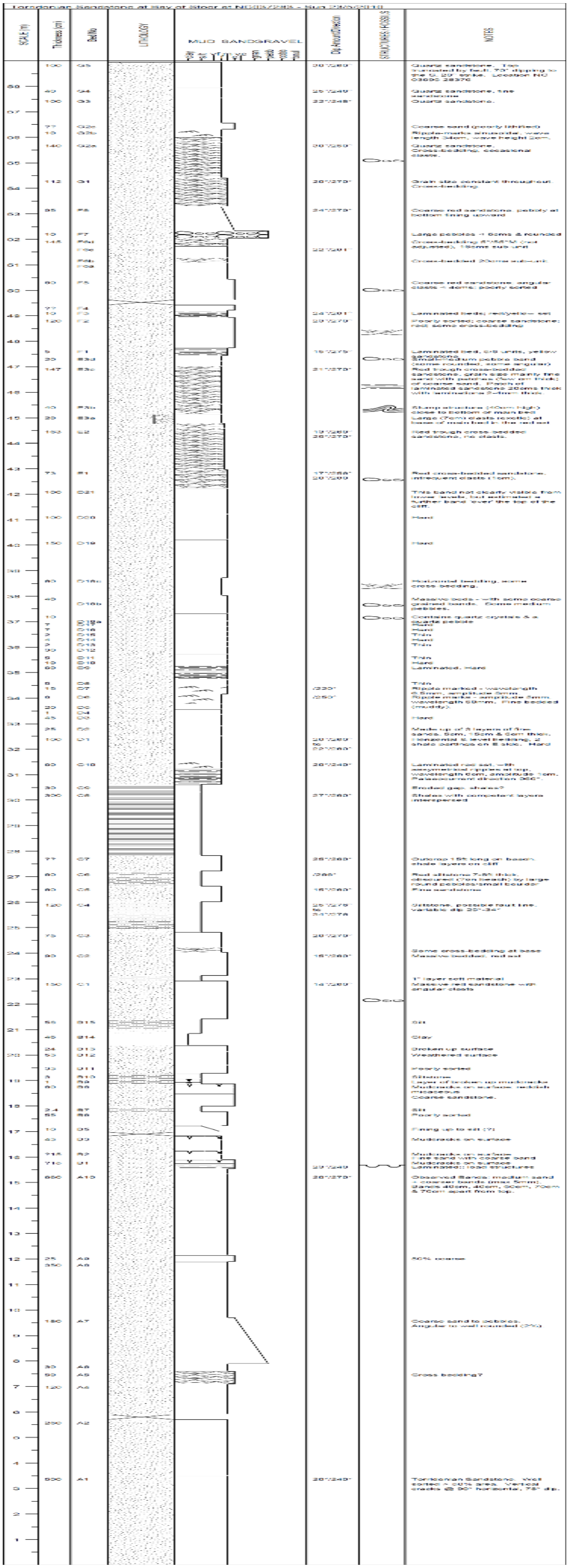
D.R Ward

APPENDICIES

Sedimentary log

Members logs

Geological map of Rienachait area



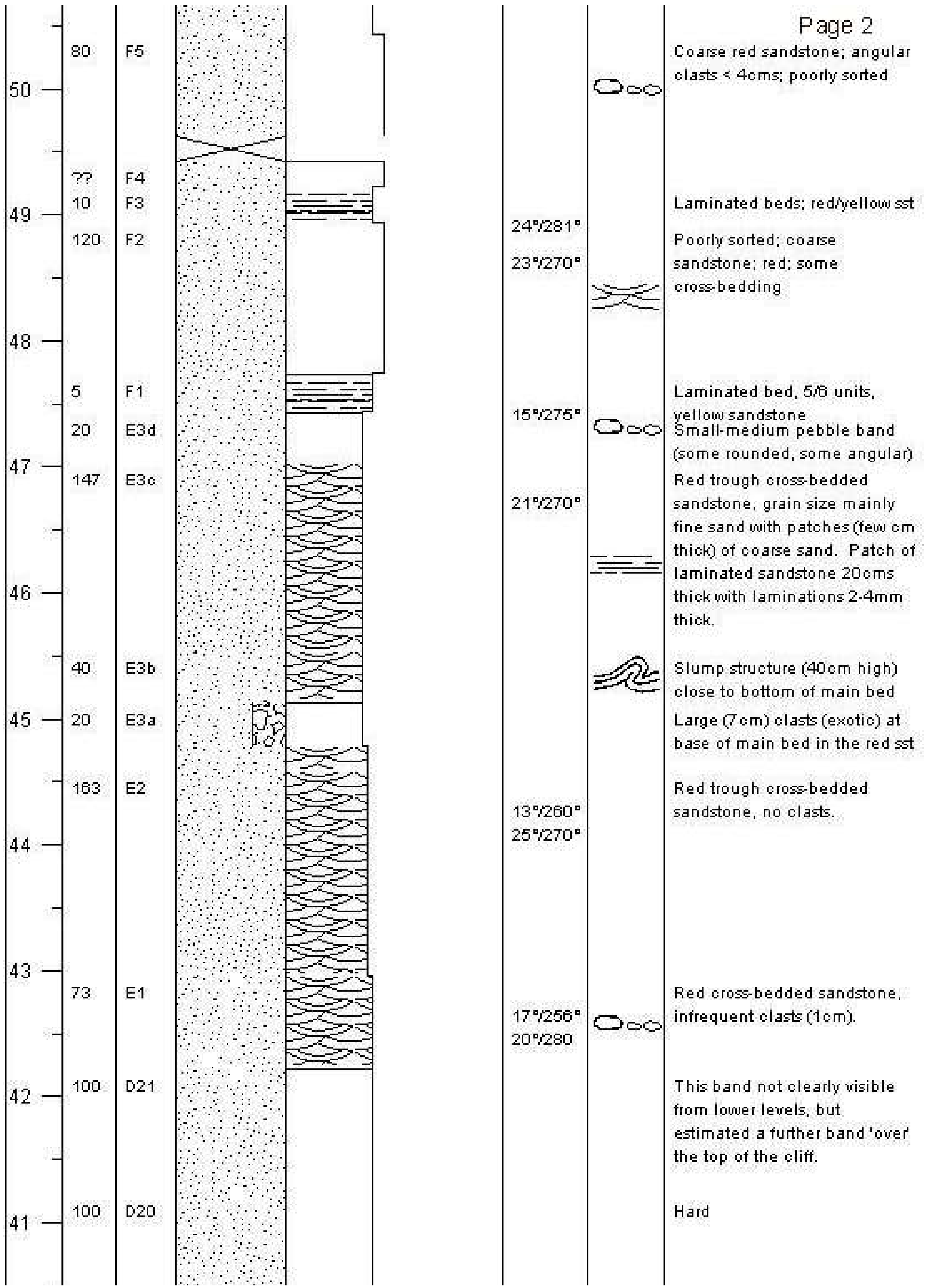
Complete Sedimentary log

PTO for enlarged sections

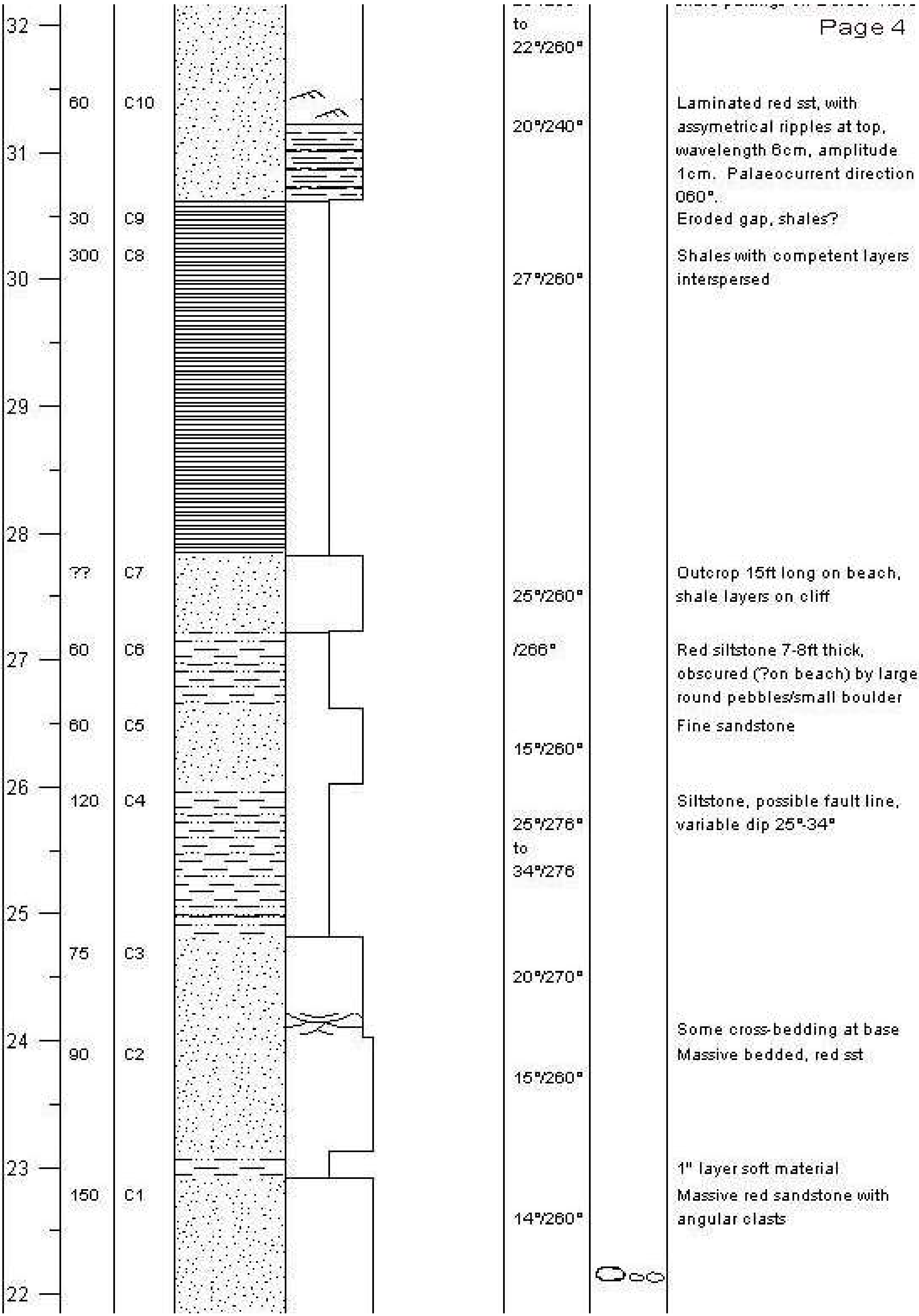
An enlargement of this log is attached

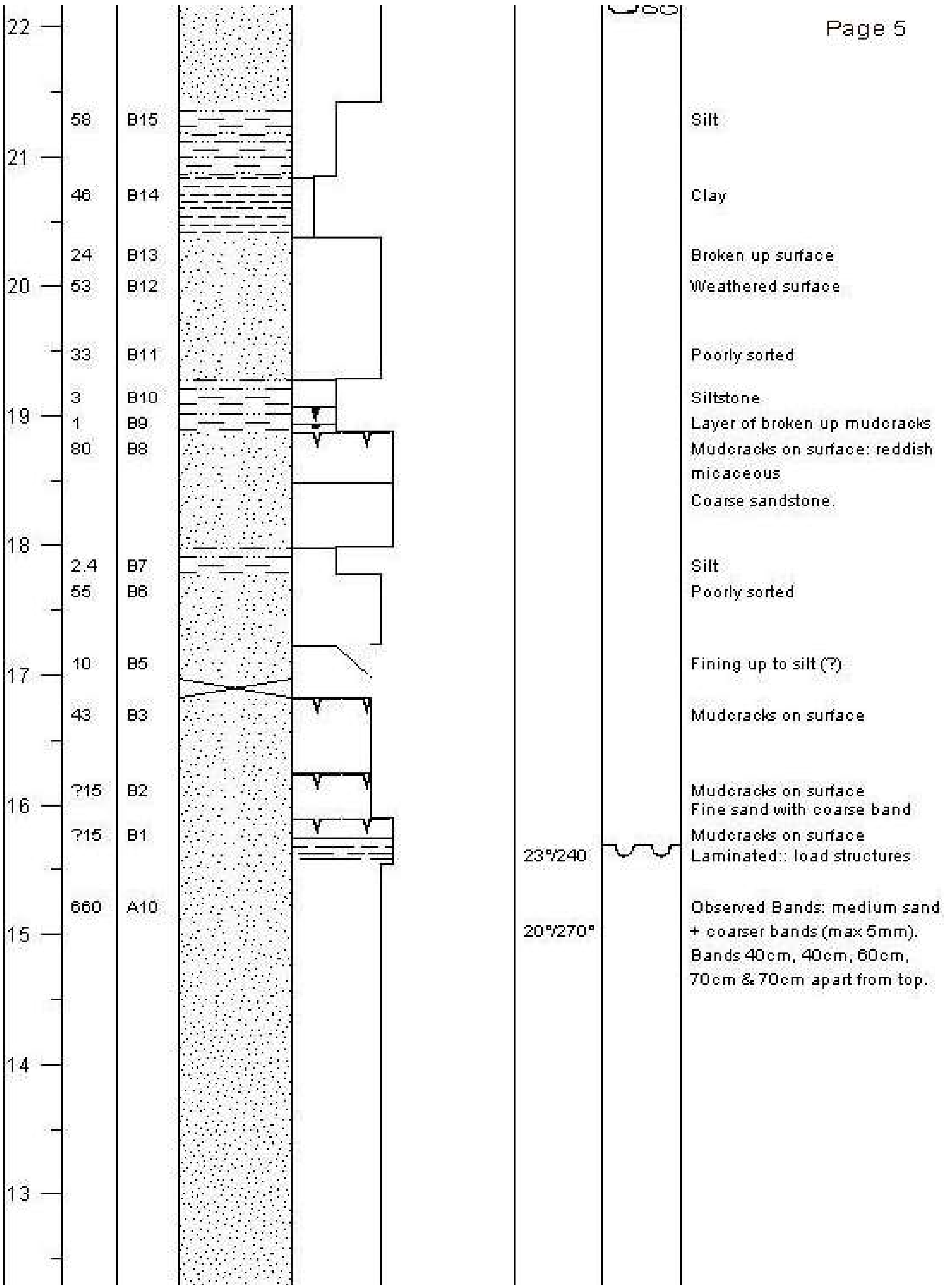
Torridonian Sandstone at Bay of Stoer at NC037283 - Sun 23/5/2010

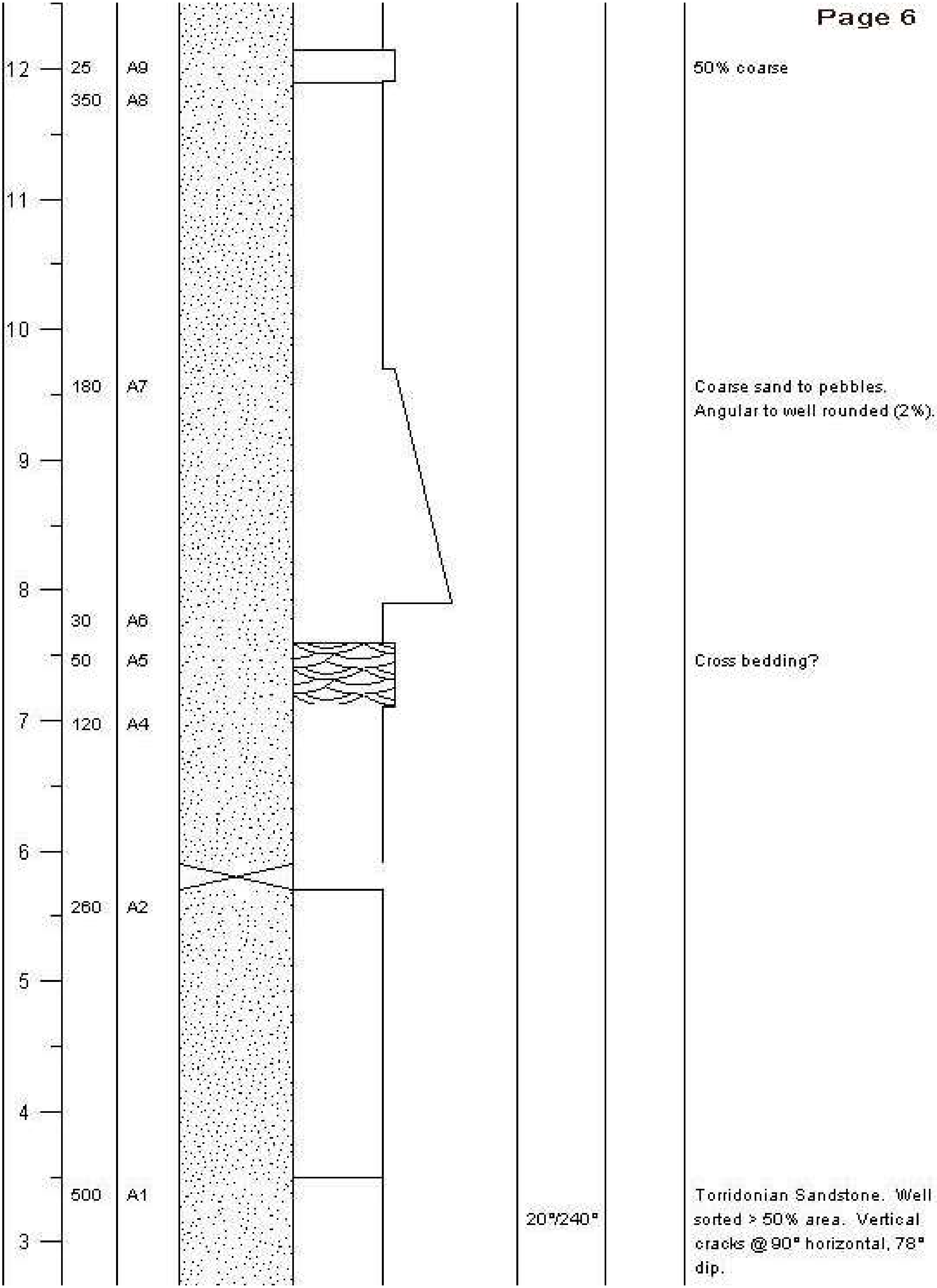
SCALE (m)	Thickness (cm)	Bed No	LITHOLOGY	MUD SANDGRAVEL (clay, silt, vf, f, m, c, vc, gran, pebb, cobb, boul)	Dip Amount/Direction	STRUCTURES / FOSSILS	NOTES
	100	G5			30°/260°		Quartz sandstone. Top truncated by fault, 70° dipping to the S, 20° strike. Location NC 03695 28376
58	40	G4			25°/248°		Quartz sandstone, fine sandstone
	100	G3			22°/248°		Quartz sandstone.
57	??	G2c					Coarse sand (poorly lithified)
	10	G2b					Ripple-marks sinusoidal, wave length 34cm, wave height 2cm.
56	140	G2a			30°/250°		Quartz sandstone. Cross-bedding, occasional clasts.
55							
54	112	G1			20°/270°		Grain size constant throughout. Cross-bedding.
53	95	F8			24°/279°		Coarse red sandstone, pebbly at bottom fining upward
	10	F7					Large pebbles < 6cms & rounded
52	145	F6d					Cross-bedding 5°/55°M (not adjusted), 16cms sub-unit
		F6c			22°/281°		
51		F6b					Cross-bedded 20cms sub-unit.
		F6a					

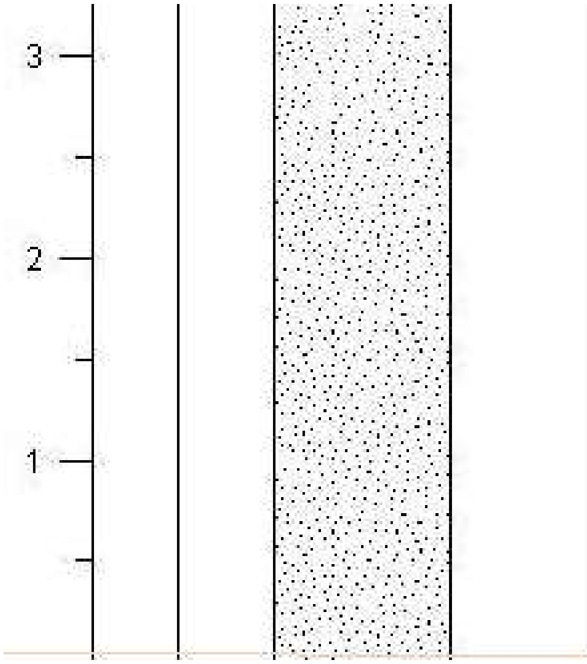

50
49
48
47
46
45
44
43
42
41
80 F5
?? F4
10 F3
120 F2
5 F1
20 E3d
147 E3c
40 E3b
20 E3a
163 E2
73 E1
100 D21
100 D20
24°/281°
23°/270°
15°/275°
21°/270°
13°/260°
25°/270°
17°/256°
20°/280
Coarse red sandstone; angular clasts < 4cms; poorly sorted
Laminated beds; red/yellow sst
Poorly sorted; coarse sandstone; red; some cross-bedding
Laminated bed, 5/6 units, yellow sandstone
Small-medium pebble band (some rounded, some angular)
Red trough cross-bedded sandstone, grain size mainly fine sand with patches (few cm thick) of coarse sand. Patch of laminated sandstone 20cms thick with laminations 2-4mm thick.
Slump structure (40cm high) close to bottom of main bed
Large (7cm) clasts (exotic) at base of main bed in the red sst
Red trough cross-bedded sandstone, no clasts.
Red cross-bedded sandstone, infrequent clasts (1cm).
This band not clearly visible from lower levels, but estimated a further band 'over' the top of the cliff.
Hard

150	D19		Hard
60	D18c		Horizontal bedding, some cross-bedding.
40	D18b		Massive beds - with some coarse grained bands. Some medium pebbles.
10	D18a		Contains quartz crystals & a quartz pebble
7	D17		Hard
7	D16		Hard
2	D15		Thin
4	D14		Hard
2	D13		Thin
30	D12		
5	D11		Thin
10	D10		Hard
60	D9		Laminated. Hard
5	D8		Thin
15	D7	/220°	Ripple marked - wavelength 6.5mm, amplitude 8mm.
8	D6	/250°	Ripple marks - amplitude 5mm, wavelength 50mm. Fine bedded (muddy).
20	D5		
1	D4		
45	D3		Hard
25	D2		Made up of 3 layers of fine sands, 5cm, 15cm & 5cm thick.
100	D1	20°/260° to 22°/260°	Horizontal & level bedding, 2 shale partings on E side. Hard


32
31
30
29
28
27
26
25
24
23
22
to
22°/260°
60 C10
20°/240°
Laminated red sst, with assymetrical ripples at top, wavelength 6cm, amplitude 1cm. Palaeocurrent direction 060°.
30 C9
Eroded gap, shales?
300 C8
27°/260°
Shales with competent layers interspersed
?? C7
25°/260°
Outcrop 15ft long on beach, shale layers on cliff
60 C6
/266°
Red siltstone 7-8ft thick, obscured (?on beach) by large round pebbles/small boulder
60 C5
15°/260°
Fine sandstone
120 C4
25°/276° to 34°/276
Siltstone, possible fault line, variable dip 25°-34°
75 C3
20°/270°
Some cross-bedding at base
90 C2
15°/260°
Massive bedded, red sst
1" layer soft material
150 C1
14°/260°
Massive red sandstone with angular clasts


22
58 B15 Silt
21
46 B14 Clay
24 B13 Broken up surface
20 53 B12 Weathered surface
33 B11 Poorly sorted
3 B10 Siltstone
19 1 B9 Layer of broken up mudcracks
80 B8 Mudcracks on surface: reddish micaceous
Coarse sandstone.
18
2.4 B7 Silt
55 B6 Poorly sorted
10 B5 Fining up to silt (?)
17
43 B3 Mudcracks on surface
?15 B2 Mudcracks on surface
16
Fine sand with coarse band
?15 B1 Mudcracks on surface
23°/240 Laminated:: load structures
660 A10 Observed Bands: medium sand + coarser bands (max 5mm). Bands 40cm, 40cm, 60cm, 70cm & 70cm apart from top.
15 20°/270°
14
13


12
25 A9
50% coarse
350 A8
11
10
180 A7
Coarse sand to pebbles.
Angular to well rounded (2%).
9
8
30 A6
50 A5
Cross bedding?
7
120 A4
6
260 A2
5
4
500 A1
Torridonian Sandstone. Well sorted > 50% area. Vertical cracks @ 90° horizontal, 78° dip.
20°/240°
3



20°/240°

sorted > 50% area. Vertical cracks @ 90° horizontal, 78° dip.

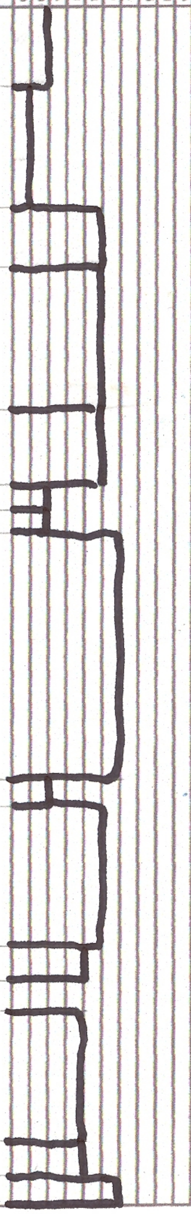
MEMBERS LOGS

The following are copies of the field logs produced by the members and are un-edited.

RGS

Location: 03779 28338

Date: 23/05/10 Sheet: of:



	Thickness	Bed No	Lithology	Grain Size	Dip/Strike	Palaeo-current	Fossils	Notes
	58	15						
	46	14						
?2.4	24	13						broken up surface.
	53	12						weathered surface
?3.3	33	11						poorly sorted
	3	10						
	1	9						layer of broken up mudcracks
	80	8						mudcracks on surface: reddish micaceous
	2.4	7						
	55	6						poorly sorted
	10	5						fining up to silt (?)
	0.5	4						
	43	3						mudcracks on surface
	?	2						fine sand with coarse band: mudcracks on surface
	?	1			330/23°N			laminated: mudcracks on surface: load structures

RGS

Location: STOER BAY ('G' upwards)

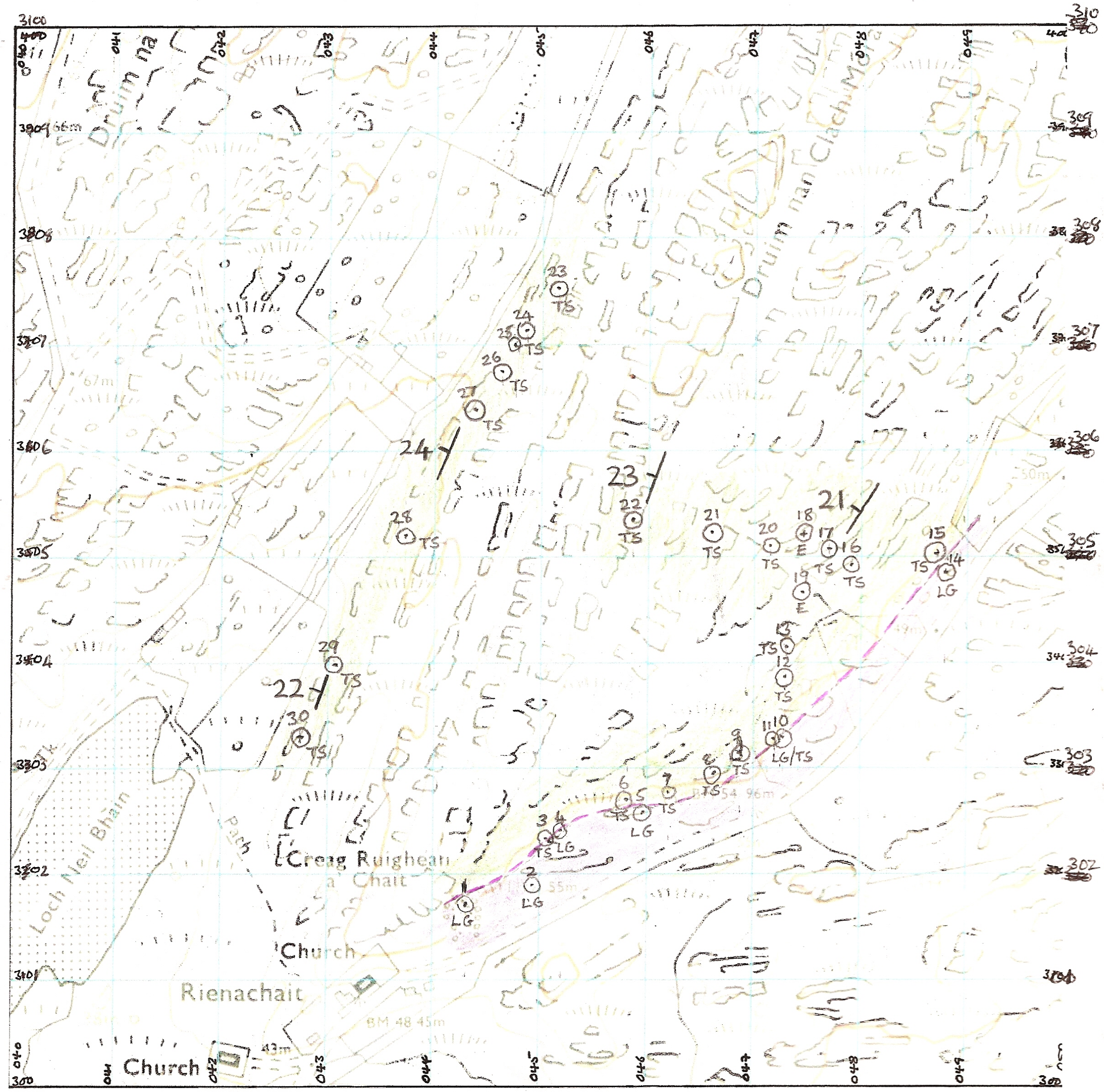
Date: 23/05/09 Sheet: 1 of: 1

	Thickness	Bed No	Lithology	clay	silt	vfs	fs	ms	cs	vcs	gran	peb	cob	Dip/Strike	Palaeo-current	Fossils	Notes
Bed 1	1.12	1						✓						20° (S) North South le 0°		none	Grain size consistant throughout. Crossbedding no fossils
Bed 2	1.5	2	Quartz Sand st.				✓							Dip 30° (S) strike 340°- 20° west			occasional clasts Crossbedding ripple marks - sinusoidal wave length 3+m height 2centimetres
Bed 3	1 metre	3	quartz sandst				✓							Dip 22° S strike 338			Coarse sandlayer poorly lithified between 2+3
increasing upwards	0.4 metre	4	quartz Sandst.				✓							Dip 25° (S) strike 338°			Quartz sandstone fine sandstone
	1 metre	5	Q.SST.				✓							Dip- 30° (S) clean strike 350°			quartz sandstone
																	NB Fault 70 degrees dipping to the south 20 degree strike location 03695 28376

CHRIS & CLARE FONE

MAPPING LOG 24.05.10

EDMUND SHIRLEY, CLARE FONE, CHRIS FONE



TS - TORRIDONIAN SANDSTONE

– – – ESTIMATED UNCONFORMITY

LG - LEWISIAN GNEISS

E - ERRATIC

IC0430

Edited Field log with Top at Top

Brian Mathews and David Riley

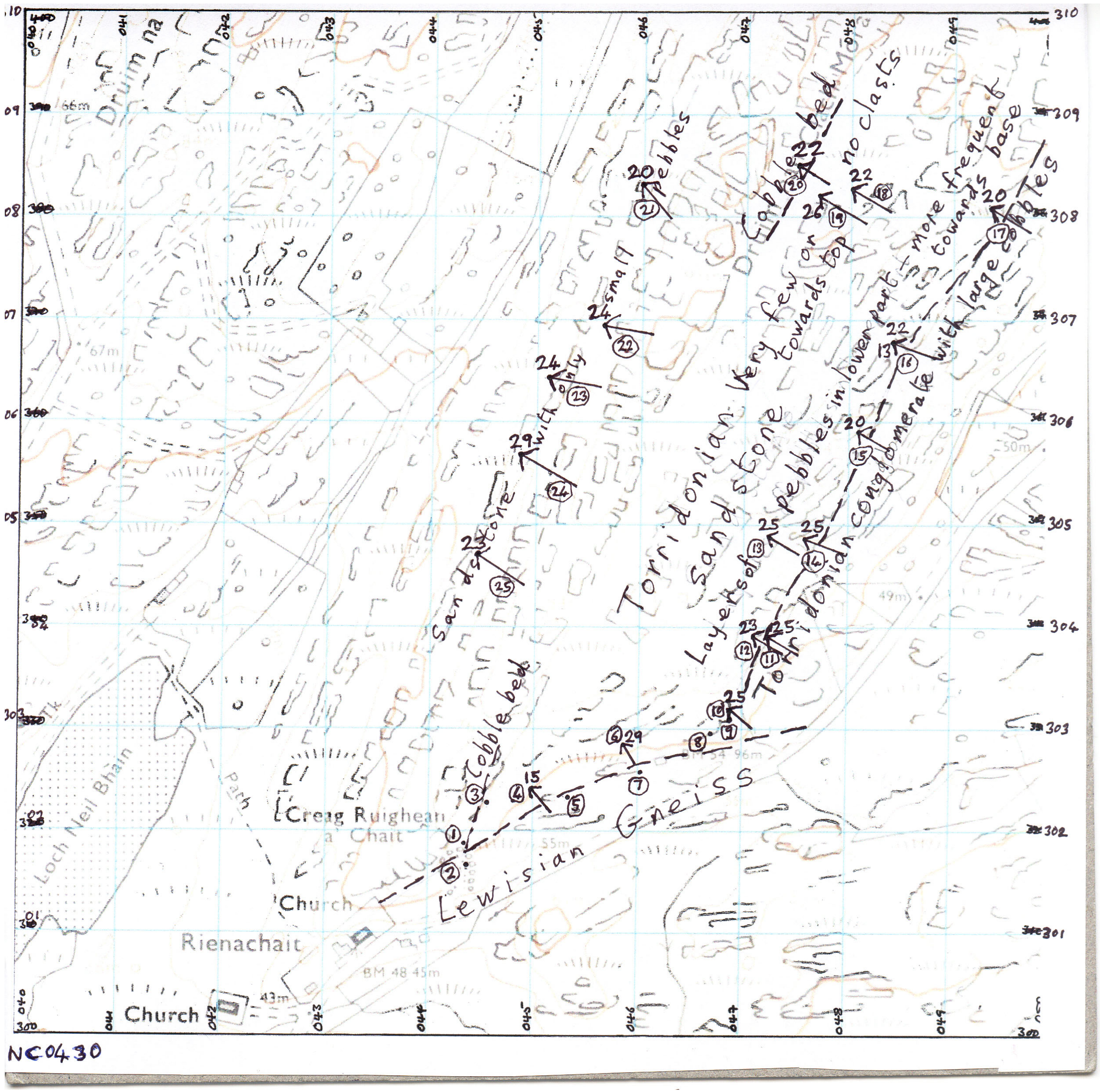
RGS

Location: ASSYNT Grid. Ref. NC 03712 253048
STOER coordinate. N 58.20021 W00534193

Date: 23 May 2010 **Sheet:** 1 **of:** 1

Thickness (cm) Top	Bed No	Lithology	clay	silt	vfs	fs	ms	cs	vcs	gran	peb	cob	Dip/Strike	Palaeo-current	Fossils	Notes
227	3					x x	 x	x x					21/270	W		At top of bed a small-medium pebble band (some rounded, some angular) Red trough cross bedded sandstone Grain size mainly fine sand with patches (few cm thick) of coarse sand Patch of laminated sandstone 20cm thick with laminations 2-4mm thick Feature close to bottom of bed (slump structure??)  Large (7cm) clasts (exotic) at base of bed in the red sandstone
163	2					x	x						13/260 25/270			Red trough cross bedded sandstone No clasts
73	1					x							17/256 20/250			Red cross bedded sandstone infrequent clasts (1cm)

(Bottom)


Creag Ruighean a' Chait
Church
Rienachait
Loch Neil Bhain
Lewisian Gneiss
Torridonian Very few on Sandstone
Layers of pebbles in lower part + more frequent towards base
Torridonian conglomerate with large cobbles
Sandstone
Cobble bed
no clasts
towards top
pebbles
NC0430

Map of Rienachait