British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Geology of the Dailly area, Ayrshire

Integrated Geoscience Surveys (Northern Britain) Programme
Internal Report IR/04/035

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/04/035

Geology of the Dailly area, Ayrshire

Alison Monaghan

Contributors:

Sarah Arkley

Mike Stephenson

Key words

Report; Ayrshire, Dailly, Geology, Carboniferous, superficial, bedrock

Bibliographical reference

MONAGHAN, A. 2004. Geology of the Dailly area, Ayrshire. *British Geological Survey Internal Report*, IR/04/035. 24pp.

Keyworth, Nottingham British Geological Survey 2004

BRITISH GEOLOGICAL SURVEY

The full range of Survey publications is available from the BGS Sales Desks at Nottingham and Edinburgh; see contact details below or shop online at www.thebgs.co.uk

The London Information Office maintains a reference collection of BGS publications including maps for consultation.

The Survey publishes an annual catalogue of its maps and other publications; this catalogue is available from any of the BGS Sales Desks.

The British Geological Survey carries out the geological survey of Great Britain and Northern Ireland (the latter as an agency service for the government of Northern Ireland), and of the surrounding continental shelf, as well as its basic research projects. It also undertakes programmes of British technical aid in geology in developing countries as arranged by the Department for International Development and other agencies.

The British Geological Survey is a component body of the Natural Environment Research Council.

Keyworth, Nottingham NG12 5GG

☎ 0115-936 3241 Fax 0115-936 3488
e-mail: sales@bgs.ac.uk
www.bgs.ac.uk
Shop online at: www.thebgs.co.uk

Murchison House, West Mains Road, Edinburgh EH9 3LA

☎ 0131-667 1000 Fax 0131-668 2683
e-mail: scotsales@bgs.ac.uk

London Information Office at the Natural History Museum (Earth Galleries), Exhibition Road, South Kensington, London SW7 2DE

☎ 020-7589 4090 Fax 020-7584 8270
☎ 020-7942 5344/45 email: bgslondon@bgs.ac.uk

Forde House, Park Five Business Centre, Harrier Way, Sowton, Exeter, Devon EX2 7HU

☎ 01392-445271 Fax 01392-445371

Geological Survey of Northern Ireland, 20 College Gardens, Belfast BT9 6BS

☎ 028-9066 6595 Fax 028-9066 2835

Maclean Building, Crowmarsh Gifford, Wallingford, Oxfordshire OX10 8BB

☎ 01491-838800 Fax 01491-692345

Parent Body

Natural Environment Research Council, Polaris House, North Star Avenue, Swindon, Wiltshire SN2 1EU

☎ 01793-411500 Fax 01793-411501
www.nerc.ac.uk

Foreword

This report is the published product of a study by the British Geological Survey (BGS) Midland Valley Integrated Survey mapping program in Ayrshire as part of the revision of the Ayr Sheet 14 (W).

Contents

FIGURES

TABLES

Summary

This report describes the Early Carboniferous bedrock geology and Devensian-Flandrian superficial deposits on sheets NS20SE and NS20SW, which form part of the revision of the Ayr sheet 14(W).

1 Introduction

This report describes the bedrock geology of the Early Carboniferous Inverclyde and Strathclyde groups and Devensian-Flandrian superficial deposits on sheets NS20SE and NS20SW in the Water of Girvan valley around Dailly [NS 23 00] to [NS 30 05]. The Ordovician-Silurian sequence of the Craighead inlier, the Siluro-Devonian Swanshaw Sandstone Formation and the Carboniferous Clackmannan Group that crop out on NS20SW and NS20SE are not described in detail here, but in Williams (2001), Floyd and Williams (2003), Monaghan (2001), Mykura et al. (1967) and Eyles et al. (1949). This work forms part of the resurvey of the sheet Ayr, 14 (W).

The Early Carboniferous Inverclyde – Strathclyde Group strata are moderately exposed in the Dailly area with the main outcrops found in deeply incised streams. The superficial deposits are poorly exposed with only a few sections visible in the rolling farmland.

Some subsurface data exists for this area. The borehole and mine abandonment plan data is concentrated in the Late Carboniferous Dailly Coalfield, with a few boreholes penetrating the Early Carboniferous succession. Appendix 1 lists the data sources available during this study.

1.1 HISTORY OF SURVEY AND AIMS OF THIS REVISION

The area was first surveyed by A Geikie in the 1868, B Peach and J Horne in the 1890's and later by J B Simpson and J E Richey in the 1920's. Partial resurveys were undertaken by W Mykura in 1962 (Late Carboniferous rocks), and J D Floyd and I B Cameron in 1991 (on the Carrick Sheet 8W). Relevant publications include Eyles et al. (1930, 1949), Mykura et al. (1967) and the 1:50, 000 scale bedrock geology map (BGS, 1978).

Assessment of existing data prior to fieldwork showed that:

- Mykura undertook thorough field resurvey of the Clackmannan Group (Lower Limestone to Upper Limestone Formation) in the Dailly syncline from in 1958-60, when the deep mines in the Limestone Coal Formation were in their last years of activity. Assessment of the mine abandonment plans showed that only a small area of coal was subsequently extracted from the Dalquaharran colliery. The opencast site in the far north-eastern corner of NS20SE was worked subsequent to Mykura's resurvey.
- Floyd and Cameron remapped the southern parts of NS20SE and NS20SW located on the Carrick sheet (8W) in 1989 and started to apply modern stratigraphical terminology to the Early Carboniferous strata, though the Strathclyde Group was not subdivided on the southern published part of the 1: 10, 000 scale map.
- The Silurian and Ordovician strata of the Craighead Inlier were remapped by Floyd in 2000.
- There had been no field remapping of the superficial deposits since the 1920's although some interesting landforms could be mapped from stereo aerial photograph pairs.

Given the already extensive coverage on the Clackmannan Group coalfield strata and the lack of subsequent major mining activity, the aims of the rapid, focussed field resurvey were to:

- rapidly reassess and subdivide the stratigraphy of the Early Carboniferous 'Calciferous Sandstone Series' rocks on the parts of NS20SE and NS20SW on the Ayr Sheet, into modern lithostratigraphical units following Browne et al. (1999) ;
- resurvey superficial deposits by the use of aerial photography and by limited ground truthing. In particular, examine previously mapped areas of sand and gravel with esker-

like ridges and propose a depositional environment, and examine areas of moundy drift or artificial /disturbed ground .

The 1:10 000 scale maps of NS20SE and NS20SW should be consulted along with this report. The outcrop limits shown on the 1:10 000 sheet are commonly inferred. The boundaries are therefore the interpretation of the surveyor, based on the information available at the time of survey and carry an element of uncertainty.

2 Generalised description

The bedrock geology of the Dailly area described here consists of Carboniferous strata cropping out in a graben structure and folded into the north-east trending Dailly Syncline, with Ordovician-Devonian strata in the footwalls of the major north-east trending, graben-bounding faults (Figure 1). Fluvial sandstone, conglomerate and siltstone with pedogenic carbonate of the Tournaisian Ballagan Formation pass upwards into siltstone, dolomitic limestone and calcareous mudstone interpreted as lagoonal – coastal plain deposits. They are overlain by the sandstone, conglomerate and pedogenic carbonate of the Clyde Sandstone Formation and a return to deposition in a fluvial environment. A major unconformity separates the Clyde Sandstone Formation from the late Visean Lawmuir Formation that consists of sandstone and siltstone with rootlets and plant remains. The overlying sequence of the Lower Limestone, Limestone Coal and Upper Limestone formations mark a change in environment from cyclical non-marine to shallow marine conditions. Palaeogene dolerite dykes cut the entire succession.

The sequence of superficial deposits overlying bedrock commences with an extensive cover of Devensian lodgement till moulded into east to east-north-easterly trending drumlins. In places, till is overlain by sand and gravel mounds and esker ridges of glaciofluvial ice-contact origin. The highest raised beach terrace at about 25 m above Ordnance Datum can be mapped along the Water of Girvan where significant deposits of sandy alluvium are also present. Artificial or disturbed ground is common over the area underlain by the Limestone Coal Formation, associated with the abstraction of coal. Landscaped coal waste bings, shaft and pit remnants can be observed.

3 Descriptive accounts - bedrock geology

3.1 REVISION OF EARLY CARBONIFEROUS STRATIGRAPHY

Large areas of NS20SE were previously mapped as Dinantian Calciferous Sandstone Measures (BGS, 1978). Subsequently, the stratigraphy was revised in the southern parts of NS20SE and NS20SW to distinguish the Tournaisian Inverclyde Group and Visean Strathclyde Group (BGS, 1994; Floyd, 1999). This resurvey subdivides the Early Carboniferous strata to formation and member level (Table 1) following the guidelines of Browne et al. (1999).

Stratigraphical nomenclature after Browne et al. (1999)		Characteristic features on NS20SE and NS20SW	Stratigraphical nomenclature of Eyles et al (1949)	
Lawmuir Formation	Strathclyde Group	Green-grey sandstone and siltstone with rootlets and plant debris.	Calciferous Sandstone Measures	Upper Group
Clyde Sandstone Formation	Inverclyde Group	Strongly coloured red-purple sandstone, conglomerate and siltstone/mudstone with pedogenic carbonate beds and nodules.		
Ballagan Formation	Inverclyde Group	Three units: 1.Basal yellow sandstone with grey silty mudstone of the Drumwhirn Member. 2.Red-purple sandstone with conglomerate and pedogenic carbonate of the Lindsayston Burn Member. 3.Grey-green mudstone with thin non-marine limestones and sandstone of the upper Ballagan Formation.		Cementstone Group

Table 1. Summary of revised Early Carboniferous stratigraphy on NS20SE and NS20SW.

The presence of grey silty mudstone and dolomitic limestone (‘cementstone’) interbedded with sandstone distinguishes the basal units of the Ballagan Formation from the underlying Kinnesswood Formation.

3.2 BALLAGAN FORMATION, INVERCLYDE GROUP

Three local lithological subdivisions of the Ballagan Formation (previously the Cementstone Group of the Calciferous Sandstone Measures) were recognised by Eyles et al. (1949) and Floyd (1999). These are summarised in ascending stratigraphic order in the following numbered paragraph.

1. Yellow, medium to fine-grained, thinly planar-bedded sandstone with grey silty mudstone and rare thin non-marine, dolomitic limestone (‘cementstone’). At least 150 m in thickness, Eyles et al. (1949) termed this unit the ‘basal sandstone’. This unit is now defined as the Drumwhirn Member with a type area between Craig and Drumwhirn farms and east of Whitehill Farm [NS 275 005] to [NS 300 016].

2. Red, brown and purple sandstone, medium to coarse grained, thickly and cross-bedded with thin conglomerate. Poorly developed calcrete (‘cornstone’) beds or nodules and red marl. Approximately 100 m in thickness, Eyles et al. (1949) termed this unit the ‘cornstone-bearing beds’ and proposed a type section in Lindsayston Burn near Dailly [NS 28 01]. This unit is now termed the Lindsayston Burn Member with a type section in the Lindsayston Burn between [NS 2824 0080] and [NS 2735 0012] (Figure 2).

3. Green-grey-brown silty mudstone, and thin non-marine, dolomitic limestone (‘cementstone’) and yellow, brown and grey sandstone. Approximately 135 m thick, Eyles et al. (1949) termed this unit the ‘shale subgroup’. This unit is referred to as the upper Ballagan Formation.

The extent of these three units was mapped on NS20SE. From examination of field slips (NS30SW and Ayr County Series 51NW) the three units could tentatively be mapped out on NS30SW (Lady Glen and stream section south of Kilkerran House) but could not be continued further northwards due to poor exposures on NS30NW.

3.2.1 Drumwhirn Member, Ballagan Formation

The basal unit of the Ballagan Formation is poorly exposed in the hills and streams east of Whitehill Farm e.g. [NS 2975 0120]. It is characterised by white-buff flaggy sandstone intercalated with finely laminated grey calcareous siltstone and mudstone. Two samples of silty mudstone analysed for palynology (ASB 155, ASB 156) gave a CM miospore zonation indicative of a Tournaisian age for the sedimentary rocks (Appendix 2). The unit is at least 275 m thick; the base was not seen on NS20SE .

3.2.2 Lindsayston Burn Member, Ballagan Formation

The Lindsayston Burn Member is almost continuously exposed in the Lindsayston Burn between [NS 2821 0082] and [NS 2755 0093] (Figure 2). In this section, the strata dip to the north-west, do not appear to be offset by faulting and reach a thickness of 134 m. The Lindsayston Burn Member is interpreted to reach up to approximately 285 m thick on other areas of NS20SE.

In the lower, south-easterly part of the section between [NS 2821 0082] and [NS 2272 0089] and 0-91 m on Figure 2, the strata are characterised by buff-white-grey, hard, flaggy sandstone, interbedded soft red-green sandstone with pedogenic carbonate nodules and pipes (Figure 3), and rarer red-green siltstone and mudstone with pedogenic carbonate nodules. Thick channelised sandstone and conglomerate a few metres thick and tens of metres wide are observed at several localities e.g. [NS 2782 0087] (Figure 4). These units are typically erosively based with local scoured surfaces and fine upwards, for example from coarse- to medium-grained sandstone to more laterally extensive fine-grained sandstone beds. Conglomerate beds are typically clast supported, rarely cross-bedded, poorly sorted with subangular clasts of chert, quartz, greywacke, altered igneous rocks and some sandstone intraclasts, up to 20 cm in diameter. Lenses and lags of conglomerate and rip-up clasts are also found within the massive, cross- and trough- bedded flaggy sandstone that forms a major component of this lithofacies.

In the most extensive exposures lateral facies variability was observed. For example at [NS2807 0084], an erosively based >1 m thick, massive coarse-grained sandstone and microconglomerate bed overlies purple, red green mudstone with well-developed pedogenic carbonate nodules. Tens of metres downstream at [NS 2795 0084] the sandstone bed thickens to approximately 4 m and cuts down into the underlying siltstone (Figure 5).

The sedimentary facies observed are interpreted as deposition in a fluvial environment. Thick-bedded erosively based sandstone and conglomerate represent channel deposits, laterally extensive sandstone beds are interpreted as sheetflood and crevasse splay deposits, and siltstone and mudstone with pedogenic carbonate (calcrete) as overbank deposits. The lateral facies variation observed illustrates how major channel facies pass laterally to channel margin, crevasse splay and overbank deposits (Figure 5). The environment must have been semi-arid with relatively well-drained soils for the pedogenic carbonate nodules and pipes to develop, but with a sizeable amount of water flow from time-to-time, reflected in the width of channel sandstones and cobble-size of conglomerate clasts.

Similar sedimentary facies are exposed in the Falfarrocher Burn [NS 2894 0210] and in the burn north of Glengee Wood [NS 2990 0240]. The Lindsayston Burn Member of the Ballagan Formation is similar to the Clyde Sandstone Formation but it is typically less of an intense red-purple colour.

In the north-western part of the Lindsayston Burn section [NS 2272 0089] to [NS 2749 0097] and 91-134 m on Figure 2, the upper part of the Lindsayston Burn Member records a gradational change to the upper Ballagan Formation. Medium- to coarse-grained sandstone interbedded with red-grey siltstone with pedogenic carbonate are still common, but intercalations of grey calcareous siltstone and mudstone and thinly bedded fine-grained sandstone in packages up to about 0.7 m thick are also observed e.g. [NS 2772 0089], 114 m on Figure 2. Sedimentary structures such as mudcracks, raindrop prints and tool-marked bases to thicker sandstone beds are observed. Indeterminate bioturbation was also observed in grey siltstone.

A similar fluvially dominated depositional environment to that described for the lower parts of the Lindsayston Burn Member is envisaged for these strata. The intercalation of grey calcareous siltstone and mudstone with mudcracks and bioturbation is interpreted as a gradual transition and change in environment to the lacustrine – marginal marine lagoonal – coastal plain environment envisaged for the upper Ballagan Formation.

Three samples (ASB 151, 152, 153) analysed for palynology and ostracods from the Lindsayston Burn Member in Lindsayston Burn gave a CM miospore zonation indicative of the Tournaisian and were barren of ostracods (Appendix 2).

Six palaeocurrents indicators measured in the Lindsayston Burn Member in Lindsayston Burn (primary current lineation, tool marks, cross beds, clast imbrication) show a dominant north-westwards flow direction for the fluvial system.

3.2.3 Upper Ballagan Formation

Lithofacies more typical of the Ballagan Formation (*c.f.* Browne et al. 1999) are observed in the moderately to poorly exposed north-western part of the Lindsayston Burn section near Dailly cemetery [NS 2737 0129], above 240 m on Figure 2. Here, thinly bedded grey, calcareous siltstone, mudstone and fine sandstone can be observed. Previous surveys recognised dolomitic limestone (‘cementstone’) but these were not observed during this resurvey.

The upper Ballagan Formation is also exposed in the Baldrennan Burn [NS 2841 0413] in the north-east of NS20SE, west of Glenton Farm. At this locality, interbedded micaceous sandstone, siltstone, grey mudstone, calcareous mudstone and yellow-grey muddy dolomitic limestone (sometimes concretionary) are found.

Poor exposures and faulted contacts make the thickness of this unit difficult to measure, but it is probably around 120 m thick near Dailly.

One palynology sample from Baldrennan Burn gave a CM miospore zonation indicative of Tournaisian age and one from Lindsayston Burn was barren of zonal miospores but probably of CM or Pu miospore zonation (Appendix 2). The samples were barren of ostracods.

The exposures of the upper Ballagan Formation are so small that interpreting a depositional environment is problematic. However, by analogy to well exposed sections with the same lithofacies types (e.g. Stephenson et al. 2003) the depositional environment is believed to be a low-relief lacustrine – marginal marine lagoonal – coastal plain with minor fluvial input.

3.3 CLYDE SANDSTONE FORMATION, INVERCLYDE GROUP

The Clyde Sandstone and Lawmuir formations (previously the Upper Group of the Calciferous Sandstone Measures) are described as sandstone, red marl with cornstone, conglomerate, greenish sandstone and fireclay with rootlets by Eyles et al. (1949). For the strata on the southern part of NS20SE and NS20SW, Floyd (1999) described the top Inverclyde Group as reddish-brown sandstone with scattered pebbles and red mudstone with pedogenic carbonate, approximately 65 m in thickness.

The Clyde Sandstone Formation is well exposed in Glenton Glen west and north of Glenton Farm e.g. [NS 2887 0422]. It is commonly comprised of fine- to very coarse-grained, strong red-buff sometimes green or grey sandstone with parallel lamination and scattered quartz clasts. Cross- and trough-bedding and scoured, erosive surfaces are common in the sandstone (Figure 6). Clast supported conglomerate beds are frequent, typically with erosive channelled and scoured bases, and containing poorly sorted, ungraded, angular quartz, chert, jasper and intraformational siltstone and sandstone clasts up to 15 cm in diameter. Interbedded with the sandstone and conglomerate are strongly coloured red-purple mudstone and siltstone with pedogenic carbonate nodules and pipes (probable rhizoconcretions).

North of Roan of Craigoch, the Clyde Sandstone Formation is moderately exposed in a stream section [NS 2924 0475]. It is characterised by yellow-orange, medium- to coarse-grained flaggy sandstone with rare cross- and trough-bedding and microconglomerate beds. The range of clast types in the sandstone appears to be quartz, chert, lithic and detrital mica. At Quarrelhill Burn [NS 2570 0235], the Clyde Sandstone Formation is recognised by the typical deep red-purple mottled siltstone and sandstone. In Baldrennan Burn, a zone of no exposure exists between the Ballagan and Clyde Sandstone formation strata, though the transition must be abrupt. The basal strata of the Clyde Sandstone Formation at [NS 2849 0405] consist of a fractured, carbonate-cemented, red-green mottled sandstone that is interpreted as a well-drained palaeosol, and passes up to a red mudstone with pedogenic carbonate.

The Clyde Sandstone Formation appears to have been deposited by a fluvial system with numerous channels and bars, and intervening areas of overbank deposits where pedogenic carbonates developed. The development of pedogenic carbonates with fluvial deposits indicates a semi-arid climate. A major shift in palaeoenvironment occurred from that of the uppermost Ballagan Formation.

A sample collected for palynology analysis in the Clyde Sandstone Formation was barren (Appendix 2). The thickness of the Clyde Sandstone Formation on NS20SE and NS20SW is interpreted to be quite variable from 160-240 m. The formation boundaries are quite well constrained in the Glenton Glen area giving a thickness of approximately 240 m.

3.4 LAWMUIR FORMATION, STRATHCLYDE GROUP

Floyd (1999) described an abrupt change from the red sandstone and mudstone with pedogenic carbonates of the Inverclyde Group, to the grey sandstone and silty mudstone with carbonaceous debris and rootlets that are representative of the Strathclyde Group in exposures just south of the Ayr sheet. This change between the Inverclyde and Strathclyde groups can be recognised in the wider Dailly area.

On NS20SE the Lawmuir Formation is moderately exposed in the stream north of Roan of Craigoch [NS 2926 0463] to [NS 2930 0456]. The contact with the underlying Clyde Sandstone Formation is not exposed but stratigraphical constraints (Smith 2003, NM-VF late Visean miospore zonations on NS30NW,) mean the surface must be an unconformity. The Lawmuir Formation strata are dominantly green-grey quartz-rich sandstone and siltstone with rootlets, coaly streaks and plant pieces up to 20 cm in length. At [NS 2929 0460] a layer of concretionary ironstone nodules was observed just above a rootlet bed, possibly indicative of an iron hardpan palaeosol. The slight disconformity with the Lawmuir Formation and the overlying Hurlet Limestone (base Lower Limestone Formation) is exposed at [NS 2930 0456]. Beneath the Hurlet Limestone, erosively based, carbonate-cemented sandstone cross-sets cut down into finely laminated, rippled and bioturbated siltstone.

Grey-buff-green, fine- and medium-grained, parallel-bedded sandstone with rootlets and plant fragments, minor conglomerate and red mottled siltstone of the Lawmuir Formation are also observed beneath the Hurlet Limestone south of Captains Bridge [NS 2855 0357].

The small exposures observed make it difficult to detail a depositional environment for the Lawmuir Formation though it appears to be non-marine, probably fluvial or fluvio-deltaic with some overbank areas colonised by, and rich in plants.

The Lawmuir Formation is about 30 m thick in the Glenton Glen area but is interpreted to be substantially thicker on the southern side of the Dailly Syncline where exposure constraints are particularly poor.

3.5 CLACKMANNAN GROUP

The Early Carboniferous Lower Limestone Formation, and Late Carboniferous Limestone Coal and Upper Limestone formations of the Clackmannan Group are exposed within the Dailly area and further described by boreholes and mine plans. Mykura et al. (1967) and Eyles et al. (1930; 1949) give detailed accounts of these strata.

3.6 NORTH BRITIAIN PALAEOGENE DYKE SUITE

The majority of dykes recorded at the surface or from mine plans have a north-west to north-north-west trend. This trend and the freshness and composition of the dykes has led them to be identified as Palaeogene, and probably related to either the Arran or Mull volcanic centres (e.g. Eyles et al., 1929, 1949; BGS, 1978). Three different compositions of dyke have been identified:

1. basaltic rock (unclassed) where mapped underground;
2. alkali olivine dolerite;
3. dolerite, unclassed.

A small number of dolerite dykes trend from east to north-north-east, these are also interpreted to be of Palaeogene age (BGS, 1978).

The observed dykes vary in width from 1 to 5 m.

4 Descriptive accounts – superficial deposits

4.1 DEVENSIAN LODGEMENT TILL

Over much of the Dailly area, the superficial succession commences with a red-brown diamicton of stiff clay and subrounded pebbles, or sandy clay and pebbles. This deposit is commonly moulded into east-north-easterly to easterly oriented drumlins or gently undulating ground, and is interpreted as a lodgement till.

In some areas the streamlined topography of the till has been dissected by hollows interpreted to be glacial meltwater channels. The most impressive of these is a westwards-oriented U-shaped hollow about 10 m deep, a few tens of metres wide and about 700 m long, north of Maitland [NS 2930 0285]. A series of smaller hollows are oriented westwards and southwards between Moorston [NS 2826 0200] and Whitehill [NS 2875 0148] and towards the sands and gravels of the Balcamie eskers, indicating drainage towards the glaciofluvial deposits.

Other areas underlain by till lithologies have an undulating, rather than streamlined appearance. In some cases this could be due to complex drainage dissection of the till e.g. north of Moorston [NS 2820 0240], in others it may be related to mining-related subsidence, shafts, pits etc e.g. east of Bargany Mains [NS 2515 0100].

North of the sand and gravel of the Balcamie eskers at [NS 2820 0170], an unusually flat area is underlain by a till lithology of sandy clay with pebbles. It may represent an area of till soliflucted from the surrounding drumlinoid topography.

4.2 LATE DEVENSIAN GLACIOFLUVIAL ICE–CONTACT DEPOSITS

North and west of Balcamie e.g. [NS 2772 0145] sand and gravel are formed into steep-sided ridges, hollows and moundy ground. Ridges and hollows are sinous, oriented westwards and commonly about 10-20 m wide and 5-10 m high. A small excavation across one of the ridges shows it to be formed of cross-bedded, sub rounded to rounded pebble gravel with poor to good sorting. These deposits are interpreted as waterlain, glaciofluvial deposits. The ridges have the characteristic features of eskers (termed here the 'Balcamie eskers'), inferring an ice-contact genesis for these sands and gravels. The deposits were probably formed during the melting and retreat of the Late Devensian ice sheet and may be linked with the meltwater channels observed in the adjacent lodgement till.

Other patches of moundy sand and gravel have been mapped previously in the Dailly area but not examined during this resurvey.

4.3 LATE DEVENSIAN RAISED BEACH DEPOSITS

On the far south of NS20SW a raised terrace at approximately 25 m above Ordnance Datum has been mapped previously along the Water of Girvan and has been interpreted as the 'third' raised beach deposit (Simpson and Richey, 1929, Ayr 50SW county series map). These deposits were not examined during this resurvey.

4.4 ALLUVIAL DEPOSITS

Alluvial deposits dominantly composed of red-brown sand are areally extensive along the Water of Girvan. One or two metres of sand are exposed at some localities and the thickness of the alluvium could be substantially greater. A striking oxbow lake lies within the alluvium east of Dalquaharran Castle [NS 2735 0220].

Patches of flat-lying alluvium have also been mapped adjacent to streams, and in low-lying hollows. Where exposed, these deposits are composed of bedded sand and gravel, overlying the bedrock, and up to a few metres in thickness. Near Lindsayston Farm [NS 2860 0093] and east of Dailly village [NS 2745 0108] river terrace deposits can be mapped along the Lindsayston Burn. Sand- and gravel-dominated alluvial fans were observed north of Quarrelhill Burn [NS 25350242] and near Lindsayston Farm [NS 2846 0075].

4.5 PEAT

Small patches of peat have been mapped previously in the northern, upland part of NS20SE.

4.6 ARTIFICIAL AND WORKED GROUND

Much of the ground underlain by the Limestone Coal Formation in the Dailly syncline has been altered by anthropogenic activity related to coal mining. Made ground is common in the form of coal waste bings, many of which have been landscaped and forested e.g. around Dalquaharran Mains [NS 2740 0290]. The former opencast site at Glenshalloch Wood [NS 2965 0497] is an example of worked ground, with infilled ground in a quarry nearby [NS 2975 0478]. Disturbed ground relating to mining at coal crops, shafts and adits is also observed at a number of localities e.g. Burning Hills [NS 2780 0325] and near Bargany Mains [NS 2490 0100].

Other types of artificial and worked ground are relatively rare in this rural area, relating mainly to embankments and cuttings along the railway e.g. [NS 2800 0300], 1-2 m high levees along the Water of Girvan e.g. [NS 2725 0200] and small quarries. Landscaped ground has been created at the Dailly golf course [NS 2600 0130].

5 Structure

This area of Ayrshire has been subject to three main phases of tectonism in the early Palaeozoic (pre-Acadian), the mid-Devonian (Acadian) and the Carboniferous (Variscan). This account focuses on the faulting and folding in the resurveyed Carboniferous strata of NS20SW and NS20SE.

The main faults crossing the area are the generally north-easterly trending Kerse Loch and Bargany faults (Figure 1). These structures are interpreted to be reactivated features that were generated by the Caledonian Orogeny and have a long history of movement. The north-east trending Bargany Fault with Siluro-Devonian strata in its footwall forms the south-eastern side of the graben structure in which the Carboniferous strata of the Dailly area are preserved. The Kerse Loch Fault forms the north-western side to the graben. The trace of the fault is not straight, trending from east-north-east to north-north-east, with several *en-échelon* strands. The Ordovician-Silurian Craighead Inlier, a gently north-east plunging anticline lies in the footwall of the Kerse Loch Fault. The north-east trending Carboniferous Dailly syncline lies in the hangingwall block of the Kerse Loch Fault. The syncline plunges towards its centre such that it closes to the north-east and south-west. A minor north-east trending anticline has been mapped on the northern side of the syncline where the Kerse Loch Fault has an east-north-east trend and an *en-échelon* step [NS 2555 0238]. Dips within the Carboniferous strata around the Dailly syncline are commonly about 30°, but on the north-western side of the asymmetric fold, dips between 40-70° are more commonly observed. Clearly, the fold has been tightened in post-Namurian times. Borehole and mining records show that the Limestone Coal Formation strata thicken and become more coal-dominated from the south-western end to the centre of the syncline (Eyles et al., 1949), indicating that some syn-depositional topography existed. However, Mykura et al. (1967) noted that major thickness variations were not related to the current day shape of the basin. Field mapping demonstrates that the Lawmuir Formation thickens from approximately 30-50 m on the north-west and south-western sides of the syncline to about 100 m on the south-east and north-east (this study; Floyd 1999; Smith, 2003).

The Carboniferous strata of the Dailly area are cut by smaller faults on a number of orientations (Figure 1). Some structures are sub-parallel to the main graben bounding faults of north-east trend and are probably related to them e.g. the fault bounding Late Carboniferous strata near Roan of Craigoch [NS 2954 0429]. Another set of faults trend from west- to north-west and are well documented by mine plans, dipping at approximately 70°. The Lawmuir Formation is interpreted as thickening over one of these west-north-west-trending faults south of Drumburle [NS 2881 0279] but this geometry is very poorly constrained, and the apparent thickening could relate to faulting and folding in the fault hangingwall block.

The thickness of the Ballagan Formation increases north-eastwards on NS20SE but is truncated by the cross-cutting Bargany Fault at its base. Smith (2003) documented this thickening continuing north-eastwards on NS30NW.

Smith (2003) documented evidence for possible sinistral oblique slip on the Kerse Loch Fault from the mid Devonian to Early Carboniferous (Clyde Sandstone Formation) on NS30NW. This tectonic framework is in agreement with local fault measurements, the thickening of strata towards a releasing bend of the Kerse Loch Fault on NS30NW and published studies from other parts of the Midland Valley (e.g. Smith, 1995; Rippon et al., 1996).

By the late Visean, the tectonic regime in the Midland Valley appears to have been dominated by dextral oblique-slip (e.g. Read, 1988). In the Dailly area, this change in tectonic regime is perhaps reflected in the presence of the Clyde Sandstone-Lawmuir Formation unconformity.

In the main Ayrshire Coalfield to the north of the Dailly area, the effects of late Visean to Late Carboniferous dextral oblique-slip were that faults such as the north-east to easterly trending Kerse Loch were active, resulting in significant syn-depositional stratal growth (Eyles et al, 1949; Monro, 1999). Smith (2003) documented post-Visean dextral strike slip measured in a fault close to the Kerse Loch Fault and interpreted stratal thickness variations around the Dailly syncline as a result of drag or growth on the fault, linked to dextral oblique slip.

Evidence from the Dailly area supports the late Visean to late Carboniferous dextral oblique-slip hypothesis, with movement on the Kerse Loch and Bargany faults and the possible development of a proto-Dailly syncline. For example, syn-depositional thickness variations in the Lawmuir and Limestone Coal formations could be related to growth fold development on a releasing bend of the Kerse Loch Fault, differential subsidence between the Bargany and Kerse Loch structures, and/or associated with coeval movement on west- to west-north-west trending faults at the releasing bend (Figure 1). The small subsidiary anticline on the north-western side of the syncline occurs at a local restraining bend of the fault in the dextral oblique-slip system.

In common with fold structures across the Midland Valley, the Dailly Syncline is interpreted to have been tightened by Late Carboniferous to Permian end-Varsican tectonism.

6 Mineral Resources

Several small, disused quarries have been mapped across the Dailly area. The quality of these rocks is variable and unlikely to meet modern requirements for aggregate or building stone. A few small pits have been recorded previously in sand and gravels.

6.1 COAL MINING

Limestone Coal Formation strata have been extensively mined in the Dailly Syncline. The oldest recorded workings are from 1415 (Eyles et al., 1949) and deep mining continued until the 1960’s. The area was attractive because although dips on the syncline margin can be quite steep there are thick coal seams occurring close together at outcrop to a few hundred metres depth. North of Dailly, coals come to crop at the ‘Burning Hills’ [NS 2780 0325], which were alight for many years. Parts of the area were examined for possible opencast coal extraction. Apart from the Glenshalloch site active on NS20SE/NE [NS 2965 0497] during the late 1960’s or early 1970’s, opencast mining was not undertaken due to the good quality of the agricultural land and/or the thick till cover. Previously, there was a mine water pollution incident into the Water of Girvan.

The mining history of the Dailly area is important because of the legacy of subsurface data and the influence on the modern landscape. During the current resurvey, many of the coal bings had been landscaped and forested. The legacy of underground working leaves a potential hazard for land use due to the presence of pit shafts and shallow mineworkings.

Appendix 1 Data sources

PREVIOUS MAPS

6.2 First Survey Ayr County Series

Field slips 50NW, 50NE, 50SW, 50 SE, 49NE, 49SE A Geikie 1868 with additions by B Peach and J Horne in 1891-1894

6.3 Second Survey: Ayr County Series

Field slips	50NE, 50 SE J E Richey 1924
	50NW J B Simpson 1928
	50SW J B Simpson and J E Richey 1929
Published maps	50NE, 50 SE J E Richey 1928
	50NW J B Simpson 1928
	50SW J B Simpson and J E Richey 1929

Third Survey

Part of NS20SW, part of NS20SE W Mykura 1962 (Upper Carboniferous strata)

Southern parts of NS20SW and NS20SE on the Carrick Sheet 8 (W) J D Floyd and I B Cameron 1991.

BOREHOLES

NS20SW all available boreholes from numbers 2-33

NS20SE all available boreholes from numbers 2-47 and SE 11934

MINE PLANS

Ex-Coal Board seam atlases for the Hartley, Main and Parrot coals held at Murchison House. Coal Authority records held at BGS Keyworth on reconnaissance for opencast sites and related boreholes.

APPENDIX 2 PALYNOLOGY RESULTS

These results were reported by M Stephenson in 2003.

MPA number	ASB number	Grid reference	Selected palynomorphs	Age	Stratigraphic position in Formation
51234	145	NS 2894 0438	Barren		Clyde Sandstone
51235	146	NS 2845 0411	*A. macra, V. nitidus, S. claviger, G. echinata, R. polyptycha, S. tubersosus, B. fusticulus, R. minuta, P. scolecophora*	CM Biozone	Top Ballagan
51236	148	NS 2813 0081	Barren		Top Ballagan
51237	150	NS 2807 0084	*A. cf. macra* (narrow margin)	No zonal indices; *A. cf. macra* (narrow margin) suggests general CM/Pu age	Ballagan, 150-154 sampled in succession up section (i.e. should get younger)
51238	151	NS 2789 0082	*A. macra, V. nitidus, S. claviger, G. echinata, B. fusticulus*	CM Biozone	Ballagan
51239	152	NS 2772 0089	*A. macra, V. nitidus, S. claviger, G. echinata, R. polyptycha, S. tubersosus*	CM Biozone	Ballagan
51240	153	NS 2755 0093	*A. macra, V. nitidus, S. claviger, G. echinata, P. scolecophora*	CM Biozone	Ballagan
51241	154	NS 2740 0131	*Leiosphaeridia* spp., *Leiosphaeridia* sp. B, *Leiosphaeridia* sp. A	No zonal indices but likely to be CM or Pu Biozone	Ballagan
51242	155	NS 2968 0119	*A. macra, V. nitidus, S. claviger, G. echinata, R. polyptycha, R. minuta, P. scolecophora*	CM Biozone	Ballagan, stratigraphically below 150-154
51243	156	NS 2980 0122	*A. macra, V. nitidus, S. claviger, G. echinata, R. polyptycha*	CM Biozone	Ballagan stratigraphically below 150-154

References

Most of the references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the references may be purchased from the Library subject to the current copyright legislation.

BRITISH GEOLOGICAL SURVEY. 1978. Ayr 14(W). Solid edition, 1:50 000. (Keyworth, Nottingham: British Geological Survey.)

BRITISH GEOLOGICAL SURVEY. 1994. Sheet 8(W) Carrick. - Solid edition. 1:50 000. (Keyworth, Nottingham: British Geological Survey.)

BROWNE, M. A. E., DEAN, M. T., HALL, I. H. S., MCADAM, A. D., MONRO, S. K. & CHISHOLM, J. I. 1999. A lithostratigraphical framework for the Carboniferous rocks of the Midland Valley of Scotland. British Geological Survey Research Report, RR/99/07.

EYLES, V A, SIMPSON, J B & MACGREGOR, M C 1929. The igneous geology of Central Ayrshire. *Transactions of the Geological Society of Glasgow*, Vol. XVIII, 361-387.

EYLES, V A, SIMPSON, J B & MACGREGOR, M C 1930. Economic geology of the Ayrshire Coalfields, Area III. *Memoir of the Geological Survey.*

EYLES, V A, SIMPSON, J B & MACGREGOR, M C. 1949. Geology of Central Ayrshire. *Memoir of the Geological Survey of Scotland, British Geological Survey,* Sheet 14 (Scotland.)

FLOYD, J D & WILLIAMS M. 2003 (for 2002). A revised correlation of Silurian rocks in the Girvan district, SW Scotland. Transactions of the Royal Society of Edinburgh: Earth Sciences, 93, 383-392.

FLOYD J.D. 1999. Geology of the Carrick - Loch Doon district. *Memoir for 1:50000 geological sheets 8W and 8E (Scotland*). London : The Stationery Office for the British Geological Survey.

MONAGHAN A. 2001. Geology of the Culzean to Dipple area. *British Geological Survey.Internal Report*, IR/01/165.

MONRO, S. K. 1999. Geology of the Irvine district. *Memoir of the British Geological Survey*, Sheet 22W and part of Sheet 21E, (Scotland).

MYKURA, W., CALVER, M. A. & WILSON, R. B. 1967. The Upper Carboniferous rocks of south-west Ayrshire. *Bulletin of the Geological Survey of Great Britain*, **26**, 23-98.

READ, W.A. 1988. Controls on Silesian sedimentation in the Midland Valley of Scotland. In: Besley, B.M. and Kelling, G. (eds). *Sedimentation in a synorogenic basin complex*: *The Upper Carboniferous of Northwest Europe*. Blackie, Glasgow, 222-241.

RIPPON, J H, READ, W A and PARK, R G. 1996. The Ochil Fault and the Kincardine basin: key structures in the tectonic evolution of the Midland Valley of Scotland. *Journal of the Geological Society of London*, Vol. 153, 573-587.

SMITH, R A. 1995. The Siluro-Devonian evolution of the southern Midland Valley of Scotland. *Geological Magazine*, Vol. 132, 503-513.

SMITH, R A. 2003. The geology of the Kirkmichael area, Ayrshire. *British Geological Survey Internal Report*, IR/03/78. 21pp.

STEPHENSON, M. H., WILLIAMS, M., MONAGHAN, A., ARKLEY, S. & SMITH, R. A. 2003. Biostratigraphy and palaeoenvironments of the Ballagan Formation (lower Carboniferous) in Ayrshire, SW Scotland. *Scottish Journal of Geology,* 38, 93-111

WILLIAMS, M. 2001. The stratigraphical palaeontology of the Craighead Inlier, Girvan District, south-west Scotland. *British Geological Survey Internal Report*, IR/01/29.

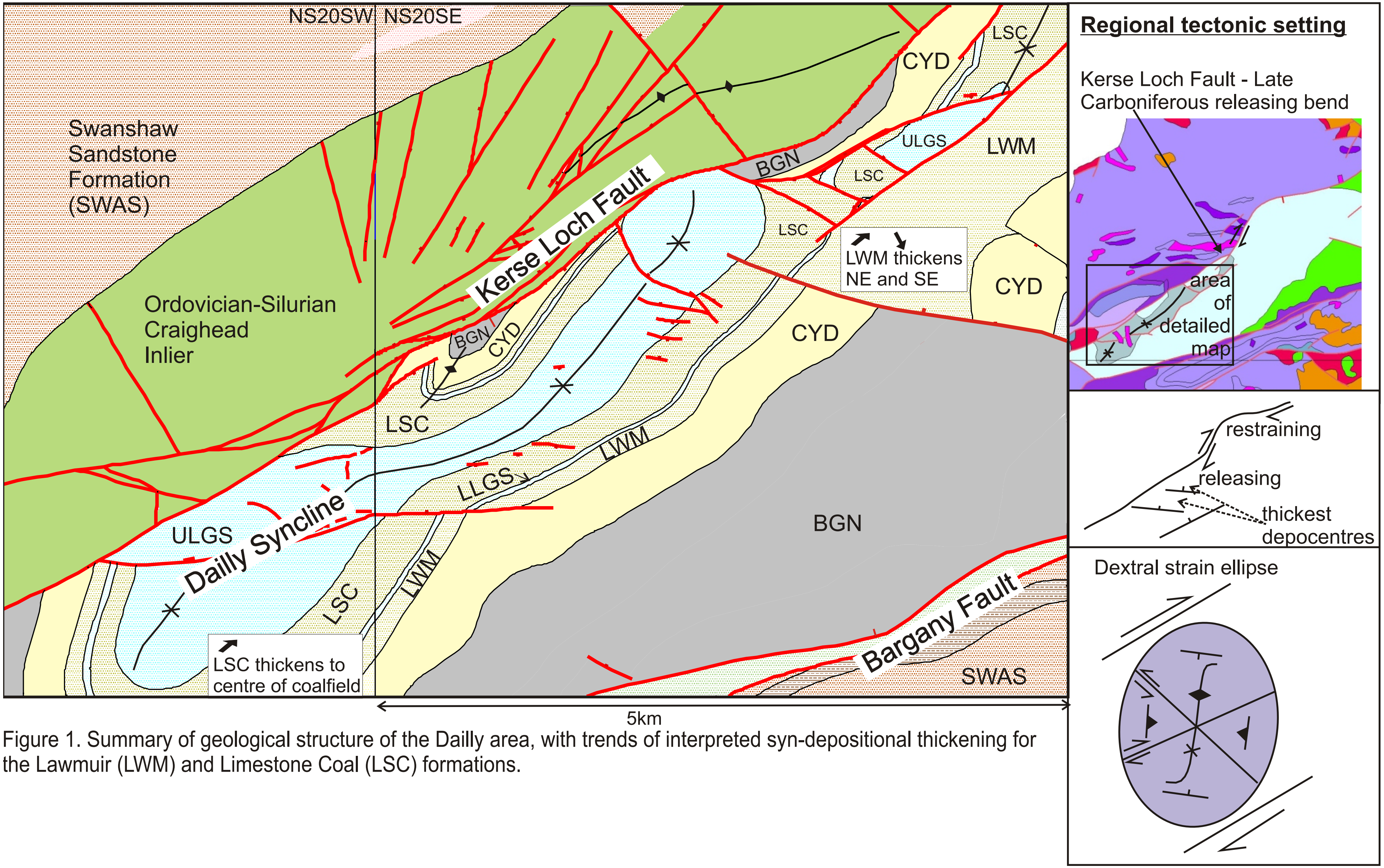
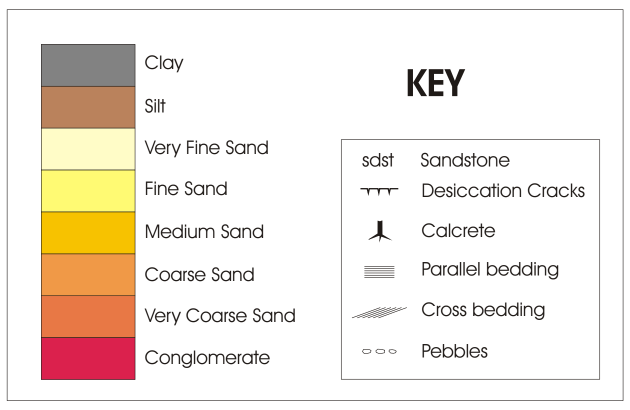


Figure 1. Summary of geological structure of the Dailly area, with trends of interpreted syn-depositional thickening for the Lawmuir (LWM) and Limestone Coal (LSC) formations.

IR/04/035. Figure 2. Sedimentary log of the Lindsayston Burn Member and upper Ballagan Formation in the Lindsayston Burn, Dailly, [NS 2821 0082] to [NS 2737 0129].



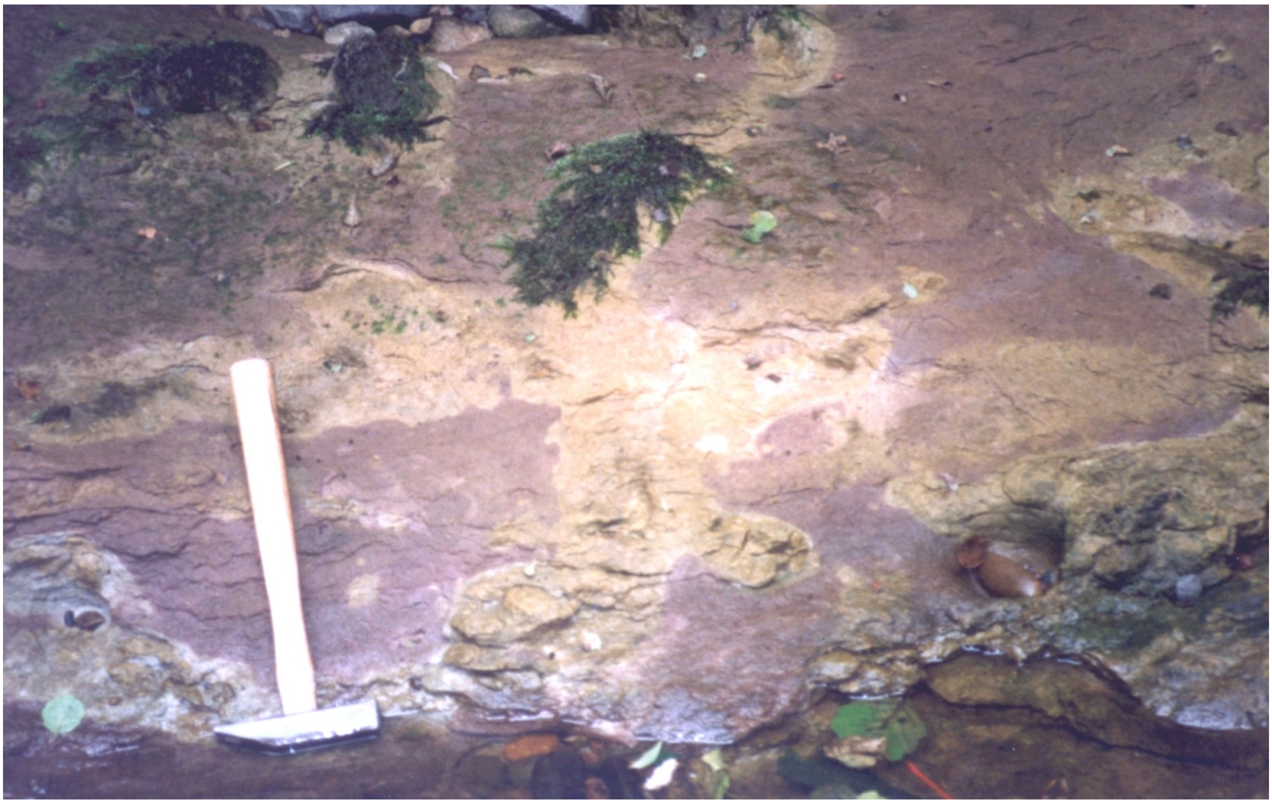


Figure 3. Well-developed pedogenic carbonate nodules and pipes in red sandstone, Lindsayston Burn Member, Ballagan Formation, Lindsayston Burn section, [NS 2815 0082], from about 18 m on Figure 2.

Figure 4.Looking NW along the axis of a conglomerate-filled channel, Lindsayston Burn Member, Ballagan Formation, Lindsayston Burn, 1 m measure for scale, [NS 2782 0087]. Note that the logged section shown on Figure 2 was measured just to right of this photo at about 62m above the base.

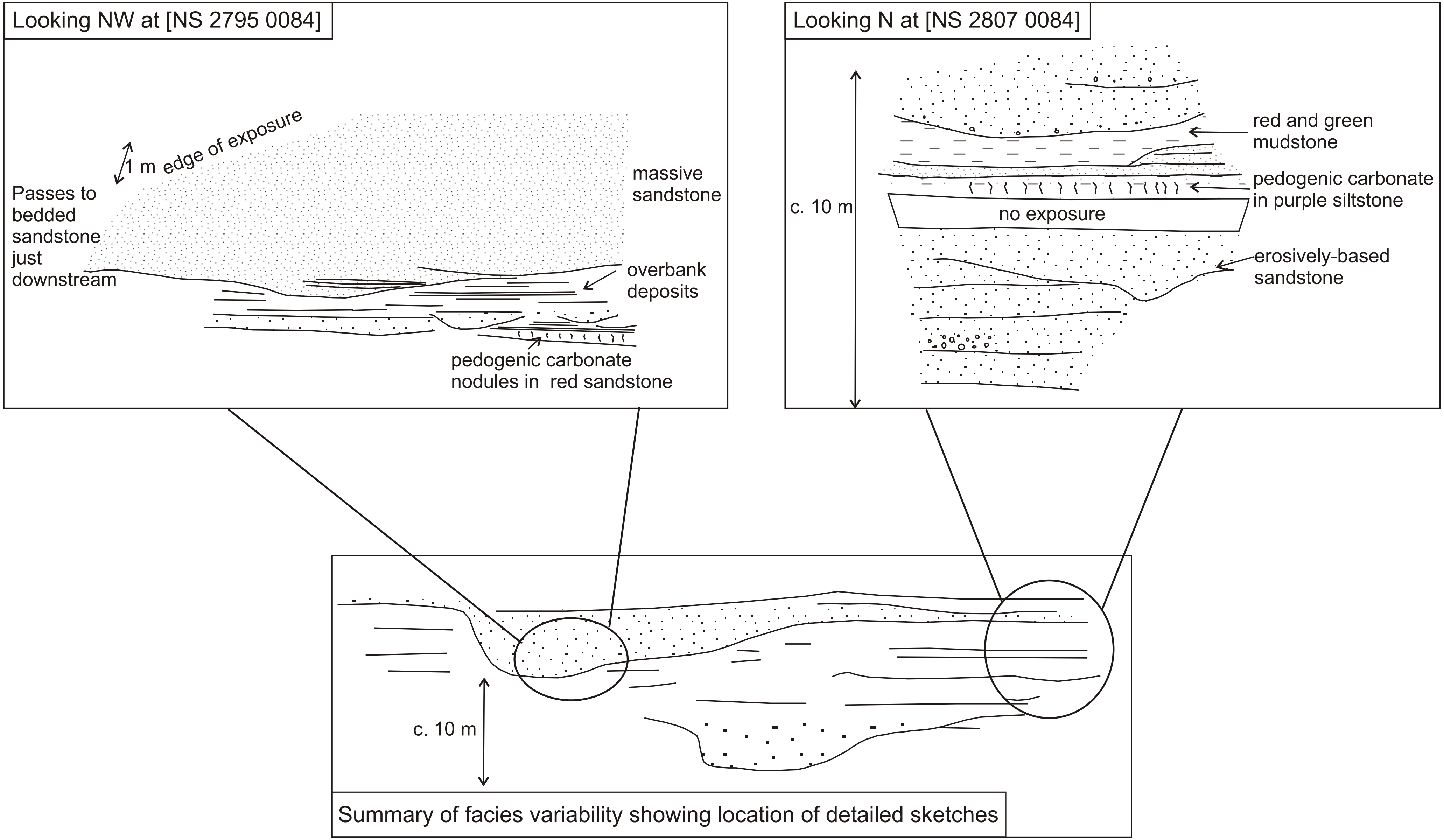


Figure 5. Example of lateral facies variability in the Lindsayston Burn Member of the Ballagan Formation, Lindsayston Burn section [NS 2795 0084] to [NS 2807 0084].

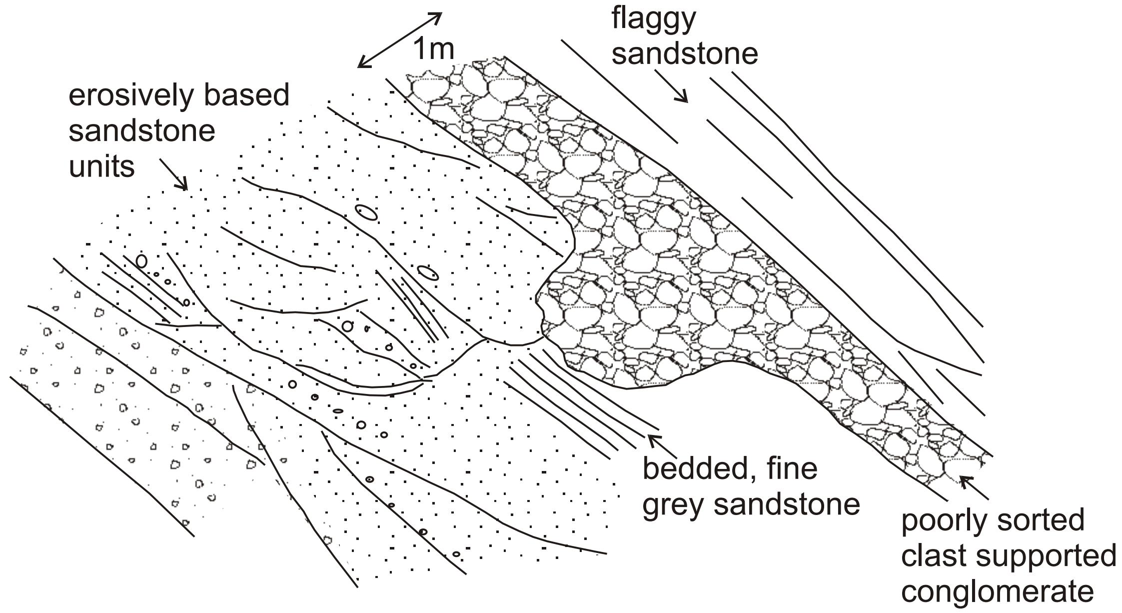


Figure 6. Superimposed channel and scour features in the Clyde Sandstone Formation, looking east at [NS 2894 0433], Glenton Glen.