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The geology of the Kirkmichael area, Ayrshire

Integrated Geoscience Surveys (Northern Britain)
Internal Report IR/03/078

BRITISH GEOLOGICAL SURVEY

INTERNAL REPORT IR/03/078

The geology of the Kirkmichael area, Ayrshire

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Key words

Geology, Kirkmichael, Ayrshire.

Bibliographical reference

SMITH, R A. 2003. The geology of the Kirkmichael area, Ayrshire. *British Geological Survey Internal Report*, IR/03/078. 21 pp.

Keyworth, Nottingham British Geological Survey 2003

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Acknowledgements

A large number of individuals within the Central Belt of Scotland Project have contributed to this report. This assistance has been received at all stages of the study. In addition to the collection of data, many individuals have freely given their advice. Of the many individuals who have contributed to the project I would particularly like to thank the following: Maxine Akhurst, Alison Monaghan, Sarah Arkley, Mike Stephenson and Emrys Phillips. Maxine Akhurst also edited the report.

The author would also like to thank the landowners in the Kirkmichael area for allowing access to the rock and superficial exposures.

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Summary

This description is of the geology of 1:10 000 Sheet NS 30 NW (Kirkmichael) which lies within 1:50 000 Geological Sheet 14W Ayr (Scotland). The area is crossed by the north-easterly trending Kerse Loch Fault (Figure 1) which separates mainly Siluro-Devonian strata to the north-west from Carboniferous strata to the south-east. The Siluro-Devonian strata comprise continental fluviatile sandstones and conglomerates, belonging to the Swanhaw Sandstone Formation, which were intruded by a suite of basic to andesitic sills and dykes in early Devonian times. The oldest Carboniferous rocks belong to the Inverclyde Group (Tournaisian to early Visean), which includes the Kinnesswood, Ballagan and Clyde Sandstone formations. They are not well exposed but represent a passage from semi-arid fluviatile sandstones through lagoonal mudstones, sandstones and limestones back into semi-arid fluviatile sandstones. These are unconformably succeeded by Visean deltaic deposits belonging to the Lawmuir Formation of the Strathclyde Group. This formation is succeeded by the Upper Visean Lower Limestone Formation and the Lower Namurian Limestone Coal Formation preserved within the core of the major Dailly Syncline. The Limestone Coal Formation contains significant coal seams which have been extensively mined. In Tertiary (Palaeocene) times minor intrusions of basaltic to microgabbroic rock were intruded as part of the Mull Dyke Swarm. The age of some of the mafic rocks is uncertain; they could be early Devonian to Palaeocene in age.

Quaternary deposits, laid down after the Late Devensian Glaciation, cover most of the sedimentary rocks. The cover generally consists of lodgement till moulded below the ice into a drumlin field. Remnants of the ice around Maybole downwasted and poorly sorted hummocky glacial deposits accumulated. Glaciofluvial sand and gravel was deposited in patches near the Water of Girvan and in a belt passing through Kirkmichael. A broad belt of alluvium was deposited by the Water of Girvan and patches elsewhere occur between drumlins and hummocky glacial deposits. Most of the soils in the area are loams. Heavy loams and peaty soils are found locally in the alluvial areas near the Water of Girvan and the small lochans south-east of Maybole. Minor areas of made ground are mapped, mostly around Maybole. Patches of worked and worked and back-filled ground are even more limited.

1 Introduction

This report describes the bedrock (Figure 1) and superficial geology of the area covered by the 1: 10 000 sheet NS30NW which includes ground extending from south-east Maybole to south-east of Crosshill including Kirkmichael. The accompanying map is included in the resurvey of 1:50 000 Sheet 14W (Ayr).

The Kirkmichael area is largely low-lying and generally covered by Quaternary superficial deposits. Solid exposures are limited to the fringing hills to the south and west and locally along watercourses. There are few geologically economic targets in the area and consequently very little subsurface data. These data are limited to a few site investigations and boreholes for water around Maybole. The present resurvey concentrated on the main Quaternary and rock exposures and attempted to up date the solid and drift geology partly using information and lithostratigraphy established on the adjacent 1:10 000 sheets. Revision of the Devono-Carboniferous stratigraphy, i.e. the former Upper Old Red Sandstone and Calciferous Sandstone Measures, was a primary task in the re-mapping.

The 1:10 000 NS30NW map should be consulted together with this report and because of the limited exposure, geological boundaries are commonly inferred. The boundaries are therefore the interpretation of the surveyor based on the information available at the time of survey. All grid references in squared brackets refer to the National Grid Square NS. Numbers preceded by the letter N or S refer to the BGS thin section collection. Numbers preceded by the letters MPA refer to samples in the BGS palaeontological collection. Numbers preceded by the letters SE refer to site investigation reports in BGS archives.

1.1 PREVIOUS WORK

The geology of the Kirkmichael area was first surveyed by Archibald Geikie in 1865-66. A geological sheet explanation was published soon after (Geikie et al., 1869). At that time the age of the Old Red Sandstone was postulated to be Middle Old Red Sandstone and was separated from the Carboniferous Calciferous Sandstone Series by a major north-east-trending fault, now known as the Kerse Loch Fault. Geikie (1897 p. 332) considered the igneous rocks on the ridges between Maybole and Dailly to be extrusive. A revision of the geological map of the area was made by J E Richey and V A Eyles from 1924-26 and by then the igneous rocks had been reinterpreted as intrusive sills (Tyrrell, 1916; Eyles et al., 1929).

A one-inch-to-the-mile map of soil textures was published for Sheet 14 by the Geological Survey of Scotland in 1932. Also in 1932, an economic memoir covering part of the Dailly coalfield which lies within the map area was produced (Simpson and MacGregor, 1932). A solid geology edition of Sheet 14 in which the post-Silurian rocks were revised was published (Geological Survey of Scotland, 1933a) together with a solid and drift edition (Geological Survey of Scotland 1933b). A second edition of the Sheet 14 explanation was published after the Second World War (Eyles et al., 1949). The Upper Carboniferous of the Dailly Coalfield was revised by Mykura (1967). The solid geology of Sheet 14W, compiled by A Davies after some revision of the Carboniferous strata, was published at the 1:50 000 scale (Institute of Geological Sciences, 1978a) together with a drift edition (Institute of Geological Sciences, 1978b). Little new work has been done on the area since that revision but the adjacent 1: 10 000 sheets to the west and east have been produced (Sowerbutts, 2000; Smith, 2001).

2 Sedimentary strata

2.1 PENWHAPPLE NORTH GROUP

A small sliver of the Penwhapple Group North (Lower Camregan Grits Formation) is mapped against the northern side of the Kerse Loch Fault and forms part of the Silurian Craighead inlier (Cocks and Toghill, 1973).

2.1.1 Lower Camregan Grits Formation (LCRG)

A faulted wedge [3003 0575] of Lower Camregan Grits Formation has been projected onto the western margin of Sheet NS30NW on the evidence of mapping on the adjacent sheet to the west. It lies within the Kerse Loch Fault zone and no outcrops of it are seen on this sheet. The formation contains turbiditic sandstone beds (Floyd, 1999), which are not described further here.

2.2 LANARK GROUP

The Lanark Group is latest Silurian to early Devonian in age and within south-west Ayrshire, it comprises the basal Greywacke Conglomerate, the Swanshaw Sandstone and the Carrick Volcanic formations. The Swanshaw Sandstone Formation is the only one of these formations cropping out on this 1:10 000 sheet as the basal conglomeratic formation is cut out by the major Kerse Loch Fault and the younger Carrick Volcanic Formation is exposed farther north.

2.2.1 Swanshaw Sandstone Formation (SWAS)

The Swanshaw Sandstone Formation lies in the north-west portion of NS30NW and extends from Maybole south-eastwards to the Kerse Loch Fault. Because of limited and isolated exposure, the stratigraphy and depositional history of the formation is difficult to establish in the Kirkmichael area. Most exposures of the formation in this area occur in the hills near the western margin of the sheet. The strata mainly dip to the north-north-west, so the oldest beds are presumed to lie in the south-west where doleritic sills have baked pale pinkish lithic sandstones.

Pink-brown fine- to medium-grained lithic sandstones that dip north-east up to 34° crop out below a ridge striking N100-110° west of Carsloe Glen at [3029 0650]. The sandstones weather deeply to an orange colour. The ridge comprises greyish and red-brown mottled conglomeratic beds estimated to be about 20 m thick. Set in a red-brown sandy matrix, the pebbles are commonly 1-6 cm in length, rounded to subrounded although the clasts of chert tend to be angular. The pebble content includes green, red, grey and black chert, fine-grained reddish sandstone, purplish micaceous sandstone, grey sandstone including some silicified pebbles up to 14 cm in length, pinkish microgranite, pink medium-grained granite, purple-brown feldspar

porphyry and andesitic rocks, fine-grained quartzite and vein quartz. Grey sandstone and chert are the most common clasts and a derivation by erosion of Lower Palaeozoic rocks and a southerly provenance is indicated due to similarity with the Isle Port Conglomerate (cf. Smith, 2000 and Armstrong and Owen, 2000). The conglomerates of the Carsloe Glen are however, lower down in the formation than the Isle Port Conglomerate. The conglomerates are weakly bedded with some fining-upward units over 0.5 m thick. The better-sorted beds are partly cemented with white sparry calcite. In a good exposure at [3042 0656], two fining upward units around 1.2 m thick have red-brown, fine- to medium-grained cross-bedded sandstone lenses towards their tops and some imbrication in the cobbles and pebbles towards their bases indicate that the palaeocurrents flowed to the south-west.

Farther north at Springgarden [301 071] another, thinner, conglomeratic unit is mapped, inferred from outcrops farther to the west. In the Capenoch Burn to the east [302 072], khaki, grey-green to grey-brown medium-grained lithic sandstones with scattered white mica flakes and feldspars up to 1-2 mm in length occur in beds 0.2-0.4 m thick. In the previous survey these sandstones were described as 'ash' but there is no evidence of contemporaneous volcanic activity. Thin sandstone interbeds are rippled. Beds vary in hardness due to variable calcareous cementation and there are sparse silty mudstone intraclasts. In the Capenoch Burn at [3024 0722], greenish grey medium-to coarse-grained sandstones contain scattered small lithic pebbles and greyish mudstone clasts up to 6 cm in length. Farther north in the same burn there is a gap in exposure, but south of Capenoch Bridge [303 077], a sequence of red-brown to yellow-brown mottled, fine- and very fine-grained sandstones are interbedded with thin red-brown siltstones and mudstones dipping up to 14° to the north or north-north-east. Some of the sandstones are calcareous and pale grey or purple-brown with common white mica flakes. Cracked surfaces occur locally on flaggy beds possibly reflecting original desiccation cracks. This fine-grained interval is at least 30 m thick and such a thickness is atypical of the Swanshaw Sandstone (or not usually exposed). Samples from it were examined for palynomorphs but none were found. To the south-east in a railway cutting [308 072], about 100 m north of the Kerse Loch Fault, red sandstones belonging to the Swanshaw Sandstone Formation contain pebble beds which dip 25° to the south-east. Since most of the formation dips north-north-east, the south-easterly dip is probably the consequence of the strata lying within the fault zone. The base of the formation is therefore cut out against the fault in this area.

The prominent conglomerate ridge [304 081] from Drummullan to Kilhenzie Castle overlies medium-grained brown lithic sandstone. The conglomeratic unit, estimated to be 20 m thick, was recorded in the railway cutting dipping 10-15° north-north-west and described as reddish, coarse, massive bedded and as containing quartz, chert and 'felstone' pebbles. The mottled reddish brown conglomerate contains clast-supported rounded pebbles up to 0.1 m in length. Some medium- to coarse-grained red-brown sandstone beds or lenses are intercalated. The overlying predominantly medium-grained khaki to red-brown lithic sandstones contain some pebbly and conglomeratic beds locally over 0.8 m thick. Dips recorded from the sandstones in Kilhenzie Burn are variable probably due to the presence of cross-bedding.

Brown medium- to fine-grained sandstone belonging to the Swanshaw Sandstone Formation was encountered below Quaternary deposits at a site on Society Street in Maybole (SE 9157) and in Littleton Farm borehole (over 85 feet or 25 m). The site investigations in this area of Maybole record little lithological variation but the 12 m variation in the sub-drift elevation of rockhead of the sandstone may reflect variation in hardness.

In Dyrock Burn [346 089] to the east of Kirkmichael, a short section within the formation exposes fine- to medium-grained trough cross-bedded purple-brown lithic sandstone. Channelled sandstone units indicate that this was an active fluviatile environment. Some flaggy and micaceous interbeds lie towards the tops of these units. In one section north of the burn at

[3462 0899] brown mudstone intraclasts up to 15 cm in length were seen in the sandstone below a micaceous, calcareous sandstone interbed, about 0.2 m thick, containing slightly rounded, pale green to dark red-brown mudstone intraclasts and grey micritic limestone fragments up to 6 cm across. These clasts appear to be reworked penecontemporaneous overbank muds and calcrete. Similar strata were formerly exposed in a quarry [347 093] to the north where pinkish grey, very feldspathic, micaceous, cross-bedded coarse-grained sandstones containing red and green mudstone pellets and limestone concretions were recorded in the original survey.

A brief petrological study of the Swanshaw Sandstone Formation in the area showed the typical sandstone (N4281 from Capenoch Burn) is medium-grained, poorly to moderately sorted with heterolithic clasts, mainly subangular, but less commonly subrounded, in shape with an interstitial carbonate matrix. Monocrystalline quartz, plagioclase feldspar, perthite, muscovite, chlorite, biotite and iron ores are common mineral constituents. Lithic clasts include basaltic and felsic igneous rock, polycrystalline metamorphic quartz, micrographic quartz and feldspar intergrowth and altered basic minerals. A sample, also with carbonate cement, from Dyrock Burn near Kirkmichael (N4292) also contains coarse carbonate lithic clasts and partly altered hornblende, clasts of micaceous and quartzose schist, psammite and microdioritic rock.

A pebbly sample (N4298) from north-east of Drummullan contains clast-supported pebbles and granules including fine-grained red mudstone, reddish radiolarian chert, vein quartz, quartzite, schist and psammite, poorly sorted fine-grained sandstone with iron ore cement, altered fine-grained rhyolitic and volcanic rock, quartz porphyry and altered basalt.

An interlaminated red mudstone and siltstone (N4295) contains very fine-grained white micas, quartz and opaque minerals with minor calcite in coarser laminae.

2.3 INVERCLYDE GROUP (TOURNAISIAN-VISEAN)

The complete Inverclyde Group comprises the Kinnesswood Formation (oldest), the Ballagan Formation and the Clyde Sandstone Formation. In the Kirkmichael area, only the Kinnesswood and Ballagan formations are exposed. However, the Clyde Sandstone Formation is inferred lie unconformably below the Lawmuir Formation of the Strathclyde Group around the Dailly Syncline.

2.3.1 Kinnesswood Formation (KNW)

The Kinnesswood Formation is the oldest formation in the Inverclyde Group and overlies unconformably Silurian rocks of the main Girvan inlier just 1.5 km south of NS30NW. The formation comprises mainly medium-grained quartzose sandstones with subordinate red and green argillaceous beds, calcrete lenses and nodular horizons. The formation is overlain by the argillaceous Ballagan Formation, which is known to be CM Biozone in age (Tournaisian) in the Straiton area to the east (Smith, 2001). While the Kinnesswood Formation is considered to be older, the boundary between the two formations could be diachronous. The junction between the two is not exposed in the Kirkmichael area, but it is inferred to cross the Water of Girvan at [347 081], and is likely to be transitional. In the Straiton area to the east (Smith, 2001), the upper boundary of the Kinnesswood Formation was taken at the top of a predominantly sandstone succession with reddish mudstones containing calcrete nodules.

The formation crops out in the tributary south of Rig Burn [3485 0505] where fine- to medium-grained well-sorted quartzose sandstones range in dip from 15° west up to 20° to the north-west. The fresh sandstones are generally pink-brown to purplish grey in colour and include horizons of calcrete concretions. Weathered sandstones are rusty brown and slightly carious. Cross-bedding is common in units 0.2-0.5 m thick and foresets dip north-west- and north-eastwards. Rarely exposed, purplish grey soft sandy siltstone and muddy siltstone interbeds occur up to 0.1 m thick, and at one locality lie above horizontal burrow marks on finely rippled sandstone.

An old limekiln at [3472 0504] is situated just to the north of a quarry which lies on NS30SW. The quarry exploited a thick calcrete (or cornstone) horizon within the formation but this horizon has not been traced onto the Kirkmichael sheet.

In the drain north-east of Barskelly [349 067], nearly in situ blocks of medium-grained, pale buff to white, quartzose sandstone are considered to belong to the Kinnesswood Formation.

Examination of one thin section (N4290) of pinkish sandstone showed a well sorted fine- to medium-grained sandstone mainly comprised of quartz, plagioclase and K-feldspar. The compact texture contains mainly subangular to subrounded grains with little or no interstitial clay or carbonate. Minor opaques or iron ores are present together with scattered white mica, chlorite and possibly zircon grains. There are also a few lithic clasts such as chert and quartzite.

2.3.2 Ballagan Formation (BGN)

The Ballagan Formation includes mostly interbedded greyish argillites, sandstones and thin non-marine limestones, commonly referred to as ‘cementstones’. In this area the Ballagan Formation contains thick sandstone sequences which is not characteristic of the formation generally as seen farther north in the Midland Valley of Scotland.

The Ballagan Formation underlies much of the area around Crosshill, as shown on the map, but it is very poorly exposed even along the Water of Girvan, which meanders across its subcrop. This lack of exposure may be the result of the soft nature of the argillaceous beds in a thick Ballagan succession or the presence of numerous unknown faults in the area associated with the Kerse Loch Fault and the Dailly Syncline (Figure 1).

In the burn north and east of Cloyntie [333 055] the Ballagan Formation contains several fine-grained and some medium-grained, well-sorted, pale grey quartzose sandstones. They are commonly calcite-cemented and weather buff-brown to yellow-brown in colour. The beds are 0.05-0.3 m thick and include rippled beds and scattered grey mudstone intraclasts up to 0.04 m in length. Subordinate interbeds of mid-grey thin-bedded silty sandstone and soft silty mudstone are less well-exposed.

The small exposures in Cloyntie Burn west of Cloyntie at [3316 0556] are of mid-grey mudstone and siltstone interbedded with fine-grained grey calcareous sandstones and thin grey micrite beds (Figure 2). Some of the sandstones contain grey mudstone intraclasts and the silty mudstones contain small carbonaceous fragments and micrite nodules. Plant remains were recorded in Cloyntie Burn in the original geological survey. To the north-west in Cloyntie Burn at [3292 0573], a sequence of medium-bedded fine- and medium-grained, yellow-buff to grey sandstones overlies thinly interbedded earthy grey siltstones, grey calcareous fine-grained sandtones and micritic beds and lenses. In Dalhowan Burn [3302 0598] dark grey calcareous mudstones, grey siltstones, rippled sandstones and thin non-marine micritic limestones are typical of the formation. Here interbeds of grey silty mudstone and sandy siltstone up to 0.5 m thick occur, locally with asymmetrical ripples indicating that palaeocurrents flowed to the north-east. Palynological samples (MPA 51250, 51251, written communication, M Stephenson

2003) from the Cloyntie and Dalhowan burns contain spores of a transitional character, such as the Cf. *Lycospora pusilla*, which are similar to those described from the CM-Pu Biozone boundary elsewhere, for example in the Birnieknowes Borehole (Stephenson, 2002). These samples lie west of the north-north-west-trending Cloyntie Fault, which could therefore cut out some the Ballagan Formation of CM Biozone age and it is possible that Ballagan Formation or Clyde Sandstone Formation of younger Pu Biozone age could occupy the unexposed ground to the west (i.e. between Cloyntie and Knockroon) in a relatively thick upper Ballagan-Clyde Sandstone succession.

The few exposures in the Water of Girvan south of Aitkenhead Toll [346 080] were recorded as a thin, laminated limestone bed above greenish 'marly' mudstone overlying about 6 m of bedded, locally rippled, greenish sandstone. South-east of Merkland, along the Water of Girvan [3432 0782] to [3421 0761] mid-grey silty mudstone is interbedded with grey to reddish brown siltstones, sandy siltstone and grey sandstone beds. Grey silty mudstones at the south-western end of this outcrop contain spores (Sample MPA 51253) which are typical of the CM Biozone (late Tournaisian Tn3c age). Most of the interbedded sandstones are fine- to medium-grained, quartzose, hard and calcite-cemented. Within this river section an example of small scale ripples with straight symmetrical crests was observed and an unusual 0.3 m bed of medium- to coarse-grained lithic sandstone with granules of felsite, quartz and reddish chert is exposed at [3423 0764]. Also at [3460 0810], south-west of the former creamery, a 0.2 m thick bed of medium to coarse-grained lithic sandstone coarsens up into pebbly sandstone including clasts of greenish grey soft mudstone, vein quartz, dark grey chert and red-brown microgranite up to 2.5 cm in length. In a meander of the Water of Girvan [323 076], about 200 m north of Garpin, greenish to dark grey calcareous mudstones were recorded dipping 30° to the south-south-east.

In the northern part of the crop, towards the Kerse Loch Fault, grey and greenish calcareous mudstones with plant remains and mica flakes were formerly exposed dipping 15° south-east in a small disused quarry at [3215 0813] 770 m north-north-west of Garpin Farm. North of Garpin, beside the Water of Girvan [323 076] mid-grey siltstone and calcareous mudstone beds up to 0.4 m thick are intercalated with thin-bedded fine-grained earthy calcareous sandstones. Some silty mudstones contain carbonaceous plant fragments. Pale grey sandstones and buff-coated grey micritic limestones are both locally laminated, in beds 2-13 cm thick, dipping about dip 20° south-east. In a meander of Dyrock Burn [3295 0828], east of Barclay, dark grey calcareous mudstone and 'cementstone' debris was formerly exposed.

Just north-west of the Kerse Loch Fault and north of the dolerite sill at [3016 0640] interbedded dark grey mudstone and grey siltstone appears to be baked and previously J D Floyd and M Williams reported a possibly shelly, possibly Silurian fauna within the strata (see Molyneux, 2001). This was not confirmed in the latest survey and the sample Floyd and Williams had examined palynologically gave no evidence for marine Lower Palaeozoic palynomorphs (Molyneux, 2001). Molyneux concluded that the sample was probably 'from the Lower Old Red Sandstone, as mapped'. However, a sample (MPA51247) was examined for spores by M Stephenson (written communication, 2003) and found to contain a sparse assemblage referred to as possibly late Tournaisian in age and similar to typical Ballagan Formation assemblages elsewhere in the Midland Valley of Scotland. A small downfaulted block of Ballagan Formation has therefore been shown on NS30NW.

A thin section (N4293) of a medium-grained sandstone from low within the formation contains quartz, plagioclase, K-feldspar, white mica, biotite and calcite clasts in a sparry carbonate matrix. There are also scattered lithic clasts such as metaquartzite, mudstone, basaltic, andesitic and felsic igneous clasts and aggregates of chlorite. Sandstones from farther up in the formation (N4286, N4288) appear to be better sorted and richer in quartz and feldspar clasts. They are set

in a ferroan dolomite matrix which also infills veinlets and cracks in mudstone clasts. Accessory minerals include microcline, tourmaline and apatite. The composition of lithic fragments is limited to a narrow range; polycrystalline quartz, chert, felsitic aggregates and rare altered volcanic clasts. A sample of fine grained grey carbonate cemented sandstone from Dalhowan Burn (N4289) contains mainly grains of quartz and feldspar, together with calcite clasts, shelly fragments and tests of probable ostracod origin. These are set in a partly laminated cryptocrystalline micrite marix with later development of sparry ferroan dolomite, infilling the test's interstices and veinlets.

2.3.3 Clyde Sandstone Formation (CYD)

No outcrops of Clyde Sandstone Formation are known within sheet NS30NW but the formationis inferred to be concealed in the area between the Lawmuir Formation and the Ballagan Formation exposures. The formation is characterised by red to brownish grey coloured medium-grained sandstones with local coarse-grained sandstones and sedimentary breccias including calcrete nodules and clasts. Blocks and pebbles of medium-grained red-brown sandstone and coarse-grained to granular, carbonate-cemented sandstone were found in the till forming the southern bank of the Water of Girvan at [310 056], north-west of Knockroon. These are typical of the Clyde Sandstone Formation seen to the north-east on the Ayr sheet. It is therefore considered that, along with the evidence of its exposure in the Dailly area, the Clyde Sandstone Formation continues round the hinge zone of the Dailly Syncline in a belt between the Lawmuir and Ballagan formations. Its thickness is speculative and could be anywhere in the area of non-exposure. The nearest exposures of the formation occur in the Lindsayston Burn to the south-west and, taking these into account, it is thought that the formation is at least 160 m thick here.

A thin section (N4283) of the coarse-grained, brown mottled, carbonate-cemented sandstone block found north-west of Knockroon contains mineral and lithic clasts generally in the order of 1-2 mm, but up to 7 mm, in length. The loosely packed clasts range from subangular to rounded in shape and are cemented by fine to coarse-grained sparry calcite matrix. The lithic fragments include vein quartz, spherulitic chalcedony, coarse-twinned K-feldspar with a fine-grained inclusion of biotite, perthite, radiolarian chert, fine-grained sandstone, micrite, fine-grained volcanic rock and igneous quartz-feldspar-epidote rock.

2.4 STRATHCLYDE GROUP

The Strathclyde Group is of Visean age and within the Midland Valley to the north of the Kirkmichael area typically contains mainly basaltic lavas and volcanic sandstones; in the south of the Midland Valley, deltaic sandstones with coaly lenses and local argillaceous and limestone interbeds become dominant. In the Kirkmichael area, only the Lawmuir Formation containing mainly deltaic sandstones is present. It unconformably overlies the Inverclyde Group but the unconformity is not exposed in this area.

2.4.1 Lawmuir Formation (LWM)

The Lawmuir Formation is interpreted to occur at outcrop in this area as sandstone beds passing conformably down from the base of the Lower Limestone Formation (Clackmannan Group) are correlated with the Lawmuir Formation (Strathclyde Group) to the north-east of NS30NW. The formation typically varies from coarse-grained sandstone to mudstone with

impersistent seatrocks and coaly wisps. No marine limestone beds or coal seams have been found here, in contrast to the Hamilton area (Paterson et al., 1998). The bulk of the exposures in the Little Craigfin area are fine- and medium-grained pale buff to brown sandstones. In the few exposures near Little Craigfin [302 055], the gritty to pebbly sandstones, which are greenish, brown or white, are thinly bedded to fairly massive. In one exposure close to the road [3023 0544], a channel filled with pebbly sandstone over 1.2 m thick, cuts down into fine-grained sandstone with planty fragments. Black and pale grey cherty pebbles, up to 3 cm long, are present in the rudaceous beds as well as vein quartz, 'felsite' and pale greenish mudstone. Locally the medium-grained sandstones include plant remains, coaly streaks, rootlets and carbonaceous flakes. These sandstones are usually buff weathered with ochreous brown spots and tend to be non-calcareous containing kaolin, probably from weathered feldspars. Near the top of the formation, in Black Glen [3015 0528], fine-grained grey sandstones contain hard iron-stained probably sideritic concretions. Micaceous, fine-grained sandstone and siltstone beds interbeds are commonly rippled and cross-bedded in units 10-15 cm thick. Subordinate reddish to greenish sandy silty mudstones and grey fireclays are interbedded. In the Water of Girvan beside the tributary junction at [3038 0510], fine-grained greyish sandstones containing some carbonaceous flakes outcrop in trough cross-bedded units about 0.5 m thick. From the disposition of the troughs it is inferred that the palaeocurrents flowed 229° south-west. In the river bank above this sandstone, a soft reddish brown silty mudstone bed, about 1 m thick, becomes buff-grey coloured towards the top and is sharply overlain by medium-grained brown sandstone.

In the southern bank of the Water of Girvan, north of Knockroon [307 055], sections in the Lawmuir Formation dip up to 20° to the south-east, possibly lying on the north-west limb of a subsidiary syncline to the main Dailly Syncline. At the base of the section in the river is a soft pale grey fireclay overlain by channelled sandstones with subordinate siltstones and mudstone (Figure 3). The pebbles in the pebbly bases include quartz, feldspar, black and greenish chert as well as grey mudstone intraclasts up to 1 cm in length.

Farther south, in the east bank of the Water of Girvan [3040 0516], medium-grained buff sandstone includes coaly wisps and a carbonaceous impression of a plant trunk up to 8 cm wide. In the south bank of the Water of Girvan [3047 0507] pale grey and khaki-coloured sandstones are intercalated with grey siltstones and seatearths some of which are rubbly textured with plant stems or roots. The sandstones contain scattered white feldspars and white micas; which may be a volcanic component. On the northern bank these beds lie in open folds plunging gently to N228° south-westwards.

Due to lack of exposure the base of the Lawmuir Formation can only be inferred as being folded around the Dailly Syncline (see the section on Structure) and lying unconformably above the Clyde Sandstone Formation. Its top is taken at the base of the Hurlet Limestone (see below), which can be mapped around the syncline but is cut out by the Kerse Loch Fault to the west. Its total thickness is difficult to determine because of the folding and faulting near the Kerse Loch Fault. However, it is estimated to be about 100 m thick in the Little Craigfin area which is considerably more that the 50 m as estimated on the southern limb of the Dailly Syncline on the Carrick Sheet (Floyd, 1999). The increase in thickness may be the result of deepening of the basin adjacent to the syn-depositional Kerse Loch Fault or due to tectonic deformation, although no stratigraphic repetition was observed.

The relatively sparse spore assemblage (MPA 51248) from grey siltstones considered to come from low down within the Lawmuir Formation west of Knockroon [3068 0551] indicates the possible presence of the NM Biozone (Asbian). Another spore assemblage (MPA 51244) from higher in the formation near Black Glen [3027 0526] was assigned to the younger VF Biozone (early Brigantian). This fairly thick succession forming the Lawmuir Formation could therefore

result from an extensive period of fairly high energy fluviatile to deltaic deposition prior to the marine incursions of the Lower Limestone Formation.

Examination of thin sections of the Lawmuir Sandstone shows that the lower sandstones (N4280, N4284) contain mainly subangular to subrounded monocrystalline and polycrystalline quartz in a compact texture with little matrix. Lithic grains include radiating chalcedony from vugs or amygdales, quartzite including some strongly deformed clasts, psammite, chert, iron ores, felsitic aggregates, fine-grained poorly sorted sandstone and mudstone. Detrital feldspar and mica clasts are relatively rare. A sample (N4285) from farther up in the formation is grey and fine-grained with siltstone laminae and small scale sedimentary structures. The finer grained bands commonly contain poorly sorted, altered volcanic clasts, biotite, chlorite and iron ores. They therefore seem have a tuffaceous component, possibly partly equivalent to the Kirkwood Formation or possibly derived from the slightly older Clyde Plateau Formation.

2.5 CLACKMANNAN GROUP (UPPER VISEAN-NAMURIAN)

The Clackmannan Group comprises strata ranging from the Lower Limestone Formation to the Passage Formation. Only the lower part, namely the Lower Limestone and the Limestone Coal formations, is present in the core of the Dailly Syncline on sheet NS30NW.

2.5.1 Lower Limestone Formation (LLGS)

The Lower Limestone Formation is represented in this area by a condensed sequence of bioclastic marine limestone beds, calcareous mudstones and sandstones. The only section in this area occurs in Black Glen where dark grey fine-grained argillaceous limestone with shell fragments is exposed [3008 0529]. A spore assemblage (MPA 51245) from grey mudstone within the formation in Black Glen [3008 0526] indicates that it lies in the range NM to NC biozones (Asbian to Pendleian, M Stephenson, written communication, 2003). In better exposed sections to the west, the basal dark grey limestone bed (Captain's Bridge Limestone of Eyles et al., 1949) contains crinoidal debris and is correlated with the Hurlet Limestone (or Patna Limestone of the Patna area to the east). An upper limestone bed may represent the Hosie Limestones in this condensed sequence (and equate to the Doon Limestone in the Patna area). It is estimated that the formation is between 10 and 15 m thick in this area. More details of the formation as it relates to the Dailly Coalfield are given by Simpson and MacGregor (1932).

2.5.2 Limestone Coal Formation (LSC)

Only a small portion of the Limestone Coal Formation crops out in the south-west corner of NS30NW [301 052], and its full thickness cannot be estimated here. The formation lies in the core of the Dailly Syncline and typically contains interbedded sandstones, siltstones and coal seams. In Black Glen [3004 0530], near the base of the formation, fine-grained medium-bedded, pale grey to buff-weathered rooty sandstones are interbedded with dark grey, subfissile mudstones, siltstones and thin ironstones. A spore assemblage (MPA 51246) from near the base of the formation in Black Glen [3004 0531] indicates a possible NC Biozone age (Stephenson, written communication, 2003). The crop of the lowest worked coal known as the Rotten Coal (Simpson and MacGregor, 1932) or the Harvey Coal (Eyles et al., 1949) or Hartley Coal (Mykura, 1967; Institute of Geological Sciences, 1978a; Floyd, 1999) is inferred from the position of an old shaft [3010 0506] and from mining information recorded to the south-west. The Hartley Coal was recorded as around 1 m thick in the eastern (Kilkerran) end of the Dailly

Coalfield.

3. Intrusive Igneous Rocks

3.1 EARLY DEVONIAN

A suite of igneous intrusions intruding the Swanshaw Sandstone Formation is considered to be early Devonian in age. This suite ranges from microgranitic through andesitic/dacitic to microdioritic and is widespread in the surrounding Siluro-Devonian strata (Smith, 2001).

3.1.1 Andesitic sills (*A*)

These high-level fine- to very fine-grained feldspathic andesite intrusions are probably related to the high level microdioritic (or basaltic andesite) intrusions (*P*) and the extrusive Lower Devonian Carrick Volcanic Formation.

The andesitic body or sill at [302 073] extends westwards to Kildoon Hill. In earlier surveys the body was described in the field as a pink porphyrite or felsite and on the earlier 1:50 000 map (Institute of Geological Sciences, 1978a) as a plagiophyre containing highly altered sparse phenocysts of albitic feldspar. More recently the intrusion (S25228) has been described as a plagioclase microporphyritic andesite with secondary quartz (Phillips, 1999). The altered red-green-grey coloured rocks are fine-grained, massive and jointed (Sowerbutts, 2000). The varied colour partly reflects alteration but also a range in the content of pinkish feldspar and dark green mafic microphenocrysts. This intrusion may be sill-like, up to 35 m thick, but has local steep and cross-cutting margins, chilled against the Swanshaw Sandstone Formation where formerly exposed south of Barmody Hill [3066 0688]. The intrusion is cut out to the east by the Kerse Loch Fault and offset by a smaller north-east trending fault [303 072]. Thin barytes veins, up to 15 cm thick, striking N4°W and dipping 70° to the west cut the body in an old quarry at [3028 0736].

A pale grey andesitic sill, estimated to be about 40 m thick, intruded a lower level of the Swanshaw Sandstone and was formerly quarried [at 302 065]. Small pink and clear feldspar phenocrysts are scattered in a fine-grained matrix. The rock alters to a brown to khaki colour. It contains scattered small chlorite- and chalcedony-filled amygdales. Petrographically this sill is similar to the body to the north and is described as altered feldspar microporphyritic andesite with secondary quartz (Phillips, 1999, S25229).

A small east-west trending sill is exposed in the burn to the east of Kilhenzie Castle [3096 0827], where it is at least 2 m thick. It is a medium-grained ‘andesite’ with pink feldspar and dark green mafic phenocrysts grading into a grey fine-grained margin against baked and locally hornfelsed Swanshaw Sandstone Formation. Thirty metres south-east of Kilhenzie Castle [3087 0821] is a grey fine-grained hornfels which may be associated with another small andesite sill.

3.1.2 Andesitic Dykes (*A*)

A porphyritic andesite dyke-like body, which is considered to be early Devonian in age and

similar in composition to the sills described above, intrudes the Swanshaw Sandstone Formation near Kirkmichael Church [3450 0891]. The andesite is grey with feldspar phenocrysts 1-2 mm in length. The intrusion is at least 10 m wide and has a steep margin to the west in contact with pinkish baked sandstone. Its eastern margin is faulted against purple-brown sandstone.

3.2 MAFIC INTRUSIONS (Lower Devonian to Palaeocene)

3.2.1 Quartz-dolerite sills (*qD*)

The two quartz-dolerite sills at [303 063] and [301 060] were classed as of uncertain age (Institute of Geological Sciences, 1978a), perhaps because their petrological affinity was most closely allied to Tertiary intrusive material (Sowerbutts, 2000). However, Eyles et al. (1949) considered them to be Lower Devonian age and that is considered the most likely conclusion here, although the northern sill appears to bake the faulted Ballagan Formation beds. The sills have been classified as belonging to the Lower Devonian Maybole-Dalmellington-Straiton suite (Monaghan, 2001). These sills are generally fine-grained and weakly plagioclase microporphyritic (Phillips, 1999) and more specifically a fine-grained sample (S25231) from the thinner northern sill on the sheet is described as altered, quartz-bearing, plagioclase microporphyritic basalt. Accessory cubic crystals of pyrite were seen in the dolerite in the present survey.

The Lower Devonian age for the quartz-dolerite sills is most likely since there is a close spacial relationship with the early Devonian andesitic sills here and both sets of sills are cut by the major north-east trending Kerse Loch Fault. North-easterly trending faults are unlikely to have moved much in the Tertiary and elsewhere intrusions of Palaeocene age continue across faults such as the Southern Upland Fault. The quartz-dolerite sills are also cut by other smaller faults with various orientations (west-north-west to north-east); it is unlikely all these faults are Palaeocene or later. This quartz dolerite suite lies well to the south of the late Carboniferous suite of similar composition and does not appear to be part of it. Close to the Kerse Loch Fault [3016 0616], major sinistral shear joints striking N30°E and dipping 78° north-west within dolerite are consistent with the model of sinistral shear movement on the Kerse Loch Fault in the Devonian to early Carboniferous times (see Section 4). The sills are similar to those near Knockgardner (Smith, 2001) but they were classed as Palaeocene in age (Phillips, 1999).

3.2.2 Basic Dykes

Because of the sparse exposure only five basic dykes have been recognised on NS30NW. The largest is a olivine ‘dolerite’, over 7 m thick, trending north-westwards across the Water of Girvan at [343 077], considered to be Palaeocene in age. It intruded the Ballagan Formation and was classed as a crinanite on the first solid edition of the Ayr Sheet (British Geological Survey, 1978a). More recently Phillips (1999) described it as an olivine dolerite (***oD***^{A}).

A basaltic dyke (***B***^{A}) with small calcite amygdales, 1.5 m wide and trending N37°W crops out in Cloyntie Burn [3330 0552]. It intruded and baked fine-grained calcareous sandstone within the Ballagan Formation. In thin section (N4287) altered olivine and clinopyroxene phenocrysts can be seen in a plagioclase rich matrix which also contains small polycrystalline quartz xenoliths. The dyke is relatively altered but its orientation is typical of the Palaeocene Dyke Swarms.

A dyke (***B***^{T}), 0.45 m thick and trending north-north-east, was classed as a Tertiary (Palaeocene)

tholeiitic basalt (British Geological Survey, 1978a) in Dyrock Burn near Kirkmichael church [3451 0891]. However, it occurs within a porphyritic andesite, which is considered to be early Devonian. It relationship is therefore not entirely clear, although it probably exploited the fault zone which marks the eastern boundary of the porphyritic andesite.

A thin west-north-westerly trending feldspathic basaltic dyke (***B***), 1.2 m thick with a fine-grained banded margin, intruded the Swanshaw Sandstone Formation above Capenoch Bridge [302 077] and could be Lower Devonian to Palaeocene in age. An olivine dolerite dyke (***oD***), about 3 m thick, trends north-west and cuts an early Devonian andesitic sill at [303 073] in Capenoch Burn. The latter dyke also could be Lower Devonian to Palaeocene in age.

4 Structure

4.1 DEFORMATION PHASES

The structural deformation in the Kirkmichael area is not well known due to the general lack of exposure. However, the Siluro-Devonian rocks have been through the Acadian orogeny prior to the Variscan orogeny, which also affected the Carboniferous strata. The Variscan orogeny is responsible for the relatively tight Dailly Syncline; the north-eastern end of which can be discerned in the vicinity of Little Craigfin [303 506]. The Dailly Syncline has a low plunge to the south-west and its trace is roughly parallel to the Kerse Loch Fault. The syncline is also cut by subsidiary faults, subparallel to the Kerse Loch Fault. Since there is no complementary anticline lying to the south-east and the north-western limb of the syncline is less than a kilometre wide compared to 3 km for the south-eastern limb, it is thought that the fold is mainly the result of drag (or growth) since the Clackmannan Group is thicker here than to the north) on the Kerse Loch Fault. Although there is little exposure in the Crosshill area, the broad outcrop pattern of the Ballagan Formation is interpreted as the result of a thick Ballagan succession lying in the north-eastwards continuation of the Dailly Syncline which is opening out in that direction.

4.2 FAULTS

The main fault crossing the area is the Kerse Loch Fault, which probably has a long history and a general north-easterly trend inherited from the Caledonian orogeny. In this area the fault is not exposed but mapped with a curvature that is concave on its downthrow side to the south-east. Its movement continued until at least late Westphalian times. During Silesian times it is thought to have been active (Read, 1988) and at that time may have had a dextral strike-slip component. In Silesian times therefore, the curvature on the fault is interpreted to create a constricting bend on its south-east side in the vicinity of Crosshill, but there is no evidence at outcrop due to lack of exposure. Near Little Craigfin [3023 0542], in Lawmuir Sandstone, a small fault strikes N4°E dipping 74° to the west with slickencrysts indicating dextral movement in Visean times or later. Near the Water of Girvan, another small fault in Lawmuir Sandstone strikes N22°W and dips 70° to the north-east. However, earlier in the Carboniferous it is possible that a sinistral regime still prevailed, continuing on from the mid-Devonian Acadian

orogeny (Smith, 1995). This would concur with the evidence of sinistral movements in the Loch Spallander area (Smith, 2001) and account for the normal faults within Lanark Group rocks in the releasing bend of the Kerse Loch Fault around Craigfin (Figure 4). These small north-east to north-north-east-trending normal faults cut the Swanshaw Sandstone and the igneous sills in the Springgarden Bridge [302 072] to Carsloe Glen [305 064] areas. Another small north-north-east-trending fault offsets the conglomerate unit within the Swanshaw Sandstone west of Kilhenzie Castle [305 082]. Some minor post-Devonian faults strike about north-south within the Swanshaw Sandstone Formation and cut early Devonian andesites.

At the eastern margin of the sheet, the Cloncaird Fault (Smith, 2001) is interpreted to intersect the east-south-east trending Blairquhan Fault. Near the southern margin of the sheet [332 054] a significant north-north-westerly-trending fault, the Cloyntie Fault, is inferred to downthrow the Ballagan Formation to the west near Cloyntie.

5 Quaternary

5.1 LATE DEVENSIAN

The Quaternary history of the area is dominated by the late Devensian glaciation (Dimlington Stadial), which reached its maximum extent about 18 000 years before present (BP) and there is no evidence in the Kirkmichael area of earlier phases of glaciation. The latest ice sheet that covered the area appears to have been sourced from the south-east and the east as indicated by the drumlin orientations, the numerous Loch Doon granite erratics and the glacial striae in the adjacent hills. The general softness of the rocks in the Kirkmichael area means that few rock outcrops or glacial striae are exposed in the area. By the time of the Windermere Interstadial (13 500–11 000BP) the area was probably free of ice. The relatively subdued relief may have resulted in the presumed periglacial effects of the succeeding Loch Lomond Stadial (11 000–10 000 BP) being inconspicuous.

One glacial striation, recorded on the old geological fieldslips at [3065 0689] in an old ‘whinstone’ quarry, trends westwards and another at [3446 0893] south-west of the church at Kirkmichael also trends east-west. A striation was observed on red sandstone in the railway cutting at [308 073], trending 300° and indicating ice-flow to the north-west. This supports the flow of ice sourced in the Southern Uplands. In the illustrations of ice-currents shown by Eyles et al. (1949), at the glacial maximum, the southern limit of Highland Ice (from the north and west) lay just south of Maybole. At a later stage the southerly derived ice pushed north of Maybole, as indicated by the Loch Doon granite and Lower Palaeozoic greywacke erratics overlying the shelly ‘Highland’ till. The general east-west drumlin trend is generally attributed to the Highland ice coming inland from the Ayrshire coast at an early stage but the glacial advances are difficult to distinguish in this area and the east-west trend could also be attributed to the later stage of advancing Southern Uplands ice. This is because in this area of generally low ground, later ice flow from the southern hills may been deflected into a more westerly direction by Highland ice lying to the north. In the Eyles et al. (1949) model the general glacial retreat was from the east to the west and south-west. Drainage channels are considered to be few and inconspicuous due to the prevalence of stagnant melt-water along the ice margin.

5.1.1 Till

Lodgement till is widespread, commonly in the form of drumlins 250-500 m in length. They are oriented east-south-east to easterly south of the Water of Girvan, but to the north of the river the drumlins are elongated east-west to north-easterly. The lodgment till is generally a stiff, compact diamicton containing facetted rock fragments of variable size set in a sandy silty clay matrix. The colour varies from reddish brown to grey-brown. In places, such as around Maybole, the lodgement till is thin to absent and hummocky glacial deposits rest on rockhead. In the railway cutting [3046 0570], west of Carsloe, up to 30 feet (10 m) of till was encountered. Elsewhere, such as east of Crosshill, the drumlins are formed of till in the order of 20 m thick, although some drumlins may be rock cored. Borehole evidence at Littleton Farm [313 088] indicates that till 28 feet (8.5 m) thick overlies a soft sandy clay 13 feet (4 m) thick above rockhead. At Society Street in Maybole, site investigation boreholes penetrated a stiff to very stiff, brown, silty, sandy till, up to 9.3 m thick, resting on brown, medium to fine-grained sandstone.

Over the more resistant igneous rocks forming Kildoon Hill and Craigfin Wood just to the west of the sheet, till is thin to absent and ice flowing from west to east over these hills appears to have deposited ‘tails’ which merge with the adjacent drumlins [309 061]. Near Ashfield [339 051] the till is also thin where the hills begin to rise to the south-east.

The widespread presence of pale biotite-granite erratic boulders, presumed to come from the Loch Doon pluton, was noted in the previous surveys from the Water of Girvan to beside Drumore Loch.

5.1.2 Meltwater channels

Channels running east-west on the hills near Craigfin appear to be resistant rock ridges scoured by icesheets and enhanced by glacial meltwater run-off. There are three main channels, which occur at [301 059], [301 061] and [301 062], cutting into the rockhead which continues westwards to the south of Craigfin Farm. The development of these channels would accord with the retreat of the ice to the west over the hills and with the meltwaters flowing down into the Water of Girvan catchment.

A small, but distinct channel extends north-westwards from Drumore Loch [339 099] at the northern margin of the sheet. This suggests that here, ice lying to the south-east blocked meltwater from flowing in that direction. Other meltwater channels may have cut through the till between drumlins but have been subsequently infilled with silt and sand.

The small channel to the north-west of Aitkenhead Toll [3444 0825] is associated with glacio-fluvial sand and gravel deposits. It may have drained water from wasting ice around Maybole into the Water of Girvan.

5.1.3 Hummocky Glacial Deposits

In the Maybole area, the irregularly moundy glacial deposits containing mainly angular sandstone clasts has been mapped in the Tunnoch Farm area [308 097]. The deposit is difficult to classify and in one scenario Eyles et al. (1949) considered it to be a ‘boulder clay’ possibly deposited by a readvance of the icesheet. Eyles et al. (1949) also called the deposit ‘upper drift’ or angular moraine (Eyles et al., 1949 p. 132- 3, Plate VIII). In another scenario, they considered it could be the result of ice wasting locally since, as they pointed out, the deposit lacks rounded striated clasts and the sandstone debris is mostly local. In places wispy lenses of

sand and gravel were reported in the deposit which are interpreted to indicate evidence of some water sorting involved with the formation of the deposits. It is concluded here that the latter explanation of ice wasting is more likely. The term melt-out till was used for the deposit (Smith, 2000; Sowerbutts, 2000) but this is not now considered the correct terminology. Where the deposit is less hummocky and appears to contain more sand and gravel south of Maybole [302 089], a sand- and gravel-rich category has been mapped separately. North of Tunnoch hummocky glacial deposits appear to pass laterally into glacio-fluvial sands and gravels which may be associated wash out from the wasting ice mass.

5.1.4 Glaciofluvial Sand and Gravel

The glaciofluvial deposits in this area are mainly of an uneven to hummocky nature and considered to be ice contact deposits. A major belt of glaciofluvial sand and gravel lies just to the south of Kirkmichael [344 085], trending north-westwards from the Water of Girvan to near Chapelton Loch. This belt forms a conspicuous feature and is up to about 500 m wide and appears to traverse the older drumlin trend. It may be related to a drainage system flowing south-east on (or beneath) the remnant ice which deposited the hummocky glacial deposits around Maybole. Or it may represent a drainage system flowing north-west into the River Doon catchment from the Water of Girvan which may have one time been blocked to the south-west near Crosshill. The sand and gravel lies in irregular mounds about 10 m high and up to 100 m in length. These appear to be modified ice-contact deposits.

Narrow, but sharp esker-like ridges are developed within the deposits near Chapelton and in the grounds of Kirkmichael House [342 085] where the ridge is about 800 m in length. Several former pits in the sand and gravel (e.g. at [343 083]) near Kirkmichael House exposed fine- to coarse-grained structureless gravels. In a former pit east of Broom Knowe [326 097] up to 25 feet (7.6 m) of coarse, sandy, locally cross-bedded gravel was recorded by the previous survey as containing many Devonian igneous rock type pebbles. At the margins of a former pit near Chapelton [3258 0939] several sections in variably stratified and cross-bedded coarse sands and gravels were seen in coarsening up and channelled beds.

Another belt of sand and gravel lies in the Auchenwynd to Littleton area south of Maybole. A borehole at Littleton Farm (NS30NW/1) penetrated 14 feet (4.27 m) of sand and gravel above till. Elsewhere only small patches of sand and gravel are mapped; some flanking the Water of Girvan e.g. at [326 074] and the Dalhowan Burn [330 059]. The sand and gravel is generally poorly sorted but lenses of sand at least 0.5 m thick are exposed. Small sand and gravel mounds associated with the alluvium near Crosshill indicate that glaciofluvial drainage from Dalhowan flowed north-west towards the Water of Girvan. A mound of sand and gravel up to 140 m in length at [328 057] flanks the drumlin west of Cloyntie.

5.2 FLANDRIAN

The milder climate, which prevailed from 10 000 BP, allowed alluvium to be deposited in hollows and along watercourses. Temperate vegetation became established but no substantial areas of peat accumulated in the Kirkmichael area. Made ground, cuttings and fill are the result of man's activity.

5.2.1 Alluvium and buried channels

The flat spreads of brown silt, sand and gravel constitute the alluvial deposits mainly found

along the Water of Girvan and its tributaries such as the Barlewan Burn. These spreads reach up to 700 m wide west of Crosshill and are considered to cover or be part of ice-dammed lakes which were ponded up as the main ice sheet retreated westwards (Eyles et al., 1949). The deposits are variable ranging from gravel to clay with peat layers.

In this area the course of the Water of Girvan appears to be partly controlled by the solid geology in that it meanders across the 'softer' Lower Carboniferous rocks (and not to the north-west of the Kerse Loch Fault). This was probably its approximate pre-glacial course, but there may be associated buried river channels in the vicinity. South-east of Maybole, a little subsurface information indicates a general south-easterly trending buried channel within the Swanshaw Sandstone subcrop. This is because traversing north-east from Kilhenzie Castle [308 082], where rock is exposed at 73 m OD, over to Littleton Farm, rockhead is down to c. 41 m OD and to the north-east again, near Heart Loch, rock is exposed at c. 50 m OD.

Other isolated patches of alluvium tend to be sandy, silty or peaty and probably accumulated in hollows formed after the late glacial ice wasted in areas such as Heart Loch and Chapelton Loch. Boreholes that penetrated below made ground at a site [301 093] south of Maybole, encountered patches of very soft peat up to 0.9 m thick above 0.2 m sand and gravel lenses, on over 8 m (unbottomed) of soft to very soft, brown, slightly clayey, sandy silt. The alluvium deposited to the east of Crosshill appears to have accumulated in inter-drumlin hollows.

5.2.2 River Terrace Deposits

South of Aitkenhead Toll [345 079], two levels of alluvial terrace occur along the Water of Girvan above the present alluvial flat. The upper terrace is obscured by the development of the former creamery. However, terraces are relatively insignificant in this area, either due to frequent reworking of the alluvial belt by the river or the building of levees to prevent flooding.

5.2.3 Alluvial Fans

Small alluvial fans, mainly comprising sandy gravel, are present, e.g. near Barlewan Burn [314 076] and south-east of Longhill [at 346 052].

5.2.4 Peat

No peat is shown on the map, but 0.9 m peat was encountered in a site investigation at [301 093] south-east of Maybole although it proved to be an impersistent lens. Other patches of peat may occur within the larger spreads of alluvium, such as around Heart and Chapelton lochs.

5.3 ARTIFICIAL GROUND

5.3.1 Made Ground

On an industrial site at [301 093] south of Maybole, boreholes proved made ground to be from 2.5 to 3.4 m thick and composed of a variety of domestic to industrial waste lying above alluvium.

Also in a site investigation on Society Street, Maybole, patches of made ground up to 2.1 m thick overlie till. Areas of made ground are present e.g. at [347 076] in the alluvial hollow north of Tranew Flushes, which was a former council tipping site. Small areas of made ground form railway embankments such as at Capenoch Bridge [304 078] and Colquhounston Wood [310 067] and flood prevention barriers along the Water of Girvan.

5.3.2 Worked Ground

The railway cutting along the Ayr-Girvan line cuts through mainly lodgement till, but locally intersects rockhead. A small disused quarry in an andesitic sill (formerly termed plagiophyre) occurs at [3014 0645], west of Carsloe Glen. A former small pit in the Ballagan Formation at [321 081] is essentially overgrown. Small sand and gravel pits in the glaciofluvial deposits are largely restored or grassed over.

5.3.3 Infilled ground

Small areas of worked and filled ground are mapped where pits and quarries (in both solid and drift) have subsequently been infilled. One quarry near Kirkmichael [347 093], now infilled, formerly exposed Swanshaw Sandstone.

5.3.4 Landscaped ground

Small areas of landscaped ground have been mapped, mainly where playing fields have been levelled near Maybole [304 099] and Crosshill [325 068]. However, these areas are located on alluvium that was flattish originally.

5.4 SOILS

Near the surface the lodgement till has produced soils that are generally light or medium loams. Because they lie on drumlinoid till slopes, they are usually well-drained. The hummocky glacial deposits are fairly sandy and also drain fairly well. The fluvio-glacial sandy soils are light. Alluvial soils are variable; heavy sand near the Water of Girvan (Geological Survey of Scotland, 1932), heavy loam south of Littleton and in places, peaty and poorly drained.

6 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.

ARMSTRONG, H A and OWEN, A W. 2000. Age and provenance of limestone clasts in the Lower Old Red Sandstone conglomerates: implications for the geological history of the Midland Valley Terrane. In: Friend, P F and Williams, B P J. New Perspectives on the Old Red Sandstone. *Geological Society, London, Special Publications*, 180, 459-471.

COCKS, L R M and TOGHILL, P. 1973. The biostratigraphy of the Silurian rocks of the Girvan District, Scotland. *Journal of*

the Geological Society, London, Vol. 129, 209-243.

EYLES V A, SIMPSON, J B and MACGREGOR, A G. 1929. The igneous geology of Central Ayrshire. *Transactions of the Geological Society of Glasgow*, Vol. 18, 361-387.

EYLES, V A, SIMPSON, J B and MACGREGOR, A G. 1949. Geology of Central Ayrshire. (2nd edition). *Memoir of the Geological Survey,* (Scotland).

FLOYD, J D. 1999. Geology of the Carrick-Loch Doon district. *Memoirs of the Geological Survey,* Sheets 8W and 8E (Scotland*)*.

GEIKIE, A. 1897. *The ancient volcanoes of Great Britain*. Volume 1. (London: MacMillan and Co. Ltd).

GEIKIE A, GEIKIE, J, and PEACH, B N. 1869. Ayrshire: Southern district. *Memoirs of the Geological Survey* Sheet 14 (Scotland).

GEOLOGICAL SURVEY OF SCOTLAND, 1932. Ayr Sheet 14. Soil Textures. 1:63 360 (Southampton: Ordnance Survey Office for Geological Survey of Scotland.)

GEOLOGICAL SURVEY OF SCOTLAND. 1933a. Ayr Sheet 14. Solid. 1:63 360 (Southampton: Ordnance Survey for Geological Survey of Scotland.)

GEOLOGICAL SURVEY OF SCOTLAND. 1933b. Ayr Sheet 14. Solid and Drift. 1:63 360 (Southampton: Ordnance Survey for Geological Survey of Scotland.)

INSTITUTE OF GEOLOGICAL SCIENCES, 1978a. Ayr, Scotland Sheet 14W. Solid. 1:50 000. (Southampton: Ordnance Survey for Institute of Geological Sciences.)

INSTITUTE OF GEOLOGICAL SCIENCES, 1978b. Ayr, Scotland Sheet 14W. Drift. 1:50 000. (Southampton: Ordnance Survey for Institute of Geological Sciences.)

MOLYNEUX, S G. 2001. Palynological investigation of a sample from Craigfin, Girvan district. *British Geological Survey Internal Report*, IR/01/041.

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

MYKURA, W. 1967. The Upper Carboniferous rocks of south-west Ayrshire*. Bulletin of the Geological Survey of Great Britain*, No. 26, 23-98.

PATERSON, I B, McADAM, A D and MacPHERSON, K A T. 1998. Geology of the Hamilton district. *Memoir of the British Geological Survey*, Sheet 23W (Scotland).

PHILLIPS, E R. 1999. Petrology of the igneous rocks exposed in the Ayr District (Sheet 14W) of the Southern Midland Valley, Scotland. *British Geological Survey Technical Report*, WG/99/18.

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

SIMPSON, J B and MacGREGOR, A G. 1932. Economic Geology of the Ayrshire Coalfields, Area IV. *Memoir of the Geological Survey*, (Scotland).

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

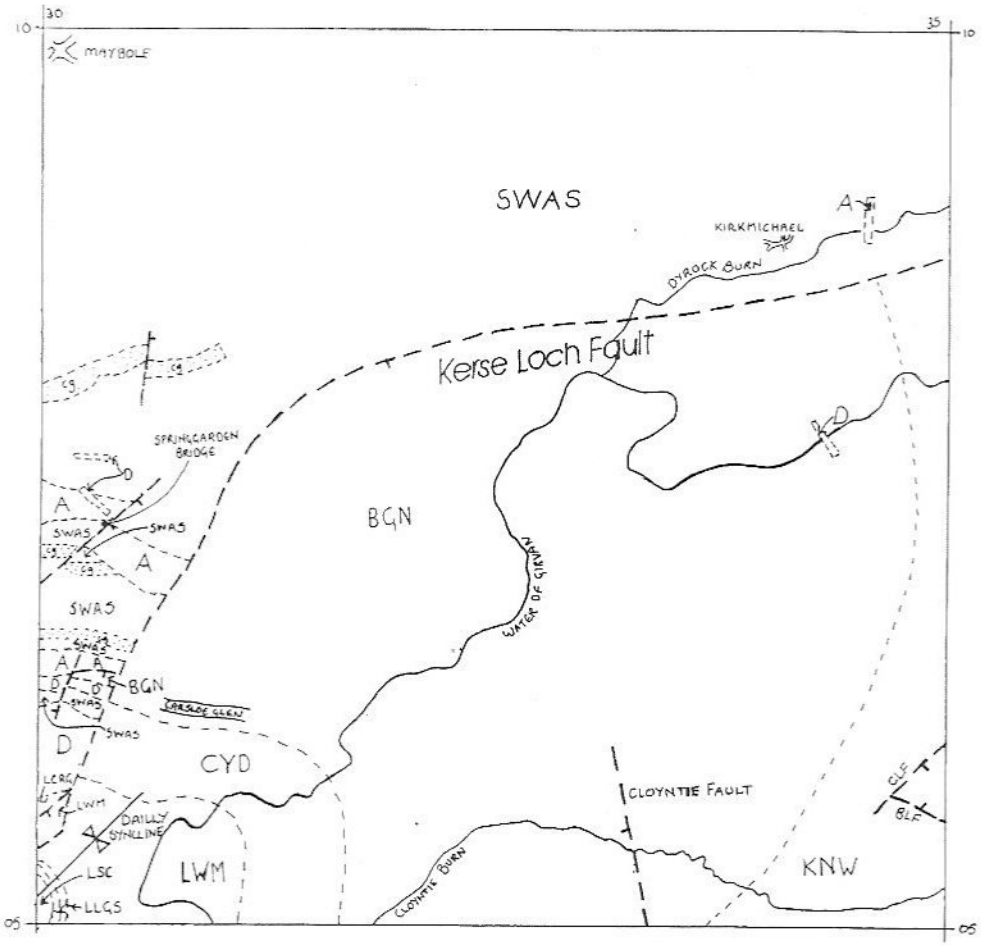
SMITH, R A. 2000. Geology of the Croy area. *British Geological Survey Technical Report*, WA/00/13.

SMITH, R A. 2001. The geology of the Straiton – Loch Spallander area, Ayrshire. *British Geological Survey Internal Report*, IR/01/148.

SOWERBUTTS, A. 2000. Geology of the south-west Maybole to Craigdow area. *British Geological Survey Technical Report*, WA/00/26.

STEPHENSON, M H. 2002. Palynology of the Ballagan Formation in the Birnieknowes and Spilmersford boreholes of the Midland Valley of Scotland. *British Geological Survey Internal Report*, IR/02/181.

TYRRELL, G W. 1916. A Petrographical Sketch of the Carrick Hills, Ayrshire. *Transactions of the Geological Society of Glasgow*, Vol. 15, 64-83.



NAMURIAN	LSC	LIMESTONE COAL FORMATION	CLACKMANNAN GROUP
	LLGS	LOWER LIMESTONE FORMATION	
	LWM	LAWMUIR FORMATION	STRATHCLYDE GROUP
DINANTIAN	CYD	CLYDE SANDSTONE FORMATION	INVERCLYDE GROUP
	BGN	BALLAGAN FORMATION	
	KNW	KINNESSWOOD FORMATION	
SILURO-DEVONIAN	SWAS / cg	SWANSHAW SANDSTONE FORMATION WITH CONGLOMERATES	LANARK GROUP
SILURIAN	LCRG	LOWER CAMREGAN GRITS FORMATION	

INTRUSIONS

A — ANDESITE

D — DOLERITE

SYNCLINE

FAULT, TICK ON DOWNTHROW SIDE

CLF - CLONCAIRD FAULT
BLF - BLAIRQUHAN FAULT

BEDROCK GEOLOGICAL BOUNDARY

Figure 1. Solid geology of the Kirkmichael area.

Figure 2. Graphic log of the Ballagan Formation exposed in Cloyntie Burn [NS 3316 0555]

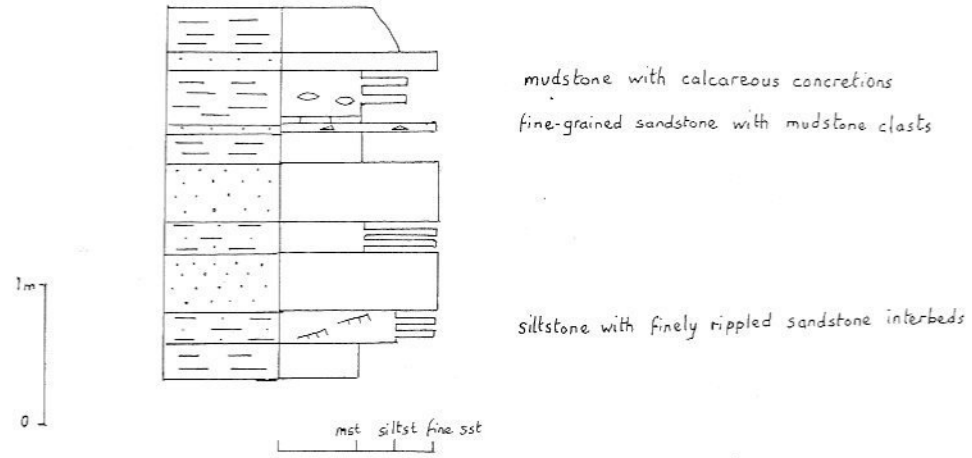
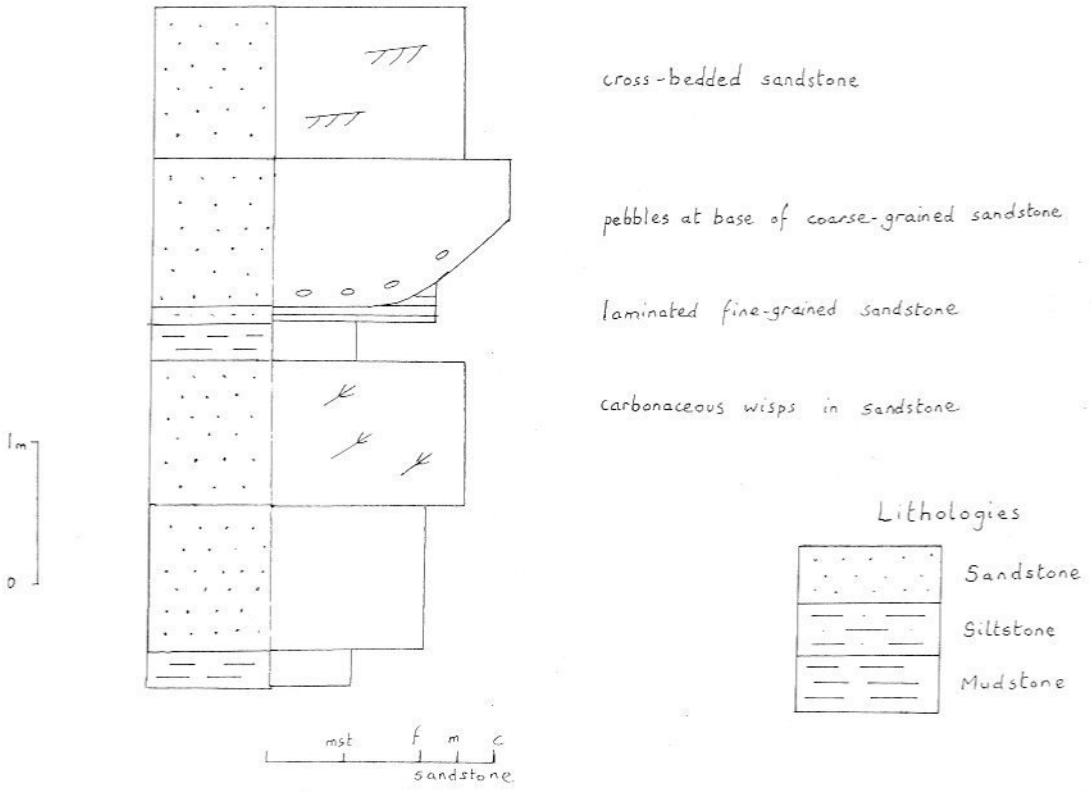
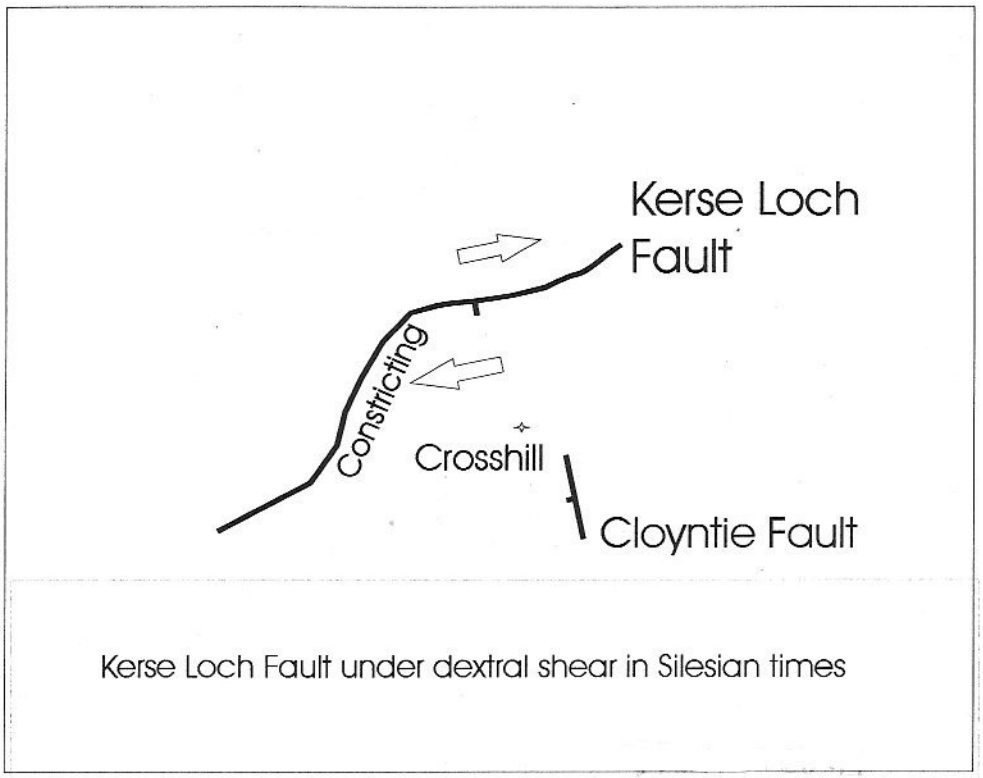


Figure 3. Graphic log of the Lawmuir Formation exposed in the Waterof Girvan [NS 3079 0551]





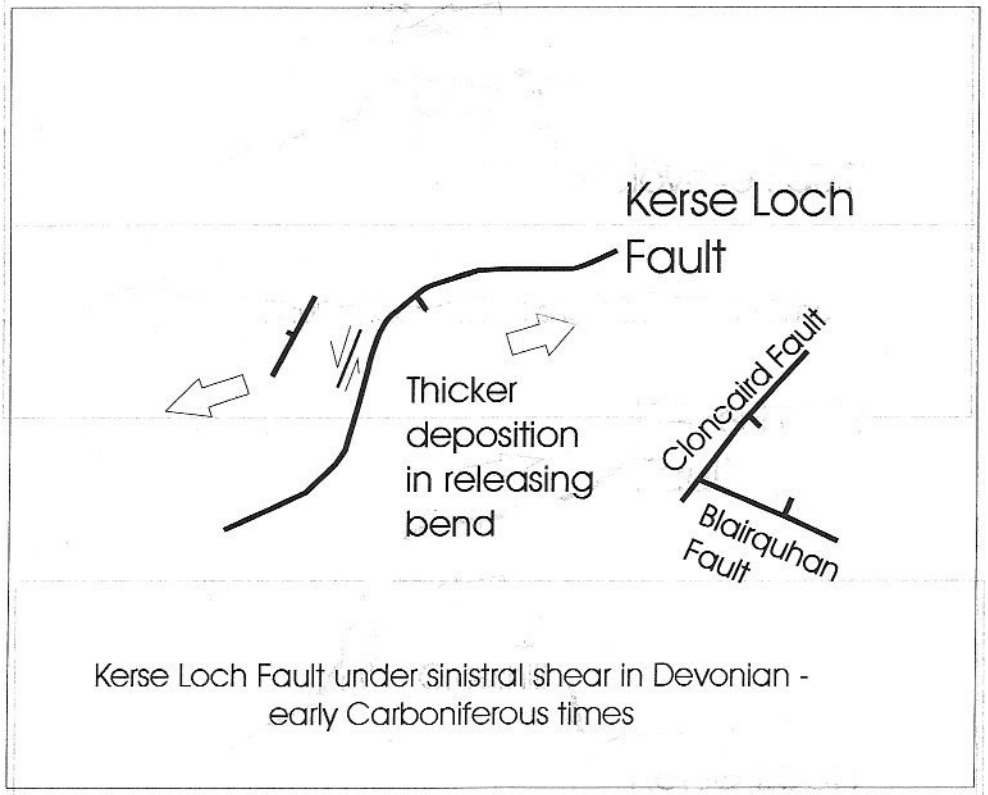


Figure 4. Models of fault movements in the Kirkmichael area