Chapter 1:

Geology and Soils

State of the Environment Report

EAST AYRSHIRE COUNCIL
STATE OF THE ENVIRONMENT REPORT
CHAPTER 1 – GEOLOGY AND SOILS

SUMMARY

Geological Status

Across Scotland the geology is diverse, formed over a period of approximately three billion years. The natural processes which have helped create this geodiversity include volcanism, plate tectonics and glaciation[1], together with erosion and deposition in water environments. The geodiversity of Scotland has helped progress knowledge in a variety of fields, including oil and gas exploration and mining.

East Ayrshire specifically contains a variety of soils and rock types. During the Quaternary Ice Age the superficial deposits of Scotland were transformed, this is reflected in the fact that 57% of East Ayrshire is covered by Glacial Till, with a further 22% made up of peat deposited in this time. The bedrock geology comprises a mixture of sedimentary rock, interspersed with igneous intrusions. Parts of this bedrock comprised the Scottish Coal Measures and as such East Ayrshire has seen large scale coal mining, in addition to other mineral mining. The Midland Valley of Scotland, identified as a potential unconventional gas resource, also lies beneath the Council area.

Trends in Geology and Soils

Historically large areas of upland bogs and lowland raised bogs were destroyed to make room for forestry and agriculture. Following the designation of Sites of Special Scientific Interest (SSSI) status to these features and the implementation of management plans the future of these peat reserves within East Ayrshire should be secured.

Coal extraction has historically been prevalent in East Ayrshire, however following improvements in techniques in the late 1980s there was a shift from deep underground mining to surface mining methods. There has been a steep decline in coal production in the UK (2015 was a new record low), Scotland and East Ayrshire and this trend is expected to continue. Imports of coal in 2015 were 39% lower than in 2014 reflecting a continuing drop in demand for coal.

As with the rest of the Central Belt, East Ayrshire has other mineral reserves, including rocks used for aggregate, however production has and will continue to be limited by relatively poorer transport links and competition from the remainder of the Central Belt.

The obtaining of shale oil and gas using unconventional methods is a topic which is attracting a lot of interest at present. East Ayrshire is underlain by the Midland Valley of Scotland, highlighted as a potential reserve of shale gas. Despite this, studies suggest that beneath East Ayrshire the reserves do not exhibit the correct properties to warrant further investigation and therefore other areas within the Central Belt are more likely to be explored. In addition to this a moratorium on granting consents for unconventional oil and gas developments in Scotland was put in place by the Scottish Government to allow time for further research and assessment of public opinion which will inform future decision making. The Scottish Government announced its preferred policy position not to support the development of unconventional oil and gas in Scotland in October 2017. This preferred position is currently subject to the necessary statutory assessments, prior to finalisation.

A separate moratorium and embargo on underground coal gasification (UCG) was also implemented in Scotland in 2016. The Scottish Government has indicated that it will not support UCG developments in Scotland following the publication of an independent report that highlighted serious environmental concerns.

1 Gordon, J.E. & Barron, H.F (2011). Scotland's geodiversity: development of the basis for a national framework. Scottish Natural Heritage Commissioned Report No. 417.

Status and Trend

OVERVIEW

1.1 Geology and Soils

1.1.1 Scotland Wide

Superficial

The ice age of the Quaternary Period had a significant effect on the formation of the superficial soils present today. During this period glaciers scoured the landscape, receding from the mountain tops and depositing till across much of Scotland. Sand and gravel deposits from seasonal and post glacial meltwaters were also left in their wake[2]. Consequently, most soils in Scotland are at most 13,000 years old, and may only be 10,000 years old in the Highlands and Islands. With such young soils the relationship between parent geology and drift type are still well defined[3]. More recently deposition of sediments (primarily clay, silt and sand) by floods, rivers, streams and lakes has occurred more locally.

British Geological Society (BGS) mapping identifies that the superficial geology of Scotland is dominated by Glacial Till, lain down by glaciers during the Quaternary Period, which began ~2.6 million years ago. The lithology of the deposits can vary; however, they normally comprise sandy, gravelly and silty clay with cobbles and boulders. They are typically weathered in the upper horizons, with higher moisture contents and lower strength. At a greater depth these typically become increasingly stiff.

Deposits of Glacial Sand and Gravel are common as a result of glacial, seasonal and final melt water deposition and Alluvium and River Terrace Deposits in the vicinity of surface waterbodies. Around some coastal areas Raised Marine Deposits are present, reflecting the changing nature of the shoreline over millions of years, in addition to Blown Sand and Marine Deposits. Peat is common across Scotland, with significant deposits in the far North, North West, South West and parts of East Ayrshire. Peat dates from the most recent part of the Quaternary Period and is composed from an accumulation of plant remains in swamps or bogs, resulting in anaerobic conditions.

Soil degradation poses a significant threat to the environment, economy and people. Soil degradation results from a number of natural and manmade causes, these and their subsequent effects are summarised below.

Table 1: Soil Degradation Processes & Consequences

Degradation Process	Primary Consequence	Knock on Effects
Loss of Soil Organic Matter	Reduction in soil fertility	Reduction in crop growth/ yield
	Discolouration of drinking water	Remedial measures required for waterbodies
	Reduction in filtration capacity	Reduced absorption of pollutants/ pollution of watercourses
	Reduced Water Storage Capacity	Increased risk of flooding
	Loss of Carbon	Release of greenhouse gasses to the atmosphere, contribute to climate change.
	Reduction/loss of habitat	Change in distribution of plants and animals, impact

2 BGS Geology of Britain Viewer

3 Brown, C. et al (1982). Soil and Land Capability for Agriculture, South West Scotland 1:250,000 Scale Sheet 6

Degradation Process	Primary Consequence	Knock on Effects
		on biodiversity.
	Impact on preservation on archaeological artefacts	Loss of items of historic significance.
	Increased risk of erosion	Loss of land
Soil Sealing (covering with an impermeable material)	Loss of productive land	Loss of arable/pastoral land.
	Loss of infiltration capacity	Increased runoff leading to increased risk of flooding. Loss of ability to filter contaminants, leading to pollution of watercourses.
	Loss of ability to store more carbon/ plant life removed.	End to photosynthesis, release of greenhouse gases to atmosphere.
	Loss and fragmentation of habitats	Interfere with natural paths and spaces.
Addition of contaminants/ loss of essential elements	Leaching of contaminants into watercourses	Damage to water quality and habitat and necessary clean up.
	Increased greenhouse gas emissions	Impact on climate
	Damage to habitats	Impact on biodiversity.
	Damage to crops	Reduction in yield/loss of crops.
	Increased soil concentrations	Risk to human health, flora and fauna. Land may no longer be suitable for purpose/ not economic to recover.
Erosion	Road closures	Loss of revenue/ repair cost/ social impacts.
	Loss of topsoil	Loss of soil fertility and consequent reduction in yields.
	Loss of infiltration capacity	Increased risk of flooding/ pollution to watercourses.
	Loss of carbon	Release to atmosphere/ water courses.
	Erosion of soil particles, releasing nutrients and potential pollutants to watercourses.	Impact on biodiversity/ water quality.
	Exposure and subsequent damage to archaeological features.	Loss of important historic information.
Compaction	Decreased infiltration	Increased risk of flooding, decrease in groundwater recharge.
	Decreased water & gas storage	Increase in greenhouse gas emissions and risk of flooding.
	Decrease plant productivity	Impact on crop yield.
Changes to soil biodiversity	Loss of soil structure	Impact on movement of nutrients, water and air through soil, reducing crop yield.
	Loss of infiltration & water storage capacity	Increased runoff leading increase risk of flooding and water pollution.

Degradation Process	Primary Consequence	Knock on Effects
	Impact on carbon cycling	Reduced carbon storage capacity.
	Reduction of single fungal species	Reduction in biodiversity.

The environmental, economic and social cost of degradation and subsequent impacts above are significant, and not only effect East Ayrshire and Scotland, but the entire UK and indeed the world. Developing specific policies and measures concerning soil degradation can help remove the pressure on soils, improving their quality or avoiding degradation in the first instance. This must be balanced with the need for new development, however considering and understanding the processes above should help local regulators, including East Ayrshire Council, in reducing and mitigating development which would result in negative environmental impacts.

Bedrock

Scotland's bedrock geology was affected by major tectonic events, proximity to plate boundaries, changes in Scotland's position on the earth, changing climates and consequently changing sea levels. As a result, the bedrock in Scotland ranges in age from the oldest to the youngest and includes igneous, metamorphic and sedimentary rocks. Significant coal reserves are found across the Central Belt of Scotland, swathes of sedimentary rock across southern Scotland, metamorphic rocks (including some of the oldest in the world) across the Highlands and multiple igneous intrusions across the country.

The bedrock geology is extremely varied across what is a relatively small country. In the south of Scotland, sedimentary rocks including sandstone, mudstone and siltstone dominate. Across the Central Belt of Scotland, a large area of Scottish Coal Measures is present, with workable coal seams at economically recoverable depths. Sedimentary rocks persist in some areas further north, including coastal areas, however the bedrock becomes dominantly metamorphic rock, commonly psammite, which is typically older and originally comprised sedimentary rocks. Large igneous intrusions dot the country, with notable areas including a band running east to west through the North, areas of the South West and North West. This presents a highly generalised view and local faulting and volcanic features create regional variations.

Land Capability

Soil is a vital, finite national resource which provides a wide range of essential environmental, social and economic functions, the most obvious of which is arable and pastoral farming. Scottish National Heritage's Land Capability for Agriculture mapping[4] records the majority of Scotland to comprise non-prime land, which is typically considered only to be suitable for a narrow range of crops, a moderate range with average production or suitable for rough grazing, this includes much of the land north of the Central Belt, and large areas of the South. However along the east coast and areas of the Central Belt the land is mainly considered prime, capable of producing a moderate to wide range of crops.

Topsoil

The amount of carbon stored within soils across Scotland is estimated to be some 3,000 million tonnes, representing the majority of the UK's carbon store[5].

Scotland's Soils Topsoil Organic Carbon Content (TOC) Map[6] is based on the digital version of the Soils of Scotland and Land Cover of Scotland maps. The carbon percentage has been

4 Soil Survey of Scotland Staff. (1981). Land Capability for Agriculture maps of Scotland at a scale of 1:250 000. Macaulay Institute for Soil Research, Aberdeen.

[5] The Scottish Soil Framework, Scottish Government (2009)

calculated from data held by Scottish Soils which comprises some 40,000 analyses. This categorises the topsoil into six groups: Low (<1.5%), Moderate (1.5-3%), High (3-5%), Humose (5-12%), Organo-mineral (12-35%) and Organic (>35%). The topsoil across much of Scotland comprises 5% or greater carbon content, however large parts of the east coast and central belt record Low to High levels.

Scottish National Heritage's (SNH) carbon rich soil (based on component soils) map[7] categorises the carbon richness of Scotland's soils based on the Soil Survey of Scotland (SSS) National Soil Map. The SNH map reclassifies the 580 soil mapping units of the SSS and places them into one of six categories, based on the peat content of the soils. The categories range from Category 6 which represents a peat soil down to a Category 1 mineral soil with no peat. Categories are dependent on whether a peat or peaty major soil subgroup is present in the main constituent of that map unit or as part of the subdominant soils which are occasionally found in the particular map unit. The map records a broadly east-west split across Scotland with mineral/organo-mineral soils in the east and across the central belt. Large areas of Category 5 organo-mineral soil with peat cover northern Scotland, the west and south west. Significant peat deposits are present in the far North and South West however large deposits are found scattered across much of the country. Peat is important as it holds large reserves of carbon which can be released into the atmosphere should the peat be disturbed.

Geological SSSI

The Geological Conservation Review (GCR) carried out by the Joint Nature Conservation Committee (JNCC) selected geological and geomorphological features which were deemed representative of Britain and therefore of national and international importance, most of which have been designated Sites of Special Scientific Interest (SSSI). These range from rocks, minerals and fossils to landform features. As of June 2012, 895 GCR sites were designated in Scotland, of which 23% had no SSSI designation, with a further 3% not fully protected. Earth Science features, GCRs with protected status, are found across Scotland however these are most concentrated in the North West. Soils are not specifically covered under SSSI designations however they are often integral parts of the features and require conversation.

SNH established a Site Condition Monitoring (SCM) Programme to assess the protected GCR sites across Scotland. Monitoring looks at attributes such as the quality of the appearance of the exposure, extent of feature, visibility and freedom to evolve naturally. The first cycle of monitoring ran from 1999 to 2005 and, of the features monitored, 89% were found to be in favourable condition whilst 1% were unfavourable recovering[8]. A review in 2012 recorded two features to be destroyed, twelve suffered some irreversible damage, 94% were in favourable condition and 3% were under positive management. The 2005 baseline established the features most commonly damaged were paleontology and mineralogy, caused by obscuring of the feature and irresponsible collection respectively.

Upland and Lowland raised bogs are one such important feature. Across Scotland the extent of lowland raised bog has declined from around 28,000ha in the 1800s to only 2,500ha now[4], mainly found across the South West, the Central Belt and the North East. Monitoring recorded 30% of raised bogs were in favourable condition, 28% unfavourable recovering and 42% unfavourable. Degradation is mainly due to historical damage including drainage and planting of forest to make way for agriculture and forestry. To maintain lowland bogs it is required to keep the water level at or close to the surface, and actions such as removing historic drains contribute to this as well as removal of encroaching heather, trees and shrub. SNH has supported a number of Lowland Bog Schemes which has resulted in an increase in these features assessed as being in favourable condition to almost 75% in March 2010.

6 Lilly, A.; Baggaley, N.; Donnelly, D. (2012) Map of soil organic carbon in top soils of Scotland. Map prepared for EU project GS-SOIL - Assessment and strategic development of INSPIRE compliant Geodata-Services for European Soil Data. ECP-2008-GEO-318004.

7 Scottish Natural Heritage (2012) Carbon-rich soils, deep peat and priority peatland habitat mapping 8 Scottish National Heritage (2010) Condition of Designated Sites

Scotland contains the vast majority of the UK's upland bog, comprising some 1.76 million of a total 2.2 million hectares, with significant concentrations in the north and west. Site Condition Monitoring by SNH recorded that 74% of sites were favourable or unfavourable recovering, although this varies depending on region. Causes for unfavourable assessments related to overgrazing and inappropriate burning. SNH has contributed to Peatland Management schemes which aim to block drains, remove scrub, manage burning and reduce grazing, despite this there has been a slight reduction in the number of favourable/recovering unfavourable conditions.

Mining and Mineral Resources (Coal & Hydrocarbons)

Scotland is rich in resources, both on and offshore. Offshore the reserves within Scotland's share of the UK Continental Shelf mean that when compared to the rest of the UK, Scotland accounts for 78% of total hydrocarbon production and 36% of total European hydrocarbon production[9].

Onshore, the main resource exploited is coal, almost all of which dates from the Carboniferous Period (~360-300 million years ago) and is formed from the remains of plants degrading over time under heat and pressure. Within Scotland exploitable coal is concentrated within the Scottish Coal Measures in the Central Belt of Scotland, consequently this area has seen large scale mining in the past and activity continues at present. Mining was historically carried out at depth underground, using techniques such as stoop and room and longwall, and nearer the surface using modern mining techniques and machinery. Seams of coal can vary in thickness from a few centimetres up to several metres.

Improvements in surface mining lead to the decline of underground mining across Scotland, with the last deep mine closing in the late 1980s in East Ayrshire.

The Midland Valley of Scotland contains Scotland's potential shale gas and shale oil resources, although the potential is less well defined than in the cases of the Bowland-Hodder and Weald Basin reserves in England due to complex geology and reduced availability of good quality constraining seismic and well data. The BGS and DECC carried out a study on the Midland Valley of Scotland to estimate the available resources. The initial scoping study area covered the Central Belt of Scotland, including East Ayrshire, however as a result of unfavourable data in some areas a smaller focussed study area was drawn up, covering the Lothians, Falkirk, Clackmannanshire and Fife. Four Carboniferous stratigraphic units contained organic rich, variably mature shale at suitable depths for shale oil and shale gas[10].

Mining and Mineral Resources (Other)

Onshore mineral resources are focussed mainly across the Central Belt of Scotland, however, they do exist elsewhere. Construction minerals in particular are located and extracted across Scotland. These include minerals for construction use, such as aggregates and for industrial use, such as iron ore. Access to markets and transportation are a significant factor in determining whether the mineral resources available are economically and legally extractable and therefore deemed mineral reserves.

4.1.1 East Ayrshire Specific

Superficial

Soil is formed by complex interactions between geology, landforms, parent materials, climate change and biological processes, with East Ayrshire no different from the rest of Scotland in containing a diverse range of soils formed from a number of different rock types under a

9 Scottish Government (March 2013) Oil and Gas Analytical Bulletin

10 Monaghan, A.A. 2014. The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation. British Geological Survey for Department of Energy and Climate Change, London, UK.

variety of environmental conditions. Broadly the Superficial geology of East Ayrshire is split as outlined in the table below and presented in Figure 1.

Table 2 - Generalised Superficial Geology

Superficial Deposit	Approximate Area (Ha)	Approximate Percent of Total Land Area (%)
Peat	28,230	22
Alluvium	5,159	4
Glacial Sand and Gravel	3,350	3
Glacial Till	72,408	57

The remaining geological resource comprises relatively small areas of Raised Marine deposits and areas for which the superficial deposits are not known and may represent shallow bedrock.

The superficial geology of East Ayrshire is similar to that found across Scotland as a whole. Glacial Till is recorded across the majority of the EAC area and is largely uninterrupted across the western half. Till typically comprises sandy, gravelly and silty clay with cobbles and boulders. These tend to become stiffer in the deeper, less weathered horizons.

Following Till, peat is the most common superficial deposit across EAC, with large deposits recorded in the south and east. These cover approximately 22% of the total superficial deposits. These are concentrated largely in the upland/moorland and forested areas.

Locally Alluvial soils are most commonly associated with the meander of larger water courses. A large strip of Alluvium, comprising clay, sand and silt, cuts through the north near Kilmarnock, approximately along the route of the River Irvine. At the start of this formation, in the west, a large area of Glacial Sand and Gravel is recorded, deposited in glacial outwash during the Quaternary Period.

A second significant area of Alluvium and Glacial Sand and Gravel is recorded in the vicinity of Garpel, where Greenock Water joins the River Ayr. The River Nith flows west from New Cumnock in the south east of East Ayrshire, large tributaries including Afton Water join it at this location and at the confluence large areas of Alluvium and Glacial Sand and Gravel are recorded. In the south west the River Doon flows west from Loch Doon and significant alluvial deposits are recorded here.

The areas noted above represent some of the most significant Alluvial and Glacial Sand and Gravel within East Ayrshire however, in the vicinity of all watercourses lesser quantities of Alluvium and Sand and Gravel deposits can be expected.

The National Soil Inventory of Scotland collected data on a regular 5km grid across Scotland, with results from a 10km grid available online, thirteen of these points are located within the East Ayrshire Council area. Of the 13, 6 record a major soil group of gley, which are soils developed under waterlogged conditions and the parent material is till, with imperfect or poor drainage. They develop under moorland or blanket bog and are principally used for rough grazing or forestry as they require better drainage for other uses. Three of the 13 record alluvial soils, from alluvium parent material, whilst a further 3 record some form of peat within their major soil group and major soil subgroup. The final sample relates to brown soil, from colluvium parent material[11].

Bedrock

Within East Ayrshire there is a succession of sedimentary rocks lain down over several geological periods, interspersed with multiple igneous intrusions and extrusions. The

11 Lilly, A., Bell, J.S., Hudson, G., Nolan, A.J and Towers, W. (Compilers) (2010) National Soil Inventory of Scotland 1 (NSIS_1) (1978-1988)

importance of many of these geological features has been recognised through the awarding of SSSI status. Although the bedrock across Ayrshire is varied the general statement of the sequence of rocks is as follows[12]:

Table 3 - Generalised Bedrock Geology

Carboniferous	Scottish Upper Coal Measures	Scottish Coal Measures Group
	Scottish Coal Measures	
	Millstone Grit	
	Upper Limestone Formation	Carboniferous Limestone
	Limestone Coal Formation	
	Lower Limestone Formation	
	Upper Sedimentary Group	Calciferous Sandstone Series
	Inverclyde Group	
Old Red Sandstone	Upper Old Red Sandstone	Pre Carboniferous
	Lower Old Red Sandstone	
Silurian	Wenlock	
	Tarannon	
	Llandovey	
Ordovician	Caradoc	
	Llandeilo	
	Arenig	

The normal succession of rocks is outlined above however, across East Ayrshire, the rock present beneath the superficial deposits varies, as seen on Figure 2. In the south Ordovician sandstones are recorded, Coal Measures are present across large areas in the centre and west, with Clackmannan Group sedimentary rock from the Carboniferous period in the north.

This bedrock sequence does not take into account the many igneous intrusions present across the Council area. Significant igneous intrusions are present in the southern tip (early Devonian granite and granodiorite), the central west (basalt surrounding Upper Carboniferous sandstone) and the north east (early Devonian to Permian rocks comprising large areas of Dalmeny and Jedburgh type lava basalt with trachyandesite and trachytic rocks), however smaller intrusions are present elsewhere.

Land Capability

Scotland's Soils Land Capability for Agriculture records East Ayrshire to comprise a range of soil classifications, shown in Figure 3. In the east and south classes 5 and 6 are predominant, representing land suitable as improved grassland or for rough grazing only respectively. In the centre large areas of category 4 soils are recorded, these may be suitable for producing a narrow range of crops, especially grass, however harvesting may be difficult. Around Kilmarnock a significant area of higher class category 3 soils is found, which represent soils which can support a moderate range of crops with average production, but potentially high yields of barley, oats and grass.

East Ayrshire has soils which are more suitable for crops than the majority of Scotland however when compared to the east coast of Scotland and neighbouring South Ayrshire, the soils are of comparatively low agricultural value.

Despite the comparatively low agricultural value soils are still a vital natural resource, not limited by their capacity for arable and pastoral use.

12 BGS Memoirs (1925) Economic Geology of the Ayrshire Coalfields Area II & Area IV

Topsoil

Scotland's Soils Topsoil Organic Carbon Content (TOC) Map, represented in Figure 4 records a large portion of East Ayrshire to comprise topsoil with carbon contents of 12-35% representing organo-mineral soils. These are focussed in the east and south and cover approximately 40% of the area. In the central and west the topsoil carbon contents are considerably lower, categorised Low to High. These levels are low compared with Scotland as a whole, with the large rural areas acting as a more significant carbon store.

Scotland's Soils soil carbon richness mapping based on component soils[13] records the majority of East Ayrshire to be covered by Category 3 organo-mineral soil (no peat) which comprises peaty major soil subgroup in the dominant soil. Northernmost East Ayrshire contains a large area of Category 6 soil, peat, and some organo-mineral soil with peat, as does a large area in the east, north of Muirkirk around Black Loch Moss, east of Cumnock at Glenmuir and in the south around Carsphairn Forest. In total Category 5 and 6 soils cover approximately a third of East Ayrshire. This is considerably greater than the coverage in East Scotland and the Central Belt however larger peat reserves are found in parts of the South West and North.

Geological SSSI

The Joint Nature Conservations Committee's Geological Conservation Review contains information regarding East Ayrshire within its database. Information can be collected via a search of 100km Ordinance Survey Grid squares, squares NS and NR cover East Ayrshire and within them 32 GCR's are recorded, these are summarised in the tables below and shown on Figure 5.

Table 4 - GCR Register Sites

GCR No.	Name	Block	Comment
1235	Ard Bheinn	Tertiary Igneous	Wide range of intrusive and extrusive igneous rocks.
1237	Drumadoon - Tormore	Tertiary Igneous	Evidence of basaltic and granitic liquids existing together.
1236	Glen Catacol	Tertiary Igneous	Inner Granite intruded without deforming earlier Outer Granite
1510	Kings Cave Drumadoon	Permian - Triassic	Not available
858	Laggan	Palaeozoic Palaeobotany	Fossils of vascular land plants
2399	North Glen Sannox	Ordovician Igneous Rocks	Section through one of the major developments of basic volcanic rocks in the Highland Border Complex.
1816	North Newton Shore	Non-Marine Devonian	Old Red Sandstone.
1239	South Coast of Arran	Tertiary Igneous	Large number of well exposed dykes.
2076	Ardrossan to Saltcoats Coast	Carboniferous – Permian Igneous	Sedimentary province
1379	Benbeoch Dalmellington	Midland Valley of Scotland	Sedimentary province
2836	Corrie Foreshore	Westphalian	-

[13] Scottish Natural Heritage (2016) Carbon-rich soils, deep peat and priority peatland habitat mapping

GCR No.	Name	Block	Comment
1524	Corrie Shore to Brodick	Permian - Triassic	-
1552	Corrie Shore, Arran	Dinantian of Scotland	-
1240	Corrygills Shore	Tertiary Igneous	-
3139	Dippal Burn	Silurian – Devonian Chordata	-
1238	Dippin Head	Tertiary Igneous	Dippin Sill contains variable dolerites.
2837	Dunaskin Glen	Westphalian	-
2389	Dunaskin Glen	Palaeozoic Palaeobotany	-
2344	Dundonald Burn	Quaternary of Scotland	Sediments at Dundonald Burn provide evidence of varying sea levels in the western Central Lowlands.
1574	Garpel Water	Dinantian of Scotland	-
400	Greenock Mains	Quaternary of Scotland	-
2430	Hare Hill (The Knipe)	Mineralogy of Scotland	-
1377	Howford Bridge	Carboniferous – Permian Igneous	-
1815	Largs Coast	Non-Marine Devonian	-
1565	Linn Spout	Dinantian of Scotland	-
1378	Lugar	Carboniferous – Permian Igneous	-
368	Nith Bridge	Quarternary of Scotland	Multiple till sequence evidence of multiple glaciers passing through the western Central Lowlands.
1566	Paduff Burn	Dinantian of Scotland	-
2804	Slot Burn	Arthropoda	-
392	Slot Burn	Silurian – Devonian Chordata	One of the richest fossil fish localities in the Silurian of Scotland
1207	Stairhill	Palaeozoic Palaeobotany	-
1567	Trearne Quarry	Dinantian of Scotland	-

Further data was not included on the state of these features however Scottish Natural Heritage's Pilot SSSI Condition Map records SSSI, which incorporates Earth Science features and records their classification. The information concerning soil and geological features within East Ayrshire is summarised below.

Table 5 - SNH SSSI Geology Sites

Name	Area	Feature Category	Feature	Date	Last Assessed Condition
Merrick Kells	South East	Quarternary Geology & Geomorphology	Quarternary of Scotland	24/09/13	Favourable Maintained
Merrick Kells	South East	Bogs (Upland)	Blanket Bog	17/09/09	Unfavourable Recovering
Merrick Kells	South East	Igneous Petrology	Caledonian Igneous	19/01/01	Favourable Maintained
Dalmellington Moss	South East	Bogs (Wetland)	Raised Bog	05/10/07	Unfavourable Recovering
Dunaskin Glen	South East	Palaeontology	Palaeozoic Palaeobotany	22/03/11	Favourable Maintained
Dunaskin Glen	South East	Stratigraphy	Upper Carboniferous (Namurian – Westphalian)	05/02/07	Favourable Maintained
Benbeoch	South East	Igneous Petrology	Carboniferous – Permian Igneous	06/08/09	Favourable Maintained
Nith Bridge	South West	Quarternary Geology & Geomorphology	Quarternary of Scotland	13/02/02	Favourable Maintained
Fountainhead	South West	Mineralogy	Mineralogy of Scotland	06/11/12	Favourable Maintained
Barlosh Moss	West	Bogs (Wetland)	Raised Bog	19/03/13	Unfavourable Declining
Muirkirk Uplands	East	Palaeontology	Silurian – Devonian Chordata	08/09/05	Favourable Maintained
Muirkirk Uplands	East	Bogs (Upland)	Blanket Bog	20/10/05	Unfavourable No Change
Blood Moss & Slot Burn	East	Palaeontology	Arthropoda	11/03/08	Favourable Recovered
Blood Moss & Slot Burn	East	Palaeontology	Silurian – Devonian Chordata	11/03/08	Favourable Recovered
Blood Moss & Slot Burn	East	Bogs (Upland)	Blanket Bog	20/10/05	Unfavourable No Change
Greenock Mains	East	Quarternary Geology & Geomorphology	Quarternary of Scotland	31/01/07	Favourable Maintained
Lugar Sill	East	Igneous Petrology	Carboniferous – Permian Igneous	12/02/02	Favourable Maintained
Garpel Water	East	Stratigraphy	Lower Carboniferous (Dinantian-Namurian)	22/01/07	Favourable Maintained
Howford Bridge	West	Igneous Petrology	Carboniferous – Permian Igneous	25/07/00	Favourable Maintained

The information above records all of East Ayrshire's peat resources designated as special geological features as in an unfavourable condition. The data contained on this site may yet

have to be updated to reflect the results of SNH's Site Condition Monitoring carried out in 2010 and any improvements which have been made as a result of the plans put in Lowland Bog Scheme and Peatland Management Schemes.

Scottish Natural Heritage's Site Condition Monitoring report on the Condition of Designated Sites records that across Scotland the number of lowland raised bogs in favourable condition rose from 58% in 2005 to 75.7% by 2010. Restorative measures can take time, potentially taking decades to re-establish.

The report also notes that in the west of Scotland the assessment of upland bogs recorded the most promising results, with 76% found to be in favourable condition whilst 14% were unfavourable recovering.

Mining and Mineral Resources (Coal & Hydrocarbons)

Scottish Coal Measures are present across the Central Belt of Scotland, including large areas of East Ayrshire. The Ayrshire Coalfield was worked using underground methods for over a century however the closure of the last deep mine at Barony, near Auchinleck in 1989 brought an end to this, with a focus shift to shallow and surface mining.

The highest potential for deep mining, classified as that at depths greater than 200m, exists in the centre, north west and south west of East Ayrshire, within the Middle Coal Measures, Lower Coal Measures and Limestone Coal Formation. Extensive shallow mining potential covers much of East Ayrshire, with locally important areas in the centre[14] , however, areas of igneous intrusions, including the central western boundary, north east and south have no potential for shallow mining. The accurate spatial extent of mining can only be confirmed at local levels using plans from the Coal Authority and even in this instance mining records are not complete.

The following table summarises the East Ayrshire entries from the 2014 Directory for Mines and Quarries relating to coal mining[15.]

Table 6 - Coal Extraction East Ayrshire

Name	Location	Lithology Worked	End Use
Crowbandsgate Rail Facility	New Cumnock	Surface -derived coal	Generator coal
Garleffan Preparation Site	New Cumnock	Surface -derived coal	Generator coal
Killoch Colliery Disposal Point	Ochiltree	Surface -derived coal	Generator coal
Duncanziemere Surface Coal Mine	Lugar	Surface	Generator coal
Greenburn Surface Coal Mine, Braehead Extension	New Cumnock	Surface	Generator coal
Greenburn Surface Coal Mine, Dalgig Farm Extension	New Cumnock	Surface	Generator coal
Greenburn Surface Coal Mine, Wellhill Farm Extension	New Cumnock	Surface	Generator coal
House of Water Surface Coal Mine Burnston Extension	Nith	Surface	Generator coal
Netherton Surface Coal Mine	Skares	Surface	Generator coal

14 Macdonald AM, Browne, MAE, Smith NA, Colman T and Mcmillan AA. 2003. A GIS of the extent of historical mining activities in Scotland: explanatory notes. British Geological Survey Commissioned report, CR/03/331. 12pp.
15 Cameron, D G, Bide, T, Parry, S F, Parker, A S, and Mankelow, J M, 2014. Directory of Mines and Quarries 2014: 10th Edition (Keyworth, Nottingham, British Geological Survey).

The list of former, present and impending future coal sites are summarised in Figure 6 (information is as correct in 2015). This shows the obvious correlation between areas where Coal Measures are recorded to comprise the bedrock, focussed mainly within the centre of East Ayrshire, and mining activity.

East Ayrshire is partially underlain by the Midland Valley of Scotland, which hosts the majority of Scotland's potential shale oil and gas resource. Carboniferous sedimentary and volcanic rocks form a succession of bands of rock over 5,500m thick in places. Bands of shale can be up to 50m thick within the bands of sedimentary rock. At present no unconventional oil and gas exploration has been carried out within East Ayrshire.

M*ining and Mineral Resources (Non Coal)*

As with the rest of the Central Belt, East Ayrshire has good mineral reserves however with many materials, transportation is an important factor in whether it is economical to mine these resources. Figure 7 presents the operational and consented quarries located in East Ayrshire (information correct as of 2015).

The following table summarises the East Ayrshire entries from the 2014 Directory for Mines and Quarries.

Table 7 - Mineral Extraction East Ayrshire (Non Coal)

Name	Location	Lithology Worked	End Use
Greenburn Surface Coal Mine, Dalgig Farm Extension	New Cumnock	Fireclay, Carboniferous	Brick Manufacture
Sorn Quarry	Sorn	Granodiorite, Silurian-early Devonian	Crushed rock aggregate
Sorn Quarry	Sorn	Sandstone, Silurian-Devonian	Crushed rock aggregate

The BGS was given a grant by the Scottish Government to produce a series of comprehensive mapping to enhance the sustainability of mineral resources across the Central Belt of Scotland, including East Ayrshire. The map shows surface mineral resources, mine workings and some specially designated areas, details on this mineral information are now summarised.

Crushed rock aggregate is used in a variety of applications including road surfacing and concrete. A variety of hard rocks are mined and their characteristics determine their application. East Ayrshire has many igneous rocks, suitable for use, however transport costs, relatively poor connections and competition within Scotland has limited the extraction. Tincornhill Quarry near Sorn, operated by Breedon Aggregates Scotland Ltd produces granodioritic rock and baked sandstone for aggregate, mined from the igneous Tincornhill Intrusion which comprises granodiorite and diorite from the Devonian and Silurian Periods. Curling stones were previously formed from quartz-diorite from Tincornhill. On the eastern boundary of East Ayrshire a large granitic intrusion from the Silurian to Devonian period, the Distinkhorn Complex, has the potential for igneous rock quarrying however this lies within the Muirkirk Uplands SSSI which is designated for its raised bogs and palaeontology.

Historically, substantial volumes of sand and gravel have been exported from the Darvel area in East Ayrshire to Glasgow and the surrounding area for production of ready mixed concrete.

Near Cumnock large sills form the Craigs of Kyle, Benbeoch, Benbain, Benquhat and High Mount, with historic olivine bearing dolerite mining taking place in these sills, however these rocks are unlikely to be suitable for roads based on their material properties. Around Kilmarnock small quarries worked lavas and sills but this was limited to local use. North of Kilmarnock an igneous extrusion from the Carboniferous period, the Troon Volcanic Member, is a potential resource for basalt.

North Drumboy Quarry has recently been consented for the phased extraction of trachyte (hard igneous rock) by blasting but it is not yet operational.

Sand and gravel are used as an aggregate, with their exact use dependent on size. The main reserves of sand and gravel in East Ayrshire are found in the Glacial Sand and Gravel deposits in the east. Within the Irvine Valley sand and gravel were quarried at Loudounhill until recently. Garpel Quarry is operational and will extract sand and gravel from glaciofluvial deposits near Smallburn in the east of East Ayrshire. The deposits in this area and further south near New Cumnock are thought to be a poorer resource than those found further north. Alluvial deposits along the channel of major rivers such as the Irvine have not been explored due to the height of the water table making extraction difficult. Silica sand, used in the manufacture of glass, is not found in East Ayrshire.

Historically metals were mined across East Ayrshire, including lead in the form of galena and other lead ore which was found in the area of Cumnock and New Cumnock. Barium ore in form of barite was also mined within the sandstone in this area, in significant quantities, however it is now likely to be economically exhausted. Ironstone was historically mined in the north near Uplawmoor and near Sorn in hematite veins however economic quantities are unlikely to remain. Gold grains were discovered by the BGS within the Permian Mauchline Volcanic and Sandstone formation in the vicinity of Mauchline however follow on commercial exploration found no significant reserves. Nickel, chrome and copper are not thought to exist in significant quantities in East Ayrshire.

A variety of sandstone is present within East Ayrshire bedrock and has historically been used as a building stone, particularly in Kilmarnock. The Ballochmyle quarries provided one of the largest sources of sandstone, with extensive workings around Mauchline. Mines near Stair in the west of East Ayrshire were previously quarried for a baked, hardened shale which was used as a whetstone, although not in use at present it may represent a specialised future resource.

Limestone is often used as aggregate however the presence of hard rock alternatives coupled with lack of high quality limestone means this is not the case in the Central Belt. Limestone was mined and quarried in East Ayrshire for use in agricultural lime. Pillar and stall mining of limestone was carried out at Craigdullyeart, east of New Cumnock, with quarrying undertaken near Muirkirk, New Cumnock and Patna. Limestone is unlikely to exist in economic quantities in East Ayrshire and tends to be of a higher quality and greater thickness elsewhere in the UK.

Brick Clay, used in the manufacture of bricks, requires a source of clays with predictable and consistent firing properties to ensure that it is economically viable to work. Glaciolacustrine clays were previously worked at Gargieston Brick and Tile Works in the Irvine valley, Burntfoot Tile Works at Ochiltree and at Cronberry. Glaciomarine deposits were worked at Kilmarnock and alluvial clays have been worked locally in East Ayrshire at Drongan and Lugar.

Fireclay, comprising clay and various minerals, is typically used for high quality bricks and is found alongside Carboniferous coal and Passage Group silica sandstone. It was formerly mined in East Ayrshire and reserves remain however they are unlikely to be economically viable.

Peat was historically used as a fuel and is present across large areas of East Ayrshire, however, it is now more likely to be used for agriculture and not thought to be of significant economic interest, particularly due to its environmental importance.

STATE AND TREND – DETAILED ANALYSIS

2.1 Superficial Deposits

East Ayrshire has large areas of carbon rich soil, peat covers approximately 22% of the Council area, and includes lowland raised bogs and upland blanket bog. Historically large areas of peat have been disturbed to make way for forestry, mining and agriculture however East Ayrshire still contains significant quantities. SNH has assessed the condition of these sites; however, up-to-date site specific information is not available. The general trends outlined suggest that the upland bogs have been improving and the majority are now in favourable condition. Lowland raised bogs are largely in a favourable/unfavourable recovering position across Scotland but site specific information available online may be out of date. With management plans in place and protection under SSSI status these sites should continue to improve and remain in place. Ensuring these features remain is of vital importance as their destruction would result in the release of vast quantities of greenhouse gases to the atmosphere and contribute to climate change.

Sand and gravel quarrying has occurred historically within East Ayrshire and is still continuing at present, with resources available elsewhere. The extent of this trend largely depends on the trend of sand and gravel quarrying elsewhere in the Central Belt as it is often more economically recoverable.

2.2 Bedrock

East Ayrshire has a varied bedrock geology, however, the effects of historical mineral activity on this, with the exception of removing mineral resources locally, is low. Mineral quarrying has occurred historically in East Ayrshire, including quarrying of aggregate, sand and gravel and metalliferous minerals. Quarrying is ongoing at present at Tincornhill for hard rock extraction, with consents in place for quarries at Garpel Quarry (sand and gravel- operational), and North Drumboy (crushed rock - operational). East Ayrshire has mineral resources remaining however transportation links and competition from the remainder of the Central Belt means it is likely mineral abstraction will remain relatively low.

2.3 Mining and Mineral Resources (Hydrocarbons)

Coal mining in East Ayrshire has a long and rich history, consistently producing levels of coal which are significant for the UK as a whole. Below ground mining was widespread in East Ayrshire, however, with the closure of the last deep mine in the 1980s and an improvement in techniques means it is unlikely deep coal reserves which remain in situ will be mined unless new technology allows enhanced recovery which would allow these to be worked economically.

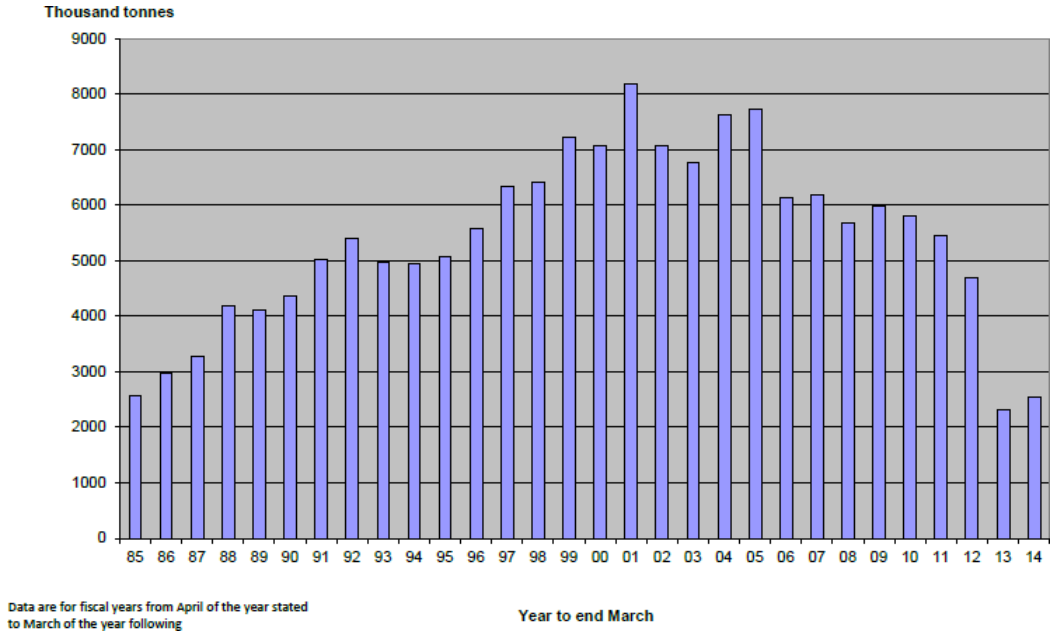
The extraction of coal using surface methods took over following the closure of the pits and East Ayrshire has provided at least 48% of Scotland's total coal production in the years 2003 to 2013. While the overall East Ayrshire share of Scottish production in 2015 was 43.5%, this does not reflect significant drops during the year. The drop in East Ayrshire production between Q1 and Q4 2015 was 91%, and in Q4 2015 East Ayrshire produced less than 20% of the Scottish total. This downward trend is expected to continue.

Table 8 – East Ayrshire Share of UK Coal Production (Source: Extracted from Coal Authority[16])

Period	*EAC share of Scottish opencast production*	*EAC share of UK opencast production*	*EAC share of UK total coal production*
2012	53.6%	25.4%	15.8%
Q3 2015	21.3%	3.5%	2.4%
Q4 2015	19.9%	2.8%	1.9%
Whole of 2015	43.5%	9.5%	6.4%

Overall saleable coal across Scotland has dropped as shown on Figure 8.

Figure 8 – Coal production in Scotland 1985 – 2014 which shows the decline (source British Geological Survey[17])

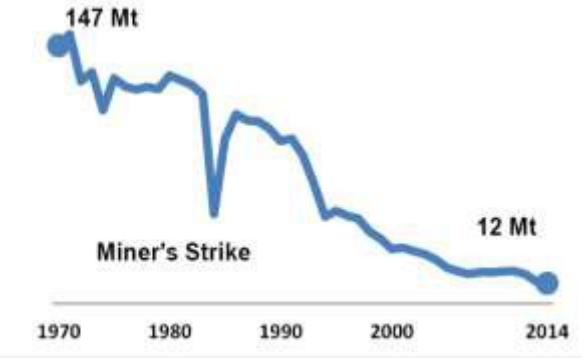


The production of coal in the UK has dropped significantly and has been recorded as a record low for 2014 (Coal Authority) as shown in Figure 9 below.

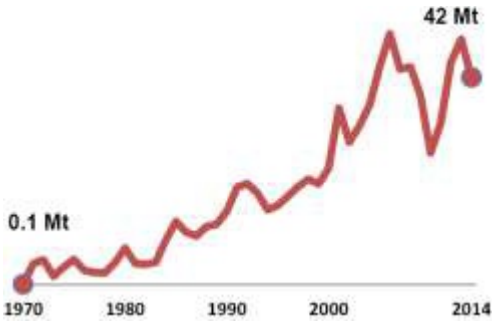
[16] https://www.gov.uk/government/statistics/solid-fuels-and-derived-gases-section-2-energy-trends

[17] https://www.bgs.ac.uk/mineralsuk/mines/coal/occ/home.html

Figure 9 – UK Coal Production 1970-2014[18] showing a previous record low in production of coal in the UK.



Coal Production in UK



Coal Imports to UK

Imports of Coal from the three main regions of US, Colombia and Russia are also in decline due to reduced demand from power stations and industry. This downward trend has continued in 2015 for both production and import. The latest Coal Authority figures for coal production for the third quarter of 2015, is at 1.5 million tonnes (a new record low), which was 52% lower than in the third quarter of 2014. This continued decline is attributed to mine closures and mines producing less coal as they are coming to the end of operation[19]. Scotland produced 171,108 tonnes of coal during Q3 of 2015 with East Ayrshire producing 21% of this volume at 36,502 tonnes.

Total coal imports in quarter 3 of 2015 were 4.4 million tonnes, 46% lower than in the same period in 2014. This was its lowest value for over 17 years.

Both the UK Government and Scottish Government are concerned with energy security and energy mix/importing of gas (Liquified Natural Gas, LNG), and the importance of moving to low carbon energy portfolio and this has prompted a review of unconventional gas resources. Shale oil, shale gas, oil-shale, coal bed methane (CBM) and underground coal gasification (UCG) are all distinct hydrocarbon resources which are grouped under the term of 'unconventional gas'

An assessment undertaken by the British Geological Survey (BGS) scoped the entire Central Belt (see Figure 10) and considered a variety of geological, geochemical and geomechanical criteria to assess whether the resources exist, at what quantities and whether they are suitable. The characteristics are based on US data and represent both essential and desirable features, including factors such as organic matter content, clay content, thermal maturity, thickness and depth amongst others. As a result of this analysis large areas were discarded prior to further study, including East Ayrshire. Within the basin four units containing organic rich, variably mature shale at depths suitable for extraction were identified including the Limestone Coal Formation, Lower Limestone Formation, West Lothian Oil-Shale unit and Gullane unit[20]. The areas covered include Glasgow, the Lothians, Falkirk, Clackmannanshire and Fife. Based on the findings of the BGS it is unlikely developers would target East Ayrshire, with more promising reserves found elsewhere in Scotland.

[18] Digest of United Kingdom Energy Statistics – Chapter 2 Coal, 2014 (published December 2015): https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/338750/DUKES_2014_printed.pdf

[19] DECC, UK Energy Statistics, Q3 2015: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/487871/Press_Notice_December_2015.pdf

[20] Monaghan, A.A. 2014. The Carboniferous shales of the Midland Valley of Scotland: geology and resource estimation. British Geological Survey for Department of Energy and Climate Change, London, UK.

Any future proposal for unconventional oil and gas development would be progressed following the established licensing (Petroleum Exploration and Development Licences (PEDL)), Planning, or the permitting regime requirements.

Figure 10 – Extract (Figure 2) from Monaghan, A.A. 2014 showing the Scoping Study area associated with the Midland Valley of Scotland.

As shale oil and gas resources do exist beneath East Ayrshire future exploration cannot be fully discounted however as resources in England and elsewhere in the Central Belt are likely to be explored first, regulation and monitoring data from elsewhere would help East Ayrshire Council with their duty as regulators. Lessons have already been learned from unconventional oil and gas exploration in the United States, informing UK legislation and licensing/permitting. Knowledge gathered from events at Preese Hall in Lancashire (induced seismic activity near the site in 2011) and resulting studies (including monitoring) also provided important information and recommendations for future works as have other more recent applications for new licenses in England. It should be noted that hydraulic fracturing (use of fluids to enhance gas recovery) is not a new method of extraction having been used in both water supply wells and fossil fuel wells for many years in the UK and has been carried out in Scotland.

The Scottish Government announced its preferred policy position not to support the development of unconventional oil and gas in Scotland in October 2017. This preferred position is currently subject to the necessary statutory assessments, prior to finalisation.

PRESSURES

3.1 Peat Loss

East Ayrshire has considerable quantities of peat and carbon rich topsoil, destruction of which releases potentially significant amounts of carbon dioxide into the atmosphere. Surface coal mining requires large areas of land, which could destroy this peat resource if carried out in the same location. As the lowland and upland bogs are protected by SSSI designation the Council would be required to consider whether they would consent to any mining activities within the immediate vicinity of one. Further information on the potential habitat impacts and impacts on designated sites resulting including loss of peat can be found in Chapter 3 Ecology. Generally, the loss of peat results in the release of greenhouse gasses to the atmosphere, reduced water storage and reduced filtration which can lead to an increased risk of flooding and pollution of watercourses, in addition to contributing to climate change.

3.2 Land Use Change

Loss of productive agricultural soils, whilst of note and potentially of local importance, is unlikely to be of high significance in the context of East Ayrshire given the quality/quantity of the soil. In adjacent South Ayrshire the quality and quantity of soil available from agriculture is much greater. In addition, if quarries or coal sites are properly reinstated they could retain some agricultural value.

When development takes place, the ground which it is built on is effectively sealed and natural processes can no longer take place. Even if the development is later demolished and the ground reinstated it can still take time to re-establish itself. Therefore the soil type upon which development is to take place and the land take of the development should be considered, and where possible developments should take place on Brownfield sites.

Compaction of soils, through earthworks and increased activity over the ground, can result in a decrease in infiltration, a reduction in water and gas storage and decreased plant productivity, which can cause issues including increased runoff, which can lead to erosion and flooding.

3.3 Contamination

Contaminations of superficial soils can impact on human health, flora and fauna, potentially making land unfit for purpose and affecting biodiversity. In turn contamination of soils can result in chemicals leaching into watercourses, damaging water quality and potentially affecting biodiversity.

Part IIA of the Environmental Protection Act 1990 (EPA) ('Part IIA'), which came into force in July 2000, provides the legislative framework for the identification and remediation of contaminated land. The East Ayrshire Council Contaminated Land Strategy[21] identified 2,240 historical industrial sites with potential for contamination risk. The Strategy sifts these sites into 5 categories:

- Priority 1 (very high risk) – further inspection required -114 sites
- Priority 2 (high risk) – further inspection required – 533 sites
- Priority 3 (medium risk) – further inspection required – 760 sites
- Priority 4 (low) and Priority 5 (very low) - no further inspection required – 813 sites

As sites with historical contamination are progressed through the planning system and are developed, the overall level of contaminated sites will decline. This, coupled with regulation of current industrial processes e.g. through Pollution Prevention and Control permitting should prevent contamination of sites in the future.

There is currently no legislative driver under Part IIA to identify sites with potential radioactive contamination – there are no designated Part IIA Radioactive Contaminated Land sites in Scotland currently. If and when any sites do become designated, East Ayrshire Council would be notified under Part IIA legislation and measures to address issues would be implemented through the planning system should development be proposed.

Where sites are not covered by Part IIA, East Ayrshire Council has a duty through development management to ensure land is 'suitable for its proposed use' and this includes ensuring that the public are protected from radioactivity from developed land. Changing how land contaminated with radioactivity is used e.g. change from industrial to residential use may increase the exposure of people using the land in the future and is regarded as a practice under the Basic Safety Standard (Scotland) Direction 2000. For members of the public the dose constraint appropriate to a practice is 0.3mSv per annum, where mSv or millisievert is a

[21] http://www.east-ayrshire.gov.uk/Resources/PDF/C/Contaminatedlandstrategy.pdf

measure of the rate of absorption of radiation by the human body. East Ayrshire Council will take account of radioactive contamination within the planning regime to ensure requirements of Basic Safety Standards Direction are met in accordance with the principals of ALARA (as low as reasonably achievable).

It should be noted that throughout the second cycle of River Basement Management Planning (RBMP), SEPA intends to work in collaboration with local authorities in order to improve evidence of impacts on the water environment from land contamination – see also Chapter 5.

3.6 Climate Change

Climate change will be one of the main pressures on soils and geology in East Ayrshire over the coming years. As our climate becomes more hostile, flood events are expected to become more severe and frequent. Such events have the ability to wash out river channels and undermine slopes, increasing the risk of landslides. It is important to ensure proper Sustainable Urban Drainage Systems (SUDS) provision for new developments are implemented along with management to limit surface water runoff in the event of flood events, with the aim of maintaining or improving the Greenfield runoff rate, preventing the developments becoming detrimental to the geodiversity. It is also important to consider the need for flood defence measures to limit damage from fluvial flooding. There is potential for other impacts of climate change in Scotland (e.g. changes to air quality/heatwaves) and these will also be important in planning considerations (see Chapter 4 Air Quality and Chapter 6 Climate Change). The need to move to a low carbon future will also shape decisions regarding the energy mix in Scotland, including any consideration of unconventional oil and gas exploration. Ensuring legislation is in place for the protection of soils is one measure through which regulators can ensure we can attempt to reduce and mitigate against the effects of climate change. Soils act as a natural store and filter for rainfall and ensuring degradation of soils is limited, and improving soils where possible, means their ability to limit surface water runoff and help filter chemicals can aid in reducing flooding, which in turn can further damage soils and cause erosion and outwash.

CONCLUSIONS

4.1 Conclusions

East Ayrshire has a good geodiversity and contains resources which are important on a Scottish, UK and European level. Protection and management plans are in place to protect important resources such as peat, however, the abandonment of surface mining sites highlights the need to focus on geology and soils in legislation to ensure it is considered and protected as part of planning policy. At present the protection of Scotland's soil geodiversity is not covered by one specific document but is instead covered in parts through different pieces of legislation for sectors such as environmental protection and farming. These areas of legislation typically only focus on protecting one aspect of soil quality rather than the resource as a whole. It is important this lack of legislation is addressed to ensure geodiversity is protected and ensure that soil degradation is halted or restored where possible.

The Scottish Soil Framework (2009) was brought in by the Scottish Government in order to begin a process of ensuring key stakeholders work together to achieve better soil protection. As an action of the Framework the Scottish Government produced The State of Scotland's Soil (2011), which collated existing data and evaluated the threats to Scotland's soils. The principal threats were identified as loss of organic matter, changes in soil diversity, erosion and landslides. The report concluded that there was a need for policy integration, to fill gaps in knowledge and to understand soil management.

Scotland's Geodiversity Charter (2012) aims to highlight the importance and value of Scotland's geodiversity. It hopes to better integrate the protection and management of sites into relevant policy and guidance in order to conserve and enhance geoheritage. Local Authorities can support this target a number of ways outlined in the Geodiversity Charter.

These include acknowledging the value and importance of geodiversity within relevant policy and guidance, promoting geodiversity as an attraction, forming partnerships with local groups to help collate information and developing plans and finally encouraging developers to consider geodiversity and allowing access to information. The Local Development Plan policy should therefore include provisions for the protection of geodiversity, bringing it more in line with the existing provisions for biodiversity.

MINERALS

5.1 Summary

East Ayrshire has a long history of minerals extraction firstly with deep coal mining which included the first deep mine opening at Barony Colliery 1908 (closure in 1989) followed by surface coaling methods of extraction. Many of the rural villages and towns in East Ayrshire have developed as a result of the coal mining industry and associated industry.

Deep mining has been in decline since 1984, following a peak of 217 million tonnes in 1954, falling to a low of 4 million tonnes in 2013 resulting from closure of a number of sites. Surface mining in contrast experienced a year on year growth to a peak in 1991 of 21 million tonnes and slower declines to current levels. Surface production fell by 20% between 2012 and 2013 due to significant sites entering into liquidation combined with geological issues at other sites making production more complex.

In Spring 2013, Scottish Coal Company Limited (SCCL) and Aardvark TMC Ltd, both with major surface mining operations across East Ayrshire, were placed into liquidation. The coal mining sector was a key industry for a number of the rural villages and towns in East Ayrshire and the closure has had a significant adverse impact upon these communities.

There is only 1 opencast coal mineral site in East Ayrshire which is operational (House of Water). This site along with 6 other sites are subject to a programme of compliance monitoring with quarterly reporting submitted to the Council's planning committee plus an annual report.

- Duncanziemere (Hargreaves-coaling operations complete.)
- Netherton (Hargreaves- coaling operations complete)
- House of Water (Hargreaves-operational)
- Wellhill Farm (Kier- coaling operations complete)
- Auchincross Farm (Kier- coaling operations complete)
- Dalgig (Kier- coaling operations complete.)
- Braehead (Kier- coaling operations complete.)

Restoration and Aftercare

A number of former opencast coal sites within East Ayrshire have commenced or completed their restoration schemes and some are on a programme of aftercare works. The following sites are subject to compliance monitoring on a quarterly basis. Information is accurate as of 23rd November 2018[1]:

- Dunstonhill (Hargreaves- now completed its restoration scheme and aftercare works remaining)
- Ponesk (Banks- restoration works completed August 2018)
- Spierslack (Banks- Restoration works completed and aftercare works remaining)
- Skares Area D (Hargreaves- Restoration works ongoing)
- Chalmerston (Restoration works to begin)
- Garlaffan/Grievehill (Restoration works to begin)
- Dalfad (Restoration works to begin)

Aggregates

A number of quarries in East Ayrshire are subject to compliance monitoring. Information correct as of 23rd November 2018. These include:

- Tincornhill Quarry (Breedon- operational)
- Garpel (Hillhouse Quarry- operational)

[1] Report to Planning Committee dated 23rd November 2018- Compliance Monitoring: Update of Major Developments in East Ayrshire, East Ayrshire Council.

- North Drumboy (Breedon- operational)
- The Meadows (Keith Montgomery LTD- operational)

Two quarries are currently progressing through their restoration schemes or have completed their restoration scheme:

- Loudoun Hill (Tarmac- restoration works concluded and aftercare works remaining)
- Clawfin (Scottish Power Energy Networks- Quarry reverted to control under Forestry Permitted Development Rights)

There are also applications pending for amendments to existing working arrangements which will be subject to scrutiny through the planning system. The Minerals Local Development Plan directs future development and restoration proposals. The Plan also provides guidance on the future restoration and reuse of abandoned and unrestored minerals sites.

5.2 Impacts from Mineral Extraction on Geology and Soils

5.2.1 Loss of Potential Development Sites

Surface mining has a considerable detrimental effect on soils and geology as it can effectively sterilise large areas of land for future development. To reach the coal seams, operators must first remove the superficial deposits and overburden, often set aside to be backfilled as part of progressive restoration. The resulting conditions comprise Made Ground and would not be suitable for redevelopment, unless the entire area was backfilled to an engineering specification, at significant cost. The area of surface coal sites currently covers 11607ha of land in East Ayrshire, representing 9% of the total land area of the county. This figure includes the planning boundaries included on Figure 7 which includes a variety of site types including those at application stage, operational and abandoned. These boundaries will not represent the actual area mined but give a strong indication of the land area taken and the need to have in place end decommissioning plans.

Backfilling of historic sites is unlikely to have been carried out to an engineering specification, and therefore the ground is prone to settlement. Although development on restored surface coal mining sites is not impossible the risks and costs to address them can render sites unsuitable or uneconomical for certain types of development.

Ground gas is an additional risk, incorporating both mine gas and gas generated by the backfill. This can include depleted oxygen and elevated levels of carbon dioxide, carbon monoxide, methane and hydrogen sulphide. If any developments were to occur within these locations ground gas monitoring is required and ground gas protection measures may be necessary. Ground gas can also migrate and therefore can impact on surrounding land. The potential for generation and spread of ground gas is site specific and is dependent on the nature and extent of the materials and underlying/surrounding ground conditions as well as the Receptors that might be impacted. A site specific risk assessment including preparation of a Conceptual Site Model (CSM) would determine potential risks associated with ground gas. This would then inform any remedial and monitoring requirements, both during the construction/development phase and post completion.

5.2.2 Resulting Seismicity

Seismicity in the UK is low by global standards, with earthquakes measuring 5ML(local magnitude) on the Richter Scale every twenty years and 4ML every 3 to 4 years. Seismicity can be induced by active mining processes, including both traditional mining and new unconventional mining techniques.

The Department of Energy and Climate Change (DECC) suspended fracking operations near Preese Hall, Lancashire due to increased seismic activity and commissioned a report into the cause. The report concluded that the seismicity was induced by hydraulic fracturing, with fluid injection entering an adjacent fault zone, affecting the stresses and causing it to fail in a series of small earthquakes[23].

Coal mining activities and the settlement of abandoned mines have induced seismicity in the UK previously however this has typically been smaller in magnitude than natural seismicity and no greater than $4M_L$[24]. The events attributed to hydraulic fracking at Preese Hall registered $2.3M_L$ and $1.5M_L$ and estimates predict that seismicity should be no greater than $3M_L$, below that experienced as a result of coal mining and below that which occurs naturally. Earthquakes within this range may be felt, however, they would be unlikely to cause damage.

The potential for hydraulic fracturing within East Ayrshire is low, based on available data; however the impact of this in terms of induced seismicity and fracturing is minor in comparison to naturally occurring seismic events and fractures. Despite this the public are apprehensive of induced seismicity and many campaign groups have been set up to oppose unconventional gas development.

5.2.3 Contamination

Although contamination resulting from mining generally has a lower impact than more heavily contaminating industries such as gas works, remedial measures may still be required to ensure sites are fit for purpose/ not impacting on the water environment. Expected contaminants include metals such as zinc, lead and copper along with acidic mine drainage contaminants - iron, sulphide, manganese. Around the infrastructure and processing works other contaminants such as hydrocarbons and asbestos may be expected, however these tend to be localised. Colliery spoil may have been left in place in the vicinity of the mine workings which can act as a potential source of mine gas and may also contain contaminants such as metals, PAH, asbestos and hydrocarbons. In order to carry out a detailed assessment of the abandoned surface mining sites within East Ayrshire chemical testing would be required, however geotechnical issues are more likely to present the most significant constraint to any future development.

Colliery spoil can present a risk of ignition and, in any future development, areas in the vicinity of this would require testing of the calorific content.

In relation to unconventional gas extraction, the primary potential sources of contaminants to soil are:

- pollution from an unexpected release of fracturing fluid, drilling fluid, produced water and flowback water e.g. from a failure in the well; and
- pollution from the uncontrolled disposal of liquid or solid waste containing potentially polluting substances either at depth or at the surface.

[23] Green, C A, Baptie, B J, Styles, P, (April 2012) Preese Hall Shale Gas Fracturing Review & Recommendations For Induced Seismic Mitigation
[24] The Royal Society & Royal Academy of Engineering (June 2012) Shale Gas Extraction In The UK: A Review Of Hydraulic Fracturing

East Ayrshire Council as planning authority would be one of a number of bodies that would be involved in consideration of any future application for unconventional gas extraction. The potential environmental impacts would be assessed through legislative and regulatory regimes including Environmental Impact Assessment (Scotland), Regulations 2011, Water Environment (Controlled Activities) Regulations 2011 (known as CAR) and Pollution Prevention and Control (Scotland) 2012 (PPC) regulations.

5.3 Conclusions

Mineral extraction has exploited the geological resource of East Ayrshire for over a century. Extraction of coal in East Ayrshire is declining steeply. The latest Coal Authority figures for coal production for 2017, in the UK is at 3,041 tonnes. This continued declined is attributed to mine closures and mines producing less coal as they are coming to the end of operation[25]. Demand for coal for power generation coupled with other energy prices is also contributing to the changes.

The extraction of coal using surface methods took over following the closure of the pits and East Ayrshire has provided at least 48% of Scotland's total coal production in the years 2003 to 2013. While the overall East Ayrshire share of Scottish production in 2015 was 43.5%, this does not reflect significant drops during the year. The drop in East Ayrshire production between Q1 and Q4 2015 was 91%, and in Q4 2015 East Ayrshire produced less than 20% of the Scottish total. This downward trend is expected to continue.

Total coal imports in 2017 were 8,498tonnes.

Many of the former surface coal mining sites are moving to a phase of restoration or have completed their restoration schemes which will bring opportunities for education in geology through interpretation and access to visible surface elements such as coal seams. It may be appropriate for East Ayrshire to complete a geodiversity audit to identify key features and options for sustainable management.

Construction aggregates are an important part of the local economy in East Ayrshire and there are a number of sites in operation across the council area.

[25] DECC, UK Energy Statistics, Q3 2015: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/487871/Press_Notice_December_2015.pdf

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DECC, UK Energy Statistics, Q3 2015	https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/487871/Press_Notice_December_2015.pdf	March 2019

GLOSSARY OF KEY TERMS

Alluvium - deposit of clay, silt, and sand left by water in a river valley or delta, typically producing fertile soil

Backfilling - Backfill is the material used to fill voids created by mining excavations

Bog - a wetland that accumulates peat, a deposit of dead plant material

Climate Change – world-wide, long term change in weather patterns and/or average temperatures of the planet caused by human activity

Contamination – introducing harmful material to another material – land can become contaminated by a variety of substances, from heavy metals to agricultural waste.

Fracking - The technique of hydraulic fracturing, also known as 'fracking'. The fracturing techniques are used to stimulate the recovery of oil and gas. The process of hydraulic fracturing involves pumping water into the source rock at high pressure so that the rock fractures and releases the trapped gas.

Geodiversity – the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them

Geomorphology - study of the physical features of the surface of the earth and their relation to its geological structures

Glaciation- the process or state of being covered by glaciers or ice sheets

Hydrocarbon - organic compound consisting entirely of hydrogen and carbon.

Igneous - Igneous rock is formed when magma cools and solidifies

Metamorphic - Metamorphic rocks are those which have changed from their former rock type, through a process called metamorphism, which means "change in form". The original rock (protolith) is subjected to heat (temperatures greater than 150 to 200 °C) and pressure (1500 bars), causing physical and/or chemical change.

Palaeontology - the study of fossils as a way of getting information about the history of life on earth

Peat - accumulation of partially decayed vegetation or organic matter

Plate Tectonics - Plate tectonics refers to the theory developed in the 1960s to explain how the continents move across the Earth's surface.

Quaternary Period – a subdivision of geological time (the Quaternary Period) which covers approximately the last two million years up to the present day

Sedimentary - Sedimentary rocks are formed from sediments that have settled at the bottom of a lake, sea or ocean, and have been compressed over millions of years

Seismicity - frequency, intensity, and distribution of earthquakes. Seismicity can be natural such as those caused by volcanic eruptions or induced if they are caused by man-made activity such as energy generation

Shale - Shale is a fine-grained sedimentary rock that forms from the compaction of silt and clay-size mineral particles.

Shale Gas - natural gas occurring within or extracted from shale

Shale Oil - A type of unconventional oil found in shale formations

Site of Special Scientific Interest - Site of Special Scientific Interest (SSSI) is a conservation designation providing protection at the UK level which best represent our natural heritage - its diversity of plants, animals and habitats, rocks and landforms, or a combinations of such natural features.

Soil Degradation - decline in soil quality resulting from activities including agricultural, industrial or urban purposes

Stratigraphy - branch of geology which studies rock layers (strata) and layering (stratification).

SUDS - Sustainable drainage systems are drainage methods that provide an alternative to the channelling of surface water through networks of pipes and sewers to nearby watercourses.

Superficial - being at, on, or near the surface

Unconventional gas - The term unconventional gas refers to natural gas held in rocks that cannot be exploited using traditional methods. Shale and coal are source rocks for unconventional gas.

Volcanism - eruption of molten rock (magma) onto the surface of the planet

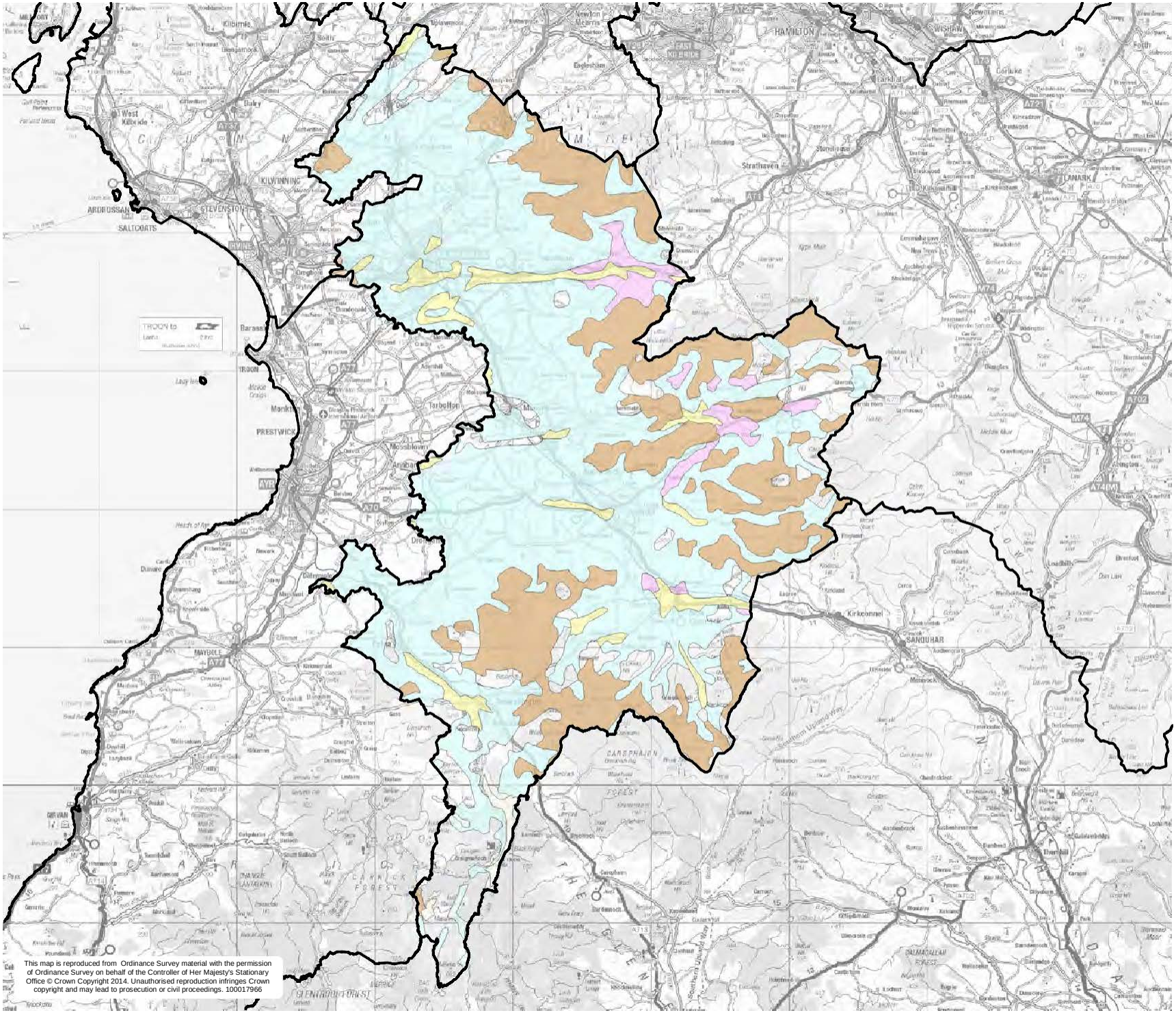

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Figure 1.1

Superficial Deposits

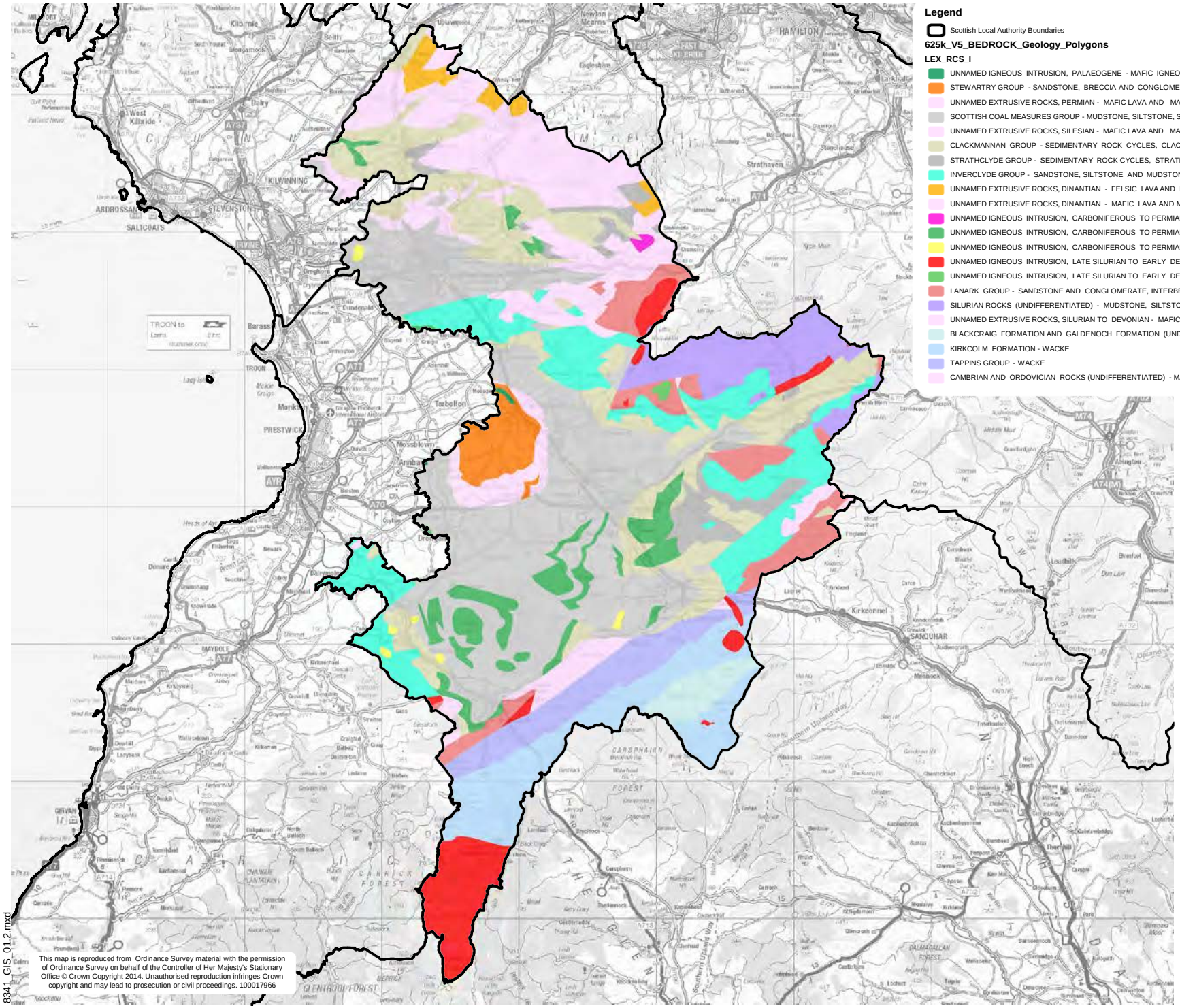

Figure 1.2

Bedrock Geology

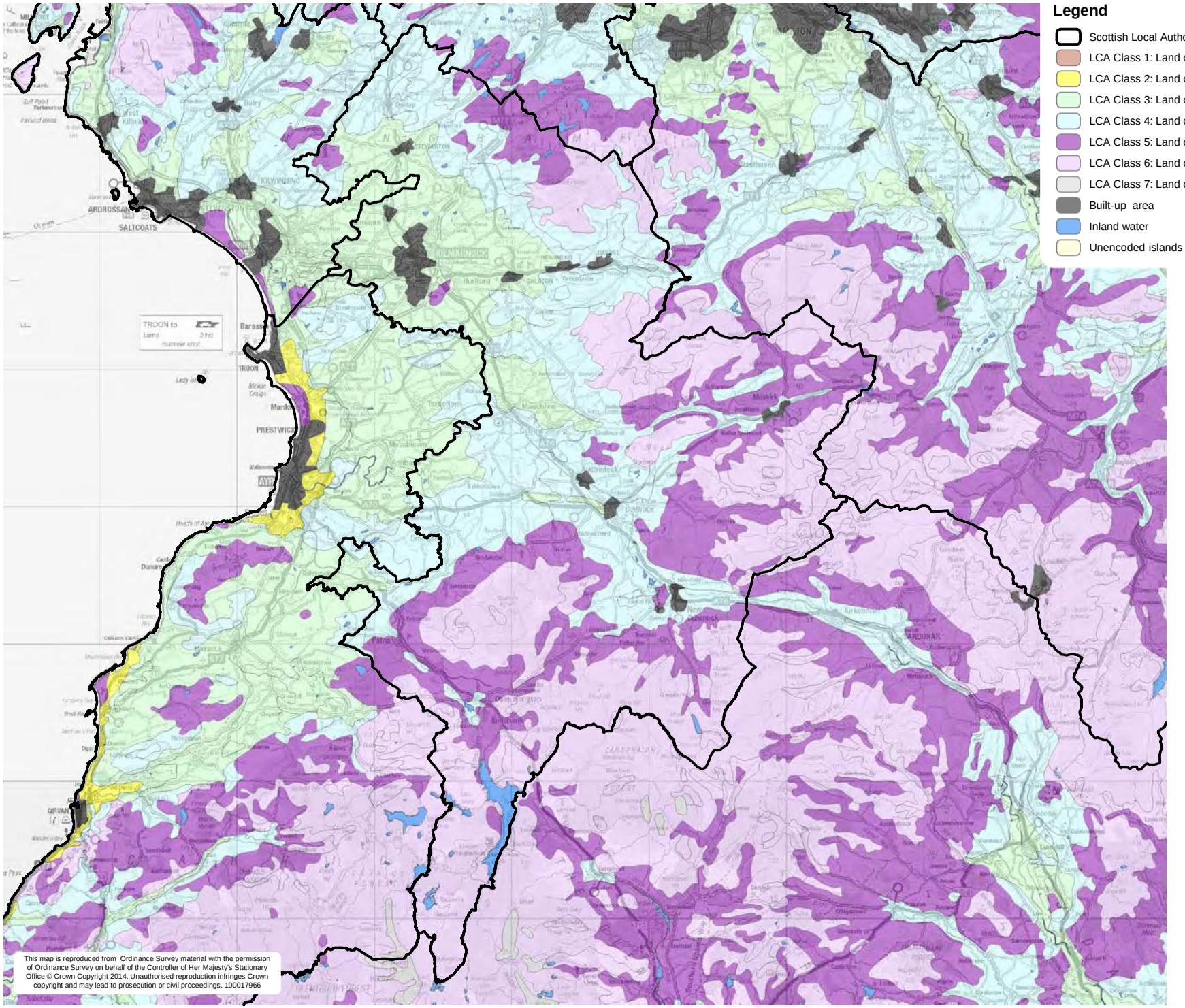

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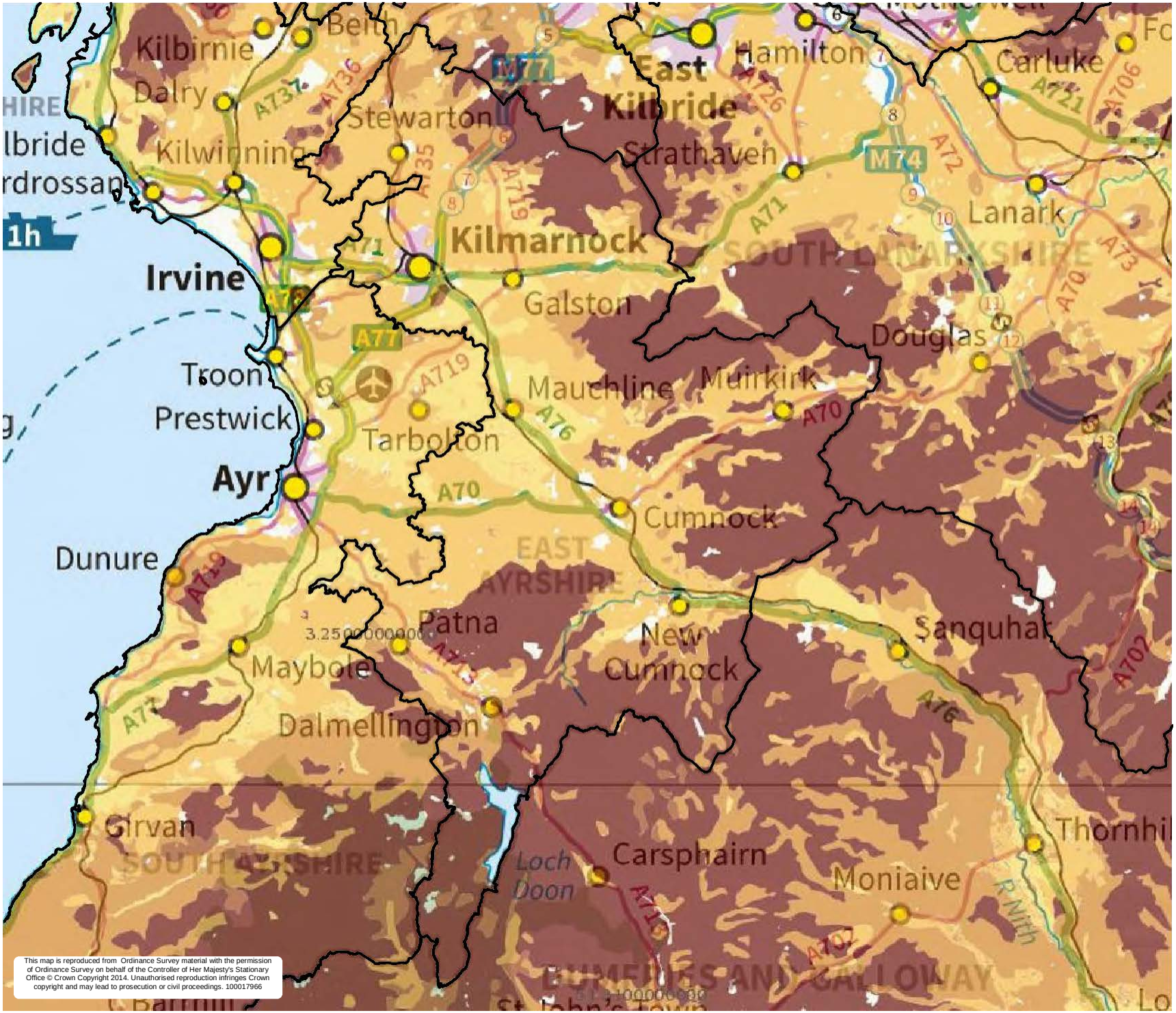
Figure 1.3

Land Capability for Agriculture



Legend

- Scottish Local Authority Boundaries
- Low (<1.5 %)
- Moderate (1.5 - 3.0 %)
- High (3.0 - 5.0 %)
- Humose (5.0 - 12.0 %)
- Organo-mineral (12.0 - 35.0 %)
- Organic (> 35 %)

0 2.5 5 10 Km

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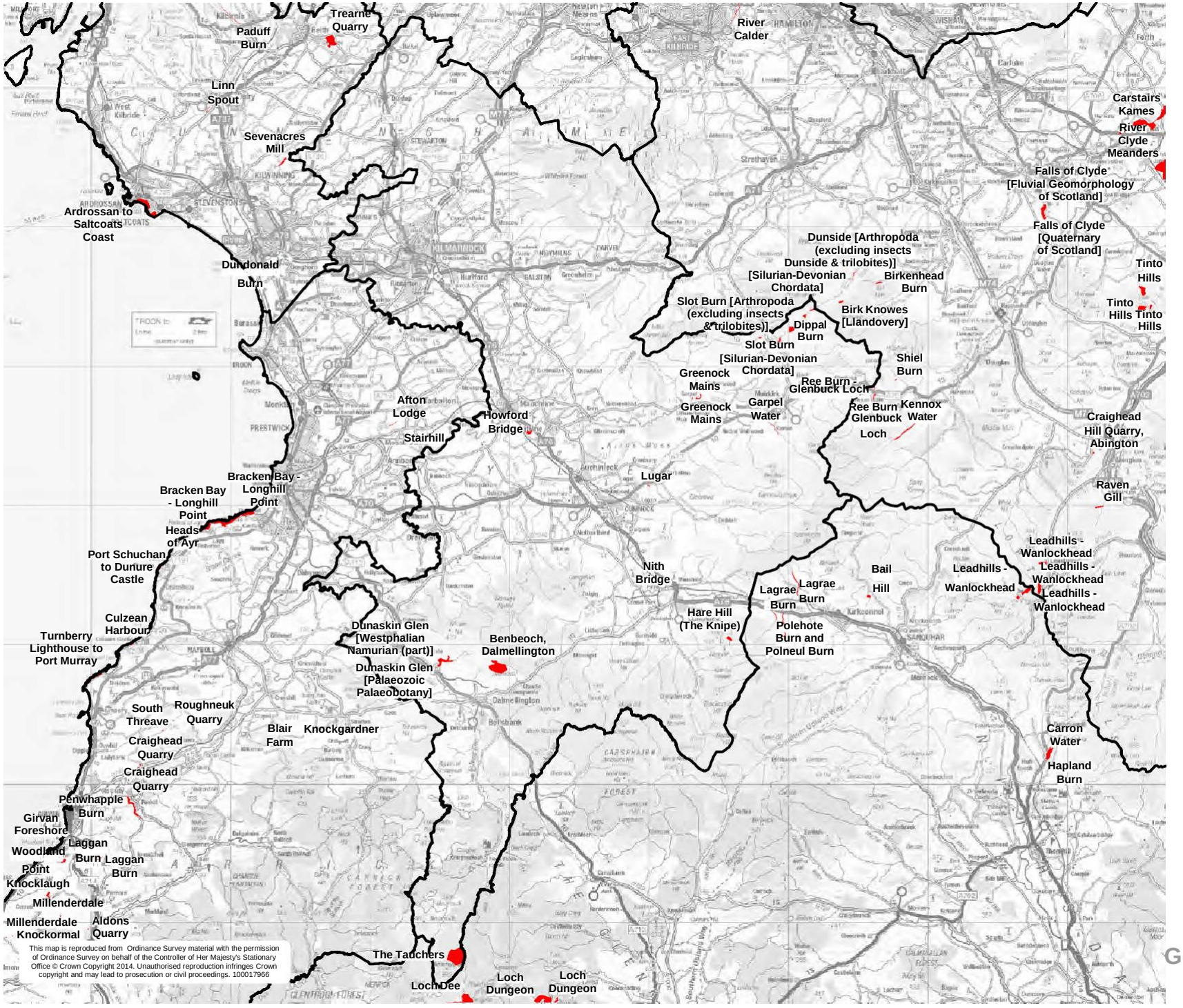
Figure 1.4

Topsoil Organic Carbon Content



Legend

- Scottish Local Authority Boundaries
- Geological Conservation Review Sites

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Figure 1.5

Geological Conservation Review sites

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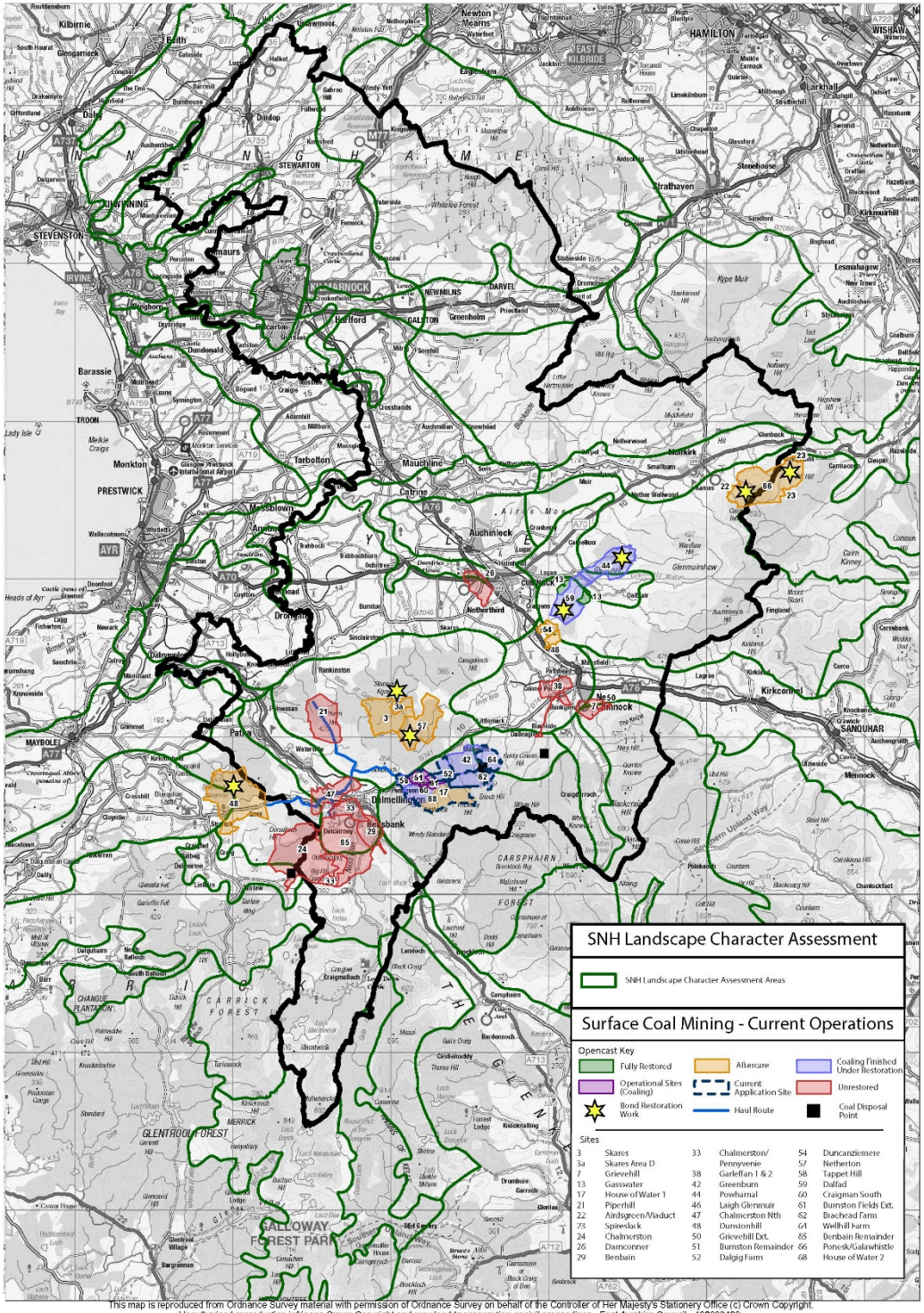
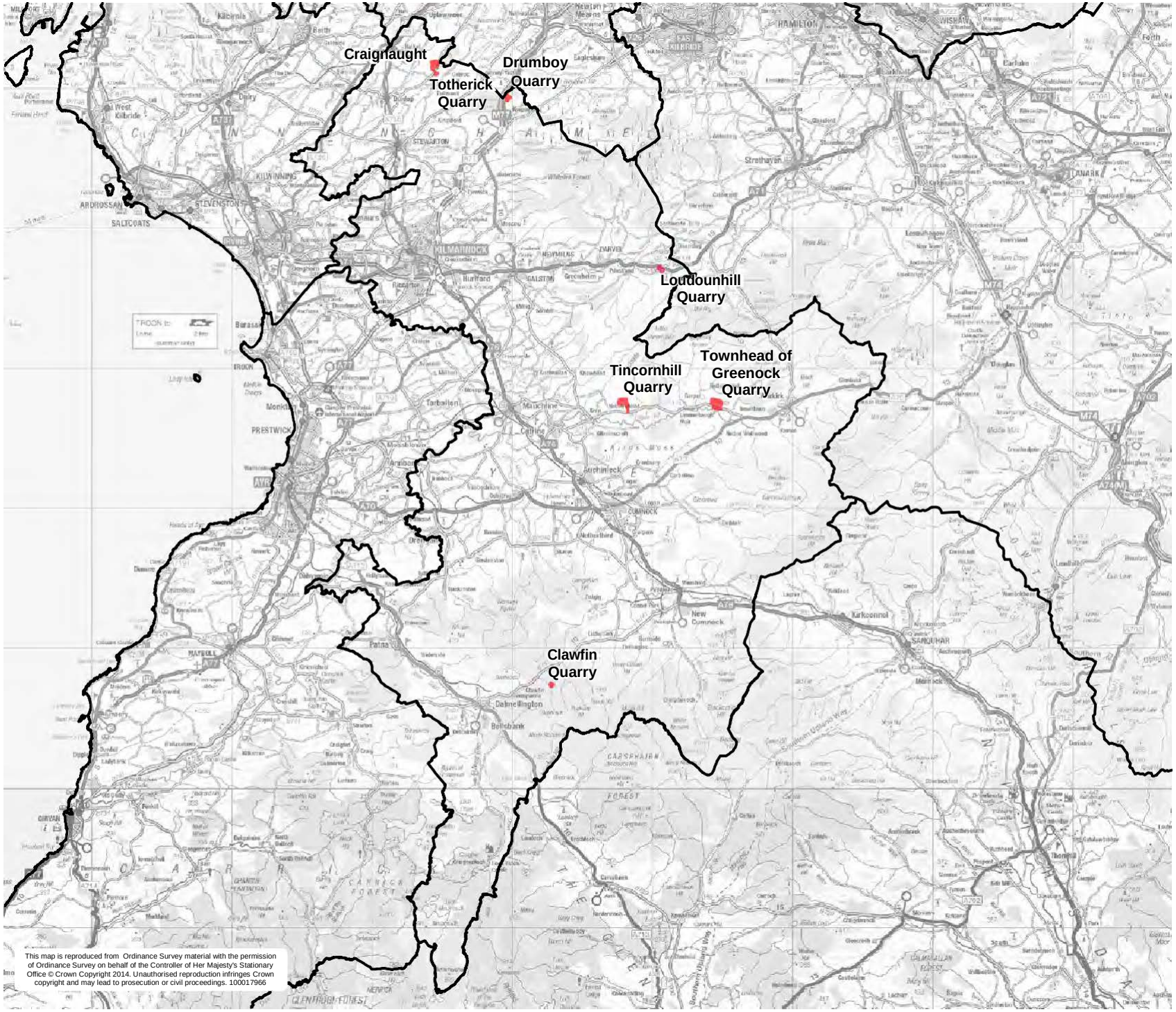


Figure 1.6

Open Cast Mine Sites



Legend

- Scottish Local Authority Boundaries
- Quarries

0 2.5 5 10 Km

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Figure 1.7

Quarries

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